THE FOUNDATION OF CLIMATE SCIENCE

HEARING

BEFORE THE

SELECT COMMITTEE ON ENERGY INDEPENDENCE AND GLOBAL WARMING HOUSE OF REPRESENTATIVES

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THE FOUNDATION OF CLIMATE SCIENCE

THURSDAY, MAY 6, 2010

HOUSE OF REPRESENTATIVES,
SELECT COMMITTEE ON ENERGY INDEPENDENCE
AND GLOBAL WARMING,
Washington, DC.

The committee met, pursuant to call, at 9:40 a.m., in room 2237, Rayburn House Office Building, Hon. Edward J. Markey (chairman of the committee) presiding.

Present: Representatives Markey, Blumenauer, Inslee, Cleaver, Speier, Sensenbrenner, Shadegg, and Sullivan.

Staff present: Ana Unruh Cohen and Jonah Steinbuck

The CHAIRMAN. Good morning.

Welcome to the Select Committee on Energy Independence and Global Warming. All eyes are focused on the economic and environmental disaster unfolding in the Gulf of Mexico. The BP oil spill is causing an immediate human and ecological tragedy. The spill is yet another dramatic example of why we must find alternatives to oil.

The American people are desperate for safe, clean energy alternatives, solutions that add jobs, end our oil addiction and heed the warnings of climate scientists who have called for pollution reductions. Eleven people tragically lost their lives in the BP rig explosion, and for the past week, an estimated 5,000 barrels of oil a day have been leaking into the ocean. As a result, the Gulf Coast fishing, seafood and tourism industries are bracing for the worst. Wildlife refuges and marine sanctuaries remain in harms way.

Congress will keep a vigilant eye on BP's efforts to stop the leak and clean up this environmental mess. However, the visible oil is not the only carbon pollution we have to worry about. Once gasoline is burned in our cars and trucks, carbon dioxide is released into the atmosphere. We can see the oil slick in the Gulf from space, but it is the buildup of invisible carbon dioxide in our atmosphere that is preventing heat from escaping back into space.

Even as carbon dioxide's concentration in the atmosphere has been accumulating, so has our scientific understanding of its effects and impacts. Based on over 150 years of scientific research, a clear picture has emerged of rising temperatures, increased droughts, severe rain storms and an acidifying ocean.

Those who deny global warming point to past uncertainties that have been refuted. They ignore the overwhelming observational evidence that the increased levels of heat-trapping pollution are already warming the planet. Instead of trying to understand the science, they use stolen e-mails about analysis of tree rings in Sibe-

ria to turn an honest discussion into a Russian tree ring circus. Or they manufacture a cooling trend by cherry-picking a few years out of a longer record of warming temperatures.

While the deniers hope to confuse the public, the real-world consequences of inaction mount. Over the weekend, killer storms blew through Tennessee, Mississippi and Kentucky. In Nashville, nearly 13 inches of rain fell in just over 2 day's time, almost doubling the previous record that fell in the aftermath of a hurricane in 1979. These storms follow the wettest March on record in Boston. Two 50-year storms occurred within two weeks of each other. The National Guard was mobilized. Hundreds of people were evacuated from their homes. The region suffered millions of dollars in damages.

No single rain storm can be attributed to climate change, nor can a snowstorm disprove its existence. But the underlying science and the observed trends do point to more extreme weather events, especially heavy precipitation events because a warmer atmosphere can hold more moisture. Extreme rainfall is just one of the consequences of the carbon pollution we are releasing into the air.

Our witnesses today will explain how science has revealed this unseen pollution for what it is and discuss the very real consequences of its continuing accumulation in the atmosphere. As we approach summer, our clean energy debate needs to acknowledge what many would like to deny: Our dependence on oil carries with it national security, economic and environmental risks. As gas prices rise and the oil slick spreads, perhaps we will finally acknowledge that we cannot drill our way to energy independence. We have 2 percent of proven oil reserves in the world.

Perhaps we can also acknowledge the basic facts that have been known for decades, increasing carbon pollution in the atmosphere is warming the planet, and that the only way to put a halt to such warming is to move to a clean energy solution.

I would now like to turn and recognize the ranking member of the committee, the gentleman from Wisconsin, Mr. Sensenbrenner.

[The prepared statement of Mr. Markey follows:]

THE SELECT COMMITTEE ON
ENERGY INDEPENDENCE AND GLOBAL WARMING

Statement of Chairman Edward J. Markey (D-MA)

Hearing on "The Foundations of Climate Science"
Select Committee on Energy Independence and Global Warming
May 6, 2010

All eyes are focused on the economic and environmental disaster unfolding in the Gulf of Mexico. The BP oil spill is causing an immediate human and ecological tragedy. The spill is yet another dramatic example of why we must find alternatives to oil. The American people are desperate for safe, clean energy alternatives. Solutions that add jobs, end our oil addiction and heed the warnings of climate scientists who have called for pollution reductions.

Eleven people tragically lost their lives in the BP rig explosion. For the past week, an estimated 5,000 barrels of oil a day has been leaking into the ocean. As a result, the Gulf Coast's fishing, seafood, and tourism industries are bracing for the worst. Wildlife refuges and marine sanctuaries remain in harms way. Congress will keep a vigilant eye on BP's efforts to stop the leak and clean up this environmental mess.

However, the visible oil is not the only carbon pollution we have to worry about. Once gasoline is burned in our cars and trucks, carbon dioxide is released into the atmosphere. We can see the oil slick in the Gulf from space, but it is the build up of invisible carbon dioxide in our atmosphere that is preventing heat from escaping back into space. Even as carbon dioxide's concentration in the atmosphere has been accumulating, so has our scientific understanding of its effect and impacts. Based on over 150 years of scientific research, a clear picture has emerged of rising temperatures, increased droughts, severe rainstorms, and an acidifying ocean.

Those who deny global warming point to past uncertainties that have been refuted. They ignore the overwhelming observational evidence that the increased levels of heat-trapping pollution are already warming the planet. Instead of trying to understand the science, they use stolen emails about analysis of tree rings in Siberia to turn an honest discussion into a Russian Tree Ring Circus. Or they manufacture a cooling trend by cherry picking a few years out of a longer record of warming temperatures.

While the deniers hope to confuse the public, the real world consequences of inaction mount. Over the weekend, killer storms blew through Tennessee, Mississippi and Kentucky. In Nashville, nearly 13 inches of rain fell in just over two days time – almost doubling the previous record that fell in the aftermath of a hurricane in 1979.

These storms follow the wettest March on record in Boston. Two 50-year storms occurred within 2 weeks of each other. The National Guard was mobilized. Hundreds of

people were evacuated from their homes. The region suffered millions of dollars in damages.

No single rainstorm can be attributed to climate change. Nor can a snowstorm disprove its existence. But the underlying science and the observed trends do point to more extreme weather events, especially heavy precipitation events because a warmer atmosphere can hold more moisture.

Extreme rainfall is just one of the consequences of the carbon pollution we are releasing into the air. Our witnesses today will explain how science has revealed this unseen pollution for what it is and discuss the very real consequences of its continuing accumulation in the atmosphere.

As we approach summer, our clean energy debate needs to acknowledge what many would like to deny. Our dependence on oil carries with it national security, economic and environmental risks. As gas prices rise and the oil slick spreads, perhaps we will finally acknowledge that we cannot drill our way to independence. We have less than 3 percent of proven oil reserves. Perhaps we can also acknowledge the basic facts that have been known for decades—increasing carbon pollution in the atmosphere is warming the planet and that the only way to put a halt to such warming is to move to clean energy solutions.

Mr. SENSENBRENNER. I thank the Chairman.

When global warming alarmists tried to advance their agenda a decade ago, they pointed to a damning graph in the 2001 IPCC report that showed a sharp rise in temperatures over the past century. This graph is commonly known as the hockey stick, and it did a good job of scaring a lot of people, especially politicians. But the authors of the Hockey Stick may not have done a good job with their math. At least that is what a couple of enterprising researchers thought. And in double-checking the hockey stick data, Stephen McIntyre and Ross McKitrick showed that it wasn't as solid as previously thought.

Lately, a lot of people have been taking a second look at the so-called settled science of climate change. Data collected by NASA may not be reliable as once believed. And the Climategate scandal shows, at best, that some researchers did everything they could to prevent review of their work, and at worst, they outright sought to manipulate data.

The debate on the accuracy of climate science is good for science. Proclamations that the science is settled are just politics. The shortfalls in the scientific record could have expensive consequences. Proponents of expensive regulatory reform must understand that they need more than political victories.

The EPA's burdensome regulatory regime must be based on sound scientific foundation. The EPA's regulations will be predicated in large part on the IPCC's most recent report. So far, the list of errors in that report includes: One, a sloppily sourced claim that Himalayan glaciers would disappear by 2035; two, reliance on an unpublished study to claim the world has suffered rising costs due to catastrophic weather events, where the author later said there was insufficient evidence to support the claim; three, stating that 55 percent of the Netherlands is below sea level when, in fact, only 26 percent is; four, failing to support the claim that Africa's agricultural output would be produced by 50 percent by 2020; and five, an unsupported claim that Bangladesh will be 17 percent under water by 2050.

A citizen's audit of the IPCC study found that 5,587 cited references, nearly a third of all the sources, were not peer-reviewed publications, but rather gray literature, such as press releases, newspaper and magazine articles, discussion papers, master's and Ph.D. theses, working papers and advocacy literature published by environmental groups. These sources lack authoritative scientific rigor and are more often than not intended as propaganda.

This week, the InterAcademy Council said that it had picked the 12 member committee to conduct an independent review of the IPCC's procedures. Hopefully the review will result in new methodologies that will give the public more confidence in the panel's conclusions before it releases its fifth assessment in 2014.

The Climategate scandal brought serious questions about the reliability of data compiled by the Climatic Research Unit at the University of East Anglia. These e-mails showed a clear bias, a systematic suppression of dissenting opinion, intimidation of journal editors and journals that would publish articles questioning the so-called consensus, manipulation of data and models, and possible criminal activity to evade legitimate requests for data and under-

lying computer holds filed under freedom of information acts. One of these e-mailers called Steven McIntyre a bozo for trying to hold him accountable for his work.

Dr. McIntyre also reviewed NASA's temperature data sets. His work resulted in forcing NASA to change its history of U.S. temperature data to show that 1934, not 1998, was the hottest year on record. Another study shows that NASA may have cherry-picked weather stations to favor those that would produce higher temperatures that produce a record that is warmer than truthful. Internal e-mails also showed that at least one senior NASA scientist raised questions about the accuracy of that agency's temperature data set.

The IPCC report relies heavily on the CRU and NASA data to support its conclusions. And the questions raised about these data sets raise even more questions about the accuracy of the IPCC's study. A report issued today by the Select Committee Republican staff shows that the EPA is violating its own rules by relying so heavily on the IPCC report. Both the EPA and the Office of Management and Budget guidelines state that an agency must base any regulatory proposal on science that is clear and transparent. OMB guidelines further state that simply because a study is peer-reviewed doesn't mean that it fulfills the requirement that the results are transparent and replicable.

I want to welcome here today Lord Christopher Monckton, the Chief Policy Advisor of the Science and Public Policy Institute. By helping to check and double-check the scientific literature, Lord Monckton is helping to improve the state of climate science.

And I look forward to hearing both his perspective and the perspective of the other witnesses today.

Thank you.

The CHAIRMAN. We thank the gentleman.

The Chair recognizes the gentleman from Oregon, Mr. Blumenauer.

Mr. BLUMENAUER. Mr. Chairman, I will just reserve my time for the inquiry. As inviting as my good friend's—from Wisconsin—comments were, I would rather save it.

The CHAIRMAN. Okay. The gentleman will reserve his time.

The Chair recognizes the gentleman from Washington State, Mr. Inslee.

Mr. INSLEE. I will reserve as well. Thank you, Mr. Chair.

The CHAIRMAN. The gentleman's time is reserved.

The Chair recognizes the gentleman from Missouri, Mr. Cleaver.

Mr. CLEAVER. Thank you, Mr. Chairman. Out of guilt, I will reserve as well.

The CHAIRMAN. The Chair recognizes the gentlelady from California, Ms. Speier.

Ms. SPEIER. Thank you, Mr. Chairman.

I am not going to reserve.

I am glad we are holding this hearing on the science of climate change. I welcome our scientific witnesses here today, and I look forward to relying on their expertise as we address the increasingly dire and challenging impacts of global warming.

I am from the San Francisco Bay area, where our most recognizable icon is the Golden Gate Bridge. A little known fact, however, is just next to the bridge is our Nation's oldest tidal gauge, a 150

year-old station that has given us the longest continuous tide record in the Western Hemisphere. The gauge shows an increased sea level rise of 8 inches over the past century. And the rate of that sea level rise has increased and is expected to accelerate further. In fact, the area is referred to as ground zero for sea level rise. San Francisco airport and surrounding communities could be under water by the end of the century.

We in the Bay Area live on the edge. We know the seriousness of this problem for our ecosystem, our infrastructure and our coastal and shoreline communities. In light of these most basic observations of our changing planet, acting on global warming in the here and now is just plain common sense.

That said, the complexity of how we act on these changes demands our utmost attention. The sharp, tried and tested knowledge of our top scientists must be the foundation for our efforts to solve the climate crisis. I am pleased we have some very qualified individuals here.

And once again, I expect to learn much more from their testimony. I yield back.

The CHAIRMAN. Thank you.

The gentlelady's time has expired.

And all time for opening statements by the members has been completed.

[The prepared statement of Mr. Sullivan follows:]

May 6, 2010

Opening Statement
Congressman John Sullivan
Select Committee on Energy Independence and Climate Change
"The Foundation for Climate Science'
2237 RHOB

Mr. Chairman, I appreciate you holding this hearing today.

In light of the Climate Gate scandal that rocked the world last year at the Climate Research Unit (CRU) at the University of East Anglia in England and the ongoing investigations into this serious matter, I believe our nation must reexamine all of the scientific evidence surrounding climate change.

For the record, I am opposed that any climate treaty that does not recognize the right of every country to protect its own national energy interests and would place the United States at a competitive economic disadvantage worldwide. I fear that pending cap and tax legislation in Congress is a backdoor attempt to enact a national energy tax that will have a crushing impact on consumers, jobs, and our economy- while doing little to protect the environment.

Families and small businesses already are struggling during this recession and with the national unemployment rate at 10% increasing their energy costs will only make matters worse to the tune of thousands of dollars in extra energy costs to drive their car, heat their home, etc.

I am interested in learning from our witnesses what the climate science community is doing to regain the public's trust on this issue and given the U.S. government' heavy reliance on Intergovernmental Panel on Climate Change (IPCC) data, much of which has been called into question, if you think the U.S. government should a full scale investigation into the state of climate science today.

I look forward to hearing the testimony of our witnesses and I yield back the balance of my time.

STATEMENT OF JAMES W. HURRELL, PH.D., SENIOR SCIENTIST AND CHIEF SCIENTIST, COMMUNITY CLIMATE PROJECTS, CLIMATE & GLOBAL DYNAMICS DIVISION, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH; JAMES J. McCARTHY, PH.D., ALEXANDER AGASSIZ PROFESSOR OF BIOLOGICAL OCEANOGRAPHY, HARVARD UNIVERSITY; LORD CHRISTOPHER MONCKTON, THIRD VISCOUNT MONCKTON OF BRENCHLEY, CHIEF POLICY ADVISER, SCIENCE AND PUBLIC POLICY INSTITUTE; CHRISTOPHER B. FIELD, PH.D., DIRECTOR, DEPARTMENT OF GLOBAL ECOLOGY, CARNEGIE INSTITUTION FOR SCIENCE, C-CHAIR, WORKING GROUP II OF THE IPCC; AND LISA J. GRAUMLICH, PH.D., PROFESSOR AND DIRECTOR, SCHOOL OF NATURAL RESOURCES AND THE ENVIRONMENT, THE UNIVERSITY OF ARIZONA

The CHAIRMAN. We will now turn to our first witness this morning. He is Dr. Jim Hurrell. Mr. Hurrell is a senior scientist within the Climate Analysis Section of the National Center for Atmospheric Research.

His research focuses on climate variability and human-caused climate change. He has contributed to the Intergovernmental Panel on Climate Change, the IPCC assessments. He is also actively involved in the International Research Program on Climate Variability and Predictability. Dr. Hurrell holds advanced degrees in atmospheric science from Purdue University. He is a fellow of the American Meteorological Society.

We look forward to hearing your testimony, Dr. Hurrell. Whenever you are ready, please begin.

STATEMENT OF JAMES W. HURRELL, PH.D.

Mr. HURRELL. Thank you.

Mr. Chairman, Ranking Member Sensenbrenner, and other members of the Select Committee, I thank you for the opportunity to speak today on observed and likely future changes in climate and the contribution from human activity to those changes.

Although uncertainties exist, significant advances in the scientific understanding of climate change now make it clear that there has been a change in climate that goes beyond the range of natural variability, and this change is almost certainly due to human activities. This conclusion is drawn from multiple lines of evidence published in thousands of thoroughly reviewed scientific studies by many different investigators and independently assessed by many groups, including the U.S. National Academy of Science.

The fact is that the globe is warming dramatically, and this change is already affecting both physical and biological systems. Global surface temperatures today are almost 1.5 degrees Fahrenheit warmer than at the beginning of the 21st century, and the rates of temperature rise are greatest in recent decades: 14 of the last 15 years are the warmest globally since 1850. And the last decade is .4 degrees Fahrenheit warmer than the 1990s. There is a very high degree of confidence in these numbers. Urban heat island effects, for instance, are real but very local, and they have been accounted for in the analysis.

There is no urban heat effect over the oceans where warming has also been very pronounced at both the surface and at depth. More-

over, warming ocean waters expand and thus contribute to sea level rise. Observed and accelerating melting of glaciers, icecaps, and ice sheets are also contributing by adding water to the ocean. Instrumental measurements of sea level indicate that the global average has increased over the last century and the rate of sea level rise is increasing. Global sea level rise is probably the single best metric of accumulative global warming since it integrates the reactions from several different components of the climate system and is accurately observed from satellite instruments.

Changes in global temperature or sea level do not imply however that changes are uniform around the globe. Regional differences arise from natural variability, and these effects can be large from year to year or even decade to decade. For instance, a historically large El Nino event helped make 1998 one of if not the warmest year on record, while strong El Nino conditions contributed to relatively cooler worldwide conditions in 2008. Simply connecting these two data points in time, as was shown in the graph, has been done by some to misleadingly argue global warming has ceased, ignoring the fact that the longer-term temperature trend is clearly upward, and the years since 2000 have remained among the warmest on record.

Because of such natural variations in the climate system, climate scientists expect occasional but temporary slowdowns in the rate of warming, even while greenhouse gas concentrations continue to increase. Climate models also predict such a behavior, and today's best climate models are able to reproduce many of the observed changes in climate observed over the past century.

Climate models are not perfect. Uncertainties arise from shortcomings in our understanding of climate processes and how to best represent them in models. Yet the best climate models are extremely useful tools for understanding and determining the factors that are driving the observed warming.

And the results are clear, the surface warming of recent decades, along with many other changes in climate, is mainly a response to increased concentrations of greenhouse gases in the atmosphere, which now far exceed pre-Industrial values.

In summary, the scientific understanding of climate change is sufficiently clear to show that climate change from global warming is already upon us. Many impacts are evident, and they will grow larger with time.

Uncertainties do remain, especially regarding how climate will change at regional and local scales. But the climate is changing, and the rate of changes projected exceeds anything seen in nature in the past 10,000 years.

Thank you again for this opportunity to address the committee, and I look forward to answering any questions.

[The statement of Mr. Hurrell follows:]

Statement of
James W. Hurrell, Ph. D.*
Senior Scientist and Chief Scientist of Community Climate Projects
Climate and Global Dynamics Division
National Center for Atmospheric Research**

Before the
U.S. House of Representatives
Select Committee on Energy Independence and Global Warming
6 May 2010

Hearing on
The Foundation for Climate Science

* Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author and do not necessarily reflect those of the National Science Foundation.
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Introduction

I thank Chairman Markey, Ranking Member Sensenbrenner and the other Members of the Select Committee for the opportunity to speak with you today on observed and likely future changes in climate and the contribution from human activity to those changes. My name is James W. Hurrell. I am a Senior Scientist at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, where I currently serve as the Chief Scientist of the NCAR Community Climate System Modeling project. My personal research has centered on empirical and modeling studies and diagnostic analyses to better understand climate, climate variability and climate change. I have authored or co-authored more than 80 peer-reviewed articles in leading scientific journals, numerous book chapters, and dozens of other planning documents and workshop papers. I have given more than 120 keynote and invited lectures worldwide, as well as many contributed presentations at national and international conferences on climate. I have also convened many national and international climate workshops, and I have served several national and international science-planning efforts. Currently, I am extensively involved in the World Climate Research Programme (WCRP) on Climate Variability and Predictability (CLIVAR), and I serve as the co-chair of the Scientific Steering Group of International CLIVAR. I have been involved as an author in both national and international assessment activities on climate and climate change, including lead author on several chapters dealing with observed change in climate. I have also served on several National Research Council panels.

In today's testimony I will address the observed changes to the climate system and the evidence that provides attribution of these changes to human activities. Indeed, significant advances in the scientific understanding of climate change now make it clear that there has been a change in climate that goes beyond the range of natural variability. The culprit is the astonishing rate at which greenhouse gas (GHG) concentrations are increasing in the atmosphere, mostly through the burning of fossil fuels and changes in land use, such as those associated with agriculture and deforestation. GHG are relatively transparent to incoming solar radiation while they absorb and reemit outgoing infrared radiation. The result is that more energy stays in the global climate system, raising not

only temperature but also producing many other direct and indirect changes in the climate system.

In the sections that follow, I will briefly summarize major observed changes in climate, with a focus on changes in surface climate. I will then summarize how natural and anthropogenic drivers of climate change are assessed using climate models. After describing projections of future climate change by these models, I will conclude with remarks on a few anticipated impacts of climate change on the United States and the world.

Observed changes in climate

Surface Temperature

The globe is warming dramatically compared with natural historical rates of change. Global surface temperatures today are more than 0.75°C (1.4°F) warmer than at the beginning of the 20th century, and U.S. average temperature has risen by a comparable amount. Moreover, rates of temperature rise are greatest in recent decades (Figure 1). Over the last 50 years, the rate of warming is nearly double that of the 100-year trend, and 14 of the 15 warmest years in the global surface instrumental temperature record (beginning around 1850) have occurred since 1995. The period since 2001 is ~ 0.2°C (0.4°F) warmer than the 1991-2000 decade. Global land regions have warmed the most (0.7°C or 1.3°F) since 1979, with the greatest warming in the boreal winter and spring months over the Northern Hemisphere continents.

There is a very high degree of confidence in the aforementioned global surface temperature values and the change estimates. The maximum difference, for instance, among three independent estimates of global surface temperature change since 1979 is 0.01°C (0.018°F) per decade. Small differences that do exist relate to how missing data are treated, especially over the Arctic where major warming is clearly evident from sea ice melt. Two of the surface temperature data sets have 2005, and not 1998, as the warmest year in the instrumental record. Spatial coverage has improved, and daily temperature data for an increasing number of land stations have also become available, allowing more detailed assessments of extremes, as well as potential urban influences on large-scale temperature averages. It is well documented, for instance, that urban heat

island effects are real, but very local, and they have been accounted for in the analyses: the urban heat island influence on continental, hemispheric and global average trends is at least an order of magnitude smaller than decadal and longer timescale trends, as cities make up less than 0.5% of global land areas.

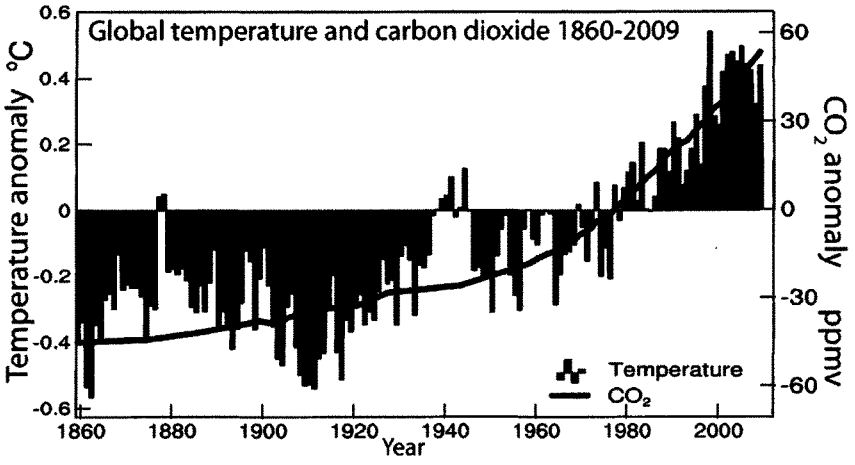

Figure 1. *Estimated changes in annual global mean surface temperatures (°C, color bars) and CO_2 concentrations (thick black line) over the past 150 years. The changes are shown as differences (anomalies) from the 1961-1990 average values. Carbon dioxide concentrations since 1957 are from direct measurements at Mauna Loa, Hawaii, while earlier estimates are derived from ice core records. The scale for CO_2 concentrations is in parts per million (ppm) by volume, relative to a mean of 333.7 ppm, while the temperature anomalies are relative to a mean of 14°C (57°F).*

Of course there is absolutely no urban heat effect (bias) in the global sea surface temperature (SST) record. Over the global oceans, surface temperatures have warmed 0.35°C (0.63°F) since 1979, and the warming is strongly evident at all latitudes over each of the ocean basins. Moreover, the warming is evident not only at the surface but deep in the ocean as well, indicating that the ocean is absorbing most of the heat being added to the climate system. Such changes in global average temperature do not imply, however, that changes are uniform around the globe. There are notable regional and seasonal variations, especially over relatively short time periods (year-to-year and even decade-to-

decade). Regional differences in SST change arise, for instance, from natural variability. One example is the very strong warming of the central and eastern tropical Pacific Ocean that occurs during El Niño events typically every few years. These events also produce regional cooling over portions of the subtropical oceans and the tropical western Pacific. Over the Atlantic, the average basin-wide ocean warming is imposed on top of strong, natural variability on multi-decadal time scales. The level of natural variability, in contrast, is relatively small over the tropical Indian Ocean, where the surface warming has been steady and large over recent decades. These important differences in regional rates of surface ocean warming also affect the atmospheric circulation, producing changes in the atmospheric flow so that some regions warm more than others, while other regions cool, especially over periods of years or even decades.

A good example of the substantial role that natural climate variability plays over shorter periods of time is the strong La Niña conditions during the northern winters of 2007-08 and 2008-09. This cooling of the tropical Pacific SSTs contributed to relatively cooler conditions worldwide; moreover, starting from the record global warmth in 1998, some have argued global warming has ceased, ignoring the fact that the long-term trend is clearly upward (Figure 2) and, over the past decade, most years have remained close to the 1998 value. Because of such natural variations in the climate system, climate scientists have long recognized that a temporary slowdown in the rate of warming is possible even while GHG concentrations continue to increase. Climate models also predict such behavior.

Another example of the strong impact of natural variability occurred this past winter, when extraordinary conditions in the North Atlantic Oscillation (NAO) combined with a moderate-to-strong El Niño to produce very distinctive and strong weather patterns across portions of the Northern Hemisphere. In particular, it was unusually cold over parts of North America and Eurasia this past winter, even as the rest of the world was well above normal in temperature (e. g., March 2010 was the warmest March on record, and the 3-month season from January through March 2010 was the fourth warmest winter season on record). El Niño and NAO conditions also contributed to the record breaking snow storms in the Washington D.C. region as well as flooding heavy rain events in New

England this past winter. Such natural variations in climate are expected and will continue, even as the overall climate system warms.

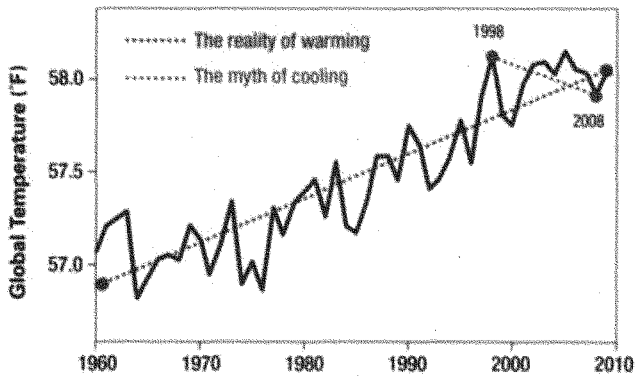

Figure 2. *Changes in annual global mean surface temperatures (°F) since 1960. Note the record surface warmth in 1998 from the major El Niño. Moreover, trends over short periods of time (1998-2008, blue) do not accurately reflect the longer-term warming (red). From NOAA/NCDC*

Sea level

The warming ocean waters expand and, thus, contribute to sea level rise. Melting of glaciers on land as well as ice caps and ice sheets also contribute by adding water to the ocean. Instrumental measurements of sea level indicate that the global average has increased approximately 17 cm (6.7 inches) over the last century, and the increase has been 0.18 cm (0.07 inches) per year since 1961. The rate has been even faster recently (about 0.33 cm or 0.13 inches per year from 1993 through 2009), when truly global values have been measured from altimeters in space (Figure 3). Prior to 2004, about 60% of global sea level rise is from ocean warming and expansion, while 40% was from melting land ice adding to the ocean volume. Since 2004 melting ice sheets have contributed more.

The observation of consistent global sea level rise over several decades, and also an increasing rate of sea level rise in the last decade or so, is probably the single best metric of the cumulative global warming. This is because sea level is a great integrator: it is not affected appreciably by a cold winter or two in Washington or London, a hot summer in

Kansas, or a hurricane like Katrina. A consequence of ocean warming and rising sea levels is increasing risk of coral bleaching and coastal storm surge flooding.

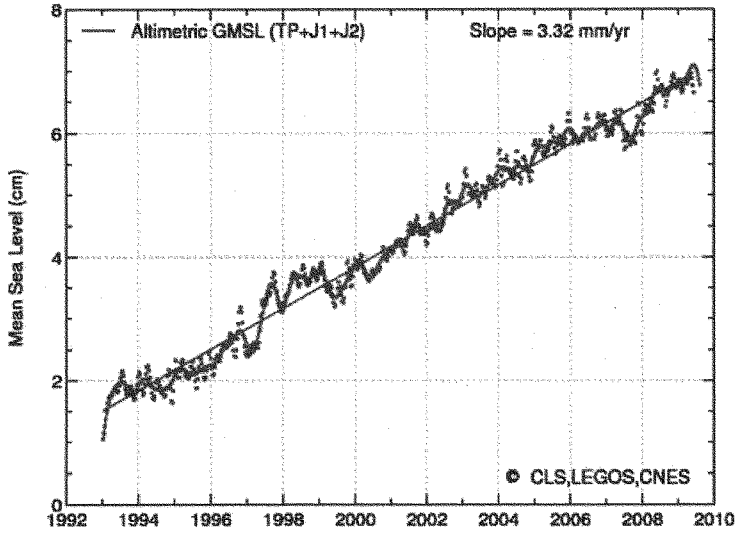

Figure 3. *This figure shows a steady rise in average global sea level since 1993 when satellite data became available using a technique called radar altimetry. Radar altimetry uses a radar on a satellite to precisely measure the distance between the sea surface and the satellite. Courtesy of www.aviso.oceanobs.com/en/news/ocean-indicators/mean-sea-level/, where one may also obtain the raw data that produced the figure. Other independent groups have also computed sea level rise (e.g. NOAA, http://ibis.grdl.noaa.gov/SAT/SeaLevelRise/ , and the results are very similar to this one.)*

Snow cover, sea and land ice

The observed increases in surface temperature are consistent with nearly worldwide reductions in glacier and small ice cap mass and extent in the 20th century. In addition, flow speed has recently increased for some Greenland and Antarctic outlet glaciers, which drain ice from the interior, and melting of Greenland and West Antarctica has increased after about 2000. Critical changes (not well measured) are occurring in the ocean and ice shelves that buttress the flow of glaciers into the ocean. Glaciers and ice caps respond not only to temperature but also to changes in precipitation, and both winter accumulation and summer melting have increased over the last half century in association

with temperature increases. In some regions, moderately increased accumulation observed in recent decades is consistent with changes in atmospheric circulation and associated increases in winter precipitation (e.g., southwestern Norway, parts of coastal Alaska, Patagonia, and the South Island of New Zealand) even though increased ablation has led to marked declines in mass balances in Alaska and Patagonia. Tropical glacier changes are synchronous with those at higher latitudes and have shown declines in recent decades. Decreases in glaciers and ice caps contributed to global sea level rise by 0.05 cm (0.02 inches) per year from 1961 to 2003, and 0.08 cm (0.03 inches) per year from 1993 to 2003. Taken together, shrinkage of the ice sheets of Greenland and Antarctica contributed 0.04 cm (0.016 inches) per year to sea level rise over 1993 to 2003. Since then evidence suggests increased melting of both Greenland and Antarctica, whereby they contribute about 0.1 cm (0.04 inches) per year to sea level rise, about equally.

Snow cover has decreased in many Northern Hemisphere regions, particularly in the spring season, and this is consistent with greater increases in spring than autumn surface temperatures in middle latitude regions. Sea-ice extents have decreased in the Arctic, particularly in the spring and summer seasons (7.4% per decade decrease from 1978 through 2005), and this is consistent with the fact that the average annual Arctic temperature has increased at almost twice the global average rate, although changes in winds are also a major factor. The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) included data only through 2005 when sea-ice extents were at record low values, which was also the warmest year since records began in 1850 for the Arctic north of 65°N. This record was smashed in 2007 when Arctic sea ice dropped to over 20% below the 2005 value. There have also been decreases in sea-ice thickness. With an unprecedented amount of first-year ice in the Arctic that is very vulnerable to melting, 2008 ranks slightly higher in terms of sea-ice extent than 2007, and 2009 ranks third, but still lower than 2005. The total peak summer time decrease in Arctic sea ice is about 40% of the 1970s values. Temperatures at the top of the permafrost layer in the Arctic have increased since the 1980s (up to 6°F locally), and the maximum area covered by seasonally frozen ground has decreased by about 7% in the NH since 1900, with an even greater decrease (15%) in the boreal spring. There

has been a reduction of about two weeks in the annual duration of northern lake and river ice cover.

In contrast to the Arctic, Antarctic sea ice did not exhibit any significant trend from the end of the 1970s through 2006, which is consistent with the lack of trend in surface temperature south of 65°S over that period. However, along the Antarctic Peninsula where significant warming has been observed, progressive break up of ice shelves occurred beginning in the late 1980s, culminating in the break up of the Larsen-B ice shelf in 2002. Antarctic conditions are uniquely influenced greatly by the ozone hole, which alters the atmospheric circulation over the southern regions.

Extremes

For changes in mean temperature, there is likely to be an amplified change in extremes. Extreme events, such as heat waves, are exceedingly important to both natural systems and human systems and infrastructure. People and ecosystems are adapted to a range of natural weather variations, but it is the extremes of weather and climate that exceed tolerances. Widespread changes in temperature extremes have been observed over the last 50 years. In particular, the number of heat waves globally has increased, and there have been widespread increases in the numbers of warm nights. Cold days, cold nights and days with frost have become rarer.

Satellite records suggest a global trend towards more intense and longer lasting tropical cyclones (including hurricanes and typhoons) since about 1970, correlated with observed warming of tropical SSTs. There is no clear trend in the annual number of tropical cyclones globally although a substantial increase has occurred in the North Atlantic after 1994. There are concerns about the quality of tropical cyclone data, particularly before the satellite era. Further, strong multi-decadal variability is observed and complicates detection of long-term trends in tropical cyclone activity. Recent community consensus is that heavy rains in tropical storms and hurricanes have increased by 6 to 8% as a result of higher SSTs and more water vapor in the atmosphere, and that hurricane intensity may be increasing.

Precipitation and drought

Changes are also occurring in the amount, intensity, frequency, and type of precipitation in ways that are also consistent with a warming planet. These aspects of precipitation generally exhibit large natural variability compared to temperature, making it harder to detect trends in the observational record. A key ingredient in changes in character of precipitation is the observed increase in water vapor and thus the supply of atmospheric moisture to all storms, increasing the intensity of precipitation events on average. Widespread increases in heavy precipitation events and risk of flooding have been observed, even in places where total amounts have decreased. Hence the frequency of heavy rain events has increased in most places but so too has episodic heavy snowfall events that are thus associated with warming.

Long-term (since 1900) trends have been observed in total precipitation amounts over many large regions. Significantly increased precipitation has been observed in eastern parts of North and South America, northern Europe and northern and central Asia. Drying has been observed in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Precipitation is highly variable spatially and temporally. Robust long-term trends have not been observed for other large regions. The pattern of precipitation change is one of increases generally at higher northern latitudes (because as the atmosphere warms it holds more moisture) and drying in the tropics and subtropics over land. Basin-scale changes in ocean salinity provide further evidence of changes in Earth's water cycle, with freshening at high latitudes and increased salinity in the subtropics.

More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics. Increased drying due to higher temperatures and decreased precipitation have contributed to these changes, with the latter the dominant factor. The regions where droughts have occurred are determined largely by changes in SST, especially in the tropics (such as during El Niño), through changes in the atmospheric circulation and precipitation. In the western United States, diminishing snow pack and subsequent summer soil moisture reductions have also been a factor. In Australia and Europe, direct links to warming have been inferred through the extreme nature of high temperatures and heat waves accompanying drought.

In summary, there are an increasing number of many independent surface observations that give a consistent picture of a warming world. Such multiple lines of evidence, the physical consistency among them, and the consistency of findings among multiple, independent analyses form the basis for the iconic phrase from the AR4 of IPCC that the "warming of the climate system is unequivocal".

Human and natural drivers of climate change

The scientific consensus is that most of the observed global temperature increase of the past 50 years is due to human activity. This conclusion is based on studies that assess the causes of climate change, taking into account all possible agents of climate change (forcings), both natural and from human activities.

Forcings are external to the climate system and may arise, for instance, from changes in the sun or from changes in atmospheric composition associated with explosive volcanic eruptions. These phenomena occur naturally. Human activities that generate heat or which change the atmospheric composition are also external to the climate system but do not occur naturally. In contrast, many feedbacks occur through interactions among the components of the climate system: the atmosphere, ocean, land and cryosphere (which includes sea, lake and river ice, snow cover, glaciers, ice caps, ice sheets, and frozen ground). Some amplify the original changes producing a positive feedback, while others diminish them: a negative feedback. Feedbacks considerably complicate the climate system, and the physical processes involved are depicted in climate models. Radiative forcing is a measure of the influence that a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism. Positive forcing tends to warm the surface while negative forcing tends to cool it.

The capability of climate models to simulate the past climate has been comprehensively assessed in the peer-reviewed scientific literature. Given good replications of the past, the forcings can be removed one by one to disassemble their effects and allow attribution of the observed climate change to the different forcings. Therefore, climate models are a key tool to evaluate the role of various forcings in producing the observed changes in temperature and other climate variables.

The best climate models encapsulate the current understanding of the physical processes involved in the climate system, the interactions, and the performance of the system as a whole. Uncertainties arise, however, from shortcomings in the understanding and how to best represent complex processes in models. Yet, in spite of these uncertainties, today's best climate models are able to reproduce the climate of the past century, and simulations of the evolution of global surface temperature over the past millennium are consistent with paleoclimate reconstructions.

As a result, climate modelers are able to test the role of various forcings in producing observed changes in climate. Human activities increase long-lived GHG, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other traces gases. They also increase aerosol concentrations in the atmosphere, mainly through the injection of sulfur dioxide (SO_2) from power stations and through biomass burning. A direct effect of sulfate aerosols is the reflection of a fraction of solar radiation back to space, which tends to cool the Earth's surface. Other aerosols (like soot) directly absorb solar radiation leading to local heating of the atmosphere, and some absorb and emit infrared radiation. A further influence of aerosols is that many act as nuclei on which cloud droplets condense, affecting the number and size of droplets in a cloud and hence altering the reflection and the absorption of solar radiation by the cloud and the lifetime of the cloud. The precise nature of aerosol/cloud interactions and how they interact with the water cycle remains a major uncertainty in our understanding of climate processes. Because man-made aerosols are mostly introduced near the Earth's surface, they are washed out of the atmosphere by rain in typically a few days. They thus remain mostly concentrated near their sources and affect climate with a very strong regional pattern, usually producing cooling.

In contrast, GHG such as CO_2 and CH_4 have lifetimes of decades or much longer. As a result, they are globally mixed and concentrations build up over time. GHG concentrations in the atmosphere have increased markedly as a result of human activities since 1750, and they are now higher than at any time in at least the last 650,000 years. It took at least 10,000 years from the end of the last ice age (18,000 years ago) for levels of CO_2 to increase 100 parts per million (ppm) by volume to 280 ppm, but that same increase has occurred over only the past 150 years to current values in excess of 385 ppm (Figure 1). About half of that increase has occurred over the last 35 years,

owing mainly to combustion of fossil fuels and changes in land use. The CO_2 concentration growth-rate was larger during the last decade than it has been since the beginning of continuous direct measurements in the late 1950s. In the absence of controls, future projections are that the rate of increase in CO_2 amount may accelerate, and concentrations could double from pre-industrial values within the next 50 to 100 years.

Methane is the second most important anthropogenic GHG. Owing predominantly to agriculture and fossil fuel use, the global atmospheric concentration of CH_4 has increased from a pre-industrial value of 715 part per billion (ppb) by volume to 1774 ppb in 2005, although growth rates have declined since the early 1990s, consistent with total emissions (natural and anthropogenic sources) being nearly constant over this period. Global N_2O concentrations have increased significantly from pre-industrial values as well. Together, the combined radiative forcing from these three GHG is +2.3 Watts per square meter ($W\ m^{-2}$), relative to 1750, which dominates the total net anthropogenic forcing ($+1.6\ W\ m^{-2}$). The total net anthropogenic forcing includes contributions from aerosols (a negative forcing) and several other sources, such as tropospheric ozone and halocarbons.

Climate model simulations that account for such changes in forcings consistently show that global surface warming of recent decades is a response to the increased concentrations of GHG and sulfate aerosols in the atmosphere. When the models are run without these forcing changes, the remaining natural forcings and intrinsic natural variability fail to capture the almost linear increase in global surface temperatures over the past 40 years or so. But when the anthropogenic forcings are included, the models simulate the observed global temperature record with impressive fidelity (Figure 4). Changes in solar irradiance since 1750 are estimated to have caused a radiative forcing of $+0.12\ W\ m^{-2}$, mainly in the first part of the 20^{th} century. Prior to 1979, when direct observations of the sun from space began, changes in solar irradiance are more uncertain, but direct measurements show that the sun has not caused warming since 1979. Moreover, the models indicate that volcanic and anthropogenic aerosols have offset some of the additional warming that would have resulted from observed increases in GHG concentrations alone. For instance, since about 2000 the sunspot cycle went from a maximum to a minimum and a very quiet sun, decreasing total solar irradiance by 0.1%.

This has contributed a slight cooling component to the planet, perhaps offsetting about 10 to 15% of the recent warming.

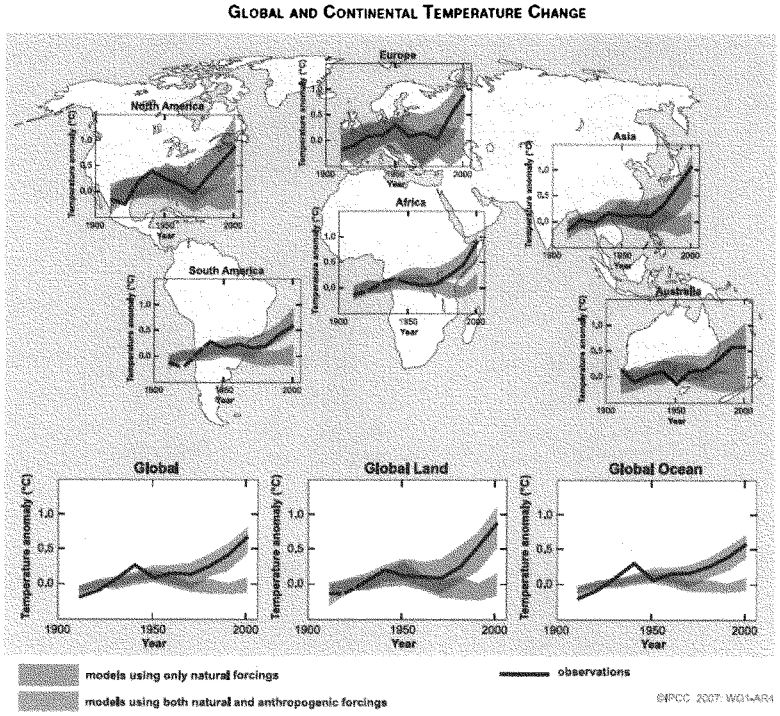

Figure 4. *Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for 1906–2005 (black line) plotted against the center of the decade and relative to the corresponding average for 1901–1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5–95% range for 19 simulations from 5 climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5–95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings. The figure is taken from the IPCC AR4 Working Group I Summary for Policymakers.*

A significant advancement is that a larger number of simulations available from a broader range of models allows for a more definitive evaluation of the role of various forcings in producing not only changes in global average temperature, but also changes in continental and ocean basin scale temperatures. The patterns of warming over each

continent except Antarctica and each ocean basin over the past 50 years are only simulated by models that include anthropogenic forcing (Figure 4). Attribution studies have also demonstrated that many of the observed changes in indicators of climate extremes consistent with warming, including the annual number of frost days, warm and cold days, and warm and cold nights, have likely occurred as a result of increased anthropogenic forcing. In other words, many of the recently observed changes in climate are now being simulated in models.

The ability of climate models to simulate the temperature evolution on continental scales, and the detection of anthropogenic effects on each continent except Antarctica, provides very strong evidence of human influence on the global climate. No climate model that has used natural forcing only has reproduced either the observed global mean warming trend or the continental mean warming trends. Attribution of temperature change on smaller than continental scales and over time scales of less than 50 years or so is more difficult because of the much larger signal of natural variability on smaller space and time scales.

Projected future climate change

The ability of climate models to closely simulate the past climate record gives us increased confidence in their ability to simulate the future. We can now look back at projections from earlier climate change assessments and see that the observed rate of global warming since 1990 (about 0.36°F per decade) is within the projected range (0.27°F– 0.54°F). Moreover, the attribution of the recent climate change to increased concentrations of GHG in the atmosphere has direct implications for the future. Because of the long lifetime of CO_2 and the slow equilibration of the oceans, there is a substantial future commitment to further global climate change even in the absence of further emissions of GHG into the atmosphere. Several of the more recent climate model experiments explored the concept of climate change commitment. For instance, if concentrations of GHG were held constant at year 2000 levels (implying a very large reduction in emissions), a further warming trend would occur over the next 20 years at a rate of about 0.2°F per decade, with a smaller warming rate continuing after that. Such committed climate change is due to (1) the long lifetime of CO_2 and other GHG; and (2)

the long time it takes for warmth to penetrate into the oceans. Under the aforementioned scenario, the associated sea level rise commitment is much longer term, due to the effects of thermal expansion on sea level. Water has the physical property of expanding as it warms; therefore, as the warming penetrates deeper into the ocean, an ever increasing volume of water expands and contributes to ongoing sea level rise. Since it would take centuries for the entire volume of the ocean to warm in response to the effects of GHG already in the air, sea level rise would continue for centuries. Further glacial melt is also likely.

The 16 climate modeling groups (from 11 countries) contributing to the AR4 produced the most extensive internationally coordinated climate change analysis ever performed. In total, 23 global coupled climate models were used to perform simulations of the 20th century climate, three scenarios of the 21st century (based on low, medium and high emission scenarios), and three idealized stabilization experiments. Some of the major results include:

- Over the next two decades, all models produce similar warming trends in global surface temperatures, regardless of the scenario. The rate of the projected warming is near 0.36°F per decade, or about twice that of the "commitment" runs.

- Decadal-average warming over each inhabited continent over the next decade or two is relatively insensitive to the emission scenario; moreover, the temperature change is very likely to exceed the model generated natural temperature variability by at least a factor of two. By the middle of the 21st century, however, the choice of scenario becomes more important for the magnitude of surface warming, and by the end of the 21st century there are clear consequences for which scenario is followed. The best estimate of the global surface temperature change from today to the end of the century is +3.2°F (with a likely range of +2.0°F to +5.2°F) for the low emission scenario (B1, corresponding to a CO_2 equivalent concentration of 600 ppm by 2100) and +7.2°F (+4.3°F to +11.5°F) for the highest emission scenario (A1F1, corresponding to 1,550 ppm). Recent emissions exceed even the A1F1 scenario owing especially to development in China, although very recently the global recession has slowed emissions somewhat.

- Geographical patterns of warming show greatest temperature increases at high northern latitudes and over land, with less warming over the southern oceans and North

Atlantic, as has been observed in recent decades. In spite of a slowdown of the meridional overturning circulation and changes in the Gulf Stream in the ocean across models, there is still warming over the North Atlantic and Europe due to the overwhelming effects of the increased concentrations of GHG.

- Snow cover is projected to contract. Widespread increases in thaw depth are projected over most permafrost regions.
- Sea ice coverage is projected to shrink. Large parts of the Arctic Ocean are expected to no longer have year-round ice cover by the middle of the 21st century. In AR4 the results were more suggestive of such changes by the end of the 21st century, but recent changes and new model results suggest that late-summer sea ice could disappear almost completely in just a few decades.
- It is very likely that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent. It is likely that hurricane intensity will increase. Models also project a 50 to 100% decline in the frequency of cold air outbreaks in most regions of the winter Northern Hemisphere. Related decreases in frost days contribute to longer growing seasons.
- Projections of sea level rise by the end of the century are similar to previous estimates, ranging from 30 to 40 cm (12 to 16 inches), but do not include possible ice sheet collapse.
- About 60-70% of the projected sea level rise is due to thermal expansion of sea water. There is less certainty of the future contributions from other sources. For instance, the projections include a contribution due to increased ice flow from Greenland and Antarctica at the rates observed over the past decade, but how these flow rates might change in the future is not known.
- Increases in the amount of precipitation are very likely in high-latitudes, while decreases are likely in most subtropical land regions, continuing recent trends.
- SLP is projected to increase over the subtropics and middle latitudes, and decrease over high latitudes. Consequently, storm tracks are projected to move poleward, with consequent changes in wind, precipitation and temperature patterns outside the tropics, continuing the pattern of observed trends over the last few decades.

Today's climate models have better and more complete representations of many physical processes. But as our knowledge of the different components of the climate system and their interactions increases, so does the complexity of climate models. Historical changes in land use and changes in the distribution of continental water due to dams and irrigation, for instance, need to be considered. Future projected land cover changes due to human land uses are also likely to significantly affect climate, especially locally, and these effects are only just now being included in climate models.

One of the major advances in climate modeling in recent years has been the introduction of coupled climate-carbon models. Climate change is expected to influence the capacities of the land and oceans to act as repositories for anthropogenic CO_2, and hence provide a feedback to climate change. Though fewer global climate models include the complex processes involved with modeling the carbon cycle, this feedback is positive (adding to more warming) in all models so far considered. Therefore, the addition of carbon cycle feedbacks increases the fraction of anthropogenic emissions that remain in the atmosphere, thereby giving higher values on the warm end of the uncertainty ranges.

Impacts

Consequences of the physical changes in climate are numerous and are only briefly mentioned in this written testimony. Considerable evidence suggests that recent warming is affecting human health, water supply, agriculture, coastal areas, and many other aspects of society and the natural environment. For instance, impacts on terrestrial biological systems include earlier timing of spring events, such as leaf-unfolding, bird migration and egg-laying, and poleward and upward shifts in ranges in plant and animal species. Moreover, the resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change, associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification), and other human effects such as land use and change, pollution, and over-exploitation of resources.

An unmistakable sign of climate change in my part of the country, for instance, is not only earlier spring snowmelt, which alters the timing and amount of water supplies, but also the extremely large clusters of dead pine trees from the southern Rockies into vast parts of Canada and Alaska. Forest managers throughout the North American West have

called the diebacks "catastrophic" and "unprecedented". The area affected is 50 times larger than the area affected by forest fire with an economic impact nearly five times as great. The trees are succumbing to the relentless attack of the mountain pine beetle. Warming temperatures have not only removed the natural line of defense against such infestations, namely sufficiently cold temperatures in winter, but they are speeding up the life cycle of the beetle. In contiguous USA, for example, warmer summer temperatures are enabling the beetle to produce two generations in a year, when previously they reproduced once a year.

Global warming promotes increases in both drought through drying (evaporation) and temperature increases. With warmer air more moisture is drawn out of plants and the soil, and the water holding capacity of the atmosphere increases as well. Thus, in many places even as rains have become more intense, so too have dry spells become longer. A consequence of more intense but less frequent precipitation events is that what were once 500 year flood events are now more like 30 or 50 year events. After a certain point where the ground is dry and plants have reached wilting point, all of the heat goes into raising temperature and creating heat waves, and then wild fire risk goes up substantially. "Dry lightning" can then be disastrous, especially in areas where trees are damaged such as by bark beetles. The risk of wild fire does not necessarily translate into a wild fire if care has been taken in managing the risk by building wild fire breaks, cutting down on litter, and removing diseased and dead trees and vegetation near buildings.

For humans, autonomous adaptation occurs to changing conditions to some degree. Climate change effects occur amidst increases in life expectancy in most places, and are thus hard to sort out. Direct effects are nonetheless evident from changes in heat, cold, storms (including hurricanes and tornadoes), drought, and wild fires. The drought-related heat wave in Europe in summer 2003, for instance, killed tens of thousands of people. On the other hand, fewer cold waves reduce mortality. Safe drinking water is jeopardized by more intense rains and runoff which can lead to contamination and increased microbial loading. Hence water-borne diseases have been observed to increase. Also drought and observed earlier snow melt and runoff jeopardize water supplies, especially in summer.

Changes in temperatures, humidity and precipitation also affect the environment for pests and disease, and have increased risk of certain problems in plants, animals and

humans. Air quality is changing from pollution, and ground level ozone and particulate matter are increasing in most regions, with increased hospital admissions for respiratory disease. Particular human health problems have occurred with spread of West Nile virus, which requires warmer temperatures to survive.

Concluding comments

The reality of anthropogenic climate change can no longer be debated on scientific grounds, a fact widely recognized by international science academies and professional scientific organizations. For instance, the American Association for the Advancement of Science states "The scientific evidence is clear: global climate change caused by human activities is occurring now, and it is a growing threat to society". The imperative is to act aggressively to reduce carbon emissions and dependency on fossil fuels, creating instead a sustainable and clean energy future. Although mitigation actions taken now mainly have benefits 50 years and beyond because of the huge inertia in the climate system, earlier cuts in emissions of carbon dioxide would have a greater effect in reducing climate change than comparable reductions made later. Still, society will have to adapt to climate change, including its many adverse effects on human health and ecosystems. The projected rate of change far exceeds anything seen in nature in the past 10,000 years and is therefore apt to be disruptive in many ways.

This opportunity to address the Select Committee concerning the science of global climate change is a distinct honor and privilege. I look forward to answering your questions.

The CHAIRMAN. Thank you, Doctor, very much.

Our second witness today is Dr. James McCarthy. Dr. McCarthy is a professor of biological oceanography at Harvard University. He served as co-chair of the Impacts, Adaptation, and Vulnerability Portion of the IPCC report published in 2001. He was also one of the lead authors on the Arctic Climate Impact Assessment. Dr. McCarthy received his Ph.D. from Scripps Institution of Oceanography. He is a former president of the American Association for the Advancement of Science, a fellow of the American Academy of Arts and Sciences, and a foreign member of the Royal Swedish Academy of Sciences.

We welcome you, Dr. McCarthy. Whenever you feel ready, please begin.

STATEMENT OF JAMES J. McCARTHY, PH.D.

Mr. MCCARTHY. Thank you.

Good morning, Chairman Markey, Ranking Member Sensenbrenner, and other members of the committee.

You asked us to address four questions.

The CHAIRMAN. Could you move that microphone in just a little closer, please?

Okay, thank you.

Mr. MCCARTHY. You asked that we address four questions. And I have done this in my testimony, and so I will very briefly run through my responses to those questions.

You asked that we talk about observations. How do we know that the climate is changing? What evidence do we have for attribution of these changes? And what are some of the anticipated impacts? And then, finally, you asked how climate scientists should be furthering the understanding of climate change?

So, I am an oceanographer. I have worked on all the oceans in my career. Ocean temperatures are changing in a way that could not have been imagined when I began my career as an oceanographer. I distinctly remember a day in 1986 when someone walked into my office and showed me the first graph suggesting ocean temperatures were changing.

Now people ask, how confident are we of these changes? If we look at the first slide, and these are the four graphics from my testimony, this shows the array of sensing instruments that are employed in the ocean today. This is a snapshot from last month. There are over 3,000 buoys that have sensing devices that profile, move up and down in the upper ocean to depths of 6,000 feet, and they report their data by satellite to shore stations. So this is how we are tracking today the changes in ocean temperature, and are very confident that they are responding to the climate system.

We know now that more than 90 percent of the heat that has been trapped in the atmosphere by the accumulated greenhouse gases is being stored in the ocean. The oceans are an intricate part of the climate system.

Now I would like to say something about sea level rise, which has already been introduced by my colleague. In 2001, when the IPCC report was put to bed, it was estimated that sea level rise over the present century would be relatively modest, perhaps as small as 12 to 24 inches. But it was also not known how rapidly

ice in Greenland and ice in the Antarctic could contribute to sea level rise. If you thought of a block of ice sitting on the counter and imagined turning up the temperature of the room, you would imagine it would melt faster; that would be true. But what we didn't understand is how it could become unstable and begin to lose ice to the ocean, and once in the ocean, the ocean is warmer than the ice, it would melt even more rapidly.

So if we look at estimates of sea level rise today, first, if you look at the next graph, you can see, if you go back to 1990, which is where the three dotted lines begin to span off to the right, these were the projections in 1990 of sea level rise for the IPCC. And you notice the red lines, which are the tide gauge data referred to earlier by Congressman Speier, we see the blue line. These are the data which are now available from satellites, which are tracking ocean elevation far more precisely for global computation than local estimates at tide gauge stations. And you will see that the blue line extends up to the upper part of this curve, and the three bounds, the upper, the middle, and the lower lines, or the dotted line, were the estimates in 1990. In other words, the IPCC underestimated quite starkly the rise in sea level.

We now know data, just in the last handful of years, how rapidly Greenland and Antarctica are changing. And best estimates of sea level rise now for this century are between 2.5 and 3 feet.

If you look at the next slide, you can see in the bars at the bottom, the lower, higher emission, and even higher emission scenarios for the IPCC, and on the left are the sea level rise that was projected in feet. And the circles at the top show what would be estimated today if you included the melt from Greenland and Antarctica. And from this, you would see this estimate I gave of 2.5 or 3.5 feet.

Next I would like to comment briefly on ocean chemistry. The carbon dioxide added to the ocean changes the balance in the mineral composition of what we call the carbonate system. Organisms in the ocean that make shells, whether they are snail-like animals that swim, there are one-celled plankton that have shells, we call them foraminifera and coccolithophorids, or corals; all make these shells out of calcium carbonate. Calcium carbonate is in a very, very delicate balance in the ocean. The organism is taking the dissolved constituents out of the water, making its hard shell, but the water is trying to pull it back in the solution and trying to redissolve it. The organism is constantly working to excrete material; the ocean is trying to dissolve it. As you add carbon dioxide to the ocean, you change the composition, change the relationship, with this buffering system. It becomes more corrosive. That is referred to as ocean acidification.

We know now the rates at which this is changing are faster than any time, any time in the history that we can reconstruct over the last several million years. Now, just finally, I am going to say something about the distribution of organisms. This is very close to where Congressman Markey and I live, which shows in the lower graph how the distribution of cod would change with the warming that is expected.

Let me just conclude by saying that these changes are in the scientific literature beyond all bounds of historic record. And I would

just like to comment with an opinion, in response to your last question, that I think that climate scientists have an obligation to do everything we can to help convey clearly this message to the public. Thank you.

[The statement of Mr. McCarthy follows:]

Testimony of

James J. McCarthy

Alexander Agassiz Professor of Biological Oceanography

Harvard University

before

The Select Committee on Energy Independence and Global Warming

U.S. House of Representatives

on

The Foundation of Climate Science

6 May 2010

Chairman Markey, Ranking Member Sensenbrenner, and Members of the Committee, thank you for this opportunity to testify today regarding climate science. I am the Alexander Agassiz Professor of Biological Oceanography, at Harvard University, where I teach courses on ocean and climate science. The ocean covers seventy percent of the Earth's surface and it is an integral part of Earth's climate system. I will attempt to address the four questions raised in the Chairman's letter of invitation through the lens of ocean science

For the past three decades my research has delved into many aspects of climate science. In addition, I have been involved in the planning and implementation of several climate science research programs and assessments of climate science. From 1997 to 2001, I co-chaired Working Group II of the Intergovernmental Panel on Climate Change (IPCC), which had responsibilities for assessing impacts of and vulnerabilities to global climate change in the Third IPCC Assessment. I was also an author on the 2005 Arctic Climate Impact Assessment, the 2007 Northeast Climate Impact Assessment, and the 2009 U.S. government report on Global Climate Change Impacts in the United States. I am Past President of the American Association for the Advancement of Science, and currently the Chair of the Board of the Union of Concerned Scientists.

My research has taken me to all the oceans to study how plankton production is affected by physical processes, in order to better understand the ocean's carbon and nitrogen cycles. I have been particularly interested in regions where seasonal climate processes result in strong mixing events. This includes the high North Atlantic, the Southern Ocean surrounding Antarctica, and the monsoonal system in the western Indian Ocean. I have also studied areas where episodic climate cycles strongly affect ocean processes, such the upwelling regions off the coasts of California, Peru, and Ecuador, and the central Pacific Ocean each of which is influenced by the El Niño – Southern Oscillation cycle. At times I have also conducted research in areas that show less seasonal and interannual variability, such the Sargasso Sea and the Caribbean Sea.

The atmosphere, land and surface ocean are heated by energy from the sun. The amount of energy reaching the surface at the Equator is greater than at the Poles, and circulation in both the atmosphere and ocean transport heat from the warmer low latitudes to the cooler high latitudes. But, surface ocean temperature is also strongly influenced by mixing, partly driven by winds, that brings deeper, cooler, water to the surface, a process known as upwelling. This is what causes surface waters to be cooler in the western Indian Ocean during the SW monsoon, along the Equator in the Eastern Pacific Ocean, and in certain regions along the western sides of continents, such as the coasts of California and Oregon during spring. Documenting significant change in surface ocean temperatures requires full knowledge of this natural variability

I. Observed Changes in Ocean Climate and Chemistry

A. Ocean Temperature

In the early 1980s land surface data in some regions were beginning to indicate unusual warming. A trend in warming or cooling of the surface ocean would, however, be much harder to detect due to the aforementioned effects of winds and Earth's rotational forces on ocean currents and vertical mixing.

In 1986, I took a leave from Harvard to start a new scientific journal and a new international research program. I had the good fortune to be hosted during that year at the National Center for Atmospheric Research in Boulder, CO. I vividly recall a day when a colleague walked into my office with a new graph showing surface ocean temperature over the past several decades, and said, "Jim, it looks like the oceans are warming". It was during this same year that Antarctic ice core data were first published showing that the cycle of atmospheric CO_2 content varies in concert with temperature over the hundred thousand year glacial – interglacial cycle. Books on the marine carbon cycle had to be rewritten. We could never again look at climate, with its manifestations in atmospheric and ocean physics, and the ocean carbon cycle, as being independent in any significant way. They are inextricably linked, and each is highly sensitive to perturbations in the other.

So, while it had long been known that variation on seasonal and interannual time scales plays out in upper-ocean physical and biogeochemical processes, and that these cycles are highly coupled, it has only been in the past few decades that we have fully appreciated the coupling of these processes on time scales of hundreds of thousands of years. From this fact flows the realization that a significant change in atmospheric temperature or greenhouse gas concentrations can cause reverberations throughout the entire climate system.

Just how much change in the ocean would a scientist expect to see over the course of a career in ocean science? Until a few decades ago, the guess would have been – not very much. The oceans are vast, with an average depth of more than 12,000 feet. It takes about a thousand years for ocean currents to fully mix the oceans, and because of strong density gradients most of the deep ocean is influenced only very slowly by what happens in the surface ocean or the atmosphere. But more significantly, we had decades, and in some cases more than a century, of data indicating relative constancy in deep ocean conditions. If you told a skilled hydrographer the depth, salt content, and temperature of a seawater sample, the hydrographer could tell you where the sample was collected. Relationships between depth, salt content, and

temperature that had been established over many decades defined a climatology for the ocean. This climatology is now changing more rapidly than could have been imagined when I began my career as an oceanographer.

Levitus et al. (2000) was one of the first to assemble a data set documenting the global extent of changes in ocean temperature to depths of 2000 feet across all ocean basins. We now know from ocean temperature data that since the 1960s the ocean has absorbed more than 90% of the heat trapped by greenhouse gasses that have accumulated in Earth's atmosphere due to human activity over the past century. Confidence in these findings is further validated as instrumented ocean buoys profile the ocean to depths of 6000 feet every ten days, and report their data via satellite to shore stations. Fig. 1 shows the locations of the 3255 Argo floats deployed in February 2010, and the shared international commitment to this effort.

B. Sea level rise

As heat from a warming atmosphere is transferred to the ocean, ocean volume increases and sea level rises. A warming atmosphere also causes land ice to melt, and if this water reaches the ocean, it too contributes to sea level rise. On this subject we have learned a great deal in the last decade as changes in ice and sea level have sped up.

In 2001, the IPCC could not identify any body of science that pointed to the likelihood of a large reduction in Greenland ice during the present century (Anisimov et al. 2001). Since then, several outlet glaciers along the perimeter of Greenland have begun retreating and thinning at unusual rates. The increasing frequency of "icequakes" correlated with glacier movement indicates that an acceleration of ice loss is now under way (Ekström et al. 2006). Satellite studies demonstrate that extensive thinning has expanded to even the highest latitudes on the northwest perimeter of Greenland (Pritchard et al. 2009). Records of numbers of summer melting days on the surface of the Greenland ice sheet continue to be broken. The trend in the total area of melt during 1979– 2008 is an increase of

approximately 6000 square miles per year. To put the ice on Greenland in perspective, it is equivalent to a layer of ice 1000 ft thick extending across the contiguous United States.

In 2001, the IPCC also reported that "[w]ithin present uncertainties, observations and models are both consistent with a lack of significant acceleration of sea level rise during the 20th century" (IPCC 2001). But a new study by Rahmstorf *et al.* (2007) has now demonstrated that sea-level rise has accelerated since 1990. This observed rate of increase is at the upper end of what was projected from the early IPCC scenarios (Fig. 2).

The more recent 2007 IPCC report projected 12 – 24 inches of sea-level rise by 2100. These estimates do not preclude higher rates of rise due to increased rates of ice loss on Greenland and Antarctica. Although the IPCC authors were aware of publications relating to recent changes in Greenland and Antarctic ice, they lacked confidence that they could extrapolate meaningfully from these data to future sea-level rise. Rahmstorf (2007) used a semi-empirical relationship from 20th-century temperature and sea-level changes to project future sea-level rise from the IPCC scenarios for warming and derived an estimate of sea-level rise of about 2 – 4.5 feet for 2100 relative to the 1990 level. Using current outlet glacier discharge rates for Greenland to improve on the IPCC 2007 projections, Pfeffer *et al.* (2008) estimated a sea level rise between 2.5 and 6.5 feet. The practical consequence of these studies is that coastal planners should plan for sea level rise that could reach 3 or more feet this century. A summary graphic showing IPCC (2007) and more recent sea level projections is shown in Fig. 3.

C. Ocean Chemistry

When Svante Arrhenius made calculations in the 1890s regarding the influence of fossil fuel combustion on climate he included estimates for the fraction of the released CO_2 that would be absorbed by the oceans. But it was a century later, in the 1990s, that scientists had the first inventory of CO_2 in the oceans, and could *begin* to

document changes in ocean chemistry. We now know that the oceans have absorbed about a third of the CO_2 released with the combustion of fossil fuel since the industrial revolution. When CO_2 is added to water it forms carbonic acid. However, an excess of carbonate and bicarbonate ions in seawater help to buffer ocean waters against large changes in the acid/base balance, and historically have tended to keep the seawater basic with a pH (the measure of acid/base balance) of about 8.2. (The neutral point of this scale is 7, with < 7 being acidic and >7 being basic.) Carbonate buffering in the ocean provides favorable conditions for the formation and maintenance of calcium carbonate skeletal material, common in plant and animal plankton, mollusks, corals, etc. Under acid conditions calcium carbonate shells dissolve. Carbonate buffering in the ocean helps to explain why organisms with calcium carbonate shells are far more successful in marine than in freshwater environments.

As theory and laboratory experiments would predict, trends of declining ocean pH are now evident, and are certain to continue as CO_2 rises. Organisms in the ocean evolved over hundreds of thousands and millions of years, and CO_2 in the atmosphere is now higher than it has likely been any time in the last several million years. Thus in the genome of today's marine species there is no recent "memory" of conditions similar to those that these organisms are now experiencing.

An important report on this topic was released by The Royal Society in 2005, *Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide.* More than a dozen models of the ocean carbon cycle were used to examine the effects of future emissions of carbon dioxide on marine organisms. The high latitude oceans around Antarctica and in the north, especially the subarctic Pacific, are areas where this effect will occur sooner for organisms that make shells of the aragonite mineral form of calcium carbonate. Early effects, such as thin and fragile shells in these high-latitude ecosystems will likely be evident within decades (Orr et al., 2005). Small aragonite shelled mollusks in the plankton, known as Pteropods, are of particular concern, as they are an important component of the diet of salmon.

II. Evidence for Attribution to Human Activities

Barnett et al. (2005) demonstrated that the observed changes in ocean heat-content since the 1960s are consistent with what would be expected from the accumulation of greenhouse gases from human activities, and that these patterns in warming cannot be solely explained by natural cycles, solar cycles or volcanic activity. Vast numbers of studies have corroborated these analyses, and there is no credible challenge to their validity.

Multiple paths of research provide consistent and irrefutable evidence that the CO_2 increase in the atmosphere since the early 1800s is arising from human activities. Initially land use caused much of the change - forest clearing and soil tilling practices facilitate the conversion of living and dead organic material to CO_2, and its release to the atmosphere. With a growing population and its needs for energy for heating, manufacturing, and lighting and increasing dependence on the internal combustion engine, fossil fuel combustion became the dominant, human-caused source of CO_2 release to the atmosphere. Stable and radioactive isotopes of carbon provide unambiguous evidence that the CO_2 accumulating in the atmosphere is due to human activities.

III. Impacts of Ocean Warming

A. Species Distributions

Many marine species, plant and animal plankton, migratory fish, bottom fish, shell fish, etc. show high sensitivity to temperature in their distributions. Species that depend on coldwater or predicable temperatures will be greatly affected. For species that live primarily on the bottom, or are dependent on resources that do, the cool bottom waters can be critical in defining a suitable habitat. Some shoals, such as Georges Bank, just east of Cape Cod provide a unique habitat for certain species – such as the Atlantic cod. The depth of the Bank and the ocean currents that swirl around it provide an environment that nourishes young cod very successfully. But the success and survival rates for cod are highly sensitive to temperature. Atlantic cod populations are generally not found where bottom temperatures exceed 54°F.

Moreover, where average annual bottom temperatures are above 47°F there is diminished and survival of young fish. Over the past few decades the cod populations have moved northward as ocean waters have warmed. Projections of warming for high global warming emissions indicate that both the 47°F and the 54°F thresholds in the vicinity of Georges Bank will be met or exceeded in this century.

The American lobster, another commercially important species in New England waters, is also known to be sensitive to temperature. It is especially susceptible to disease at the southern (higher temperature) extent of its range. With warming the center of production for lobster would likely move further north, in the Gulf of Maine and waters off the Maritime Provinces, but overall its stock may not decline significantly (Frumhoff et al. 2007). These are but two examples of what can be expected with continued warming of waters all along the coasts of the US.

B. Sea Level Rise

A sea-level rise of 2.5 to 6.5 feet during this century would be of enormous consequence for lives, livelihoods, and property in coastal regions across the globe. Major cities, large portions of nations, indeed entire island nations will become uninhabitable. With additional tropical storm intensity, damage from any rise in sea level becomes intensified.

Changes in sea level experienced at a particular location along the coast depend not only on the increase in the global average sea level, but also on changes in regional currents and winds, proximity to the mass of melting ice sheets, and on the vertical movements of the land due to geological processes. Thus regional variations in relative sea-level rise are to be expected in the future. For example, assuming historical geological movement continues, a 2-foot rise in global sea level by the end of this century would result in a relative sea-level rise of 2.3 feet at New York City, 2.9 feet at Hampton Roads, Virginia, 3.5 feet at Galveston, Texas, and 1 foot at Neah Bay in Washington state.(Karl et al. 2009)

As population continues to increase in coastal regions at a greater rate than the overall population increase, and with an expectation that this trend will continue, the combined effects of future climate change and socioeconomic development means that coastal storm damage will be that much greater for coastal populations and infrastructure. (Karl et al. 2009)

A significant fraction of America's energy infrastructure is located near the coasts, from power plants, to oil refineries, to facilities that receive oil and gas deliveries. One-third of the national refining and processing capacity lies on coastal plains adjacent to the Gulf of Mexico. Several thousand offshore drilling platforms, dozens of refineries, and thousands of miles of pipelines are vulnerable to damage and disruption due to sea-level rise and the high winds and storm surge associated with hurricanes and other tropical storms. In the Gulf Coast area alone, an estimated 2,400 miles of major roadway and 246 miles of freight rail lines are at risk of permanent flooding within 50 to 100 years as global warming and land subsidence (sinking). Seven of the 10 largest ports (by tons of traffic) are located on the Gulf Coast.(Karl et al. 2009)

A summary statement in the U.S Climate Change Research Program (2009) report on sea level rise describes well the urgency of new work on this topic:
The prospect of accelerated sea-level rise and increased vulnerability in coastal regions underscores the immediate need for improving our scientific understanding of and ability to predict the effects of sea-level rise on natural systems and society. These actions, combined with development of decision support tools for taking adaptive actions and an effective public education program, can lessen the economic and environmental impacts of sea level rise.

C. Declining Ocean pH aka Ocean Acidification

A report released by NOAA in 2008, points to concerns about ecosystem implications for many species, notably those of economic importance with commercial and recreational harvests of fish and shellfish and associated tourism. There may also be ecosystem implications of a declining ocean pH for animals that do not have shells. From laboratory studies it is known that many physiological processes, such as the oxygen binding capacity in squid blood, are to sensitive to changes in pH. We have no idea as to how far-reaching the effects of reduced pH in the ocean might be on these processes. But given that the CO_2 captured by the ocean today will be retained for thousands of years, this is not an experiment that we should welcome on our planet. There is no known practical way to reverse the current trend towards lower ocean pH. But we can hope to slow and ultimately arrest this trend with substantial reductions in CO_2 emissions before the consequences for important marine species become grave.

IV. Public Understanding of Climate Change

Scientific knowledge is always evolving. Science progresses because scientists constantly question every aspect of scientific understanding. New findings, seemingly credible, and perspectives that prevailed for decades are sometimes proven to be wrong. The process of science is one of always questioning and challenging both the new and the well-established findings.

A scientist is always asking these questions: Does evidence adequately support the prevailing view as to how a particular process works? Is there a contradictory body of evidence? Is there an alternative explanation that is also, or perhaps even more, consistent with the highest quality evidence?

All good scientists ask these questions about everything they have either been taught or have discovered themselves. We train our students to go beyond what we can teach them – to use newer methods for gathering evidence, to subject their data to ever more sophisticated analyses, to always keep their mind open to other views

in order to advance, in the most genuine sense of the word, the science. The very best students will discover errors and inadequacies in what their mentors thought to be the best understanding of the natural world.

There are many examples of dramatic shifts in prevailing views in science. In my scientific lifetime examples that come readily to mind are the discovery of plate tectonics in the 1960s, the linking of an asteroid impact to extinctions at the Cretaceous–Tertiary boundary (65 million years ago) in the early 1980s, and the role of chloroflurocarbons in the depletion of ozone in the Antarctic stratosphere in the late 1980s. In each of these cases even though a consensus among experts emerged within a few years of the finding of key evidence, it is noteworthy that a small number of experts, some very senior and distinguished, remained unconvinced for the rest of their lives that the new mainstream view was correct.

For many of us in ocean science the compelling evidence for human-caused climate change came with the observations of deep ocean warming, the ice core data linking Earth's past temperature and atmospheric greenhouse gas content, the acceleration in sea level rise, the abrupt melting of land ice and ice shelves that had been in place for many thousands of years, and an ocean-wide decline in pH. All of these are linked, and can only be consistently explained by an unusual rate of greenhouse gas release to the atmosphere.

The idea that greenhouse gases from fossil fuel combustion affect climate, which was studied by Arrhenius a century ago and developed further by Calendar a half century later, is correct. Interestingly, Arrhenius did not anticipate the explosive growth in human population and our increasing demands for energy - he thought that it would take 3 millennia rather than a just a century to double the pre-industrial atmospheric CO_2 concentration.

State of the art fully coupled climate models can now simulate the natural processes that affect climate (solar cycles, volcanoes, and internal cycles such as the El Niño –

Southern Oscillation) and the human-caused processes that affect climate (greenhouse gases and aerosols) to show the relative importance of each of these components in the climate of the past and present. Using assumptions about trends in population, type of energy used, etc. these same models can make projections about future climate. One very clear finding from these studies is that one of the largest uncertainties about future climate relates to the choices that we and our children will make regarding energy use. The more energy we use and the more dependent we are on CO_2-emitting sources of energy, the more climate will change.

In the public media there is a lot of misinformation and, unfortunately even disinformation, about climate. Many myths about climate change are exposed for what they are in publications like the Royal Society's 2007 *Climate Controversies, a Simple Guide.* Most National Academies and professional societies have issued statements about climate science. The American Meteorological Society, for example, in a 2007 two-page statement says:
Despite the uncertainties noted above, there is adequate evidence from observations and interpretations of climate simulations to conclude that the atmosphere, ocean, and land surface are warming; that humans have significantly contributed to this change; and that further climate change will continue to have important impacts on human societies, on economies, on ecosystems, and on wildlife through the 21st century and beyond.

Last October scientific organizations in the United States issued a common statement that says in part:
Observations throughout the world make it clear that climate change is occurring, and rigorous scientific research demonstrates that the greenhouse gases emitted by human activities are the primary driver.... If we are to avoid the most severe impacts of climate change, emissions of greenhouse gases must be dramatically reduced.
(Appendix 1)

To this point in my testimony I have dealt with climate science - now I offer an

opinion. Climate scientists have a responsibility to use every opportunity we have to share our understanding of climate science with the public and with policy makers across the land. Some of us have such opportunities as professional educators, and all of us need to be receptive to invitations to talk to non-scientists in business organizations, religious groups, etc. This is what brings me here today. Thank you for this opportunity.

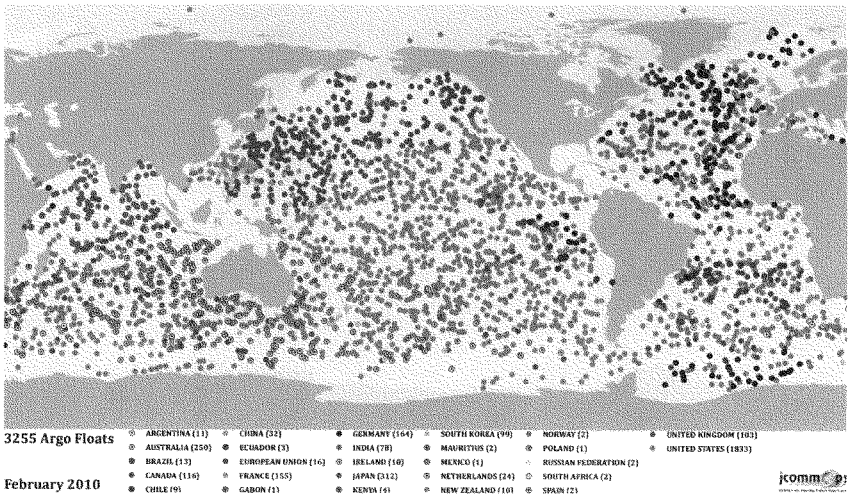

Fig. 1. The global distribution of Argo floats in February 2010. They profile the ocean to 6000 ft. every ten days and relay their data to shore stations. (http://www.argo.ucsd.edu/)

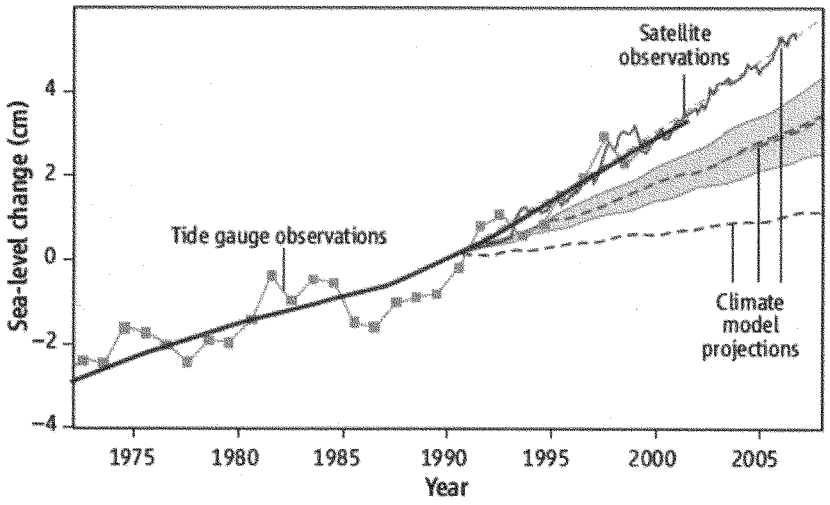

Fig. 2. Sea level Rise. Sea-level data based on tide gauges (annual, red) and satellite altimeter measurements (3-month data spacing, blue, up to mid-2006), and their trends. McCarthy (2009, adapted from Pfeffer et al. 2008)

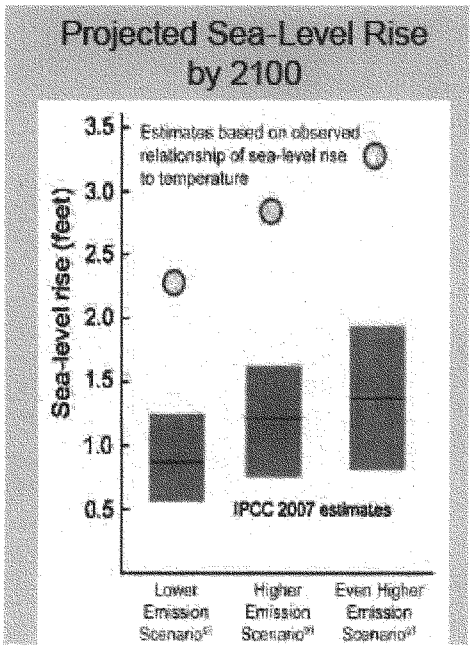

Fig. 3. Estimates of sea-level rise by the end of the century for IPCC 2007 projections excluding changes in ice sheet flow (blue bars), and more recent estimates (blue circles) using the observed relationship of sea-level rise to temperature.

Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.), Cambridge University Press, 2009.

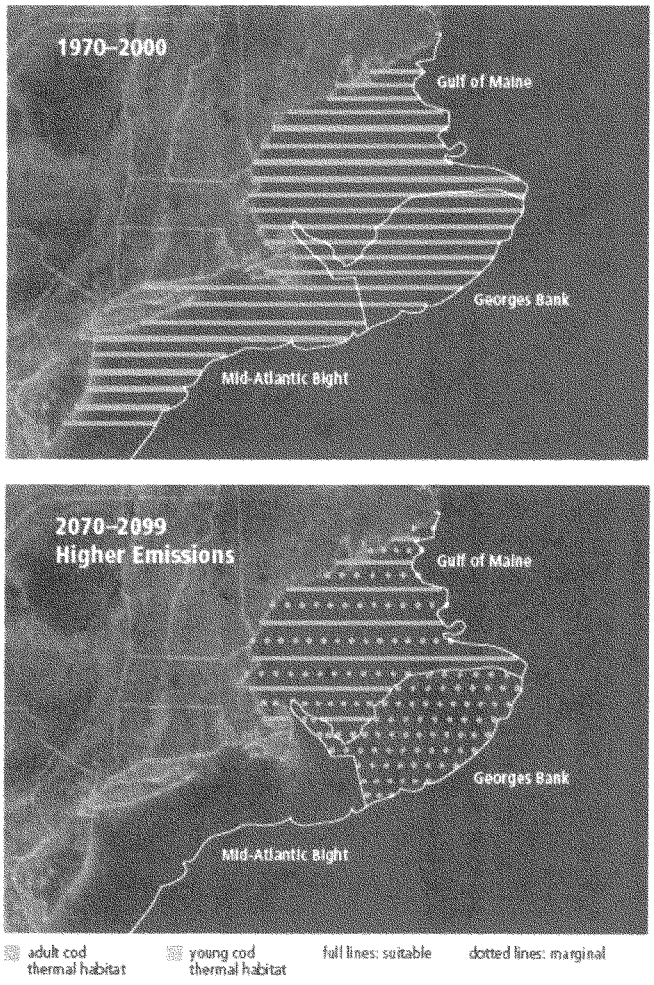

Fig. 4. Present and projected habitats for Atlantic Cod. The Mid-Atlantic Bight is currently too warm for reproductive success, hence young cod are restricted to Georges Bank and the Gulf of Maine. With projected warmer conditions late in this century, young cod will only be viable further north in the Gulf of Maine, and the adult cod habitat on Georges Bank will be marginal. (Frumhoff et al. 2007)

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Appendix I

October 2009 letter from the heads of 18 U.S. science organizations to members of the U.S. Senate regarding climate science (three attached pages).

October 21, 2009

American Association for the Advancement of Science

American Chemical Society

American Geophysical Union

American Institute of Biological Sciences

American Meteorological Society

American Society of Agronomy

American Society of Plant Biologists

American Statistical Association

Association of Ecosystem Research Centers

Botanical Society of America

Crop Science Society of America

Ecological Society of America

Natural Science Collections Alliance

Organization of Biological Field Stations

Society for Industrial and Applied Mathematics

Society of Systematic Biologists

Soil Science Society of America

University Corporation for Atmospheric Research

Dear Senator:

As you consider climate change legislation, we, as leaders of scientific organizations, write to state the consensus scientific view.

Observations throughout the world make it clear that climate change is occurring, and rigorous scientific research demonstrates that the greenhouse gases emitted by human activities are the primary driver. These conclusions are based on multiple independent lines of evidence, and contrary assertions are inconsistent with an objective assessment of the vast body of peer-reviewed science. Moreover, there is strong evidence that ongoing climate change will have broad impacts on society, including the global economy and on the environment. For the United States, climate change impacts include sea level rise for coastal states, greater threats of extreme weather events, and increased risk of regional water scarcity, urban heat waves, western wildfires, and the disturbance of biological systems throughout the country. The severity of climate change impacts is expected to increase substantially in the coming decades.[1]

If we are to avoid the most severe impacts of climate change, emissions of greenhouse gases must be dramatically reduced. In addition, adaptation will be necessary to address those impacts that are already unavoidable. Adaptation efforts include improved infrastructure design, more sustainable management of water and other natural resources, modified agricultural practices, and improved emergency responses to storms, floods, fires and heat waves.

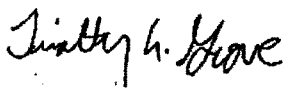
We in the scientific community offer our assistance to inform your deliberations as you seek to address the impacts of climate change.

[1] The conclusions in this paragraph reflect the scientific consensus represented by, for example, the Intergovernmental Panel on Climate Change and U.S. Global Change Research Program. Many scientific societies have endorsed these findings in their own statements, including the American Association for the Advancement of Science, American Chemical Society, American Geophysical Union, American Meteorological Society, and American Statistical Association.

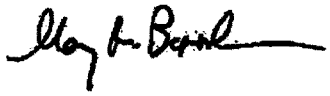
American Association for the Advancement of Science
1200 New York Avenue, NW, Washington, DC 20005 USA
Tel: 202 326 6600 Fax: 202 289 4950 www.aaas.org

Alan I. Leshner
Executive Director
American Association for the
Advancement of Science

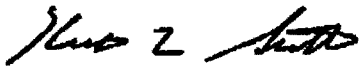
Thomas Lane
President
American Chemical Society



Timothy L. Grove
President
American Geophysical Union

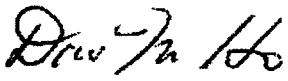


May R. Berenbaum
President
American Institute of Biological
Sciences

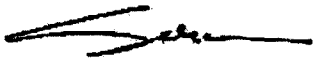


Keith Seitter
Executive Director
American Meteorological Society

Mark Alley
President
American Society of Agronomy

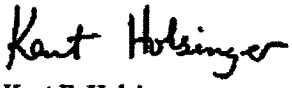


Tuan-hua David Ho
President
American Society of Plant Biologists



Sally C Morton
President
American Statistical Association

Lucinda Johnson
President
Association of Ecosystem Research
Centers



Kent E. Holsinger
President
Botanical Society of America

Kenneth Quesenberry
President
Crop Science Society of America

William Y. Brown
President
Natural Science Collections Alliance

Douglas N. Arnold
President
Society for Industrial and Applied Mathematics

Paul Bertsch
President
Soil Science Society of America

Mary Power
President
Ecological Society of America

Brian D. Kloeppel
President
Organization of Biological Field Stations

John Huelsenbeck
President
Society of Systematic Biologists

Richard A. Anthes
President
University Corporation for Atmospheric Research

The CHAIRMAN. Thank you, Dr. McCarthy, very much.

Our third witness is Lord Christopher Monckton.

He is chief policy advisor for the Science and Public Policy Institute. He holds a diploma in journalism from the University College Cardiff. He has worked as an editor at various news outlets, including the Universe, the Telegraph Sunday Magazine, Today newspaper, and the Evening Standard.

From 1982 to 1986, he was an advisor to UK Prime Minister Margaret Thatcher and gave policy advice on a variety of issues. He is the founder and director of Christopher Monckton, Limited, which consults in public administration.

We welcome you, sir. Whenever you are ready, please begin.

STATEMENT OF LORD CHRISTOPHER MONCKTON

Mr. MONCKTON. Mr. Chairman, sir, and Ranking Member Sensenbrenner, it is a pleasure to see you both again and also many other faces on your committee.

Thank you for having the courtesy to ask me to testify in front of you. I am going to testify, not of course as a scientist, because I am not one, but as a policy maker. And the role of policy makers when confronted with scientists is to know what questions to ask. And I am going to raise one or two questions now about some of the evidence you already heard.

If you look at the slide now before you, that slide purports but does not demonstrate that the rate of global warming is itself increasing. This is taken from the IPCC's 2007 report where it appears three times, large and in full color. However, it relies on a bogus statistical technique which is applying multiple trend lines to a single stochastic data set. And if you choose your starting and ending points carefully enough, you can make it go in any direction you want.

This graph is regularly relied upon by Mr. Pachauri of the IPCC. I challenged him on it recently in Copenhagen. It is also relied upon by the EPA. It is defective, as I shall now show.

Next one, please. This graph is the same data, but this time with different trend lines on it. From 1905 to 1945, you will see that the temperature rose faster than from 1905 to 2005. Does this mean that the rate of global warming is slowing down? No, it doesn't. But this graph and the previous one are bogus, but they are using the same technique on the same data to produce opposite conclusions. That is why the IPCC should not have used that first graph, which has been so heavily relied upon.

Let us now see what the true position is. Next slide, please. You will see, in fact, there have been three periods of quite rapid warming over the last 150 years, 1860 to 1880; 1910 to 1940; and 1976 to 2001. Those three rates of warming are exactly parallel. Recently when Senator Vitter questioned Mr. John Holdren about this, he tried to claim that the third rate of increase was greater than the other two. It isn't. They are exactly parallel at roughly 1.6 Celsius per century.

Now, we can't explain what caused the first two rapid rates of warming because we didn't have the instrumentation to find out. However, in the satellite area, to the right of the green vertical line

there, we are able to observe what caused most of the third piece of rapid warming.

Next slide, please.

And this is from a paper by Dr. Pinker and her colleagues in 2005 showing a very rapid increase in what is called global brightening, the amount of sunlight actually reaching the surface of the earth, enough global brightening, in fact, to cause a warming of 1 Celsius degree, though only .37 Celsius degrees was noticed over that 18-year period. So if anyone tries to tell you that we cannot explain the global warming over the last 30-years except by reference to carbon dioxide, this graph and many others like it in the scientific literature should suggest otherwise.

Next slide, please.

And if we now include that data from Dr. Pinker, together with the various forcings and temperature increases from the individual greenhouse gases, we will see that what we end up with is a fourfold overstatement of the rate of increase in global temperature that was actually observed if we use the IPCC's methods to calculate what the warming would have been, a fourfold exaggeration.

Next slide, please. And this result is confirmed most recently by Professor Richard Lindzen and his colleague Yong-Sang Choi in a paper published in 2009 and published again this year, showing 11 models all predicting various rates of warming from 1.4 to infinity Kelvin if you double CO2 concentration. Next slide, please. The reality however is just .7, which is less than a quarter of what the UN would predict for a doubling of CO2 concentration.

The conclusion from this is that we can explain the warming by other methods. Not very much warming is going to happen, and therefore, one should be very careful before spending money—next slide, please—on cap and trade, because even if we were to shut down the entire global economy for 23 years, all you would forestall is 1 Fahrenheit degree of global warming, even if the UN is right in estimating the amount of warming from CO2. Therefore, the correct policy is to have the courage to do nothing. You will lose nothing thereby. There are many other problems to address. I would recommend you address those and not this.

[The statement of Mr. Monckton follows:]

Testimony of The Viscount Monckton of Brenchley

Before Congress, 6 May 2010

The Select Committee, in its letter inviting testimony for the present hearing, cites various scientific bodies as having concluded that –

1. The global climate has warmed;
2. Human activities account for most of the warming since the mid-20th century;
3. Climate change is already causing a broad range of impacts in the United States;
4. The impacts of climate change are expected to grow in the coming decades.

The first statement requires heavy qualification and, since the second is wrong, the third and fourth are without foundation and must fall.

The Select Committee has requested answers to the following questions:

1. What are the observed changes to the climate system?

Carbon dioxide concentration: In the Neoproterozoic Era, ~750 million years ago, dolomitic rocks, containing ~40% CO2 bonded not only with calcium ions but also with magnesium, were precipitated from the oceans worldwide by a reaction that could not have occurred unless the atmospheric concentration of CO2 had been ~300,000 parts per million by volume. Yet in that era equatorial glaciers came and went twice at sea level.

Today, the concentration is ~773 times less, at ~388 ppmv: yet there are no equatorial glaciers at sea level. If the warming effect of CO2 were anything like as great as the vested-interest groups now seek to maintain, then, even after allowing for greater surface albedo and 5% less solar radiation, those glaciers could not possibly have existed (personal communication from Professor Ian Plimer, confirmed by on-site inspection of dolomitic and tillite deposits at Arkaroola Northern Flinders Ranges, South Australia).

In the Cambrian Era, ~550 million years ago, limestones, containing some 44% CO2 bonded with calcium ions, were precipitated from the oceans. At that time, atmospheric CO2 concentration was ~7000 ppmv, or ~18 times today's (IPCC, 2001): yet it was at that time that the calcite corals first achieved algal symbiosis. In the Jurassic era, ~175 million years ago, atmospheric CO2 concentration was ~6000 ppmv, or ~15 times today's (IPCC, 2001): yet it was then that the delicate aragonite corals came into being.

Therefore, today's CO2 concentration, though perhaps the highest in 20 million years, is by no means exceptional or damaging. Indeed, it has been argued that trees and plants have been part-starved of CO2 throughout that period (Senate testimony of Professor Will Happer, Princeton University, 2009). It is also known that a doubling of today's CO2 concentration, projected to occur later this century (IPCC, 2007), would increase the yield of some staple crops by up to 40% (lecture by Dr. Leighton Steward, Parliament Chamber, Copenhagen, December 2009).

Global mean surface temperature: Throughout most of the past 550 million years, global temperatures were ~7 K (13 F°) warmer than the present. In each of the past four interglacial warm periods over the past 650,000 years, temperatures were warmer than the present by several degrees (A.A. Gore, *An Inconvenient Truth*, 2006).

In the current or Holocene warm period, which began 11,400 years ago at the abrupt termination of the Younger Dryas cooling event, some 7500 years were warmer than the present (Cuffey & Clow, 1997), and, in particular, the medieval, Roman, Minoan, and Holocene Climate Optima were warmer than the present (Cuffey & Clow, 1997).

The "global warming" that ceased late in 2001 (since when there has been a global cooling trend for eight full years) had begun in 1695, towards the end of the Maunder Minimum, a period of 70 years from 1645-1715 when the Sun was less active than at any time in the past 11,400 years (Hathaway, 2004). Solar activity increased with a rapidity unprecedented in the Holocene, reaching a Grand Solar Maximum during a period of 70 years from 1925-1995 when the Sun was very nearly as active as it had been at any time in the past 11,400 years (Hathaway, 2004; Usoskin, 2003; Solanki, 2005).

The first instrumental record of global temperatures was kept in Central England from 1659. From 1695-1735, a period of 40 years preceding the onset of the Industrial Revolution in 1750, temperatures in central England, which are a respectable proxy for global temperatures, rose by 2.2 K (4 F°). Yet global temperatures have risen by only 0.65 K (1.2 F°) since 1950, and 0.7 K (1.3 F°) in the whole of the 20th century. Throughout the 21st century, global temperatures have followed a declining trend. Accordingly, neither global mean surface temperature nor its rates of change in recent decades have been exceptional, unusual, inexplicable, or unprecedented.

Ocean "acidification": It has been suggested that the oceans have "acidified" – or, more correctly, become less alkaline – by 0.1 acid-base units in recent decades. However, the fact of a movement towards neutrality in ocean chemistry, if such a movement has occurred, tells us nothing of the cause, which cannot be attributed to increases in CO2 concentration. There is 70 times as much CO2 dissolved in the oceans as there is in the atmosphere, and some 30% of any CO2 we add to the atmosphere will eventually dissolve into the oceans. Accordingly, a doubling of CO2 concentration, expected later this century, would raise the oceanic partial pressure of CO2 by 30% of one-seventieth of what is already there. And that is an increase of 0.4% at most. Even this minuscule and chemically-irrelevant perturbation is probably overstated, since any "global warming" that resulted from the doubling of CO2 concentration would warm the oceans and cause them to outgas CO2, reducing the oceanic partial pressure.

Seawater is a highly buffered solution – it can take up a huge amount of dissolved inorganic carbon without significant effect on pH. There is not the slightest possibility that the oceans could approach the neutral pH of pure water (pH 7.0), even if all the fossil fuel reserves in the world were burned. A change in pH of 0.2 units this century, from its present 8.2 to 8.0, even if it were possible, would leave the sea containing no more than 10% of the "acidic" positively-charged hydrogen ions that occur in pure water. If ocean "acidification" is happening, then CO2 is not and will not be the culprit.

2. What evidence provides attribution of these changes to human activities?

In the global instrumental record, which commenced in 1850, the three supradecadal periods of most rapid warming were 1860-1880, 1910-1940, and 1975-2001. Warming rates in all three periods were identical at ~0.16 K (0.3 F°) per decade.

During the first two of these three periods, observations were insufficient to establish the causes of the warming: however, the principal cause cannot have been atmospheric CO2 enrichment, because, on any view, mankind's emissions of CO2 had not increased enough to cause any measurable warming on a global scale during those short periods.

In fact, the third period of rapid global warming, 1975-2001, was the only period of warming since 1950. From 1950-1975, and again from 2001-2010, global temperatures fell slightly (HadCRUTv3, cited in IPCC, 2007).

What, then, caused the third period of warming? Most of that third and most recent period of rapid warming fell within the satellite era, and the satellites confirmed measurements from ground stations showing a considerable, and naturally-occurring, global brightening from 1983-2001 (Pinker *et al.*, 2005).

Allowing for the fact that Dr. Pinker's result depended in part on the datasets of outgoing radiative flux from the ERBE satellite that had not been corrected at that time for orbital decay, it is possible to infer a net increase in surface radiative flux amounting to 0.106 W m^{-2} $year^{-1}$ over the period, compared with the 0.16 W m^{-2} $year^{-1}$ found by Dr. Pinker.

Elementary radiative-transfer calculations demonstrate that a natural surface global brightening amounting to ~1.9 W m^{-2} over the 18-year period of study would be expected – using the IPCC's own methodology – to have caused a transient warming of 1 K (1.8 F°). To put this naturally-occurring global brightening into perspective, the IPCC's estimated total of all the anthropogenic influences on climate combined in the 256 years 1750-2005 is only 1.6 W m^{-2}.

Taking into account a further projected warming, using IPCC methods, of ~0.5 K (0.9 F°) from CO2 and other anthropogenic sources, projected warming of 1.5 K (2.7 F°) should have occurred.

However, only a quarter of this projected warming was observed, suggesting the possibility that the IPCC may have overestimated the warming effect of greenhouse gases fourfold. This result is in line with similar result obtained by other methods: for instance, Lindzen & Choi (2009, 2010 submitted) find that the warming rate to be expected as a result of anthropogenic activities is one-quarter to one-fifth of the IPCC's central estimate.

There is no consensus on how much warming a given increase in CO2 will cause.

3. Assuming *ad argumentum* that the IPCC's projections of future warming are correct, what policy measures should be taken?

Warming at the very much reduced rate that measured (as opposed to merely modeled) results suggest would be 0.7-0.8 K (1.3-1.4 F°) at CO2 doubling. That would be harmless and beneficial – a doubling of CO2 concentration would increase yields of some staple crops by 40%. Therefore, one need not anticipate any significant adverse impact from CO2-induced "global warming". "Global warming" is a non-problem, and the correct policy response to a non-problem is to have the courage to do nothing.

However, *ad argumentum,* let us assume that the IPCC is correct in finding that a warming of 3.26 ± 0.69 K (5.9 ± 1.2 F°: IPCC, 2007, ch.10, box 10.2) might occur at CO2 doubling. We generalize this central prediction, deriving a simple equation to tell us how much warming the IPCC would predict for any given change in CO2 concentration –

$$\Delta Ts \approx (8.5 \pm 1.8) \ln(C/Co)\ \text{F}^\circ$$

Thus, the change in surface temperature in Fahrenheit degrees, as predicted by the IPCC, would be 6.7 to 10.3 (with a central estimate of 8.5) times the logarithm of the proportionate increase in CO2 concentration. We check the equation by using it to work out the warming the IPCC would predict at CO2 doubling: $8.5 \ln 2 \approx 5.9$ F°.

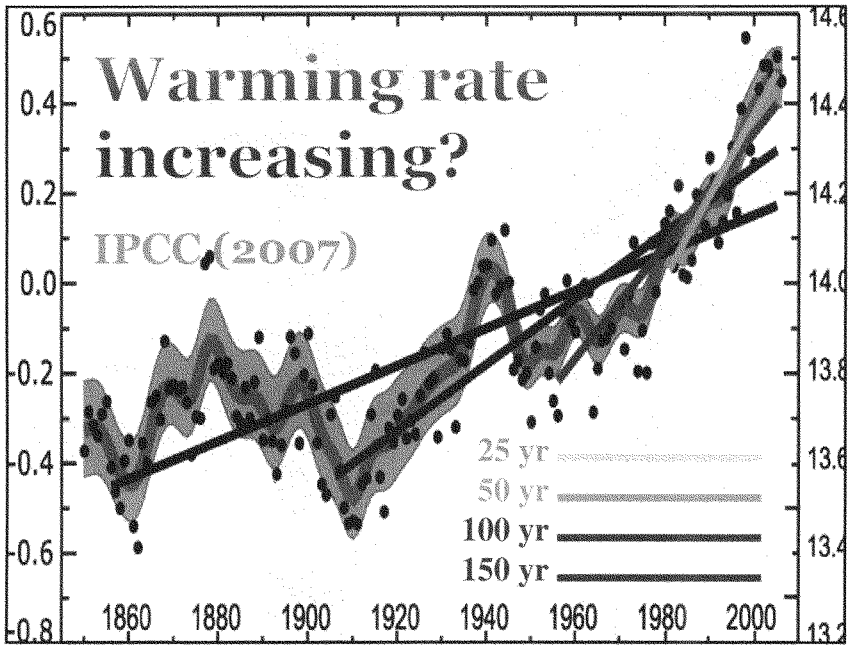
Using this equation, we can determine just how much "global warming" would be forestalled if the entire world were to shut down its economies and emit no carbon dioxide at all for an entire year. The atmospheric concentration of CO2 is 388 parts per million by volume. Our emissions of 30 bn tons of CO2 a year are causing this concentration to rise at 2 ppmv/year, and this ratio of 15 bn tons of emissions to each additional ppmv of CO2 concentration has remained constant for 30 years.

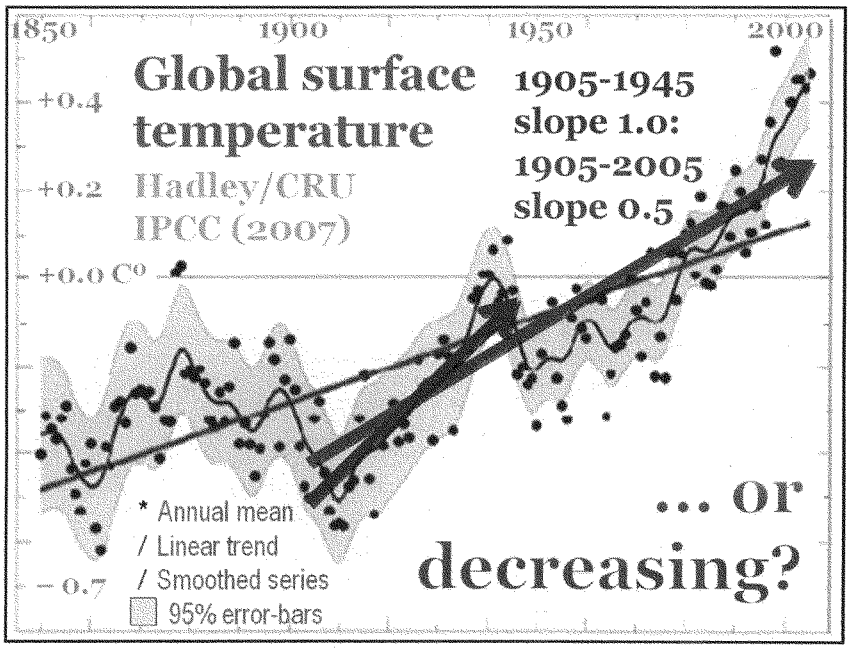
Then the "global warming" that we might forestall if we shut down the entire global carbon economy for a full year would be $8.5 \ln[(388+2)/388] = 0.044$ F°. At that rate, almost a quarter of a century of global zero-carbon activity would be needed in order to forestall just one Fahrenheit degree of "global warming".

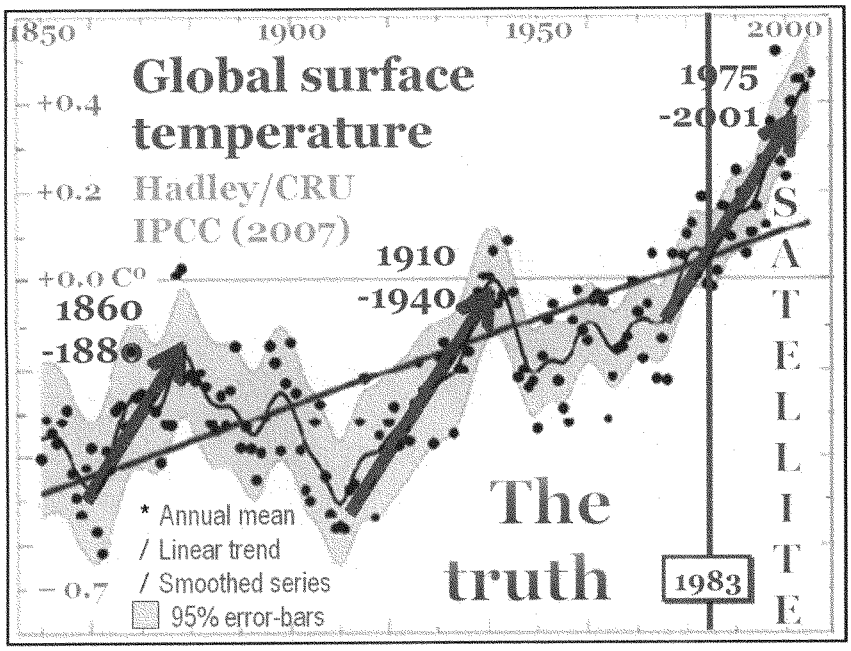
Two conclusions ineluctably follow. First, it would be orders of magnitude more cost-effective to adapt to any "global warming" that might occur than to try to prevent it from occurring by trying to tax or regulate emissions of carbon dioxide in any way.

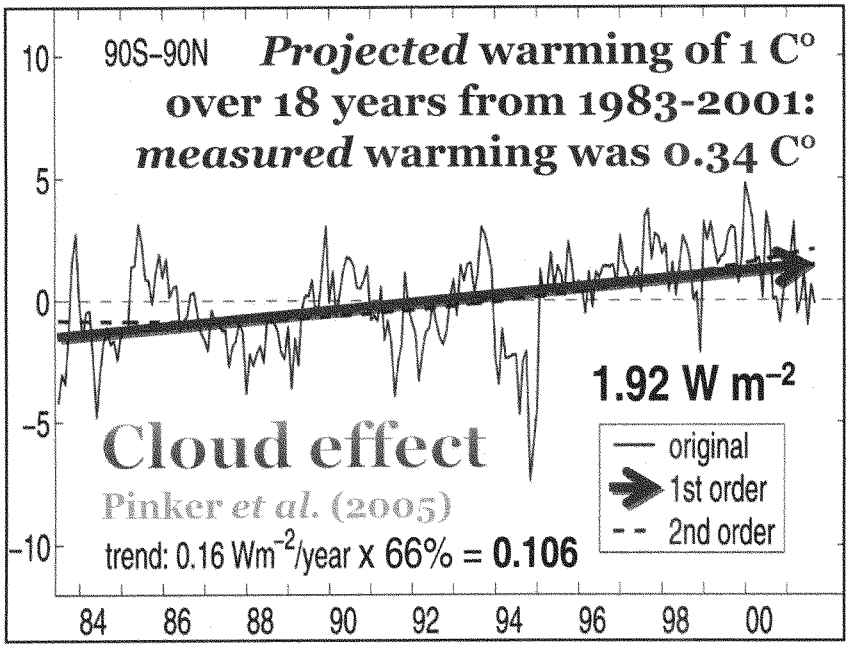
Secondly, there is no hurry. Even after 23 years doing nothing to address the imagined problem, and even if the IPCC has not exaggerated CO2's warming effect fourfold, the world will be just 1 F° warmer than it is today. If the IPCC has exaggerated fourfold, the world can do nothing for almost a century before global temperature rises by 1 F°.

There are many urgent priorities that need the attention of Congress, and it is not for me as an invited guest in your country to say what they are. Yet I can say this much: on any view, "global warming" is not one of them.

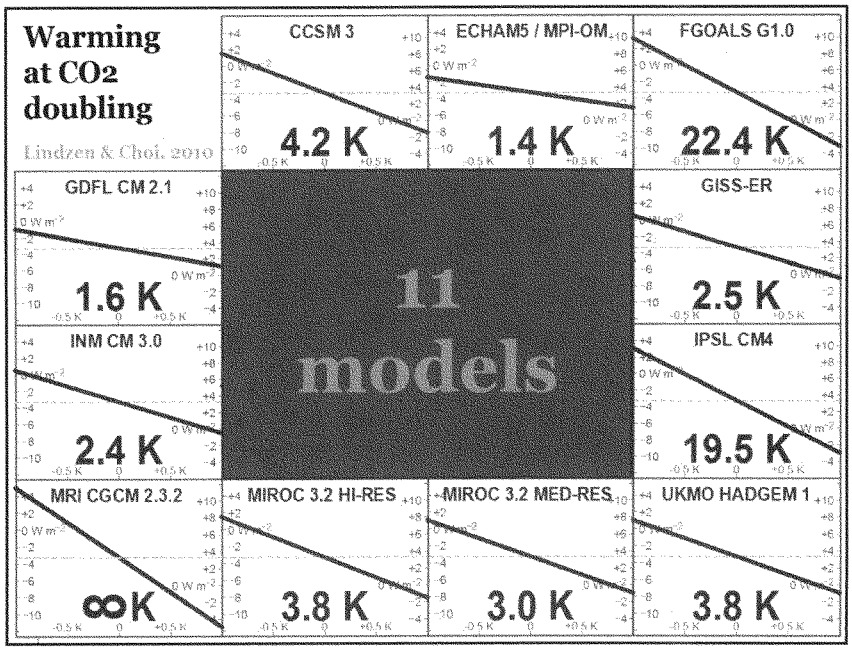

Warming rate increasing?
IPCC (2007)
25 yr
50 yr
100 yr
150 yr
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
1860
1880
1900
1920
1940
1960
1980
2000

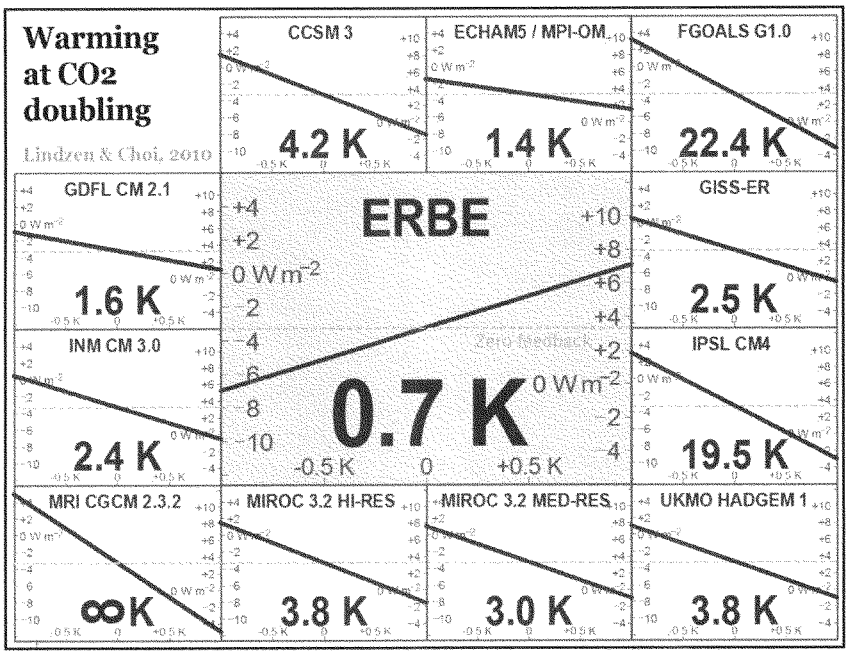

1850
1900
1950
2000
Global surface temperature
Hadley/CRU
IPCC (2007)
1905-1945 slope 1.0:
1905-2005 slope 0.5
+0.4
+0.2
+0.0 C°
-0.7
* Annual mean
/ Linear trend
/ Smoothed series
95% error-bars
... or decreasing?

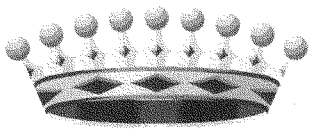

1850
1900
1950
2000
Global surface temperature
Hadley/CRU
IPCC (2007)
+0.4
+0.2
+0.0 C°
-0.7
1860
-1880
1910
-1940
1975
-2001
* Annual mean
/ Linear trend
/ Smoothed series
95% error-bars
The truth
1983
SATELLITE


90S-90N
Projected warming of 1 C°
over 18 years from 1983-2001:
measured warming was 0.34 C°
10
5
0
-5
-10
84
86
88
90
92
94
96
98
00
1.92 W m-2
Cloud effect
Pinker et al. (2005)
trend: 0.16 Wm-2/year x 66% = 0.106
original
1st order
2nd order

1983-2001	$q = 0.719$	Transient warming
Global brightening	0.185 x 2.813 x 1.917	0.995 K
Carbon dioxide	342-370 ppmv: 0.421q	0.303 K
Methane	1630-1775 ppbv: 0.054q	0.039 K
Nitrous oxide	304-312 ppbv: 0.024q	0.018 K
Ozone	Proport. to CO_2: 0.077q	0.055 K
CFC-11	183-256 pptv: 0.018q	0.013 K
CFC-12	343-541 pptv: 0.065q	0.047 K
$\Delta T_{S,proj}$	Projected warming	1.470 K
$\Delta T_{S,obs}$	Observed warming	0.337 K
Excess ratio	$\Delta T_{S,proj} / \Delta T_{S,obs}$	4.4
At CO_2 doubling	3.26 K / 4.4	0.74 K







Cap & trade cannot work

Atmospheric CO2 concentration, 2010	NOAA global CO2	**388 ppmv**
Adding 2 ppmv/yr causes warming of	UN estimate: 8.5 ln(390/388)	**0.044 F°**
No. of years to stop 1 F° warming	Based on UN est.: 0.044^{-1}	**23 years**
If warming was overstated 4.4 times	23 years x 4.4	**100 years**

The CHAIRMAN. Thank you, Lord Monckton, very much.

Our fourth witness today is Dr. Chris Field. Dr. Field is the founding director of the Carnegie Institution's Department of Global Ecology. He is also a professor of biology in environmental earth science at Stanford University. He was a coordinating lead author for the 2007 fourth assessment report of the Intergovernmental Panel on Climate Change. Currently he is co-chair of the Impacts, Adaptation, and Vulnerability Portion of the upcoming IPCC report. Dr. Field received his Ph.D. from Stanford in 1981. Among his many distinctions, he is a member of the National Academy of Sciences.

We welcome you, Dr. Field.

STATEMENT OF CHRISTOPHER B. FIELD, PH.D.

Mr. FIELD. Thank you, Chairman Markey, Ranking Member Sensenbrenner, and other distinguished members of the committee.

What I would like to do today is take a couple of minutes to talk about observed changes in the climate system. I won't be focusing at all on projections, but only things that have been observed and are clear in the record.

If I could have the slides, please.

As Dr. Hurrell has said, it is very clear that during the period when we have had good instrumental records from weather stations, the global climate has warmed. The record you see here is the land temperatures from all the world's meteorological stations. Since the late 19th century, the warming has been about 1.5 Fahrenheit, with all of the warmest years in the record in the last dozen; 2009, based on the data from the NASA Goddard Institute for Space Studies, was the third warmest year on record.

If we look at the United States, next slide, please, you see a very similar pattern but with a lot more jumpiness, as you would expect for a region that represents only about 2 percent of the planet's surface.

What I would like to do is spend a couple of minutes talking about whether there are other ways we could infer whether or not the climates change. Is nature telling us how climates change? And the next slide, please, gives an overview of what the IPCC has concluded.

We have a wide range of observations, now spanning many decades, on a tremendous number of physical and biological systems. These are things like, what are the locations of the snouts of glaciers? What are the times when buds burst or when flowers flower?

The IPCC examined a bunch of these records and concluded that there were over 29,000 statistically significant changes in these physical and biological systems. And then it said, well, which of these are changing in the direction that is consistent with climate change being the forcing, and which are changing in the direction that is not consisting? The overwhelming conclusion is that the vast majority of these natural thermometers are indicating that global warming is occurring.

Fully 94 percent of the statistically significant changes in physical systems are consistent with global warming. Fully 90 percent of the statistically significant trends in biological systems are consistent with global warming.

One couldn't look at any single one of these trends and conclude that it is proof that the climate system is warming. But when you step back and look at all 29,000, there is a tremendous level of confidence in the numbers.

Now, a lot of these trends are issues that don't necessarily have a lot of traction on human systems, but I want to focus on three that do. Next slide, please.

Most States in the American west get at least half of their water supply for summertime from snowpack. And we have seen dramatic changes in the water content of the spring snowpack, the April 1st snowpack, over the last 50 years. In the Pacific Northwest, there has been a decrease of about 30 percent. In the interior ranges, there has been a decrease of about 20 percent. This is the water supply that water-short regions depend on in order to make it through the summer, and over the last 50 years, we have seen profound decreases.

Next slide, please.

Another impact that is really clear from the data is that wildfires have been increasing across the American West and that the frequency of wildfires is strongly sensitive to temperature anomalies. What you can see in the plot is that the black line tracing annual temperature almost traces precisely the variation in the number of wildfires. Essentially, the risk of wildfires goes up dramatically as the temperature goes up.

A third observed trend I want to talk about is in the next slide. And this is the trend of observed changes in the days with the heaviest precipitation. What you can see is that, from the middle of the last century, there has been a 67 percent increase in the days with the heaviest precipitation in New England. Over all of the eastern U.S., there has been at least a 20 percent increase in days with heavy precipitation. Heavy precipitation is essentially the driving force for the kinds of floods that we have seen in Tennessee recently.

We can't look at any single weather event and ascribe it with 100 percent confidence to climate. But what we can see is that this kind of change in the climate system is increasing the risk of damaging weather events.

You know, I think that all of us would agree that you can't get in a car with a bald tire and have confidence that you are going to have an accident, but you can say that you would consider the risk unacceptable. With climate, I think it is very clear that we have now pushed the system to a point where it basically has four bald tires and a flashing "check engine" light. Thank you very much.

[The statement of Mr. Field follows:]

Statement of
Christopher B. Field, PhD[1]

Director, Department of Global Ecology
Carnegie Institution for Science[2]
Co-chair, Working Group II of the IPCC

Mailing Address:
Carnegie Institution for Science
260 Panama Street
Stanford, CA 94305

Before the
U.S. House of Representatives
Select Committee on Energy Independence and Global Warming
"The Foundation for Climate Science"

9:30 a.m., May 6, 2010
Room 2237, Rayburn House Office Building

[1] Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author and do not necessarily reflect those of the Carnegie Institution for Science or the IPCC
[2] The Carnegie Institution for Science is a not-for-profit organization dedicated to basic research for the benefit of humanity.

The Foundations for Climate Science

Introduction

I thank Chairman Markey, Ranking Member Sensenbrenner, and the other Members of the Select Committee for the opportunity to speak with you today on observed and likely future changes in climate and the contribution from human activity to those changes. My name is Christopher Field. I am director of the Department of Global Ecology at the Carnegie Institution for Science, a not-for-profit organization dedicated to basic research for the benefit of humanity. In addition, I am a professor in the Department of Environmental Earth System Science and the Department of Biology at Stanford University. Since September of 2008, I have served as co-chair of Working Group 2 of the Intergovernmental Panel on Climate Change. Working Group 2 is tasked with assessing scientific information concerning impacts of climate change, options for adaptation to climate changes that cannot be avoided, and vulnerability to climate change.

My personal research focuses on interactions among climate, the carbon cycle, and ecosystem processes, using approaches that range from ecosystem-scale climate manipulations to global climate models. I have published over 200 peer-reviewed papers in leading scientific journals, and was a coordinating lead author on the topic "North America" for the Working Group 2 contribution to the IPCC Fourth Assessment Report. I have served on many committees of the National Research Council and International Scientific Organizations. I am an elected member of the US National Academy of Sciences and the American Academy of Arts and Sciences as well as an elected Fellow of the American Association for the Advancement of Science.

In today's testimony, I will address all four of the questions in the charge, with a focus on observed impacts on land systems. All of the observations and projections concerning questions 1-3 in my statement are based on publications in peer-reviewed scientific journals or on national or international assessments of thousands of scientific sources.

Two sources are particularly valuable in providing systematic, thoroughly assessed responses to the questions. These are the 2009 report from the US Global Change Research Program, "Global Climate Change Impacts in the United States" (Karl et al. 2009) and the Fourth Assessment Report of the IPCC (IPCC 2007a, c, b). These documents provide a scientifically rich picture of a changing climate, the mechanisms that underlie observed and projected changes, impacts of climate change on individuals, ecosystems, economies, and regions, and the costs and benefits of changing practices to decrease the amount of climate change from a business-as-usual scenario. To assure consistency with these sources, the points here are either verbatim or changed only as necessary for the sake of clarity.

1. What are the observed changes to the climate system?

- Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The

global increases in carbon dioxide concentration are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture. (IPCC 2007d)

- Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. (IPCC 2007d)

- Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases. (IPCC 2007e)

- The understanding of anthropogenic warming and cooling influences on climate has improved since the IPCC Third Assessment Report, leading to very high confidence that the global average net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W m^{-2}. (IPCC 2007d)

- At continental, regional and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones. (IPCC 2007d)

- Some aspects of climate have not been observed to change. (IPCC 2007d)

- Palaeoclimatic information supports the interpretation that the warmth of the last half century is unusual in at least the previous 1,300 years. The last time the polar regions were significantly warmer than present for an extended period (about 125,000 years ago), reductions in polar ice volume led to 4 to 6 m of sea level rise. (IPCC 2007d)

- Climate-related changes have already been observed globally and in the United States. These include increases in air and water temperatures, reduced frost days, increased frequency and intensity of heavy downpours, a rise in sea level, and reduced snow cover, glaciers, permafrost, and sea ice. A longer ice-free period on lakes and rivers, lengthening of the growing season, and increased water vapor in the atmosphere have also been observed. Over the past 30 years, temperatures have risen faster in winter than in any other season, with average winter temperatures in the Midwest and northern Great Plains increasing more than 7°F. Some of the changes have been faster than previous assessments had suggested (Karl et al. 2009).

- U.S. average temperature has risen more than 2°F over the past 50 years and is projected to rise more in the future; how much more depends primarily on the amount of heattrapping gases emitted globally and how sensitive the climate is to those emissions (Karl et al. 2009).

- U.S. precipitation has increased an average of about 5 percent over the past 50 years. Projections of future precipitation generally indicate that northern areas will become wetter, and southern areas, particularly in the West, will become drier (Karl et al. 2009).

- In the U.S. the amount of rain falling in the heaviest downpours has increased approximately 20 percent on average in the past century, and this trend is very likely to continue, with the largest increases in the wettest places (Karl et al. 2009).

- Many types of extreme weather events, such as heat waves and regional droughts, have become more frequent and intense during the past 40 to 50 years (Karl et al. 2009).

2. What evidence provides attribution of these changes to human activities?

- 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. This is an advance since the TAR's (Third Assessment Report's) conclusion that "most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations". Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns (IPCC 2007d).

- The scientific evidence for a human influence on global climate has accumulated over the past several decades, from many hundreds of studies. No single study is a "smoking gun." Nor has any single study or combination of studies undermined the large body of evidence supporting the conclusion that human activity is the primary driver of recent warming (Karl et al. 2009).

- The first line of evidence is our basic physical understanding of how greenhouse gases trap heat, how the climate system responds to increases in greenhouse gases, and how other human and natural factors influence climate. The second line of evidence is from indirect estimates of climate changes over the last 1,000 to 2,000 years. The third line of evidence is based on the broad, qualitative consistency between observed changes in climate and the computer model simulations of how climate would be expected to change in response to human activities. Finally, there is extensive statistical evidence from so-called "fingerprint" studies. Each factor that affects climate produces a unique pattern of climate response, much as each person has a unique fingerprint. Fingerprint studies exploit these unique signatures, and allow detailed comparisons of modeled and observed climate change patterns (Karl et al. 2009).

3. What are the observed and anticipated impacts of climate change in the United States and throughout the world?

- The United States frequently experiences weather-related challenges, with substantial economic costs from severe storms, drought, flood, extreme heat, and extreme cold (Field et al. 2007). Weather-related impacts are persistent features of the American landscape. Over the last several decades, however, the United States has experienced substantial

amounts of warming, especially in Alaska, and recent scientific research documents an increasing number of impacts that appear to be a result of climate changes that have already occurred (Field et al. 2007). For one-time events, like heat waves, drought, or wildfires, it will rarely be possible to say with certainty that a single event was caused by climate change (Hegerl et al. 2007). Nevertheless, several kinds of extremes will likely become more common with climate change. Increasingly, it is possible to assess the probability that a heat wave, wildfire, or drought would have occurred in the absence of climate change (Hegerl et al. 2007).

- In recent decades, the United States has experienced an increasing number of stresses projected to increase in a warming climate. Some of these are iconic one-time events like the need to move the Alaskan village of Shishmaref, which is being progressively lost to the sea after 400 years of habitation, a consequence of melting of the permafrost on which it sits and increased wave action related to a decreased period when ice protects the village (http://www.arctic.noaa.gov/detect/human-shishmaref.shtml). Others are more gradual and progressive. Examples include the clear decrease in the season for high-latitude ice roads, the dramatic decrease in water stored in the snowpack of the Western mountains, or the strong increase in the area burned in Western wildfires (Field et al. 2007). Drought is among the largest climate-related concerns for the United States. Many parts of the Western US have limited water security. Some of these are in parts of the country where decreased snowpack is cutting into water storage capacity or where groundwater pumping has led to large drops in the water table (Field et al. 2007). Projected decreases in precipitation (Meehl et al. 2007) could push many of these areas from water insecure to chronically critically short of water.

- With climate change in coming decades, the United States will have vulnerable people, businesses, and activities in all regions. The people most vulnerable to impacts of climate change tend to be those who are very young, old, sick, or poor. People who live in communities dependent on single industries based on resources at risk (e.g. fisheries) will likely experience large impacts, especially if they cannot switch activities or relocate (Field et al. 2007). Continuing increases in the value of the infrastructure in the coastal zone exacerbate the risks from sea-level rise. The United States has abundant adaptive capacity with the potential to provide an important measure of protection, but deploying that capacity to effectively provide protection will require mainstreaming adaptation at a level far above the historical norm (Field et al. 2007).

- For the next two decades, a warming at the global scale of about 0.36°F per decade is projected for a range of emission scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.18°F per decade would be expected. (IPCC 2007d)

- Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century. (IPCC 2007d)

- Anthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilized. (IPCC 2007d)

Sector-Specific Projected Impacts

- **Water Resources**: Climate change has already altered, and will continue to alter, the water cycle of the United States, affecting where, when, and how much water is available for all uses. Floods and droughts are likely to become more common and more intense as regional and seasonal precipitation patterns change, and rainfall becomes more concentrated into heavy events (with longer, hotter dry periods in between). Precipitation and runoff are likely to increase in the Northeast and Midwest in winter and spring, and decrease in the West, especially the Southwest, in spring and summer. In areas where snowpack dominates, the timing of runoff will continue to shift to earlier in the spring and flows will be lower in late summer. Surface water quality and groundwater quantity will be affected by a changing climate. Climate change will place additional burdens on already stressed water systems. The past century is no longer a reasonable guide to the future for water management (Karl et al. 2009).

- **Energy**: Warming in the United States will be accompanied by decreases in demand for heating energy and increases in demand for cooling energy. The latter will result in significant increases in electricity use and higher peak demand in most regions. Energy production is likely to be constrained by rising temperatures and limited water supplies in many regions. Energy production and delivery systems are exposed to sea-level rise and extreme weather events in vulnerable regions. Climate change is likely to affect some renewable energy sources across the nation, such as hydropower production in regions subject to changing patterns of precipitation or snowmelt (Karl et al. 2009).

- **Transportation**: Sea-level rise and storm surge will increase the risk of major coastal impacts on the United States, including both temporary and permanent flooding of airports, roads, rail lines, and tunnels. Flooding from increasingly intense downpours will increase the risk of disruptions and delays in air, rail, and road transportation, and damage from mudslides in some areas. The increase in extreme heat will limit some transportation operations and cause pavement and track damage. Decreased extreme cold will provide some benefits such as reduced snow and ice removal costs. Increased intensity of strong hurricanes would lead to more evacuations, infrastructure damage and failure, and transportation interruptions. Arctic warming will continue to reduce sea ice, lengthening the ocean transport season, but also resulting in greater coastal erosion due to waves. Permafrost thaw in Alaska will damage infrastructure. The ice road season will become shorter (Karl et al. 2009).

- **Agriculture**: Many crops show positive responses to elevated carbon dioxide and low levels of warming, but higher levels of warming often negatively affect growth and yields. In the United States, extreme events such as heavy downpours and droughts are likely to reduce crop yields because excesses or deficits of water have negative impacts on plant growth. Weeds, diseases, and insect pests benefit from warming, and weeds also benefit from a higher carbon dioxide concentration, increasing stress on crop plants and

requiring more attention to pest and weed control. Forage quality in pastures and rangelands generally declines with increasing carbon dioxide concentration because of the effects on plant nitrogen and protein content, reducing the land's ability to supply adequate livestock feed. Increased heat, disease, and weather extremes are likely to reduce livestock productivity (Karl et al. 2009).

- **Ecosystems**: Ecosystem processes, such as those that control growth and decomposition, have been affected by climate change. Large-scale shifts have occurred in the ranges of species and the timing of the seasons and animal migration, and are very likely to continue. In the United States, fires, insect pests, disease pathogens, and invasive weed species have increased, and these trends are likely to continue. Deserts and drylands are likely to become hotter and drier, feeding a self reinforcing cycle of invasive plants, fire, and erosion. Coastal and near-shore ecosystems are already under multiple stresses. Climate change and ocean acidification will exacerbate these stresses. Arctic sea ice ecosystems are already being adversely affected by the loss of summer sea ice and further changes are expected. The habitats of some mountain species and coldwater fish, such as salmon and trout, are very likely to contract in response to warming. Some of the benefits ecosystems provide to society will be threatened by climate change, while others will be enhanced (Karl et al. 2009).

- **Human Health**: In the United States, increases in the risk of illness and death related to extreme heat and heat waves are very likely. Some reduction in the risk of death related to extreme cold is expected. Warming is likely to make it more challenging to meet air quality standards necessary to protect public health. Extreme weather events cause physical and mental health problems. Some of these events are projected to increase. Some diseases transmitted by food, water, and insects are likely to increase. Rising temperature and carbon dioxide concentration increase pollen production and prolong the pollen season in a number of plants with highly allergenic pollen, presenting a health risk. Certain groups, including children, the elderly, and the poor, are most vulnerable to a range of climate-related health effects (Karl et al. 2009).

- **Society**: Population shifts and development choices are making more Americans vulnerable to the expected impacts of climate change. Vulnerability is greater for those who have few resources and few choices. City residents and city infrastructure have unique vulnerabilities to climate change. Climate change affects communities through changes in climate-sensitive resources that occur both locally and at great distances. Insurance is one of the industries particularly vulnerable to increasing extreme weather events such as severe storms, but it can also help society manage the risks. The United States is connected to a world that is unevenly vulnerable to climate change and thus will be affected by impacts in other parts of the world (Karl et al. 2009).

- Many estimates of aggregate net economic costs of damages from climate change across the globe (i.e., the social cost of carbon (SCC), expressed in terms of future net benefits and costs that are discounted to the present) are now available. Peer-reviewed estimates of the SCC for 2005 have an average value of US$43 per ton of carbon (i.e., US$12 per ton of carbon dioxide), but the range around this mean is large. For example, in a survey

of 100 estimates, the values ran from US$-10 per ton of carbon (US$-3 per ton of carbon dioxide) up to US$350 per ton of carbon (US$95 per ton of carbon dioxide). (IPCC 2007f)

- Non-climate stresses can increase vulnerability to climate change by reducing resilience and can also reduce adaptive capacity because of resource deployment to competing needs. For example, current stresses on some coral reefs include marine pollution and chemical runoff from agriculture as well as increases in water temperature and ocean acidification. Vulnerable regions face multiple stresses that affect their exposure and sensitivity as well as their capacity to adapt. These stresses arise from, for example, current climate hazards, poverty and unequal access to resources, food insecurity, trends in economic globalisation, conflict, and incidence of diseases such as HIV/AIDS. Adaptation measures are seldom undertaken in response to climate change alone but can be integrated within, for example, water resource management, coastal defense and risk-reduction strategies. (IPCC 2007f)

4. How is the climate science community furthering public understanding of climate change and its consequences?

- Climate change is one of the most important, complex, and far-reaching challenges we face in the 21st century. The complexity and technical nature of the challenge place a special burden of responsibility on the scientific community to provide balanced, accurate, timely, and understandable information to governments and other stakeholders. Especially in an environment with high economic and political stakes, it is critical for the information from the scientific community to be absolutely trustworthy.

- Broad-based scientific assessments, like the US National Assessments and the IPCC Assessments, are the scientific community's central tool for insuring that balanced, thoroughly vetted information receives the prominence it deserves. Especially the IPCC assessments, which involve a unique partnership between the scientific community and the world's governments, function effectively to insure balance and accuracy. Assessments like these deserve the broad support of the scientific community, national governments, and other stakeholders.

- Because climate change is so important and so complex, the challenge of advancing public understanding must be addressed with strategies that go beyond the existing assessment model. The scientific community needs to make extra investments in providing sufficient information for the public to understand the issue, and the public needs to make a genuine commitment to educating itself. This kind of novel partnership, extending across whole societies, will be critically important for enabling smart decisions on dealing with climate change.

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The CHAIRMAN. Thank you, Dr. Field, very much.

And our final witness today is Dr. Lisa Graumlich.

Dr. Graumlich is the director of the School of Natural Resources and the Environment at the University of Arizona. Her research focuses on the interplay of global climate change and natural resources management. She has also directed the University of Arizona's Institute for the Study of Planet Earth and Montana State University's Big Sky Institute. Recently she served on the Oxburgh inquiry panel that reviewed the scientific work of the University of East Anglia's Climate Research Unit following the release of private e-mails of some of their scientists.

Dr. Graumlich received her Ph.D. from the College of Forest Resources at the University of Washington. She is a fellow of the American Association for the Advancement of Science.

We welcome you, Dr. Graumlich.

STATEMENT OF LISA J. GRAUMLICH, PH.D.

Ms. GRAUMLICH. Chairman Markey and Ranking Member Sensenbrenner and the rest of the members of the committee, thank you so much for inviting me to speak with you today in this very important hearing.

In what I am going to say today and in my written testimony, I have focused on the observational record of current and past climate variability. And I do that as a tree ring scientist, as a dendrochronologist by training. And I want to spend a moment talking a bit about the kind of perspective that one brings to this question as someone that has looked at tree ring records of the past.

And I am going to take you back in time 20 years, when I was an assistant professor at UCLA. As a tree ring scientist, I was off to the Sierra Nevada to look for very, very old trees, and in fact found them, very, very old Foxtail Pines, a relative of Bristlecone Pines, high up at the upper tree line in the Sierra Nevada. But what shocked me when I got there was not the old trees, I expected to find those there, but as you went above the tree line, there were very large dead trees, I mean very large dead trees, above current tree line. Not just a couple, hundreds of them. And what that meant was that, in previous eras, tree line had been higher, implying that temperatures had been warmer.

So as a trained tree ring scientist it turns out that we can very accurately date the innermost rings of those dead trees that tells us when the trees were established and the outermost ring with a little sort of 50 year or so error because of the loss of sap which tells us when those trees died. So what we know is over the last 3,000 years, tree line was higher, and then somewhere around 950 A.D., there was this massive die-off, and tree line reestablished at the current rate.

So I went back to the lab, started looking at those data and started to also reflect on the fact that if you thought about those dates, those dates were very consistent with the time in which the Norse Vikings colonized Greenland and Iceland. And the dates at which my trees died were about the same time as those colonies failed.

So, recall this is 20 years ago, there were two outcomes. One is that I became fascinated with, what caused this long-term variability in climate? But the second outcome that is apropos today was that I was very much struck by the fact that, when I described my research to the public, it was very clear that it appeared to them that I had this very strong ability to say that, yes, current climate trends were well within the envelope of natural variability because I had trees in Sierra Nevada and historical data in the North Atlantic.

That is not climate science. That is assembly of a couple of just-so stories that tell us something about climate at two places on the surface of the earth. And what has happened subsequently is that, along with dozens of colleagues, we have very carefully scanned the earth for other kinds of high-resolution proxy data; tree ring records, historical documents, speleothems, ice cores, any number of barb sediments, if you try to understand how they reflect or don't reflect temperature data.

In doing that, we discovered that in fact there were a couple of other places around the globe that had this medieval warm period, in particular the Eurasian part of the Arctic and parts of, of course, the North Atlantic and the western part of the U.S.

In other places, like the Northwest, the tropical Pacific, temperatures were also cooler during the so-called medieval warm period, and that this, dozens and dozens of peer-reviewed studies have allowed us to be able to assert with great confidence, after 20 years of looking for these kinds of records, that in fact the late 20th Century is the warmest period of earth history in the last 500 to 1,000 years.

So, finally, it is these kind of data that were assembled by the Climatic Research Unit at the University of East Anglia. I had the opportunity to participate as one of the panel members in Lord Oxburgh's Scientific Assessment Panel. And in looking at that, and I want to quote the key response, is that we saw no evidence of any deliberate scientific malpractice in any of the work of the climate research unit, and had it been there, we believe that we would have detected it. Rather, we found a small group of dedicated, if slightly disorganized, researchers who were ill-prepared for being the focus of public attention. The full report from that panel is appended to my own testimony. Thank you.

[The statement of Ms. Graumlich follows:]

Testimony of Dr. Lisa J. Graumlich
Before The Select Committee on Energy Independence and Global Warming
U.S. House of Representatives
On The Foundation for Climate Science
May 6, 2010

Chairman Markey, Ranking Member Sensenbrenner, Members of the Committee: I thank you for inviting me to testify today at this important and timely hearing. In what follows I will address the first of the questions posed in the Chairman's letter of invitation: "What are the observed changes to the climate system?" In my testimony, I will focus on the past 1000 years of climate history, drawing on my expertise in paleoecology, which includes reconstructing climate from tree ring and other proxy records. I will also comment on the report of the Scientific Assessment Panel, led by Lord Oxburgh, that provided an independent reappraisal of the science of the Climatic Research Unit (CRU), University of East Anglia as reflected in its key publications.

Executive Summary:
Climate has changed at various time scales throughout Earth's history, driven by a variety of factors such as continental drift, solar activity, and greenhouse gas concentration. Long-term records of "natural" climate variability offer a context to assess the significance of the current observed trends in global temperature. Many lines of evidence, including but not limited to tree rings, indicate that the Earth has experienced periods of relative warmth and cooling over the past 500-1000 years. In the Northern Hemisphere, there is regional evidence for relatively warm temperatures during medieval times and regional evidence for cooler temperatures during the 17th, 18th, and 19th centuries. Importantly, these records indicate that average Northern Hemisphere temperatures during the second half of the 20th century are likely warmer than any other 50-year period in the past 1000 years.

The key points of my testimony are the following:

- Estimates of global temperature trends on century time scales are non-trivial to calculate, requiring large-scale (e.g., hemispheric to global) data sets with sufficient coverage to average out local variation.
- Tree-ring data have been critical to the estimate of past climate variability because they resolve seasonal to annual climate conditions, and exist in spatially extensive networks with high replication.
- Independent research groups have combined tree-ring data with other annual- or decadal-resolution proxy climate records, such as annually laminated sediments, ice cores, coral growth bands, and historical documents to estimate Northern Hemisphere temperature trends. In all of these studies, there is a clear indication that the late 20th century is the warmest period in the past 500-1000 years.
- Recently, one of these research groups (the Climatic Research Unit at the University of East Anglia) was the subject of investigation requested by the House of Lords. An international panel headed by Lord Oxburgh found no

evidence that climatic data had been dishonestly selected, manipulated and/or presented to arrive at pre-determined conclusions that were not compatible with a fair interpretation of the original data.

1. Taking the Earth's temperature is a complex enterprise.

While we have an abundance of weather measurements, integrating these data into a single indicator of planetary warmth is not straightforward. The global and hemispheric temperature series, presented in the earlier testimony by Dr. Hurrell, incorporates land and marine station data. Over 3000 station records are used that have been corrected for non-climatic errors, such as station shifts and/or instrument changes. The geographic coverage of the station records is not uniform. Coverage is most dense in the most heavily populated parts of the world, particularly the United States, southern Canada, Europe and Japan. Further, the temporal coverage of the station data is not uniform. The number of available stations was small during the 1850s but increased to over 3000 stations after World War II. The marine data consist of sea surface temperatures (SSTs) that incorporate *in situ* measurements from ships and buoys. The SST record has been corrected for different types of buckets used in the ship-based measurement prior to 1942. Like the land data, coverage is not uniform and is most dense in the main shipping lanes in the Northern Hemisphere.

The irregular distribution of the available station data requires that some form of gridding is necessary in order for analyses (e.g., hemispheric averages) not to be biased. Typically, the land and marine data are combined by interpolating each to a uniform grid system over the surface of the earth (e.g., 5° latitude by 5° longitude). Several different methods have been used to interpolate station temperature data to a regular grid. Most often, researchers use a climate anomaly approach in which all station data are reduced to anomalies from a common 30-year period (e.g., 1961-1990). Gridbox anomaly values are the simple average of the station anomaly values within each grid box. Small differences arise in different analyses due to differences in gridding methods, such as treatment of spatial gaps in the data.

Great care has been taken to assess the accuracy of the resulting global and Northern Hemisphere temperature anomaly series and, in most publications, accuracy estimates are included in time series graphs. In general, accuracy declines as one goes back in time. Error analyses indicate that values are about four times as uncertain during the 1850s with a steady increase in accuracy between 1860 and 1950.

The several research groups that have used available station data and independently calculated global and Northern Hemisphere temperature series come up with estimates that are largely coherent. All analyses indicate relatively stable temperatures from the beginning of the station records through 1910, relatively rapid warming through the 1940s, followed by relatively stable temperatures

through the mid-1970s. From the mid-1970s onwards, temperatures rise rapidly. For example, the period 2001-2009 is 0.19°C warmer than the 1991-2000 decade and the 1990s were the warmest complete decade in the series.

The rise in temperatures since the 1970s, along with other evidence of warming (e.g., melting of snow and ice, sea level rise) support one of the key findings of Working Group I of the IPCC Fourth Assessment Report that the "warming of the climate system is unequivocal." Given that we know that climate has changed throughout the Earth's history, it is critical to put the recent warming trend into the context of the natural variability of the Earth's climate system. Paleoclimatic data provide such as context.

2. Past records of climate play a central role in climate change science because they define "natural variability" over decades to centuries.

On time scales of decades to centuries, global and regional temperatures vary due to changes in solar radiation, volcanic gases and ash, ocean-atmosphere interactions, and greenhouse gas concentrations. Detection of human impacts on the climate system requires an understanding of how recent changes fit into a larger pattern of natural variability. High-resolution paleoclimatology plays a key role in this enterprise, making use of natural archives such as tree rings, coral growth bands, laminated and high-accumulation freshwater and marine sediments, speleothems, and annual bands in polar and high-elevation ice caps to infer changes in climate at annual time steps. Decades of field and laboratory research developing these data sources has resulted in global networks of well-replicated data that rival the spatial coverage of the observational climate records. Tree-ring records are uniquely widespread relative to other natural archives of climate and thus figure prominently in regional to hemispheric scale analyses.

There are a number of critical issues that must be faced in using tree rings and other proxy records to infer climate variation. These include the precision and accuracy of the chronology; the degree to which the processes producing each archive are understood and may be compared with observed climate; the consistency or inconsistency of response to climate throughout the period of interest; and the extent to which each type of record can capture climate variability over a wide range of timescales, from interannual to millennial, as well as spatial scales. For tree-ring data, arguably the most critical questions have arisen regarding the best way to separate the inherent biological growth trends from the climatic signal. A large portion of the scientific literature in paleoclimatology focuses on addressing these issues and ongoing research seeks to fine-tune our understanding of the nature of the climate signal in proxy records.

3. Analyses of large-scale networks of high-resolution proxy climate data indicate that the medieval period experienced warmer temperatures in certain regions and at different time periods. There is also broad agreement that late 20th century is warmest period in past 500-1000 years.

Historical and paleoclimatic records in western Europe and the North Atlantic lend support to the concepts of a "Medieval Warm Period". For example, Norse seafaring and colonization around the North Atlantic at the end of the 9th century indicated that regional North Atlantic climate was warmer than during the cooler "Little Ice Age" of the 15th - 19th centuries. While the logic underlying this argument is oversimplified, the notion that a "Medieval Warm Period" could occur in the absence of human-induced changes in greenhouse gas concentrations has captured public imagination.

Several peer-reviewed studies that have produced very large spatial-scale reconstructions have come to the same conclusion: medieval warmth varied widely in terms of its precise timing and regional expression. However, there is widespread agreement that the warmest period prior to the 20th century very likely occurred between AD 950 and 1100. The analysis of the spatial extent of the expression of warmth during the medieval is restricted to the availability of proxy records from this period, records that ultimately need to be more widespread to capture global patterns and forcing. However, in studies to date, there is a clear indication that the late 20th century is the warmest period in the past 500-1000 years. Global climate models with a variety of natural (volcanic and solar) and anthropogenic forcing (greenhouse gases) factors have been used to simulate changes in climate through the last 1000 years. Varying levels of natural forcings account for the observed response in proxy records pre-1765, but the addition of anthropogenic forcing is required to induce the response observed in recent centuries.

4. Recently, an international panel was given the charge to investigate the scientific integrity of the Climate Research Unit at the University of East Anglia, known for the development of observational and paleoclimate data products. The panel concluded that there was no evidence that climatic data had been dishonestly selected, manipulated and/or presented to arrive at pre-determined conclusions that were not compatible with a fair interpretation of the original data.

Earlier this year, I served as one of seven members of the Independent Panel, chaired by Lord Oxburgh, to assess the integrity of the research published by the Climatic Research Unit (CRU) in the light of various external assertions. The Panel worked by examining representative publications by members of the Unit and subsequently by making two visits to the University and interviewing members of the Unit. The CRU publications focus on estimating hemispheric and global temperatures from observational and paleoclimatic data networks. As indicated above, this line of research involves an iterative process of seeking new data sources, addressing data inconsistencies and errors, and, in the case of tree-ring data, separating climatic signals from biological growth trends.

The Independent Panel concluded that, "We saw no evidence of any deliberate scientific malpractice in any of the work of the Climatic Research Unit and had it been there we believe that it is likely that we would have detected it. Rather we found a small group of dedicated if slightly disorganized researchers who were ill-prepared for being the focus of public attention." The full report in appended to my testimony.

Beyond the specific findings of Lord Oxburgh's Independent Panel, I would like to suggest that the interest of the public in the data and methods used by paleoclimatologists has benefited the scientific community in several ways. There is new motivation and, to some degree greater resources for, archiving data and software products. There is more open access software for tree-ring analyses under development, which will increase the transparency of the analytic procedures. Yet more scientific attention is being devoted to the understanding of the biological processes of formation of tree-ring and other proxy data. Finally, within the university community, we see greater professional recognition for devoting efforts to communicate science to the general public. All of this bodes well for progress in linking our scientific understanding of climate change with sensible and robust strategies for mitigation and adaptation.

Report of the International Panel set up by the University of East Anglia to examine the research of the Climatic Research Unit.

Introduction

1. The Panel was set up by the University in consultation with the Royal Society to assess the integrity of the research published by the Climatic Research Unit in the light of various external assertions. The Unit is a very small academic entity within the School of Environmental Sciences. It has three full time and one part time academic staff members and about a dozen research associates, PhD students and support staff. The essence of the criticism that the Panel was asked to address was that climatic data had been dishonestly selected, manipulated and/or presented to arrive at pre-determined conclusions that were not compatible with a fair interpretation of the original data. The members of the Panel are listed in Appendix A at the end of this report.

2. The Panel was not concerned with the question of whether the conclusions of the published research were correct. Rather it was asked to come to a view on the integrity of the Unit's research and whether as far as could be determined the conclusions represented an honest and scientifically justified interpretation of the data. The Panel worked by examining representative publications by members of the Unit and subsequently by making two visits to the University and interviewing and questioning members of the Unit. Not all the panel were present on both occasions but two members were present on both occasions to maintain continuity. About fifteen person/days were spent at the University discussing the Unit's work.

3. The eleven representative publications that the Panel considered in detail are listed in Appendix B. The papers cover a period of more than twenty years and were selected on the advice of the Royal Society. All had been published in international scientific journals and had been through a process of peer review. CRU agreed that they were a fair sample of the work of the Unit. The Panel was also free to ask for any other material that it wished and did so. Individuals on the panel asked for and reviewed other CRU research materials.

4. The Panel's work began with a detailed reading of the published work. Every paper was read by a minimum of three Panel members at least one of whom was familiar with the general area to which the paper related. At least one of the other two was a generalist with no special climate science expertise but with experience of some of the general techniques and methods employed in the work. Most of the members of the Panel read all the publications. The publications provided a platform from which to gain a deeper understanding of the Unit's research and enabled the Panel to probe particular questions in more detail.

5. Broadly the work of the Unit falls into two parts:
    - Construction and interpretation of tree ring chronologies extending over some thousands of years with a view to gaining information about past climates:
    - Studies of temperatures over the last few hundred years from direct observations.

Dendroclimatology

1. Tree growth is sensitive to very many factors including climate. By piecing together growth records from different trees, living or dead, it is possible to determine the temporal variation of growth patterns going back many hundreds of years. The dendroclimatological work at CRU seeks to go beyond this and to extract from the dated growth patterns the local and regional history of temperature variations. The Unit does virtually no primary data acquisition but has used data from published archives and has collaborated with people who have collected data.

2. The main effort of the dendroclimalogists at CRU is in developing ways to extract climate information from networks of tree ring data. The data sets are large and are influenced by many factors of which temperature is only one. This means that the effects of long term temperature variations are masked by other more dominant short term influences and have to be extracted by statistical techniques. The Unit approaches this task with an independent mindset and awareness of the interplay of biological and physical processes underlying the signals that they are trying to detect.

3. Although inappropriate statistical tools with the potential for producing misleading results have been used by some other groups, presumably by accident rather than design, in the CRU papers that we examined we did not come across any inappropriate usage although the methods they used may not have been the best for the purpose. It is not clear, however, that better methods would have produced significantly different results. The published work also contains many cautions about the limitations of the data and their interpretation.

4. Chronologies (transposed composites of raw tree data) are always work in progress. They are subject to change when additional trees are added; new ways of data cleaning may arise (e.g. homogeneity adjustments), new measurement methods are used (e.g. of measuring ring density), new statistical methods for treating the data may be developed (e.g. new ways of allowing for biological growth trends).

5. This is illustrated by the way CRU check chronologies against each other; this has led to corrections in chronologies produced by others. CRU is to be commended for continuously updating and reinterpreting their earlier chronologies.

6. With very noisy data sets a great deal of judgement has to be used. Decisions have to be made on whether to omit pieces of data that appear to be aberrant. These are all matters of experience and judgement. The potential for misleading results arising from selection bias is very great in this area. It is regrettable that so few professional statisticians have been involved in this work because it is fundamentally statistical. Under such circumstances there must be an obligation on researchers to document the judgemental decisions they have made so that the work can in principle be replicated by others.

7. CRU accepts with hindsight that they should have devoted more attention in the past to archiving data and algorithms and recording exactly what they did. At the time the work was done, they had no idea that these data would assume the importance they have today and that the Unit would have to answer detailed inquiries on earlier work. CRU and, we are told, the tree ring community generally, are now adopting a much more rigorous approach to the archiving of chronologies and computer code. The difficulty in releasing program code is that to be understood by anyone else it needs time-consuming work on documentation, and this has not been a top priority.

8. After reading publications and interviewing the senior staff of CRU in depth, we are satisfied that the CRU tree-ring work has been carried out with integrity, and that allegations of deliberate misrepresentation and unjustified selection of data are not valid. In the event CRU scientists were able to give convincing answers to our detailed questions about data choice, data handling and statistical methodology. The Unit freely admits that many data analyses they made in the past are superseded and they would not do things that way today.

9. We have not exhaustively reviewed the external criticism of the dendroclimatological work, but it seems that some of these criticisms show a rather selective and uncharitable approach to information made available by CRU. They seem also to reflect a lack of awareness of the ongoing and dynamic nature of chronologies, and of the difficult circumstances under which university research is sometimes conducted. Funding and labour pressures and the need to publish have meant that pressing ahead with new work has been at the expense of what was regarded as non-essential record keeping. From our perspective it seems that the CRU sins were of omission rather than commission. Although we deplore the tone of much of the criticism that has been directed at CRU, we believe that this questioning of the methods and data used in dendroclimatology will ultimately have a beneficial effect and improve working practices

Temperatures from Historical Instrumental Records

1. The second main strand of work at CRU has been the collection and collation of instrumental land temperature records from all over the world and the construction of regional, hemispherical and global scale temperature records. These records are irregularly distributed in space and time. Modern records come largely from land-based meteorological stations but their geographical distribution is uneven and strongly biased in favour of the northern hemisphere

where most of the Earth's land masses are located. Oceans cover two thirds of the Earth's surface and away from the main shipping routes coverage is thin. For earlier centuries the record is much sparser. Deriving estimates of past temperatures on a global, hemispheric and regional scale from incomplete data sets is one of the problems faced by the Unit and in consequence an important current interest is the discovery of useable old temperature records from a variety of sources.

2. In the latter part of the 20th century CRU pioneered the methods for taking into account a wide range of local influences that can make instrumental records from different locations hard to compare. These methods were very labour intensive and were somewhat subjective. Much of this work was supported by the US Department of Energy and was published with the details of station corrections several times a year. Since the 1980s the Unit has done no more of this work and have concentrated on the merging and interpretation of data series corrected by others. There have been various analyses of similar publicly available data sets by different international groups. Although there are some differences in fine detail that reflect the differences in the analytical methods used, the results are very similar.

3. The Unit has devoted a great deal of effort to understanding how instrumental observations are best combined to derive the surface temperature on a variety of time and space scales. It has become apparent from a number of studies that there is elevation of the surface temperature in and around large cities and work is continuing to understand this fully.

4. Like the work on tree rings this work is strongly dependent on statistical analysis and our comments are essentially the same. Although there are certainly different ways of handling the data, some of which might be superior, as far as we can judge the methods which CRU has employed are fair and satisfactory. Particular attention was given to records that seemed anomalous and to establishing whether the anomaly was an artefact or the result of some natural process. There was also the challenge of dealing with gaps in otherwise high quality data series. In detailed discussion with the researchers we found them to be objective and dispassionate in their view of the data and their results, and there was no hint of tailoring results to a particular agenda. Their sole aim was to establish as robust a record of temperatures in recent centuries as possible. All of the published work was accompanied by detailed descriptions of uncertainties and accompanied by appropriate caveats. The same was true in face to face discussions.

5. We believe that CRU did a public service of great value by carrying out much time-consuming meticulous work on temperature records at a time when it was unfashionable and attracted the interest of a rather small section of the scientific community. CRU has been among the leaders in international efforts to determining the overall uncertainty in the derived temperature records and where work is best focussed to improve them.

6. The Unit has demonstrated that at a global and hemispheric scale temperature results are surprisingly insensitive to adjustments made to the data and the number of series included.

7. Recent public discussion of climate change and summaries and popularizations of the work of CRU and others often contain over-simplifications that omit serious discussion of uncertainties emphasized by the original authors. For example, CRU publications repeatedly emphasize the discrepancy between instrumental and tree-based proxy reconstructions of temperature during the late 20th century, but presentations of this work by the IPCC and others have sometimes neglected to highlight this issue. While we find this regrettable, we could find no such fault with the peer-reviewed papers we examined

Conclusions

1. We saw no evidence of any deliberate scientific malpractice in any of the work of the Climatic Research Unit and had it been there we believe that it is likely that we would have detected it. Rather we found a small group of dedicated if slightly disorganised researchers who were ill-prepared for being the focus of public attention. As with many small research groups their internal procedures were rather informal.

2. We cannot help remarking that it is very surprising that research in an area that depends so heavily on statistical methods has not been carried out in close collaboration with professional statisticians. Indeed there would be mutual benefit if there were closer collaboration and interaction between CRU and a much wider scientific group outside the relatively small international circle of temperature specialists.

3. It was not the immediate concern of the Panel, but we observed that there were important and unresolved questions that related to the availability of environmental data sets. It was pointed out that since UK government adopted a policy that resulted in charging for access to data sets collected by government agencies, other countries have followed suit impeding the flow of processed and raw data to and between researchers. This is unfortunate and seems inconsistent with policies of open access to data promoted elsewhere in government.

4. A host of important unresolved questions also arises from the application of Freedom of Information legislation in an academic context. We agree with the CRU view that the authority for releasing unpublished raw data to third parties should stay with those who collected it.

Submitted to the University 12 April 2010

Addendum to report, 19 April 2010

For the avoidance of misunderstanding in the light of various press stories, it is important to be clear that the neither the panel report nor the press briefing intended to imply that any research group in the field of climate change had been deliberately misleading in any of their analyses or intentionally exaggerated their findings. Rather, the aim was to draw attention to the complexity of statistics in this field, and the need to use the best possible methods.

APPENDIX A
PANEL MEMBERSHIP

Chair: Prof Ron Oxburgh FRS (Lord Oxburgh of Liverpool)

Prof Huw Davies, ETH Zürich
Prof Kerry Emanuel, Massachusetts Institute of Technology
Prof Lisa Graumlich, University of Arizona.
Prof David Hand FBA, Imperial College, London.
Prof Herbert Huppert FRS, University of Cambridge
Prof Michael Kelly FRS, University of Cambridge

APPENDIX B

Peer-reviewed publications for assessment.

1. Brohan, P., Kennedy, J., Harris, I., Tett, S.F.B. and Jones, P.D., 2006: Uncertainty estimates in regional and global observed temperature changes: a new dataset from 1850. *J. Geophys. Res.* **111**, D12106.

2. Briffa, K. R., F. H. Schweingruber, P. D. Jones, T. J. Osborn, S. G. Shiyatov, and E. A. Vaganov. 1998a. Reduced sensitivity of recent tree-growth to temperature at high northern latitudes. *Nature* **391**:678-682.

3. Briffa, K. R., F. H. Schweingruber, P. D. Jones, T. J. Osborn, I. C. Harris, S. G. Shiyatov, E. A. Vaganov, and H. Grudd, 1998b. Trees tell of past climates: but are they speaking less clearly today? *Philosophical Transactions of the Royal Society of London Series B – Biological Sciences* 353, 65-73.

4. Briffa, K. R. 2000. Annual climate variability in the Holocene: interpreting the message of ancient trees. *Quaternary Science Reviews* **19**, 87-105.

5. Briffa, K.R., Osborn, T.J., Schweingruber, F.H., Harris, I.C., Jones, P.D., Shiyatov, S.G. and Vaganov, E.A., 2001: Low-frequency temperature variations from a northern tree-ring density network. *J. Geophys. Res.* **106**, 2929-2941.

6. Briffa, K. R., V. V. Shishov, T. M. Melvin, E. A. Vaganov, H. Grudd, R. M. Hantemirov, M. Eronen, and M. M. Naurzbaev. 2008. Trends in recent temperature and radial tree growth spanning 2000 years across northwest Eurasia. *Philosophical Transactions of the Royal Society B-Biological Sciences* **363**, 2271-2284.

7. Jones, P.D. and Moberg, A., 2003: Hemispheric and large-scale surface air temperature variations: An extensive revision and an update to 2001. *J. Climate* **16**, 206-223.

8. Jones, P.D., Raper, S.C.B., Bradley, R.S., Diaz, H.F., Kelly, P.M. and Wigley, T.M.L., 1986a: Northern Hemisphere surface air temperature variations: 1851-1984. *Journal of Climate and Applied Meteorology* **25**, 161-179.

9. Jones, P.D., Raper, S.C.B. and Wigley, T.M.L., 1986b: Southern Hemisphere surface air temperature variations: 1851-1984. *Journal of Climate and Applied Meteorology* **25**, 1213-1230.

10. Jones, P.D., Groisman, P.Ya., Coughlan, M., Plummer, N., Wang, W-C. and Karl, T.R., 1990: Assessment of urbanization effects in time series of surface air temperature over land. Nature 347, 169-172.

11. Jones, P.D., Lister, D.H. and Li, Q., 2008: Urbanization effects in large-scale temperature records, with an emphasis on China. Journal of Geophysical Research, 113, D16122.

Supporting documentation

Briffa and Melvin (2009) which is online at
http://www.cru.uea.ac.uk/cru/people/briffa/yamal2009/

TR017 – Bradley, R.S., Kelly, P.M., Jones, P.D., Goodess, C.M. and Diaz, H.F., 1985: A Climatic Data Bank for Northern Hemisphere Land Areas, 1851-1980, U.S. Dept. of Energy, Carbon Dioxide Research Division, *Technical Report TRO17*, 335 pp.

TR022 – Jones, P.D., Raper, S.C.B., Santer, B.D., Cherry, B.S.G., Goodess, C.M., Kelly, P.M., Wigley, T.M.L., Bradley, R.S. and Diaz, H.F., 1985: A Grid Point Surface Air Temperature Data Set for the Northern Hemisphere, U.S. Dept. of Energy, Carbon Dioxide Research Division, *Technical Report TRO22*, 251 pp.

TR027 – Jones, P.D., Raper, S.C.B., Cherry, B.S.G., Goodess, C.M. and Wigley, T.M.L., 1986: A Grid Point Surface Air Temperature Data Set for the Southern Hemisphere, 1851-1984, U.S. Dept. of Energy, Carbon Dioxide Research Division, *Technical Report TR027*, 73 pp.

The CHAIRMAN. Thank you, Dr. Graumlich, very much.

The Chair will now recognize himself for a round of questions.

Today is election day in the United Kingdom, and it is unclear which party will emerge as the winner. What is clear is that the leaders of the three major parties believe carbon pollution must be addressed. Nick Clegg, the leader of the Liberal Democrats, has said, "climate change scientists now agree that time is running out; the next Parliament is the last chance we have as a nation to introduce the bold measures of radical legislation leading us to set us on the path to green and sustainable growth in the future."

Gordon Brown, leader of the Labor Party, has said, "everybody knows the importance of climate change; it is one of the key issues that has moved me most and has made me determined to act internationally as well as nationally over the past few years."

David Cameron, leader of the Conservatives, has said, "we all agree that climate change is one of the greatest and most daunting challenges of our age; we have a moral imperative to act and act now."

And this concern about global warming is not new for British politicians. Please play the videotape.

[Video shown.]

The CHAIRMAN. So Dr. Hurrell, despite all the stolen e-mails, IPCC issues, what is your conclusion in terms of the strength of the case that has been made that global warming is real and that the consequences are catastrophic?

Mr. HURRELL. I very much agree with those conclusions. I think, as I tried to state in both my written and my oral testimony, much of the strength lies not in individual papers, individual data sets, individual analyses, but rather the fact that there are many multiple lines of evidence conducted by multiple investigators, as we heard in the other oral testimonies, spanning many different physical and biological variables that all give a very consistent picture of global warming, of a warming world, and the science has advanced to the point that we can clearly attribute these changes to human activities and, in particular, the buildup of greenhouse gas emissions in the atmosphere.

The CHAIRMAN. Dr. McCarthy, Lord Monckton had a very complicated explanation of the global temperature record. Can you tell us simply what is happening in the global temperature record and if it is attributable to human activities?

Mr. MCCARTHY. There have been a number of efforts over the last maybe 10 to 15 years to use the knowledge we have of what could change climate, and some of these factors were referred to by Mr. Monckton.

We know that greenhouse gases influence climate. We know that clouds influence climate. We know that solar variability can influence climate. And we know that there are natural cycles, referred to earlier as, for example, the El Nino cycle.

And when you use these known aspects of climate to reconstruct climate over the last few decades, you find that there aren't big missing pieces, that the changes in climate that we have observed can be explained. Why was 1998 such an exceptionally warm year? As already referred to by Jim Hurrell, a year of an exceptionally

warm, probably the warmest El Nino that we know for the last 100 years.

Why was 1992, 1993 and 1994 unusually cool relative to the years before, immediately following the eruption of Mount Pinatubo, the largest volcano to have affected climate? Our most recent volcano that was very much in the news will probably not have much effect on climate because the release of material from that volcano was low in the atmosphere and, of course, we know interrupted air traffic.

So when you put these pieces together you find that there aren't big gaps. There aren't periods where you can't explain how climate has changed.

Now, when you go back further in time, it becomes more difficult. But if you mark from like 1980, which is when we have satellite observations of Earth's surface, satellite observations of ice. In 1991, when Mount Pinatubo was erupted, satellites could measure directly its contribution to the upper atmosphere. When you put these pieces together, there are no great mysteries about how climate has changed over the last 10 to 20 years, and it is entirely consistent with the forcing by greenhouse gases.

The CHAIRMAN. And Dr. Field, why don't you just quickly try to answer that question as well?

Mr. FIELD. You know, one of the major focal areas in climate science over the last several decades has been a topic that is called fingerprinting; how could we really be sure that the climate change that is now unequivocal is a consequence of human actions?

And there are a large number of independent climate fingerprints for human action, most of which don't require fancy climate models at all. A good example of a fingerprint is that if climate change is caused by greenhouse gases, we expect most of the warming to be in the lower atmosphere, with cooling in the upper atmosphere, exactly as we see.

Dr. McCarthy already mentioned this balance between the heat that you calculate should be in the climate system, and the amount of heat that we actually see in the oceans.

These fingerprinting techniques are very, very powerful at discriminating alternative explanations, and they point overwhelmingly at the human release of heat-trapping gases as the dominant cause of warming over the last half century.

The CHAIRMAN. And you agree, Dr. Graumlich?

Ms. GRAUMLICH. Yes, I do.

The CHAIRMAN. Let me ask this, do you each disagree with Lord Monckton's analysis of whether or not there is global warming trend and it is a danger to the planet? Do you disagree with him, Dr. Hurrell?

Mr. HURRELL. Yes I do.

The CHAIRMAN. Dr. McCarthy.

Mr. MCCARTHY. Mr. Monckton said he is not a scientist; he works in the policy arena and, on the basis of the sciences he reads, that he doesn't think it calls for policy action.

I think most scientists who look at the data believe that it does need policy action.

The CHAIRMAN. Thank you.

Dr. Field.

Mr. FIELD. Many scientists have looked at the issue. Warming is unequivocal. The evidence for the human fingerprint is very, very strong, and the prospect of continued warming in the future is very strong.

The CHAIRMAN. So you do disagree with Lord Monckton?

Mr. FIELD. I do disagree with Lord Monckton.

The CHAIRMAN. Dr. Graumlich?

Ms. GRAUMLICH. I disagree with Lord Monckton's conclusions based on the evidence that he presented as well.

The CHAIRMAN. Thank you.

My time is expired.

Let me turn and recognize the gentleman from Wisconsin, Mr. Sensenbrenner.

Mr. SENSENBRENNER. Thank you very much, Mr. Chairman.

Dr. Graumlich, you were on the Oxburgh panel, weren't you?

Ms. GRAUMLICH. Yes, I was.

Mr. SENSENBRENNER. Do you have a professional relationship with any of the scientists who were criticized during Climategate?

Ms. GRAUMLICH. I, as a member of the paleoclimatic community, have an acquaintanceship with many of the people that were mentioned in the e-mails. You are probably aware that both Dr. Malcolm Hughes and I are from the University of Arizona and that we both have professional relationships with the Laboratory of Tree Ring Research there.

Mr. SENSENBRENNER. Have you co-authored papers with Dr. Hughes?

Ms. GRAUMLICH. I have co-authored one book chapter with Dr. Hughes.

Mr. SENSENBRENNER. Has your work relied on information or data from the CRU?

Ms. GRAUMLICH. No, it hasn't.

Mr. SENSENBRENNER. Pardon?

Ms. GRAUMLICH. No, it hasn't.

Mr. SENSENBRENNER. The tree ring data in the hockey stick graph were directly called into question by Climategate. Have you relied on any of that in any of your professional work?

Ms. GRAUMLICH. The data that myself and my students have produced have been at times part of these very, very large compilations of data that have allowed us to assess the nature of climate variability over the last 500 to 1,000 years. The hockey stick, per se, is never quoted in my own professional work.

Mr. SENSENBRENNER. What did the panel learn from critics of the CRU's scientists during its review?

Ms. GRAUMLICH. What I think the panel took away from the critics of the CRU scientists is that, in particular, what we discovered was that, for example, the archiving of raw data and the development of documentation on computer code, such that it could be widely distributed and understood by the general public, was something that for years had not really been a high priority. Often it was unfunded by the kind of scientific funding sources that were available. And what was clear to the panel was that the stolen e-mails, as well as other things, other events, had motivated both scientists and science funders to do more public archiving of data.

Mr. SENSENBRENNER. Did the panel interview any of the critics of the CRU data?

Ms. GRAUMLICH. No. That wasn't our charge. We were charged to——

Mr. SENSENBRENNER. Well, why not? How can you get an objective viewpoint if you just look at one side of the issue?

Ms. GRAUMLICH. The charge to the panel was to look at the scientific integrity of the publications of the CR unit, and we fulfilled that charge.

Mr. SENSENBRENNER. Were—well, then, that was an extremely limited charge, you know, that pre-ordained a conclusion. Was there any analysis of the actual e-mails or the biases that they exposed?

Ms. GRAUMLICH. That was not part of our charge, and that was actually part of other kinds of inquiries that have gone on.

Mr. SENSENBRENNER. Okay. Now, were you aware of any of the biases of the other members of this seven-person panel?

Ms. GRAUMLICH. I believe that the panel was chosen to minimize bias.

Mr. SENSENBRENNER. Well, Lord Oxburgh has strong personal and financial interests in the anti-global warming policy. He is director of an international environmental organization called Globe International. He is also chairman of a green energy firm called Falck Renewables, and president of the Carbon Capture Storage Association.

And there was an article that appeared in the Times of London on April 14th where Lord Oxburgh himself even told the university that he was unfit to chair the panel because of conflicts of interest and warning the UEA that people might question his independence. Were any of those issues raised either on Lord Oxburgh or any of the other members of the panel?

Ms. GRAUMLICH. Those issues weren't raised. What we were focusing on was the science of the climate research unit as revealed in their publication record and in their day-to-day operations. And Lord Oxburgh was actually a—functioned very much as someone who has a Ph.D. in Earth sciences and brought his scientific mindset to that task.

Mr. SENSENBRENNER. Well, if he is a director of an advocacy organization called Globe International, you know, I have had meetings with and tiffs with ever since Kyoto, you know, together with the intertwining of you and other members, I don't think that that was an objective review. I don't know how universities in the United Kingdom get to the bottom of potential scandals, but I don't think our news media here in the United States would allow any university to get away with a panel that would come to a pre-ordained conclusion.

And I yield back the balance of my time.

Mr. BLUMENAUER [presiding]. I guess I am having these terms echoing in my ear. I mean, it seems to me that it is a very stark difference. Dr. Graumlich, you were talking about focusing on the science. Our purpose today was to do precisely that; and I find it a little embarrassing and sad that the minority's witness is a journalist with no scientific training, who didn't come here with any information against the science.

It has been intriguing to me. I have heard Mr. Monckton—I have often thought appropriately named—in the past; and it is entertaining, but it doesn't deal very much with the essence of what we are talking about here. My sense is that it wasn't Dr. Graumlich. There were several other studies. There has been one by the British House of Commons. There has been one by the university itself, if I understand it correctly, one by Penn State.

Ms. GRAUMLICH. Yes.

Mr. BLUMENAUER. All have looked at the science——

Ms. GRAUMLICH. Right.

Mr. BLUMENAUER [continuing]. And concluded that this is a tempest in a teapot. I mean, there is nothing here that contradicts the basic science that has been reiterated by the other three distinguished scientists that join you on the panel; is that correct?

Ms. GRAUMLICH. That is correct.

And if I could add to the list of reviews that have happened, at my own institution, the University of Arizona, at the request of the president, all of the e-mails—an inquiry was made. Every single e-mail was read, including those that dealt with Dr. Hughes; and there was a finding that there was no impropriety that affected the scientific conclusions of Dr. Hughes and others.

Mr. BLUMENAUER. Though I suppose I should declare, for the purposes of the record, I have worked with GLOBE International in other areas, dealing, for instance, with serious problems dealing with international water supplies. I don't think it has affected my objectivity, nor did I notice any sinister underlying motives or an international agenda at work.

Dr. McCarthy, it is good to see you again. I am remembering that we first met in your office 10 or 12 years ago, where you were kind enough to help walk me through some of these issues. In the course of those 10 or 12 years, not going back now to 1986 when you talked about the trends that first sort of caught your attention, but just in the 10 or 12 years since we first met, have you seen anything in terms of the trend lines? Could you talk about whether the situation has gotten more urgent or less in that decade or more?

Mr. MCCARTHY. Congressman, one thing I remember quite distinctly was our discussion about infrastructure and wondering the degree to which planning, particularly for a built infrastructure—the bridges, tunnels, mass transit systems, utilities of all sorts—should begin to be taken into consideration for our coastal cities the prospect of sea level rise. And at that time I can only guess that I would have said, well, this is something that we need to be concerned about in the future. But if you took the best estimates of the IPCC at that time, the planning horizons were out many decades. Now that has all become very compressed in time in the last decade because of the new knowledge of the rate at which ice loss is going to affect sea level rise.

So you look at any of our coastal cities, if you look at the shape of Florida, with 2½ or 3½ feet of sea level rise a century, it is a very different-looking Florida. And although you think that rise—just the height of the counter here is not a lot, but when you consider low-lying land and how far that reaches inland, our Gulf Coast, very much in the news these days, will be dramatically af-

fected by a sea level rise of that sort. And, of course, there are entire island nations that, with the combination of the sea level rise and the loss of coral through the change of pH in the ocean, will be at risk. So that would be my biggest sense of change.

And, of course, in that period, as has been pointed out, we have seen temperature record after temperature record broken for the global average temperature.

Mr. BLUMENAUER. And in terms of the, quote, "mistakes of the IPCC," I mean, what you have demonstrated with your testimony is that the studies, the projections were actually very conservative.

Mr. MCCARTHY. People tend not to appreciate how conservative the IPCC process is. When you get a bunch of scientists together and get them to agree on a statement, trimming as many caveats out as you can because the scientists always want to add caveats, well, we are not entirely sure, but this would be what would be expected, you end up with a conservative statement. You end up without extremes on other side being represented. In this case, in sea level, it was a very conservative statement.

Mr. BLUMENAUER. Thank you.

And it is. In terms of the risks that are at stake, we take in the Northwest very seriously that diminution of the snow pack, the less water content, pretty dramatic just in the community that I live in. And the fact that more than half of the American population is in the 673 coastal counties, when you are talking about inches, let alone feet, this is pretty compelling, at least in my mind.

But the point I guess in terms of a policy perspective, based on the potential risks, based on the economic, the security problems, and just the waste of resources, is there any good scientific reason not to advance sound policies, even if we weren't concerned about global warming?

Stunned silence. All right. That is fine. Why don't we—I will turn to Mr. Shadegg for your inquiry.

Mr. SHADEGG. Thank you, Mr. Acting Chairman, if that is what you are.

First, let me begin by apologizing. I have had to duck in and out a couple of times because I have another hearing going forward downstairs on the health care issue.

Second, I want to welcome Dr. Graumlich. You are now at my alma mater, the University of Arizona, where I received both my undergraduate and law degree. I am pleased to have you here, and I am proud of the University of Arizona and proud of it being recognized for the knowledge and skill of its scientists and professors.

I guess I have to begin, Dr. Monckton, by expressing a little shock at the questioning that just went forward and some reference to your name. I think that is a little inappropriate, but if that is what we are going do in this hearing, so be it.

I do believe you were just told that, because you are not a scientist, you didn't bring forward any scientific information or any information of any value to this hearing. Somehow I don't seem to agree with that. I think you brought forth an analysis of scientific information, which I thought was fairly clear. And I guess I would like to see you at least have an opportunity to repaint that picture, because, apparently, some people in the room didn't understand that what you said was, here is scientific data, here is how it was

presented, here is the conclusion that was drawn from that scientific data, and here is why that conclusion is, in fact, unsupported. And, apparently, that escaped the attention or the understanding of some people here. Is there a possibility we could call that graph back up and you could explain it to us? Maybe we can get it the second time.

Mr. MONCKTON. I am most grateful. I think obviously what is happening here is that a certain amount of politics has crept in on one side of this debate——

Mr. SHADEGG. What a shock.

Mr. MONCKTON [continuing]. And, therefore, inconvenient science has been dismissed as not being science at all.

That is the IPCC's graph with the four separate trend lines on it. That, as I have said, is an inappropriate statistical technique.

Next slide again.

Mr. SHADEGG. While we are on that one, the purpose of those lines, this actually appears in the IPCC report?

Mr. MONCKTON. It does three times, yes.

Mr. SHADEGG. And all those lines slope upward at different angles.

Mr. MONCKTON. That is right. As you get nearer to the present, they slope up at steeper and steeper angles. The implication which is stated three times in the report being that there is an acceleration of the rate of global warming. No, there isn't, as we see from the subsequent slides.

First of all, if you choose different starting points and ending points for where you do your trend lines, you can make the lines go completely—make the trend go in completely the other direction. There you have got 1905 to 1945 it was warming at twice the rate of 1905 to 2005.

Mr. SHADEGG. So it is the exact same data.

Mr. MONCKTON. Same data, same technique. It is a bogus technique, of course, and that is why you get completely opposite results depending on where you choose to start and end your trend line.

Mr. SHADEGG. Incorrectly analyzed in the earlier graph to show a rapid increase in warming.

Mr. MONCKTON. Exactly, and incorrectly analyzed again here.

Next slide.

Here is the true position where you have the three parallel rapid rates of warming. The first two cannot have been caused by CO_2 on any view. The increase in CO_2 over those periods wasn't enough, even on the U.N.'s formula, to cause that. The third one we know was largely caused because it falls in the satellite era, largely caused by a naturally occurring decrease in cloud cover chiefly in the tropics allowing more sunlight to hit the ground. And that, if you use the U.N.'s multiplying up of the warming effect of that should have caused one Celsius degree or 1.8 Fahrenheit of warming. Only naught .37 Celsius was, in fact, observed. So we now know that that third of the three rapid rates of warming was caused by a natural event almost entirely.

Mr. SHADEGG. Could you clarify something for the panel and for the people in the room listening? What is the satellite era?

Mr. MONCKTON. The satellite era, from about 1983 onwards, we had satellites up there not only measuring changes in global surface temperature, which they do by reference to platinum resistance thermometers, comparing that with the temperatures they see on the ground, but also changes in outgoing radiation and changes in cloud cover. All of these satellite data show us exactly what has caused the warming of that most recent rapid period; and it was largely, in fact, very nearly all, to do with the reduction in cloud cover that happened quite naturally over the period. Nothing to do with CO_2.

Mr. SHADEGG. And with regard to—I mean, you don't take the position that there has not been warming.

Mr. MONCKTON. There has been warming. You can see it on the graph there. Of course there has been warming. Mr. Chairman, you have got that slightly wrong when you said I didn't say there had been warming. Of course there has been warming. What I am saying is that in the one period we can tell about what caused the warming, the satellite period, it is clear that the warming was largely naturally caused, and there is paper after paper in the literature establishing this.

Go on again, please. Next slide.

This is Dr. Pincus' paper establishing that the warming of that period was caused largely by a naturally occurring reduction in cloud cover, extra sunlight reaching the ground.

Next slide, please, and the next one. We will miss that one out.

We go on here to the 11 models, I should say, all predicting very, very rapid rates of warming, but this is the relationship between warming at the surface and extra outgoing long-wave radiation. Most of the models predict there will be less radiation escaping into space if you warm the surface. The truth, however, as you see in the middle panel now, that is the earth radiation budget experiment satellite measurement, it shows a very rapid increase in the amount of outgoing radiation escaping to space as you warm the surface. What that means very simply is that the radiation isn't being trapped down here to cause warming at anything like the rate that the U.N. predicts, and that is why Professor Lindzen of MIT has concluded that the amount of warming you can expect to get from a doubling of CO_2 concentration—this is scientific measurement, not playing with Xbox 360 models—is only naught.7 Kelvin, compared with a 3.26 plus or minus naught.69, which is the best estimate of the U.N.'s climate panel. Now, naught.7 Kelvin for a doubling of CO_2 concentration is small, harmless, and generally beneficial.

Mr. SHADEGG. I thank the gentleman, and I appreciate the indulgence of the chair in allowing you to answer.

I guess your conclusion was we—I will just conclude with this remark—that we should do nothing. Certainly it appears to me that the majority got to pick four witnesses here. We got to pick one witness here. It is pretty evident that whether we do nothing, or what we do, there is clearly at least a dispute about the evidence. And it is not, in fact, apparently agreed upon.

Mr. Chairman, I would also like at some point to ask unanimous consent to put into the record the actual e-mails which were ex-

changed which I believe show the dialog going on with regard to the analysis of the IPCC report.

The CHAIRMAN. Without objection, it will be included in the record.

[The information is in Select Committee records and is available at: *http://globalwarming.house.gov/files/WEB/shadegg Materials.pdf* or *http://globalwarming.house.gov/pubs?id=0018*]

The CHAIRMAN. The gentleman's time has expired.

The chair recognizes the gentleman from Washington State, Mr. Inslee.

Mr. INSLEE. And I would note there is a dispute about whether we actually landed on the moon, and there is a dispute about whether the earth is round, and there is a dispute about gravity in some places, but there is no——

We will get to you, Lord Monckton, shortly, but I want to talk to the scientists on the panels, first, if that is okay. Thank you very much.

Dr. McCarthy, I appreciate you bringing up the ocean acidification issues, which Dr. Jane Lubchenko of NOAA has called the evil twin of climate change. I would like you to describe what actually happens to species when they are exposed, and I want to put up a slide that I believe I got from Dr. Lubchenko.

This slide basically shows what happens when you put a pterapod, a small creature, in the water. In the left, you see its picture. These are relatively small. And this shows what happens when you put a pterapod in water that will be in the same acidic conditions that will exist in the year 2100 if we do not change our course. So it basically shows that, according to Dr. Lubchenko, the pterapod melts. Its little calcium carbonate structure actually melts.

And I just wonder if you can describe what the oceans will look like from an acidity standpoint in the next hundred years if we don't change course and what that does to the plankton that serves or could do to the bottom of the food chain.

Mr. MCCARTHY. Thank you.

This, like a lot of the other change we are talking about, is not simply a difference of one condition to another but the time period over which it happens. So if we look at changes in the ocean over the last million years, every 100,000 years or so we saw ice advance, retreat. We saw organisms that lived in the high north moving closer to the Equator, during the cool periods moving back on land, out of the ocean. In fact, it is interesting. There are very few extinctions during that period, that the memory, the genetics of organisms know in their history that being able to accommodate those changes is essential for survival.

But when you crank those rates of change up, pH changed during those periods. Temperature changed. When you crank those rates of change up 100 or close to 1,000 fold, in some cases, then you exceed the capacity of ecosystems to adjust.

Now, in this case, the pterapod—I was tempted to put a picture of a colorful animal in there. Pterapods are absolutely beautiful animals. And if you could have one in here in a beaker, the foot of the mollusk is thin and flaps like a wing. They are called sea butterflies. If you ever see them swimming, they are really—they

are just spectacularly beautiful. It is a very delicate shell. They are a very, very important part of the food web in the north Pacific, particularly for salmon. We know that the pink salmon depends heavily on the pterapod for its food.

That was just one example. I mentioned others, microscopic plankton, the foraminifer, and, of course, corals are all subject to the same condition. That is, as carbon dioxide is added to the ocean more rapidly than it can adjust, and if this were being added over the thousands of years, rather than over 100, it would be a whole different story, more rapidly adjust. Then the constant tension of the animal, of trying to keep its skeletal material, its shell from dissolving becomes more and more in the favor of water. That is, water pulls those minerals back into solution. So this is the condition.

And, of course, we know in the past, there has been more carbon dioxide in the atmosphere. We know that in the past the pH of the oceans have been different. We also know that there are periods in the past where organisms like this disappeared, that the conditions were not suitable for corals or mollusks to survive. So this is a very important issue.

Mr. INSLEE. So I am told that the waters are more acidic, 30 percent more acidic than they were in pre-industrial times. What will they be at the end of the century, approximately, if things don't change?

Mr. MCCARTHY. Well, I don't know how to express it in terms of percent, but if you take these extrapolations, as is done here experimentally, you can show what the effect would be of that changing acid base balance referred to in the vernacular as acidification. The oceans aren't becoming acid. They are becoming less alkaline. But it will dissolve these minerals.

Mr. INSLEE. Thank you.

I was impressed—we are here as the House of Representatives to have the state of the science discussed about climate change. And I was impressed that those who have denied the threat this poses to the planet Earth couldn't produce one scientist, not one scientist to propose the hypothesis to explain what the Earth is undergoing, all the changes we are undergoing now. They produced somebody that doesn't even have a field, a background in science, and that is what they produce to try to convince Americans somehow that this is a big hoax. I think that is impressive or unimpressive, depending on how you look at it. So I want to ask about Lord Monckton's viewpoint and basis for that.

Lord Monckton, when did you start serving in the House of Lords? I noticed you brought fraternal greetings from the mother of parliaments to Congress to our athletic democracy. When did you start serving in The House of Lords?

Mr. MONCKTON. Sir, I have never sat or voted in The House of Lords, as you have probably been informed.

Mr. INSLEE. Thank you.

So, basically, I want to understand—thank you. You have answered my question.

You come here, you call yourself a Lord, to try to convince the world to ignore something that threatens our grand kids; and you are not even a Lord.

Now let me finish my question, and then I will let you speak. Lord Monckton, in our athletic democracy, we will ask the questions, and you will answer them. Thank you very much.

You come to our athletic democracy, sir, calling yourself Lord Monckton. Not only are you not a scientist, you are not even a Lord who served in the House of Parliament. Isn't that correct? In The House of Lords. Is it correct you did not serve in the House of Lords?

Mr. MONCKTON. I think I have already answered that one, sir.

Mr. INSLEE. Okay. Thank you.

So we not only have the deniers who have denied this clear science upon which there is enormous global consensus, they cannot only not produce one scientist to deny this clear consensus, they can't even send us a real Lord from The House of Lords.

Now, I think that says a lot about the status of this debate which we should not be having. Because we have an overwhelming consensus, and I note that it is not just by these four scientists. Joe Barton, our good friend, asked the National Oceanographic and Atmospheric Administration to review your testimony, Lord Monckton, and this is what they said:

"The fact that globally average surface air temperature has shown no trend or even slight cooling over the last 7 years is not an accurate reflection of long-term general trends. In fact, calculation of a trend over the last 7 years is a gross mischaracterization of the longer-term trend. The last 7 years have been part of a strong warming trend that began in the 1970s which is attributable to human influences, citing IPCC 2007. During the last 7 years, six of the seven warmest years on record have all been observed based on NOAA's global land and ocean data. Deducing long-term trends over such a short period of time is comparable to estimating the height of a sea swell by looking at the short period waves on top of a swell."

NOAA, the people who work for our athletic democracy, have concluded we don't need a fake Lord to tell us not to act. We need real science, and we need us to have a clean energy policy. Thank you.

The CHAIRMAN. The gentleman's times has expired.

The chair recognizes the gentleman from Oklahoma, Mr. Sullivan.

Mr. SULLIVAN. Thank you, Mr. Chairman.

And, Lord Monckton, I guess I think you have a right to explain why you are a Lord, and I don't think you had an opportunity to.

Mr. MONCKTON. I will do that very briefly, because this is not the subject of this hearing; and, once again, I see politics of a not particularly pleasant kind creeping in.

My grandfather was created a hereditary peer, one of the last to be created, in 1957 and by letters patent issued by the Queen. Until those letters patent are revoked—and they have not been—I remain and am correctly addressed as the Viscount Monckton of Brenchley. I am therefore a Lord, but by virtue of the 1999 House of Lords Act I no longer have the right to sit or vote. That was taken away from my father, so I have never sat or voted in The House of Lords, nor have I pretended otherwise. And I think that really should deal with that matter. Thank you, sir.

Mr. SULLIVAN. Thank you.

Lord Monckton, what could the climate scientists do to regain the public trust in their work? What can they do to insure transparency and accountability in the climate scientist community, especially as we look towards the development of the upcoming IPCC's fifth assessment report?

Mr. MONCKTON. Let me first of all begin with the quotation from NOAA's response to my written testimony which, incidentally, I wasn't given a copy of before this hearing, and I think somebody has slipped up there.

But the passage that was quoted focused on one short sentence which mentioned that for the last 7 or 8 years there has been, if anything, a certain amount of global cooling. So there has. But, however, my temperature record goes back as far as the Neoproterozoic era, 750 million years ago. The graphs I showed today are for the last 150 years. So I don't think I can be fairly accused of having unreasonably cherry-picked the periods over which I was looking at the data.

Now, what I think scientists therefore need to do if they want to start commanding the respect of the public, because they are losing that respect over this issue, is to stop chattering about consensus. Science has never been done by consensus, and it isn't going to be done by consensus now. Stop using in the IPCC's documents references to documents not produced by peer-reviewed sources but by green propaganda groups and by journalists and confine their analysis to the peer-reviewed literature, as I did today.

And, also, they must make sure that, instead of trying to push one agenda and shout down anyone who dares to put an alternative point of view, as I have politely sought to do today, they should treat those who disagree with them with courtesy, hear with some care what they have to say, and instead of dismissing an argument they perhaps don't understand, as one of the panelists here did when asked to comment on my testimony, they should instead engage in a rational debate via the columns of the peer-reviewed literature with the many scientists who disagree with the official line.

And, of course, scientists could have been paraded here today, but, quite rightly, the minority group, knowing that the majority would merely want to throw brickbats at them, decided that, instead, somebody with a certain amount of experience in politics and a thick skin should sit and take the cow pats flung at him, which I am more than happy to do, so as to spare the many thousands of diligent scientists who are questioning every aspect of this ludicrous scare to get on with their work, and that is what in the end is going to decide this matter. It is going to be diligent, scientific inquiry and not the hurling of childish political insults.

Mr. SULLIVAN. Lord Monckton, some of these scientists—or I guess anyone can answer this question. Do some of these scientists—how are they funded? Do they get grants or are their organization that give them funding? Do you think that that has a potential to corrupt the process? And do they feel beholden to certain results because of that?

Mr. MONCKTON. That is a very shrewd point, sir. The only reason why the notion that consensus decides science has unfortunately

crept in is that science these days effectively is a monopsony. There is only one paying customer, and that is the unwilling taxpayer. And because of that and because of the grant-funding structure and because of the resultant academic pressures to come forth, it take enormous courage for any scientist to stand out against the political line that is now being taken among the scientific institutions and to say, hang on a moment; the numbers don't add up.

I have just shown you today various points at which the numbers very plainly don't add up, and they are established in the peer-reviewed literature, and they are established by measurement and not by modeling.

You have heard the rather qualitative replies of the four scientists here. They didn't really quote numbers much. They were quoting models. But science is best done and most accurately done by measurement, and those papers that rely chiefly on measurement are finding that there isn't the problem that we are told there is.

Mr. SULLIVAN. Thank you, sir.

Mr. BLUMENAUER [presiding]. Congressman Cleaver.

Mr. CLEAVER. Thank you, Mr. Chairman.

Dr. Field—and I may want to get the other three to respond to this as well. I think all of the denials and all of the talk of Climategate has had an impact, at least in the United States. In 1997, Gallup began conducting polls on attitudes in the United States on climate change; and, tragically, the number of people who believe that climate change has been exaggerated, according to Gallup, the latest poll is 48 percent. And until the latest poll, the number of those who embraced climate change as being impacted by human activity was on the way up. So the folk who have been fighting this have, unfortunately, from my vantage point, been winning.

The poll also shows that—and maybe this is one of the reasons—that in areas where there was extreme cooling over the past winter, the people polled in those areas tend to embrace the theory that there has been exaggeration.

One of the questions that I would like to ask is, what atmospheric condition needs to be at play for a higher level of snow on the planet?

Mr. HURRELL. Well, perhaps one comment along those lines. Indeed, as I tried to emphasize in my testimony, global warming does not mean that changes are uniform everywhere. There are pronounced regional and seasonal variations, and this is due to the natural variability in the system. We still expect under climate change that we will have snowstorms. We will still have cold periods. Cold periods may become less frequent as we go into the future, but they will certainly occur.

In terms of some of the heavy precipitation events, as my colleagues have spoken to today, a key ingredient in that is that, as the atmosphere warms, as it has unmistakably been observed, the warming, the atmosphere can hold more moisture; and, therefore, any given storm will precipitate more than it otherwise would have. As we have also been very explicit, that does not mean that you can attribute any individual storm to climate change, but, on average and statistically, we would expect to see an increasing

trend in heavy precipitation events, including heavy snowstorms; and this indeed is being observed over many parts of the world.

Mr. CLEAVER. Though it is counterintuitive, the scientific truth is we have more snows if it is warmer.

Mr. HURRELL. Yes. Again, that relates to the ability of the atmosphere to hold moisture. A warm atmosphere can hold more moisture, so when it does snow it will snow more.

Mr. CLEAVER. Dr. McCarthy.

Mr. MCCARTHY. Thank you.

This is a very complicated subject and one can take one little piece of it and make a headline out of it and find that it may be true but it sounds like a contradiction.

So the place I live right now in the Northeast, what limits snowfall in the winter is not temperature but moisture, and that moisture may come off the Atlantic with a Nor'Easter. It may come up from the Gulf, or it may come off the lakes, the Great Lakes.

So one of the early projections in climate models was in a warmer world we would have more snow accreting in Greenland and in Antarctica. Now that to many people sounded like a contradiction. But indeed, for exactly the reason that Dr. Hurrell just explained, a warmer atmosphere holds more moisture. The air comes off the ocean over Antarctica, over Greenland.

Now early studies showed that that was indeed happening, not possible until we had very precise estimates of the elevation of these ice masses with satellites. But what we see at the edges, even though they are gaining snow more rapidly, Antarctica, it is the coldest continent. It is also the highest average elevation of any continent. It is the windiest. It is also the driest. That is our biggest desert. So as the ocean warms up around it, more moisture into the air, more moisture into the interior. But what we see now as you look more carefully is it is gaining in the middle, but it is losing at the edges; and, on balance, Antarctica and Greenland are losing ice more rapidly than it is being formed.

So you can take any—back here where you started with this comment. Any sort of one of those short phrases you could make a headline out of it. And, often, the public is very confused because they see these fragments of information and don't understand how they fit together.

Mr. CLEAVER. Thank you. That is important. And I don't know, one of the things we have got to do is to be able to figure out a way to present complicated information in a—you know, I think the newspapers are supposed to be printed at a sixth-grade level. And I think something as important as this, we have got to figure out how to simplify the language for the public. Because, otherwise, they are going to get a headache and bail out because they—not because they are not concerned, but they don't get it. Now, we, some of this we learned in eighth grade. But my frustration is simplifying the language, and I don't know how to do it.

Mr. MCCARTHY. Could I make a further comment?

Mr. CLEAVER. Yes, sir.

Mr. MCCARTHY. Consensus seems to get a bad word at times. But when decisionmakers come to groups of scientists and say, tell us the simplest version of this story, that is where the consensus statement comes from.

If you get scientists together and say, what do you want to talk about, we don't talk about things we agree on. We talk about the parts that we disagree on, the things that we don't understand, where all the interest in furthering the science lies. So if you made two rosters and say, where are the statements on this subject that say there is a problem? Because the climate is changing. We know the causes of that. If those trends continue, all of the sort of impacts we talk about will come in play.

Who is on that ledger? All the national academies of sciences—in my testimony, I included a statement that came out last October—eighteen organizations, scientific organizations of the United States. Look at any of our societies—the American Meteorological Society, the American Geophysical Union, the American Ecological Society—all of their statements are very similar; and I have given an example here.

So we are asked at times to try and simplify this, and this is the consensus or where consensus comes into play. Scientists don't sit around talking about what they agree on. They talk about what they disagree on.

Mr. BLUMENAUER. Thank you all.

The gentleman's time has expired. We are about to be summoned to the floor with bells and whistles for our robust democracy on the floor of the House. We deeply appreciate your coming here. I think any review of the record today, as well as the materials you have submitted, illustrates the purpose of the hearing. But you have been so patient with us.

We want to make sure that—and apologize for trying to bring it to a conclusion—but we would like to give every member of the panel a minute, a minute and a half just for any summary conclusion that you may have, any takeaway. If you have decided that it was just cloud cover and you were wrong, any wrap-up thoughts?

Mr. HURRELL. Sir, I appreciate the opportunity to make some concluding comments.

I think that transparency in process, making data available, making model codes available is extremely important; and that is something that, by and large, the climate science community does a very good job of. I work at the National Center for Atmospheric Research in Boulder, Colorado, where we develop one of the world leading climate models in the world that is used to understand climate, as well as project future changes in climate; and that entire code and all of the data that go into that model are publicly available. You can go out to the Web site right now and download that data. And I think that climate science spanning the breadth of the sciences makes a very valiant attempt to be as transparent as possible.

I also want to emphasize, in terms of the IPCC process, that it is indeed an assessment; and, as Dr. McCarthy pointed out, the consensus view is indeed a very powerful view. The IPCC report does an exhaustive job documenting not only what we do know but also what we don't know and where the grand challenges are and where the uncertainties are. There are many, many peer-reviewed papers that are thoroughly assessed in those international assessment reports.

When we saw some of Lord Monckton's evidence today, those are largely based on single studies, and I could take the time, if you wanted, to go through those on an individual basis and point out some of the flaws in those studies as well. That is the scientific process; and, indeed, for the papers that he has highlighted, there are other papers in the literature that counter those points and raise issues.

And very quickly, the final last word, what I did not address was indeed the importance of communicating; and I thoroughly agree that that is a very fundamental, very critical thing that all scientists need to be doing.

Mr. BLUMENAUER. Thank you very much.

Dr. McCarthy.

Mr. MCCARTHY. Thank you. I will try and make four points very briefly.

I want to emphasize a point that I made in my testimony, that what we are talking about here are not just changes, changes that we may see analogs for in the past, but very rapid changes, rapid rates of change, rapid rise of sea level, rapid changes in ocean chemistry; and that is a very, very important part of the message.

Secondly, I would like to say that we should think about this like assessing risk. What if we are right? What if we are wrong? What is the worst thing we could do? And you will puzzle your way through that logic. Think of how we assess risk, whether we buy fire insurance for our houses or not. I don't think my house is ever going to burn down, but I would not own a house without fire insurance. And we look, we assess the risk here. We say, could we err on the right side or the wrong side? I think we want to err on the right side.

Then you look at all the projections for cost; and, increasingly, from the report from Sir Nicholas Stern and many others, you see that doing the right thing to move us away from dependence upon fossil fuel is not inordinately expensive and that there are enormous benefits, many of which have never been cost in this ledger.

Then just finally, if you go through these exercises, you see that we have a limited period in which to act if we are going to avoid some other things we didn't even talk about today, some of the high consequence, low probability, high consequence changes. And a lot of models show that if we do not act within the next decade to begin to bend these curves then we are entering dangerous territory.

Finally, we all need to communicate better. Scientists are clumsy at this. It is not our profession. We learned how to do science, not how to communicate well, and we need to work on that.

Mr. MONCKTON. The central point I should like to leave the panel with is that there is no hurry. If you do nothing about this at all for the whole of the next 23 years, the worst that will happen, using the U.N.'s own estimate, is a 1 Fahrenheit degree warming, which will be largely harmless and beneficial. So you have plenty of time to check the studies, just a few of which I have shown you today in the peer-reviewed literature suggesting that there is another side to this story, another side based not on modeling but on measurement, which establishes and with increasing clarity establishes that there is no scientific problem. Even if there were, adap-

tation, as and where and if necessary, would be orders of magnitude cheaper and more cost effective than trying to stop the emission of carbon dioxide.

Who is going to get hurt if you start closing down coal-fired power stations, putting up the price of gasoline and electricity? Who is going to get hurt? It is the working people of America. Is that a good thing? I don't think so and nor should you.

Mr. FIELD. Thank you very much for the opportunity to make a couple of concluding remarks.

One of the things I think really needs to be emphasized is that the scientific evidence on climate change is based on many lines of independent evidence, on thousands and thousands of scientific studies that are quantitatively careful. Some are based on models, many are based on observations, and they all fit together in a fabric in which the general kinds of conclusions that indicate that the climate is changing, that the changes are important are very, very real.

It is also important to note, however, that there are important unknowns. Some of those have been discussed today, and many of the unknowns are in the direction of risks that are potentially higher than we have been able to accurately categorize. The risks of sudden sea level rise, the risks of carbon release from ecosystems, and the risks of dramatic changes in the Earth's system have all been very difficult to quantify and are not generally recognized in the more conservative kinds of assessments that typically come from the IPCC and other organizations.

I also want to emphasize the point that Dr. McCarthy made about the importance of viewing climate science as essentially problem in risk management. We don't know precisely what the future will look like, but we have a very clear picture of the risk elements that are introduced by changes that people are causing in the earth's system, and we can have an increasingly clear picture of the consequences of commonsense investments in decreasing those impacts.

Now, finally, I want to conclude with a very strong comment that Lord Monckton's conclusion that we don't need to do anything now is fundamentally misleading. We haven't seen crises that we can unambiguously attribute to climate change, but we have seen increasing risk to a wide range of Earth's systems, and we also know that the longer we delay the more difficult it gets to address the problem and the more expensive it gets. This is a problem where commonsense investments in the shorter term are likely to pay big dividends relative to waiting and hoping against hope that the situation isn't as bad as the science indicates.

The CHAIRMAN [presiding]. Great. Thank you, Dr. Field very much.

Dr. Graumlich.

Ms. GRAUMLICH. Thank you for the opportunity to make a final comment.

I would like to, first off, simply agree with my colleagues on this panel that the scientific consensus is clear and that the urgency to act is very much upon us. But I am struck by Congressman Cleaver's comments about the degree to which public perception is per-

haps lagging behind the perceptions of some of you on this particular committee and want to give my view from the Southwest.

I am part of a land grant institution that has a very strong relationship with the ranching community in the Southwest. Since 2002, we have been in a deep drought; and there is very good scientific evidence that that is due to the northern migration of the westerlies that are no longer bringing as much precipitation to the Southwest as there was before. Our ranching community is not arguing about whether climate change is here or not. They are coming to us saying, what are we going to do about it? And climate is the number one issue in this community, and they are asking us to give them guidance about how to adapt, both in the short term and the long term. So I think that the public perception that climate is an issue, whether it is called climate change or whether it is not called climate change, is particularly keen among the peoples of the Southwest.

Secondly, as a professor in a large public university, we share your concern about the increase in scientific literacy that is going to be demanded to address the complex trade-offs that we are coming up against, and we are very much engaged in that enterprise.

Thank you.

The CHAIRMAN. Thank you, Dr. Graumlich, very much.

We thank each of you for your participation in this very important hearing. We will continue with additional hearings on this issue so that we can ensure that all of the science is out in a way that it makes it possible for the public to be able to make an informed decision as to whether or not there really is such a thing as global warming that has been caused by manmade activity. We think that there is no more important debate that we can have in the Congress or in our country, and the experts that we had today I think very clearly laid out the scientific reality and has only added to my conviction that we have to act and we have to act soon.

The Waxman-Markey bill passed last June 26, 2009. The Senate has a bill which, with a little bit of luck, it will begin consideration of in the relatively near future. But time is of the essence.

So with the thanks of the committee, this hearing is adjourned.

[Whereupon, at 11:20 a.m., the committee was adjourned.]

Questions for the Record

James W. Hurrell, Ph. D.*
Senior Scientist and Chief Scientist of Community Climate Projects
Climate and Global Dynamics Division
National Center for Atmospheric Research**

1. *In his written testimony, and paraphrased in his spoken testimony, Lord Monckton claimed that "there is no hurry [to reduce carbon dioxide emissions]. Even after 23 years doing nothing to address the imagined problem ... the world will be just 1 F° warmer than it is today."[1] Therefore, Monckton says, global warming is not an urgent problem. Is Monckton's calculation approximately correct? Is this analysis a meaningful way to judge the urgency of reducing human-induced carbon dioxide emissions?*

The urgent need to act cannot be overstated. Anthropogenic climate change is already affecting our lives and livelihoods through extreme storms, unusual floods and droughts, intense heat waves, rising seas, and many changes in biological systems. Uncertainties do remain, but they concern things like the rate of melting of major ice sheets or the specific impacts of climate change on particular regions, not the broader issue of whether the climate is changing. The biggest questions are what choices we and our children will make about energy use. Economists have analyzed the costs of various policy responses and they tell us that the most cost-effective emission trajectories involve starting now to control emissions. Further delay will be costly.

In terms of the rate of change, most climate models produce warming trends in global surface temperature over the next two decades similar to that observed since 1990 (about 0.36°F per decade), regardless of the greenhouse gas emission scenario. By the middle of the 21st century, however, the choice of scenario becomes more important for the magnitude of surface warming, and by the end of the 21st century there are clear consequences for which scenario is followed. The best estimate of the global surface temperature change from today to the end of the century is +3.2°F for a low emission scenario (e.g., corresponding to a carbon dioxide (CO_2) equivalent concentration of 600 parts per million (ppm) by 2100) and +7.2°F for the higher emission scenarios (e.g., corresponding to 1,550 ppm).

2. *In arguing against the EPA Endangerment Finding, the minority staff report questions the statement of Administrator Lisa Jackson that "nothing in the emails undermines the science upon which the findings are based."[2] Do you agree with Administrator Jackson*

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* Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author and do not necessarily reflect those of the National Science Foundation.

** The National Center for Atmospheric Research (NCAR) is sponsored by the National Science Foundation.

[2] Minority Staff Report: The Unsettling Science behind EPA's Endangerment Finding, House Select Committee on Energy Independence and Global warming, May 6, 2010.

that the Climatic Research Unit (CRU) emails do not undermine the body of scientific evidence for the causes and consequences of climate change?

I strongly agree with Administrator Jackson. The emails reveal human traits and shortcomings that are sometimes inappropriate and embarrassing to the individuals involved, but they do not reveal any manipulation of the data or findings. This has been confirmed by all investigations to date. Moreover, the reality is that the evidence of climate change is vast, and the scientific community – often working closely with governments – has produced numerous carefully reviewed national and international assessments of the scientific understanding of climate change. The latest comes from the "America's Climate Choices" reports recently released by U.S. National Academy of Sciences, and it firmly states that the "scientific evidence that the Earth is warming is now overwhelming."

3. *The minority staff report[3] states that the EPA "failed to develop its own scientific foundation"[4] to support its Endangerment Finding for greenhouse gases, instead relying on the scientific assessments of the IPCC and the U.S. Climate Change Science Program (CCSP). In your professional opinion, do the IPCC and CCSP assessments provide a strong basis for evaluating the social risks of climate change as represented in the peer-reviewed scientific literature? Does the EPA's reliance on the IPCC and CCSP assessments expose the agency to a high risk that it will develop "policies that may not be scientifically supportable"[5]?*

No, the EPA's reliance on the IPCC and CCSP assessments does not expose the agency to a high risk that it will develop "policies that may not be scientifically supportable". The IPCC and CCSP assessments accurately reflect the scientific understanding of climate change. For instance, the IPCC mandate is to provide policymakers with an *objective assessment* of the scientific and technical information available about climate change, its environmental and socio-economic impacts, and possible response options. The IPCC reports on the science of global climate change and the effects of human activities on climate. It does not do or manage research. Each IPCC report reviews all the published literature over the previous 5 years or so, and assesses the state of knowledge, while trying to reconcile disparate claims, resolve discrepancies and document uncertainties. The IPCC assessments, moreover, are produced through a very open and inclusive process. For the Working Group I (WGI) report (on the physical science basis of climate change) of the 2007 IPCC assessment, there were more than 30,000 comments from over 600 reviewers, as well as formal coordinated reviews by dozens of world governments, including the U.S. All review comments were addressed, and review editors were in place for each chapter of the report to ensure that this was done in a satisfactory, transparent and appropriate manner.

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[3] Minority Staff Report: The Unsettling Science behind EPA's Endangerment Finding, House Select Committee on Energy Independence and Global warming, May 6, 2010.
[4] Minority Staff Report: The Unsettling Science behind EPA's Endangerment Finding, House Select Committee on Energy Independence and Global warming, May 6, 2010.
[5] Minority Staff Report: The Unsettling Science behind EPA's Endangerment Finding, House Select Committee on Energy Independence and Global warming, May 6, 2010.

4. *In criticizing the IPCC's Fourth Assessment Report, the minority staff report[6] claims that "increasingly, evidence has mounted that the IPCC's agenda-driven process has in fact led to serious factual errors and, ultimately, an unreliable report." Do you agree that "serious factual errors" have made the Fourth Assessment report "unreliable"?*

I strongly disagree. There is no basis for such a conclusion. Because people are involved, the IPCC is not perfect; yet, to my knowledge, only two errors have been found in the 3,000+ page report, and only one was bordering on egregious. This, of course, was the statement in the Working Group II (WG2) report that the likelihood of the Himalayan glaciers "disappearing by the year 2035" was "very high" if the Earth keeps warming at the current rate. This claim did not make it into either the summary for policy makers or the overall synthesis report, and so it cannot be described as a "central claim" of the IPCC. It is also important to realize that the Himalayan glaciers are indeed rapidly retreating, but will not disappear by 2035.

It is worth pointing out that the WG2 report on impacts does not get the same amount of attention from the physical science community as does the higher profile Working Group I report, and the science of climate impacts is generally less mature and clear than the physical basis for climate change. Moreover, I am not aware of any known errors of substance in the WG1 report. In future reports, extra effort will be needed to make sure that the links between WG1 and the other two reports are stronger (they currently work in parallel, not in sequence).

5. *In his testimony[7], Lord Monckton points to a single study, Lindzen and Choi (2009)[8], to argue that the IPCC greatly overestimates the climate sensitivity. Do you agree with Monckton's argument? Since this study post-dates the most recent IPCC report, do you agree that it produces sufficient doubts about the social risks of climate change that policy to limit greenhouse gas emissions is unnecessary or should be delayed until uncertainties about the climate sensitivity can be resolved?*

I do not agree that it adds any doubt at all. On the contrary, it adds to the evidence that the previous findings are robust.

The paper by Lindzen and Choi (2009) (LC09) purported to demonstrate that climate had a strong negative feedback and that climate models are quite wrong in their relationships between changes in surface temperature and corresponding changes in outgoing radiation escaping to space. However, LC09 has been completed discredited by two very recent, peer-reviewed studies (Murphy 2010; and Trenberth et al. 2010; complete references below).

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[6] Minority Staff Report: The Unsettling Science behind EPA's Endangerment Finding, House Select Committee on Energy Independence and Global warming, May 6, 2010.
[7] Testimony of The Viscount Monckton of Brenchley Before Congress, 6 May 2010.
[8] R.S. Lindzen and Y.S. Choi (2009) On the determination of climate feedbacks from ERBE data. *Geophysical Research Letters* 36, L16705, doi:10.1029/2009GL039628.

Briefly, these two studies show: (1) the LC09 results are not robust; (2) more robust methods show no discrepancies between models and observations; and (3) LC09 incorrectly computed climate sensitivity. (Climate sensitivity is a measure of the equilibrium global surface air temperature change for a particular forcing, usually a doubling of the carbon dioxide concentration in the atmosphere).

Murphy, D. M., 2010: Constraining climate sensitivity with linear fits to outgoing radiation. *Geophys. Res. Lett.*, **37**, L09704, doi:10.1029/2010GL042911.

Trenberth, K. E., J. T. Fasullo, C. O'Dell, and T. Wong, 2010: Relationships between tropical sea surface temperatures and top-of-atmosphere radiation. *Geophys. Res. Lett.*, **37**, L03702, doi:10.1029/2009GL042314.

6. *In Lord Monckton's testimony before the Select Committee, he discussed the results of Pinker et al. (2005).*[9] *Dr. Pinker has commented on his analysis previously, stating: "the CO2 'radiative forcing' value that Mr. Christopher Monckton is quoting refers to the impact on the Earth's Radiative balance... the numbers that we quote in our paper represent the change in surface SW [shortwave radiation] due to changes in the atmosphere (clouds, water vapor, aerosols). These two numbers cannot be compared at their face value. To the best of my understanding this is the source of the misunderstanding."*[10] *Do you agree with Dr. Pinker"s criticism of Lord Monckton's comparison of these two values? If you disagree, please explain.*

Yes, I agree with Dr. Pinker. Pinker et al. (2005) deals with the surface radiation and not the radiation at the top of atmosphere. Moreover, Pinker et al. (2005) use data sets that are known to be flawed.

There have been real changes in surface radiation, sometimes referred to as "global dimming" and "global brightening". Lord Monckton used these terms; however, it is important to note such measurements only apply to land areas and not the ocean domain. Thus, since the oceans cover 70% of the Earth, neither the observed dimming nor brightening is global.

7. *What procedural flaws do you believe lend to the IPCC's errors? Do you agree with the IPCC's reliance on grey literature?*

The peer-review process works to make the IPCC reports credible because many different eyes with different perspectives and knowledge look over the same text. This tends to make the resulting product reflect more than just the opinion of a single author. However, in the case of the Himalayan glacier statement, it appears that not enough people with relevant experience saw the text, or if they saw it, did not comment publicly. As stated in my answer to *Q4*, the WG2 report on impacts does not get the same amount of attention from the physical science community as does the WGI report, and the science

[9] R. T. Pinker, B. Zhang, E. G. Dutton, 2005.Do Satellites Detect Trends in Surface Solar Radiation? Science. Vol. 308. no. 5723, pp. 850 – 854.

[10] http://scienceblogs.com/deltoid/upload/2010/02/debate_australia_tim_lambert.pdf

of climate impacts is generally less mature and clear. Thus, in future reports I believe it will be necessary to more strongly engage physical scientists in the review of the other two reports, and procedures should be implemented to make sure the links between the three IPCC Working Groups are stronger.

Regarding "grey literature", the Himalayan glacier statement was based on a World Wildlife Fund (WWF) report published in 2005. Those who examined the drafts and comments noted the statement was barely commented in the reviews, and that the WWF (2005) reference seems to have been a last minute addition. It did not, for instance, appear in either the First- or Second- Order Drafts. Thus, I believe my earlier comments on procedure are more relevant, and references to "grey literature" are not a problem. Moreover, I would disagree that IPCC has a "reliance" on the grey literature. The basis for the report lies in an assessment of the peer-reviewed literature, and this is especially the case for the WGI report.

8. *By its own admission, EPA has said that its Endangerment Finding for greenhouse gases relied on IPCC data and reports. In light of the errors revealed within the IPCC 4th AR, how can this Congress and the current administration justify implementing legislation that will lead to fewer jobs and cost taxpayers more money?*

Please see especially my answers to *Q3* and *Q4*, but also *Q1*. The science is sound. Also, while I am not a policy expert, I would argue that the economic cost of inaction must be seriously considered in the debate. There is already considerable evidence of many negative impacts from climate change, and these will only worsen and become more costly in the future.

9. *The Climategate e-mails scandal reveals a troubling pattern of behavior among a group of scientists influential to the IPCC process and reports that have been issued thus far. The e-mails sent between scientists at the University of East Anglia's Climatic Research Unit show a pattern of data manipulation and secrecy that undermine the British academic body's credibility, and even demonstrate CRU researchers violating UK law by plotting to avoid Freedom of Information requests. For example:*

From: Phil Jones, Date: Thu Jul 8 16:30:16 2004: I can't see either of these papers being in the next IPCC report. Kevin and I will keep them out somehow - even if we have to redefine what the peer-review literature is!
(http://www.eastangliaemails.com/emails.php?eid=419&filename=1089318616.txt)

10. *Do these e-mails raise any concerns regarding scientific integrity? Do you condone this behavior?*

The selective publication of some stolen emails taken out of context and distorted is mischievous and cannot be considered a genuine attempt to engage with the climate change issue in a responsible way. The emails do show a few scientists talking frankly among themselves – sometimes being rude and dismissive – but the email content in no way indicates that climate data and research have been compromised. The published

work of the CRU scientists, for instance, has always been fully peer-reviewed by the relevant journals, and is only one strand of research underpinning the strong consensus that human activity is affecting the world's climate. Lord Oxburgh's Independent Panel cleared CRU of any scientific impropriety and dishonesty. Moreover, their report points out that CRU has done a public service of great value by carrying out meticulous work on temperature records when it was unfashionable and attracted little scientific interest, and that the Unit has been among the leaders in international efforts to determine the overall uncertainty in the derived temperature records. The Report also emphasizes that all of CRU's published research on the global land-based instrumental temperature record included detailed descriptions of uncertainties and appropriate caveats. Statements from professional societies, such as the American Meteorological Society (http://www.ametsoc.org/policy/climatechangeclarify.html), reaffirm these points.

The specific quote above (from Phil Jones) was naïve and inappropriate. As this was the first time Jones was on the writing team of an IPCC assessment, it was sent before he understood the process and before the lead author meetings were held. It was not sanctioned by his convening lead co-author, Kevin Trenberth of NCAR. Both of the papers referred to in the quote were in fact cited and discussed in the 2007 IPCC report. They were not excluded.

Regarding scientific integrity, scientists should always be as open as possible with their data and methods. Transparency is critical for accountability on all sides.

11. *What recommendations would you make to regain public trust in the climate science discipline?*

Climate science is very complicated, and climate scientists have traditionally been relatively poor at explaining the science to the public. Moreover, in the public media there is a lot of misinformation and, unfortunately, even disinformation about climate, adding further confusion and doubt.

Climate scientists need to be proactive and improve their communications skills, for instance through formal training and education. They also need to work more closely with communication experts at their home institutions. Many are doing just this. In addition, climate scientists need to use every opportunity to share their understanding with the public and with policy makers. Opportunities abound – talks at schools, public lectures at libraries, business organizations, religious groups, etc. I am personally committed to communicating science to the public and I spend considerable time doing so. For this reason, I very much appreciate the opportunity to testify before the Select Committee and answer these questions.

12. *It has been acknowledged that certain sets of primary data have been intentionally destroyed and other sets of data are not shared within the scientific community. Do you believe that sharing of primary data sets will lead to more transparency in scientific work and is a step towards climate scientists being held more accountable?*

Transparency, openness and the sharing of data are important, and for the most part these are practices upheld to the extent possible in climate science (in my judgment, much more so than for many other scientific fields). At my home institution, for instance, we develop one of the comprehensive climate system models used to simulate historical climate and predict future climate. It is one of the key models assessed by IPCC. It is noteworthy that all of the model code, as well as the data sets that drive the model and the model output, are fully documented and openly accessible. Similarly, we make all of our observational data openly available for analysis, and this is the case at most research centers.

The "destruction" of data at CRU has been mischaracterized. At the center of the issue is raw data, including surface temperature averages, from weather stations around the world. According to CRU's Web site, "Data storage availability in the 1980s meant that we were not able to keep the multiple sources for some sites, only the station series after adjustment for homogeneity issues. We, therefore, do not hold the original raw data but only the value-added (i.e. quality controlled and homogenized) data." Moreover, less than 5% of the original raw station data were deleted from the database, and most of those stations are located in areas where there are already dense monitoring networks. In addition, the original raw data are still available from other sites, including the NOAA National Climatic Data Center (NCDC).

The salient point is that raw data were not secretly destroyed to avoid efforts by other scientists to replicate the CRU and Hadley Centre-based estimates of global-scale changes in near-surface temperature. In fact, other groups – primarily the NOAA NCDC and the NASA Goddard Institute for Space Studies (GISS) – have replicated the major findings of the CRU and UK Hadley Centre groups. The NCDC and GISS groups performed this replication completely independently. They made different choices in the complex process of choosing input data, adjusting raw station data for known inhomogeneities (such as urbanization effects, changes in instrumentation, site location, and observation time), and gridding procedures. NCDC and GISS-based estimates of global surface temperature changes are in excellent accord with the HadCRUT data results.

In summary, the so-called destruction of data at CRU was due to the fact that it was impossible at the time to store everything. Moreover, while computer storage and processing has advanced considerably since the 1980s, even now we cannot keep everything (e.g., massive amounts of data from satellites and models).

13. *Can you address the Medieval warming period and why temperatures were much higher in recent pre-industrial time periods? Are you able to model why such periods took place?*

Global average temperature increases in recent decades are primarily due to increases in atmospheric concentrations of greenhouse gases due to human activities. Evidence for a warmer world is also reflected in other independent measures as well, as documented in

my written testimony. Some of these are regional in character, such as: (1) the rapid melting of glaciers in non-polar regions around the world; (2) decreases in the areal coverage and thickness of Arctic sea ice, especially during summer, and of snow cover over northern continents; and (3) reductions of a few weeks in the annual duration of northern lake and river ice cover. Yet, in spite of this and other evidence (e.g., rises in global sea levels) that gives a collective picture of a warming world, the magnitude of the anthropogenic influence on regional climate remains uncertain. A principal reason is because the effects of human activities are superimposed on the background "noise" of internal (natural) climate variability, which can be very large regionally and results in the redistribution of heat by regional climate processes. Thus, global warming does not mean that temperature increases are spatially uniform or monotonic: some places warm more than the average and some places cool.

Natural variability was, of course, the dominant source of regional climate variability during medieval times. So, as now, climate was unlikely to have changed in the same direction, or by the same magnitude, everywhere. Because of this, at some times, some regions may have experienced even warmer conditions than those that prevailed throughout the 20th century. As discussed extensively in IPCC (2007), regionally restricted evidence by itself, especially when the dating is imprecise as is the case with many paleoclimate records, is of little practical relevance to the question of whether climate in medieval times was globally as warm or warmer than today. Only very large-scale climate averages can be expected to reflect global forcings over recent millennia.

To define medieval warmth in a way that has more relevance for exploring the magnitude and causes of recent large-scale warming, widespread and continuous palaeoclimatic evidence must be assimilated in a homogeneous way and scaled against recent measured temperatures to allow a meaningful quantitative comparison against 20th century warmth. A number of studies that have attempted to produce very large spatial-scale reconstructions have come to the same conclusion: that medieval warmth was heterogeneous in terms of its precise timing and regional expression.

The uncertainty associated with present palaeoclimate estimates of Northern Hemisphere (NH) mean temperatures is significant, especially for the period prior to 1600 when data are scarce. However, scientists have concluded that the warmest period prior to the 20th century very likely occurred between 950 and 1100, but NH temperatures then were probably between 0.2°F and 0.4°F below the 1961 to 1990 mean and significantly below the warmth shown by instrumental data after 1980. In short, the evidence is not sufficient to support a conclusion that NH mean temperatures were as warm, or the extent of warm regions as expansive, as those in the 20th century as a whole, during any period in medieval times. Moreover, there are far from sufficient data to make any meaningful estimates of *global* medieval warmth. There are very few long records, for instance, with high temporal resolution data from the oceans, the tropics or the Southern Hemisphere.

Regarding modeling of past climates, there is broad consistency between simulations of the past millennium and paleoclimate reconstructions of NH temperatures. Despite this

consistency, however, one must be cautious given the uncertainty in the reconstructed temperature records (as discussed above) as well as in the total radiative forcing estimates used to drive the models. Model simulations of the instrumental period (since 1850 or so) are a much more powerful test of models, as described in detail in my written testimony.

14. *All of the climate research seems to be focusing on the previous 100 years and examining the recent rise in atmospheric CO2 levels. Given the incredible complexities associated with the global climate, is it possible that this timeframe is not adequate? How can one overcome the lack of accurate data dating back before 1800?*

This is largely addressed in my answer to the previous question. It is certainly not true that "all of the climate research seems to be focusing on the previous 100 years". Tremendous efforts are made to reconstruct past climate variations and changes from a wide array of paleoclimate evidence, and there are many challenges associated with this work (which are addressed in considerable detail in Dr. Graumlich's written testimony). There is also an entire chapter in IPCC (2007) devoted to the paleoclimate perspective of climate change, including the uncertainties.

Paleoclimate research is important in order to determine how recent changes in climate fit into the longer-term perspective of changes driven by natural variability, and how the climate system has responded to past, naturally-driven changes in radiative forcing (e.g., from changes in solar radiation). Decades of field and laboratory research developing paleoclimate records has resulted in global networks of well replicated data. A few key findings include:

- Average Northern Hemisphere temperatures during the second half of the 20th century were very likely higher than during any other 50-year period in the last 500 years, and likely the past 1,300 years.
- The last time polar regions were significantly warmer than present was about 125,000 years ago. At that time average polar temperatures were up to 9°F warmer than present, because of differences in the Earth's orbit. Global average sea level was also likely 13-19 feet higher than during the 20th century, mainly due to the retreat of polar ice.
- It is very likely the glacial-interglacial carbon dioxide variations strongly amplified climate change, but it is unlikely they triggered the end of glacial periods. Polar temperatures, for instance, started to rise several centuries before atmospheric carbon dioxide concentrations rose.
- It is very likely current atmospheric concentrations of greenhouse gases exceed by far the natural range over the last 650,000 years, and that the rates of increase have been five times faster over the past 40 years than over any other comparable period the past 2,000 years.

15. *Dr. Hurrell, your testimony is quite bullish on the performance of climate models, although you do make reference to "uncertainties" arising "from shortcomings in the understanding and how to best represent complex processes models" on page 12.*

However, the rosy picture painted in your testimony appears to be in conflict with the contents of the paper[1] *by you and your colleagues that was published in the December 2009 issue of the Bulletin of the American Meteorology Society. There, you talk about "biases in models that make observations possibly incompatible with the model climate state", "profound gaps in our prediction abilities" with respect to the El Niño-Southern Oscillation phenomenon," and that "[f]or decadal and longer time scales, the problem of quantifying prediction skill becomes even more difficult" and "[e]ven if we could test long-term climate metrics proposed in the last decade of journal papers, we have no current method to prioritize or weight their impact in measuring uncertainty in predicting future climate change for temperature, precipitation, soil moisture and other variables of critical interest to society".*

Please reconcile your testimony with your recently published work.

There is no conflict between my testimony and the Hurrell et al. (2009) article in the *Bulletin of the American Meteorology Society.* The reason is that they refer to two different classes of prediction problems. One is long-term (several decades to centuries) climate change, and this is what I mostly refer to in my written testimony. Long-term climate change is fundamentally a "boundary value problem", where the evolution of climate depends on external changes in radiative forcing, such as anthropogenic changes in atmospheric composition or changes in solar forcing. Since the details of individual weather systems are not being tracked in such long-term predictions, the initial conditions of the system are not important.

The capability of climate models to simulate the past climate and evaluate the role of past changes in external forcing has been comprehensively assessed in the peer-reviewed scientific literature and is discussed extensively in IPCC (2007). As I state in my written testimony, "today's best climate models are able to reproduce the climate of the past century, and simulations of the evolution of global surface temperature over the past millennium are consistent with paleoclimate reconstructions." Certainly, climate models are not perfect, and some complex processes are not well represented. For instance, the precise nature of aerosol/cloud interactions and how aerosols interact with the water cycle remains a major uncertainty in our understanding of climate processes and, thus, their representation in models. Also, cryospheric, biospheric and biogeochemical processes just now being included in models, and they will be important in further improving predictions of future climate, including possible abrupt changes. Yet, the ability of today's models to simulate the past record means that the processes being simulated are accurate on a scale that makes the models very valuable tools.

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[1] James Hurrell, Gerald A. Meehl, David Bader, Thomas L. Delworth, Ben Kirtman, and Bruce Wielicki 2009: A Unified Modeling Approach to Climate System Prediction. *Bull. Amer. Meteor. Soc.*, 1819-1832.

The statements extracted above from Hurrell et al. (2009) deal mostly with a second category and a new frontier of climate prediction, often referred to as "decadal prediction". Over the next decade or two, changes in external radiative forcing, mostly from the continuing build-up of greenhouse gases in the atmosphere, will change climate. However, on these shorter time scales, the imprint of natural variations in climate can be quite large, especially on regional spatial scales. A key question, then, is to what degree such natural variations in climate (e.g., associated with changes in the El Niño/Southern Oscillation or the Pacific Decadal Oscillation) can be predicted if we "initialize" climate models with the current, observed state of the system, much in the same way that initial conditions are necessary for accurate predictions of the weather. Thus, "decadal prediction" is *both* an initial value and boundary value problem, and the associated challenges are discussed in Hurrell et al. (2009). For instance, given imperfect observations of climate (e.g., measurements from the deep ocean) and systematic errors in models, the best method of initialization has not yet been established.

These are very different issues than those associated with long-term climate change prediction. For instance, if accurate initial conditions were the essence of long-term climate change, we would have had far less success in interpreting and modeling past climate. Consider the proven ability of climate models to simulate the annual cycle of seasonal variations (i.e., the changes in climate from winter to summer) or their ability to capture past excursions of climate resulting from changes in both natural and anthropogenic forcing, including the amount of solar energy reaching the Earth, the amount of particulate matter in the atmosphere from volcanic eruptions, and atmospheric concentrations of anthropogenic gases and particles. The impressive fidelity of the 20th century climate simulations assessed in IPCC (2007) and referred to in my testimony is a good example, as are many published studies of model simulations of past, very different climate states such as the mid-Holocene and the Last Glacial Maximum. None of these simulations depend on the details of the initial climate state, but rather are driven by changes in external forcing.

16. *In your testimony you reference the rapid rate of global warming and that your models are capable of explaining the climate. I want to read you an email from your colleague Kevin Trenberth, sent on October 2009 to a group of your colleagues:*

> *"The fact is that we can't account for the lack of warming at the moment and it is a travesty that we can't. The CERES data published in the August BAMS 09 supplement on 2008 shows there should be even more warming: but the data are surely wrong. Our observing system is inadequate."*
>
> *The same month Dr. Trenberth wrote the following to Tom Wigley: "How come you do not agree with a statement that says we are no where close to knowing where energy is going or whether clouds are changing to make the planet brighter. We are not close to balancing the energy budget. The fact that we can not account for what is happening in the climate system makes any consideration*

of geoengineering quite hopeless as we will never be able to tell if it is successful or not! It is a travesty!"

You and your colleagues make confident claims in public, but in private, you admit a lot more uncertainty. Why weren't these uncertainties presented in the IPCC Report? Why did we only learn about them when the CRU emails were leaked?

First, I strongly disagree that scientists "admit a lot more uncertainty" in private than they do in the peer-reviewed literature. As a case in point, the discussion above regarding the adequacy of the climate observing system in place today is indeed the topic of peer-reviewed journal articles (e.g., Trenberth, 2009: An imperative for climate change planning: tracking Earth's global energy. *Current Opinion in Environmental Sustainability*, **1**, 19-27, doi:10.1016/j.cosust.2009.06.001; Trenberth and Fasullo, 2010: Tracking Earth's energy. *Science*, **328**, 316-317). In the quote above, Dr. Trenberth is noting that while the heating of the climate system continues to increase (as shown by satellite measurements) because of the build-up of greenhouse gases in the atmosphere, we are unfortunately not able to follow that flow of heat through the climate system because of inadequate observations. While some of the added heat might go into increasing surface temperature, for instance, some of it might melt ice or warm deeper regions of the ocean. Quantifying the partitioning of the energy flow is important thus important, but our ability to do so is inadequate because of observational limitations. This is the point being made by Dr. Trenberth, and it is openly discussed in the literature.

Second, it is important to understand the scientific process, the essence of which is the cyclical process of observing nature, formulating theories consistent with the observations, and challenging the theories with new observations, until the resulting findings develop into a body of robust understanding. Such is the case with climate science: theories and observations are tested, retested and reviewed, and a key part of the entire process is documenting uncertainty. Today, a huge body of evidence has been accumulated in support of the broad scientific understanding that recent warming of the global climate system is unprecedented in past millennium and that this change is due to human activities. This conclusion is supported by many lines of evidence based on decades of rigorous research by thousands of scientists and endorsed by all the world's major national science academies. Uncertainties do remain, but they concern things like the rate of melting of major ice sheets or the specific impacts of climate change on particular regions – not the broader issue of whether the climate is changing.

Third, the IPCC provides policy makers with an objective assessment of the scientific and technical information available about climate change, its environmental and socio-economic impacts, and possible response options. Each new IPCC report reviews all the published literature over the previous 5 years or so, and assesses the state of knowledge, while trying to reconcile disparate claims, resolve discrepancies and *document uncertainties*. There are also several independent reviews at various stages, including a full governmental review, and all comments must be addressed and documented by the review editors. Final approval is through an intergovernmental meeting. This means that the report cannot be selective in what it deals with, and an expression of the key

uncertainties has been a major facet of each IPCC report. It is certainly an imperative for the public and policymakers to question and debate the range of options for addressing climate change, based on the scientific evidence, including the level of certainty about that evidence.

17. *In your testimony you note "widespread changes in temperature extremes have been observed over the last 50 years." What sort of data collection is available to measure the number of heat waves and frost nights prior to the last 50 years of observations? Is it possible that in previous climatic periods, heat waves and frost nights were more commonplace than now?*

There is increasing concern that extreme events may be changing in frequency and intensity as a result of human influences on climate, and some observations of changes in extremes are documented in my written testimony. Assessments of extremes in IPCC (2007) and elsewhere are based on long-term observational series of weather elements. Changes in extremes are assessed at a range of temporal and spatial scales, for example, from extremely warm years globally to peak rainfall intensities locally. To span this entire range, data are required at a daily (or shorter) time scale, and such observations are mostly limited to recent times. Moreover, the availability of observational data restricts the types of extremes that can be analyzed. Global studies of daily temperature and precipitation extremes over land suffer from both a scarcity of data and regions with missing data. The main reason is that in various parts of the globe there is a lack of homogeneous observational records with daily resolution covering multiple decades that are part of integrated and digitized data sets. In addition, existing records are often inhomogeneous; for instance as a result of changes in observing practices. This affects, in particular, the understanding of extremes, because changes in extremes are often more sensitive to inhomogeneous climate monitoring practices than changes in mean conditions.

The situation with observational data sets is improving, although efforts to update and exchange more data must be continued. Results are now available from newly established regional- and continental-scale daily data sets; from denser networks, from temporally more extended high-quality time series and from many existing national data archives, which have been expanded to cover longer time periods. Moreover, the systematic use and exchange of time series of standard indices of extremes, with common definitions, is providing an unprecedented global picture of changes in daily temperature and precipitation extremes.

For many of the reasons mentioned above, observational evidence for changes in extremes is assessed for the period since about 1950 with even greater emphasis on the last few decades, although longer data sets exist for a few regions (including the U.S.), enabling more recent events to be placed in a longer context.

Because of the presence of natural variability, certainly in some regions conditions have been warmer or cooler than they are today for an extended period of time, with corresponding implications for extreme events. However, as a result of the anthropogenic

build-up of greenhouse gases in the atmosphere, the *global* warming we are witnessing goes beyond the range of natural variability and explains why observed changes in extremes are widespread and are mostly going in one direction: the number of heat waves globally has increased; there have been widespread increases in the numbers of warm nights; the number of cold days, cold nights and days with frost have become rarer; substantial increases have been found in heavy precipitation events; and droughts have become more common.

18. *When Chairman Markey asked if you disagreed with Lord Monckton's testimony, you replied that you did. Please explain why. Do you disagree with the information in the slideshow Lord Monckton presented?*

The reasons I disagree with Lord Monckton's testimony are mostly explained in my answers to *Q1, Q4, Q5, Q6* and *Q10.* In addition, Lord Monckton spoke of the lack of warming since 1998, but failed to mention the role of natural variability. For instance, a historically large El Niño event made 1998 one of, if not the warmest year on record, while strong La Niña conditions contributed to relatively cooler worldwide conditions in 2008. Simply connecting these two points in time was done by Lord Monckton to misleadingly argue global warming has ceased, ignoring the fact that the longer-term temperature trend is clearly upward and most years since 2000 have remained very close to the record or near-record 1998 global warmth. Because of such natural variations in the climate system, climate scientists expect occasional, but temporary, slowdowns in the rate of warming even while greenhouse gas concentrations continue to increase. This is also addressed in my written testimony (e.g., see Figure 2).

MUSEUM OF COMPARATIVE ZOOLOGY
The Agassiz Museum

HARVARD UNIVERSITY
26 OXFORD STREET
CAMBRIDGE, MASSACHUSETTS 02138

23 June 2010

Ms. Sarah Butler
Chief Clerk
Select Committee on Energy Independence and Global Warming
U.S. House of Representatives
Washington, D.C. 20515

Dear Ms. Butler,

Answers to the questions posed in your letter of 28 May, are given below.

1. *In his written testimony, and paraphrased in his spoken testimony, Lord Monckton claimed that "there is no hurry [to reduce carbon dioxide emissions]. Even after 23 years doing nothing to address the imagined problem ... the world will be just 1 F° warmer than it is today."*[1] *Therefore, Monckton says, global warming is not an urgent problem. Is Monckton's calculation approximately correct? Is this analysis a meaningful way to judge the urgency of reducing human-induced carbon dioxide emissions?*

Regardless of actions taken to mitigate the release of greenhouse gas emissions the average temperature of Earth may well rise another 1 F° by mid century. To imply that this will be benign and without negative impacts that far outweigh positive effects on natural and socioeconomic systems worldwide is counter to an enormous body of evidence from recent observations and extrapolations of these trends over the next few decades. Moreover, even the most simplistic analysis will demonstrate that inaction today, based upon the assumption that, corrective actions can come later, will demonstrate that the cuts necessary to avoid potentially large consequences of climate disruption will be increasingly difficult with each passing year.

2. *In arguing against the EPA Endangerment Finding, the minority staff report questions the statement of Administrator Lisa Jackson that "nothing in the emails undermines the science upon which the findings are based."*[2] *Do you agree with Administrator Jackson that the Climatic Research Unit (CRU) emails do not*

[1] Testimony of The Viscount Monckton of Brenchley Before Congress, 6 May 2010.

[2] Minority Staff Report: The Unsettling Science behind EPA's Endangerment Finding, House Select Committee on Energy Independence and Global warming, May 6, 2010.

undermine the body of scientific evidence for the causes and consequences of climate change?

My exposure to the purloined CRU email messages is through stories in the popular press and scientific publications describing their content and the results of investigations conducted within the UK and at the home universities for US scientists involved in these exchanges. Thus my information is all secondary, and incomplete. In nothing I have seen, however, has there been any information that has diminished the central messages from climate science over the past two decades. Phrases taken out of context and misunderstandings of scientific jargon (a "trick", for example) were the gist of most of the high profile stories about these email messages in the popular press.

3. *The minority staff report[3] states that the EPA "failed to develop its own scientific foundation"[4] to support its Endangerment Finding for greenhouse gases, instead relying on the scientific assessments of the IPCC and the U.S. Climate Change Science Program (CCSP). In your professional opinion, do the IPCC and CCSP assessments provide a strong basis for evaluating the social risks of climate change as represented in the peer-reviewed scientific literature? Does the EPA's reliance on the IPCC and CCSP assessments expose the agency to a high risk that it will develop "policies that may not be scientifically supportable"[5]?*

The IPCC, CCSP and numerous other national and international assessments of climate science have all come to similar conclusions. Such assessments have evolved over time as evidence for anthropogenic climate change becomes stronger and as observations can be compared with model projections from prior periods. In short, there is no body of findings in the published scientific literature that present a sufficiently different view to warrant the enormous investment of time to re-evaluate climate science. The EPA needs to be mindful of new findings that will result in changes in details of the understanding of climate science, but the risk of their developing policies inconsistent with the science if they rely on IPCC and CCSP assessments is trivial.

4. *In criticizing the IPCC's Fourth Assessment Report, the minority staff report[6] claims that "increasingly, evidence has mounted that the IPCC's agenda-driven process has in fact led to serious factual errors and, ultimately, an unreliable report." Do you agree that "serious factual errors" have made the Fourth Assessment report "unreliable"?*

---

[3] Minority Staff Report: The Unsettling Science behind EPA's Endangerment Finding, House Select Committee on Energy Independence and Global warming, May 6, 2010.
[4] Minority Staff Report: The Unsettling Science behind EPA's Endangerment Finding, House Select Committee on Energy Independence and Global warming, May 6, 2010.
[5] Minority Staff Report: The Unsettling Science behind EPA's Endangerment Finding, House Select Committee on Energy Independence and Global warming, May 6, 2010.
[6] Minority Staff Report: The Unsettling Science behind EPA's Endangerment Finding, House Select Committee on Energy Independence and Global warming, May 6, 2010.

There are errors in any 3000 - page document, no matter how careful the authors, especially when the report is researched, written, and edited by a largely volunteer organization. Few people outside the climate science community realize that scientists are not compensated for their time on these labor-intensive reports. As soon as IPCC reports are finalized, scientists find minor errors – typos (like yr 2035 rather than yr 2350), new overlooked work, etc. Reflecting back over the two decades of IPCC reports the most common errors are failure to properly account for strong reinforcing feedback processes – those that make the response to climate change even stronger. Sea level estimates are a good example of this. Due to the absence of evidence for changes in Greenland and Antarctic ice dynamics, projections of sea level rise have consistently underestimated actual rise. Between now and the release of the next IPCC assessment, more errors will surely be found in the Fourth (2007) IPCC assessment. None found to date would justify calling the report "unreliable".

5. *What procedural flaws do you believe lend to the IPCC's errors? Do you agree with the IPCC's reliance on grey literature?*

I think that the IPCC became lax with respect to their well-established policies and procedures. In some cases errors were caught by reviewers and not fixed by authors in subsequent revisions of the text. In my impression this was the result of the individual chapter review editors not paying strict attention to every reviewer comment and insuring that meaningful criticism was addressed in the subsequent revision. The grey literature is very dangerous ground, and polices for its use require a different level of scrutiny. Strict policies have long been in place with respect to the use of this material, and this may be another area where there was laxness during the preparation of some of the recent reports.

6. *By its own admission, EPA has said that its Endangerment Finding for greenhouse gases relied on IPCC data and reports. In light of the errors revealed within the IPCC 4th AR, how can this Congress and the current administration justify implementing legislation that will lead to fewer jobs and cost taxpayers more money?*

The first part of this question was addressed in my answers to questions above. The second part is a matter of climate policy, rather than climate science, which is beyond my expertise. I would offer, however, that assertions about fewer jobs and expenses are contextual and one-sided in that they do not reflect the job opportunities for US workers that are linked to alternatives to greenhouse gas emitting sources of energy, and they ignore the burden of costs associated with climate disruption in a warmer world.

7. *The Climategate e-mails scandal reveals a troubling pattern of behavior among a group of scientists influential to the IPCC process and reports that have been issued thus far. The e-mails sent between scientists at the University of East Anglia's Climatic Research Unit show a pattern of data manipulation and secrecy that undermine the British academic body's credibility, and even demonstrate*

CRU researchers violating UK law by plotting to avoid Freedom of Information requests. For example:

i. *From: Phil Jones, Date: Thu Jul 8 16:30:16 2004*
ii. *I can't see either of these papers being in the next IPCC report. Kevin and I will keep them out somehow - even if we have to redefine what the peer-review literature is! (http://www.eastangliaemails.com/emails.php?eid=419&filename=1089318616.txt)*

8. *Do these e-mails raise any concerns regarding scientific integrity? Do you condone this behavior?*

Again, as per above, several committees have been appointed to answer questions like this, and I defer to them as to whether these clippings from email messages reflect bad behavior.

9. *What recommendations would you make to regain public trust in the climate science discipline?*

I hope that the press that has covered the email and IPCC error stories will be as interested in covering new developments in climate science that will better help the non-scientist understand how climate is now changing and likely to change in the future.

10. *It has been acknowledged that certain sets of primary data have been intentionally destroyed and other sets of data are not shared within the scientific community. Do you believe that sharing of primary data sets will lead to more transparency in scientific work and is a step towards climate scientists being held more accountable?*

Under no circumstances should data ever be willfully destroyed. Decades after its collection and publication it may be difficult to reconstruct old data bases, but we should endeavor to preserve them in the most accessible and transparent way possible. It is not fully appreciated outside the scientific community that scientific data within atmosphere and ocean science communities is readily shared. Where the rub sometimes occurs is when non-specialists want the data and access to all the ancillary support services to make the data fully useful – without being willing to cover the costs required to provide this.

11. *Can you address the Medieval warming period and why temperatures were much higher in recent pre-industrial time periods? Are you able to model why such periods took place?*

Paleoclimate is not my area of expertise – so I don't model any of these data.

12. All of the climate research seems to be focusing on the previous 100 years and examining the recent rise in atmospheric CO2 levels. Given the incredible complexities associated with the global climate, is it possible that this timeframe is not adequate? How can one overcome the lack of accurate data dating back before 1800?

I don't know how one could possibly say what is asserted in the first sentence of this question. Enormous effort has been invested in studies that put the recent changes in the context of longer-term climate cycles, for the purpose of understanding the natural and anthropogenic components of recent climate change. Many published studies show a seamless linkage of time series for contemporary atmospheric CO_2 data and the ice core data from both hemispheres extending back in time well before 1800.

13. Dr. McCarthy, in your testimony you referred to the Antarctic ice cores, specifically stating that "the cycle of atmospheric CO2 content varies in concert with temperature over the hundred thousand year glacial - interglacial cycle." As I understand it, however, the temperature change comes before the CO2 change in that record. In other words the two series do not vary "in concert," but are separated by a lag of hundreds of years, and the change in CO2 is a response to temperature change, not vice versa. Can you comment on this?

My statement "vary in concert" stands as correct, regardless of whether T or CO_2 lead even with a lag of a few hundred years over a span of a hundred thousand years. There are several papers that address these chronologies and refinements of dating for T and atmospheric concentration of CO_2. I am unaware of any published climate paper that has claimed that changes in CO_2 lead temperature. I just pulled up one the first papers to discuss this, published in the journal Nature in 1900 by C. Lorius, J. Jouzel, D. Rayaud, J. Hansen and H. Le Treut, v 347 pp 139-145. Lorius et al. 1900 It establishes the high correlation between the onset of the glacial – interglacial cycle warming periods and specific Earth - Sun orbital properties (known as Milankovich Cycles). Once this warming begins it is amplified by strong releases of CO_2 and CH_4. Here is a quote from their paper "The discovery of significant changes in climate forcing linked with the composition of the atmosphere has led to the idea that changes in the CO_2 and CH_4 content have played a significant part in the glacial-interglacial climate changes by amplifying, together with the growth and decay of the Northern Hemisphere ice sheets, the relatively weak orbital forcing and by constituting a link between the Northern and Southern Hemisphere changes." Today the evidence is strong that much of this early burst of CO_2 comes from the ocean as Southern Hemisphere sea ice begins to retreat with favorable warming conditions, and the CO_2 accumulated under the ice over the thousands of years of the cool period is now free to equilibrate with the atmosphere.

To take a leap and argue (as some non-scientists have) that therefore changes in atmospheric CO_2 concentration are unlikely to cause a change in atmospheric T totally misses the point made in papers like Lorius et al. above, and furthermore ignores fundamental physics that 150 years ago firmly established that CO_2 is a radiatively active

(greenhouse) gas. Questioning this physics would be like questioning whether adding insulation to the walls of a building would change the flux of heat across the wall of the building.

14. In an email sent by Phil Jones to some of his colleagues in November 1999. He says:

> *"I've just completed Mike's Nature trick of adding in the real temps to each series for the last 20 years (ie from 1981 onwards) amd from 1961 for Keith's to hide the decline."(http://www.eastangliaemails.com/emails.php?eid=154&filename=942777075.txt)*

He's talking about a graph that went onto the cover of a report by the World Meteorological Organization in which a long segment of declining temperature data was removed to make the various data sets look like they all showed warming. Have you ever written an email to a colleague in which you talk about using a "trick" to hide a data trend that contradicts a conclusion you want to present? If you had received this email would you have felt at all uncomfortable about what he was doing?

No, I have not. I am not a climate modeler, but "trick" in the vernacular as a clever way to solve a problem is not uncommon. In order for me to feel comfortable or uncomfortable I would need the context. If it implied a method that would not be fully revealed to the reader of the paper containing these data then I would be more than uncomfortable. If it were to be fully revealed it would be up to the experts on the topic to judge whether this was a legitimate "trick".

15. *In your testimony, you make the observation that there are a vast number of studies proving the accumulation of greenhouse gases in the atmosphere are a result of human activity and that this – not natural cycles, solar cycles or volcanic activity - is the cause for warming trends in the earth. You say there exist no credible challenges to the validity of these studies. Let me read you a portion of a 2003 e-mail from Michael Mann to Phil Jones and others:*

> *"...This was the danger of always criticising the skeptics for not publishing in the "peer-reviewed literature". Obviously, they found a solution to that--take over a journal! So what do we do about this? I think we have to stop considering "Climate Research" as a legitimate peer-reviewed journal. Perhaps we should encourage our colleagues in the climate research community to no longer submit to, or cite papers in, this journal. We would also need to consider what we tell or request of our more reasonable colleagues who currently sit on the editorial board..." (http://www.eastangliaemails.com/emails.php?eid=295)*

Is it possible that the reason for a lack of credible challenges to the validity of the studies you cite is because of a concerted effort by some of your colleagues to coerce journals to quash them?

This assertion about my testimony is inaccurate. The author of this question has invented something that I have neither said nor written in this testimony or anywhere else. Recalling that my testimony was about the ocean, here are the statements in my testimony which you grossly misrepresented: (page 7) "Barnett et al. (2005) demonstrated that the observed changes in ocean heat-content since the 1960s are consistent with what would be expected from the accumulation of greenhouse gases from human activities, and that these patterns in warming cannot be solely explained by natural cycles, solar cycles or volcanic activity. Vast numbers of studies have corroborated these analyses, and there is no credible challenge to their validity." NOTE, this does not say that natural [climate] cycles, solar cycles, or volcanic activity are not important influences on climate. The cited paper by Barnett et al. states clearly, however, that alone and in aggregate they cannot explain the observed changes. See also the following (page 11 – 12): "State of the art fully coupled climate models can now simulate the natural processes that affect climate (solar cycles, volcanoes, and internal cycles such as the El Niño –Southern Oscillation) and the human-caused processes that affect climate (greenhouse gases and aerosols) to show the relative importance of each of these components in the climate of the past and present."

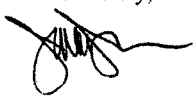
To the follow-on point, which I judge to be irrelevant given the misrepresentation of my testimony, take a look to see how the sloppy handling of the paper being referred to in "Climate Research" led to a shake-up in the management of the journal. Editors resigned and the publisher publicly apologized for publishing this paper.

16. When Chairman Markey asked if you disagreed with Lord Monckton's testimony, you replied that you did. Please explain why. Do you disagree with the information in the slideshow Lord Monckton presented?

If one reads my testimony and that of Mr. Monckton, he will see why we disagree. The evidence supports what is contained in my testimony. Moreover, in the appendix to my testimony you will see a list of professional scientific societies restating as a common statement what is contained in their various statements on climate: "*Despite the uncertainties noted above, there is adequate evidence from observations and interpretations of climate simulations to conclude that the atmosphere, ocean, and land surface are warming; that humans have significantly contributed to this change; and that further climate change will continue to have important impacts on human societies, on economies, on ecosystems, and on wildlife through the 21st century and beyond.*" Every national academy of sciences that has issued a statement on climate change (one could start by looking at those of the G-8, plus India, China, Brazil, Mexico, South Africa, Australia, and keep going if you wish) has issued similar singular or joint statements. Simply put, Mr. Monckton disagrees with them all. Why would a student of classics and a journalist have understanding superior to the world's experts on a scientific matter?

If the American Medical Association, the American Cancer Society, the American Lung Association, the American for Thoracic Surgery, etc. all say that smoking contributes to lung disease, would you prefer to continue smoking in the belief that that one person out there, maybe even with M.D. or Ph.D. behind his name, is still saying not to worry?

Yours sincerely,



James J. McCarthy
Alexander Agassiz Professor of
Biological Oceanography

CARIE ❀ RANNOCH ❀ PH17 2QJ
01882 632341 ❀ Fax 632776 ❀ Cell 07814 556423
monckton@mail.com
From: The Viscount Monckton of Brenchley

Monday, May 31, 2010

Ms. Sarah Butler, Chief Clerk,
Select Committee on Energy Independence and Global Warming
sarah.butler@mail.house.gov; 202-225-4012

Dear Ms. Butler,

Questions from the Select Committee concerning my recent testimony

On Friday, you sent me a list of questions from the Select Committee. Here are the answers. I have taken the liberty of conflating questions 8 and 12. I shall do my best to supply any additional information on request.

1. **In an open letter from you to two members of the United States Senate, you described yourself as "a member of the Upper House of the United Kingdom legislature." How do you reconcile this representation to elected members of the Senate with your more recent statement to the Select Committee that "I have never sat or voted in The House of Lords, *nor have I pretended otherwise*"?**

The House of Lords Act 1999 debarred all but 92 of the 650 Hereditary Peers, including my father, from sitting or voting, and purported to – but did not – remove membership of the Upper House. Letters Patent granting peerages, and consequently membership, are the personal gift of the Monarch. Only a specific law can annul a grant. The 1999 Act was a general law. The then Government, realizing this defect, took three maladroit steps: it wrote asking expelled Peers to return their Letters Patent (though that does not annul them); in 2009 it withdrew the passes admitting expelled Peers to the House (and implying they were members); and it told the enquiry clerks to deny they were members: but a written Parliamentary Answer by the Lord President of the Council admits that general legislation cannot annul Letters Patent, so I am The Viscount Monckton of Brenchley (as my passport shows), a member of the Upper House but without the right to sit or vote, and I have never pretended otherwise.

2. **In your testimony to the House Energy and Commerce Committee, you claimed that "there has been global cooling for seven years" on the basis of a temperature trend calculated over the selected period January 2002 to January 2009.[1] In a review of your testimony, the National Oceanic and Atmospheric Administration concluded that your "calculation of a trend over the last seven years is a gross mischaracterization of the longer term trend."[2] How do you reconcile your approach to trend calculation with your recent statement: "if you choose your starting and ending points carefully enough, you can make it go in any direction you want"[3]?**

In my testimony of 25 May 2009, I produced a graph of which an updated version is reproduced below, showing that for what is now nine and a half years there has been a global cooling trend, notwithstanding continuing increases in atmospheric CO_2 concentration. I note that the National Oceanic and Atmospheric Administration no longer seeks to avoid admitting that there has indeed been a global cooling trend over the period.

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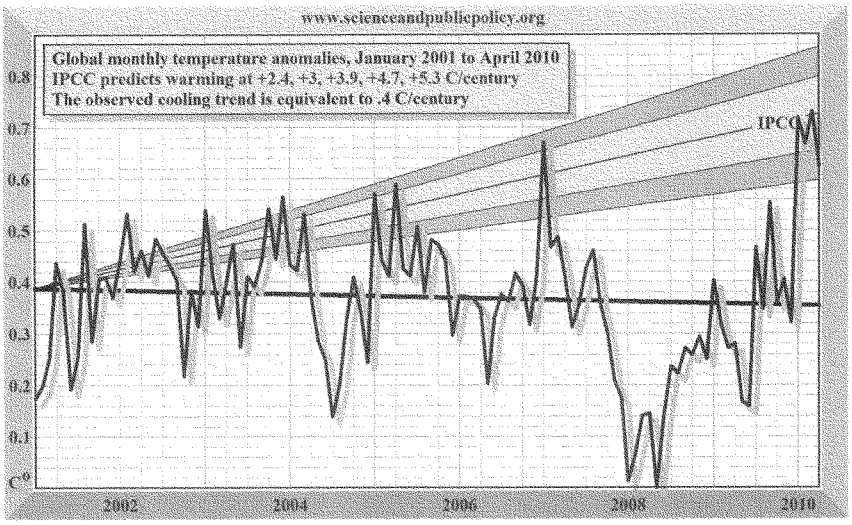
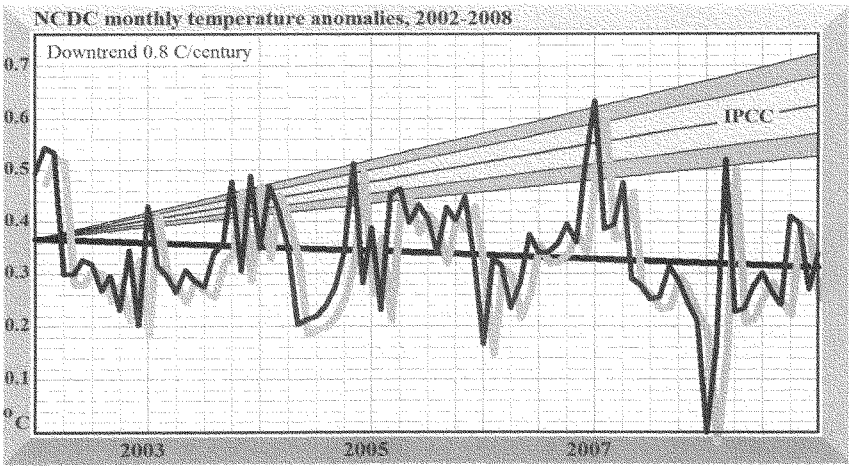
[1] Testimony of Lord Monckton before the Energy and Commerce Committee, May 25, 2009.
(http://energycommerce.house.gov/Press_111/20090325/testimony_monckton.pdf)
[2] NOAA Response to Congressional Questions Regarding Climate Change (http://www.noaa.gov/images/climate_cooling_testimony111909.pdf)
[3] Unedited and unofficial hearing transcript of the House Select Committee on Energy Independence and Global Warming, May 6, 2010.



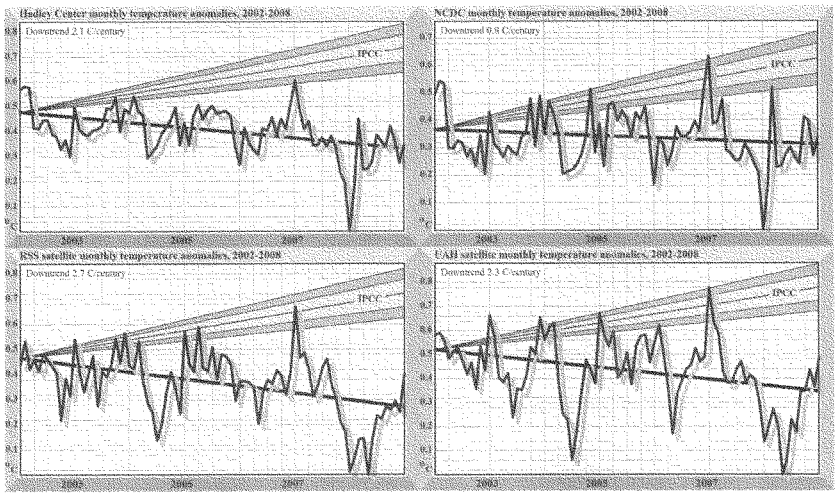
RSS and UAH combined monthly global mean surface temperature anomalies, 2001-2010

When I put forward the graph of which the above is an updated version, Representative Joe Barton (R: TX), the ranking Minority member on the Energy and Commerce Committee, was visibly startled by it, commenting to the effect that in months of testimony from various official sources no one had told the Committee looking into "global warming" that there had in fact been global cooling for the best part of a decade. He turned to Mr. Tom Karl, the director of the National Climatic Data Center, a division of NOAA, and asked him whether it was true that there had been global cooling. Mr. Karl was not honest enough to admit that there had been global cooling. Accordingly, Mr. Barton asked Mr. Karl and me to submit evidence for and against the fact of global cooling. I submitted a letter to the Committee including a graph showing the least-squares linear-regression trend on the NCDC's own dataset:



NCDC monthly global mean surface temperature anomalies, 2002-2008

I also supplied to the Energy and Commerce Committee a graph showing that all four of the principal global temperature datasets showed global cooling over the period –



Linear regressions on four monthly global mean surface temperature anomaly datasets, 2002-2008

From the data, it is apparent that there has indeed been some measure of global cooling since the turn of the millennium nine and a half years ago. From Mr. Barton's surprised reaction, it is evident that official witnesses appearing before the Energy and Commerce Committee, over a period of many months, had concealed from the Committee the fact that global temperatures have been falling. In fact, for more than 15 years the "global warming" that has occurred has been barely statistically significant. Mr. Karl's less than honest attempt to conceal from that Committee, upon the direct request of its ranking Minority member, the fact that "global warming" has scarcely been occurring for 15 years and has been replaced by global *cooling* since the turn of the millennium, was regrettable. Since the scientific establishment is demanding trillions from taxpayers, it must be seen to be truthful.

In an attempt to recover from this disastrous position, Mr. Karl – or at any rate the NOAA – huffs and puffs about how little it matters that there should have been global cooling over as short a period as seven years (now nine and a half years and counting). Mr. Karl – or the NOAA – points out that the recent global cooling is overlain by a longer warming trend, going back to the beginning of the satellite era in the early 1980s:

> "The fact that globally averaged surface air temperature has shown no trend or even slight cooling over the last 7 years is not an accurate reflection of long-term general trends. In fact, calculation of a trend over the last seven years is a gross mischaracterization of the longer term trend. The last seven years have been part of a strong warming trend that began in the 1970s, which is attributable to human influences (IPCC, 2007). During the last seven years six of the seven warmest years on record have been all been observed based on NOAA's global land and ocean data. Deducing long-term trends over such a short period of time is comparable to estimating the height of a sea swell by looking at the short period waves on top of the swell."

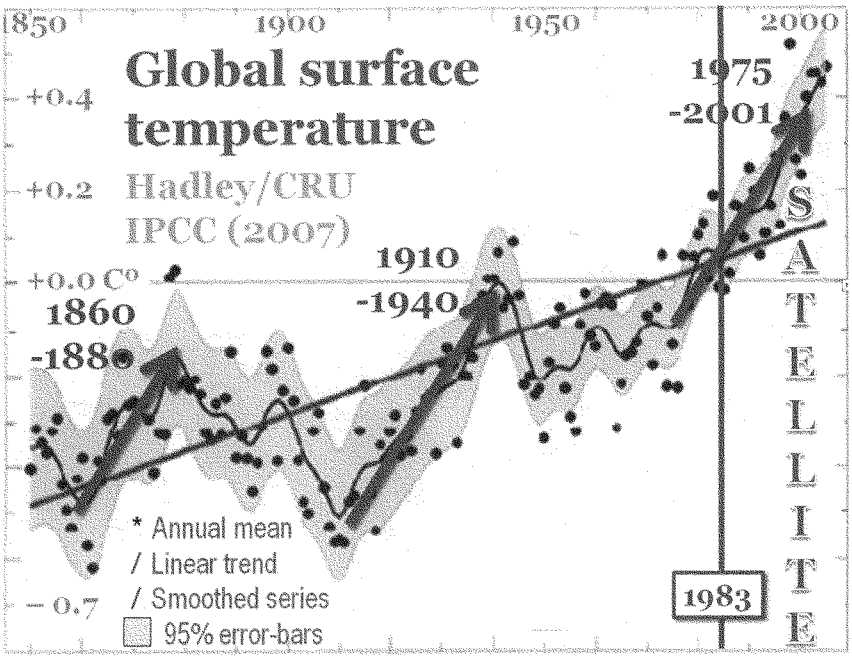
Yet in my testimony I had not drawn any conclusion about "long-term trends", still less "mischaracterized" them: I had merely reported – accurately, as Mr. Karl had not conceded but as NOAA's testimony now testily concedes – that for several years there has indeed been global cooling.

NOAA states that there has been –

> "a strong warming trend that began in the 1970s, which is attributable to human influences (IPCC, 2007)".

This statement is misleading in at least two respects.

First, the "strong warming trend" is not unprecedented. As I demonstrated before the Select Committee, the three periods of most rapid warming in the 160-year global instrumental temperature record – 1860-1880, 1910-1940, and 1976-2001 – are at rates identical to one another within the measurement error, at ~0.16 K (0.3 F°)/decade –



Three parallel rates of warming at ~0.16 K (0.3 F°) per decade. Where is the anthropogenic signal?

I arranged for a Parliamentary Question to be put down in the House of Lords to confirm that these three rates of warming were indeed parallel. Lord Hunt of King's Heath replied on behalf of the then Government:

> "Observations collated at the Met Office Hadley Centre and the University of East Anglia Climate Research Unit indicate that the rate of increase in global average surface temperature between 1975 and 1998 were similar to the rates of increase observed between 1860 and 1880 and between 1910 and 1940 (approximately 0.16 C° per decade). ..."

Senator Vitter recently asked Dr. John Holdren, the current US Administration's Science Advisor, the same question. Dr. Holdren replied that the rate of warming from 1976-2001 had been significantly greater than in the two earlier periods. It may be that Dr. Holdren was not relying upon the same global-temperature dataset as the IPCC (i.e. the Hadley/CRU dataset). If so, Dr. Holdren was surely under an obligation to make that fact plain, and to explain that the global-temperature record relied upon by the IPCC showed that the three rates of warming were indeed parallel. He did not do so. Once again, it is not clear to me that a senior official of the Administration is giving complete, fair, and honest answers to elected representatives in Congress on a major and potentially very costly matter of policy concern. Once again, that would be a very serious matter in the UK Parliament.

The second respect in which NOAA's statement is misleading is the assertion that the "strong warming trend that began in the 1970s ... is attributable to human influences (IPCC, 2007)." First, the IPCC in fact states no more than that (with 90% confidence – not a standard or compelling confidence interval) more than half of the warming since 1950 is attributable to human influences, not that all of it is. It would have been less dishonest if NOAA had made that explicit.

Secondly, as I pointed out in my testimony to the Select Committee, multiple lines of evidence in the peer-reviewed literature establish that there was a substantial global brightening from 1983-2001, during which up to 3 Watts per square meter of additional radiant-energy flux reached the Earth's surface. A surface flux increase of anything like this magnitude would be expected to have caused more warming than any anthropogenic influence over the period.

Finally, in my testimony before the Select Committee I began by showing three successive graphs each of which displayed the entire 160-year instrumental global-temperature record. It cannot credibly be maintained, therefore, that I have adopted too short a period of observation.

3. **In your testimony before the Select Committee, you discussed the results of Pinker et al. (2005).[4] Dr. Pinker and co-author Dr. Dutton have since commented on your testimony[5] (attached) and have identified discrepancies between your statements and their paper related to (1) your attempt to link the change in solar radiation to a temperature change and (2) the data used in their study. They also question whether your radiative transfer calculations are consistent with the IPCC's methodology, as you claimed. Please submit your detailed radiative transfer calculations. If you agree with the authors' criticism, please update the applicable portion of your written testimony and resubmit it for the record. If you disagree, please explain.**

I have not been sent Dr. Pinker's commentary on my testimony, and should be grateful if the Select Committee were to forward it to me, whereupon I shall be happy to respond to it. However, my testimony does not rely on her paper alone but on many others in the peer-reviewed literature. Therefore, I am happy to set forth here, in some detail as requested, an outline of the radiative-transfer calculations on which my testimony was based.

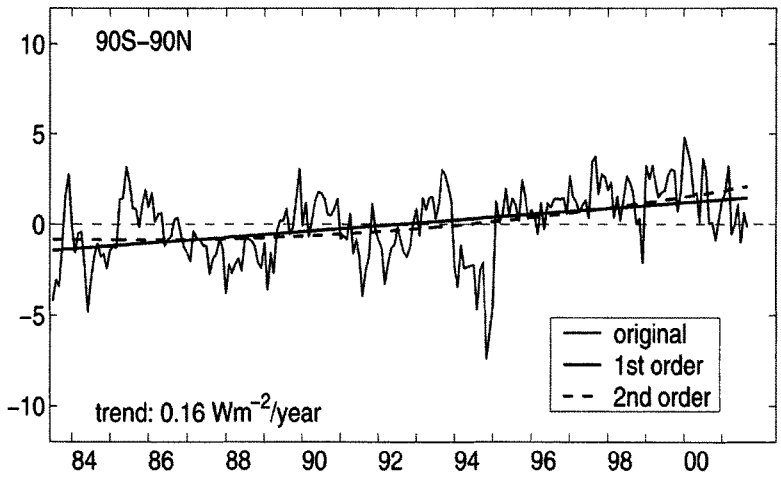
I begin by noting that it is intriguing that the faction on the Select Committee that is responsible for this question should have seen fit to cast doubt upon the notion of linking an increase in solar radiation at the Earth's surface (known as a "global brightening") to an increase in global temperature (known as "global warming"). If the members of that faction would care to step outside their air-conditioned offices and go out on to the National Mall, they would be able to conduct a remarkably simple experiment. If the Sun shines directly upon their balding pates, they will notice that it is warmer than when the clouds are in the way. If that phenomenon takes place globally, natural "global brightening" and hence "global warming" occurs.

As previously noted, the rapid rate of global warming from 1975-2001, at ~0.16 K/decade, was near-identical to the rates observed from 1860-1880 and from 1910-1940. Warming in the two earlier periods preceded any significant anthropogenic influence on the climate. The third and most recent period of rapid warming may also have been chiefly of natural origin: observations indicating a global brightening of up to 2.9 W m^{-2} at the Earth's surface from 1983-2001 would imply a naturally-caused transient warming of ~0.9 K or, after adding anthropogenic warming, ~1.2 K. However, little more than 0.3 K global warming was observed over the period, suggesting that currently-accepted estimates of the amplifying influence of temperature feedbacks on natural and anthropogenic global warming may be excessive. Improved observations of variations in cloud cover and in other influences on the solar radiative flux reaching the Earth's surface will be important for the eventual determination of climate sensitivity. I shall now explain these results in detail.

The data

The Hadley/CRU global mean surface temperature dataset (Jones *et al.*, 1999, and Brohan *et al.*, 2006, cited in Solomon *et al.*, 2007) shows a rapid and sustained global warming from 1975-2001 at ~0.16 K/decade, a rate identical, within measurement error, to those observed from 1860-1880 and again from 1910-1940. Warming in the two earlier periods preceded any significant anthropogenic influence on the climate. The third and most recent period of rapid warming may also have been chiefly natural. Satellites first made well-calibrated measurements of global mean surface temperature and of radiant-energy flux leaving the top of the atmosphere in the early 1980s. Pinker *et al.* (2005), finding agreement between satellite and terrestrial records for the first time, reported a significant global brightening from 1983-2001, possibly caused by a decline in cloud cover accompanied by changes in water vapor and aerosols. Pinker, relying chiefly on data from the International Satellite Cloud Climatology Project (ISCCP: Rossow & Schiffer, 1991, 1999), applied linear and second-order least-squares fits to the satellite-derived time-series of globally-averaged short-wave anomalies in solar radiative flux at the Earth's surface from 1983-2001, after removal of the annual cycle. They found the linear slope positive at 0.16 W m^{-2} yr^{-1}.

[4] R. T. Pinker, B. Zhang, E. G. Dutton, 2005. Do Satellites Detect Trends in Surface Solar Radiation? Science 308: 5723, 850-854.
[5] Pinker, R. T. and E. G. Dutton, 2010. Response to: Testimony of The Viscount Monckton of Brenchley Before Congress, 6 May 2010.



A globally-averaged o.16 W m^{-2} yr^{-1} trend in short-wave solar surface radiative flux anomalies, 1983-2001, after removal of the mean annual cycle. From Pinker, Fig. 1.

The Earth Radiation Budget Experiment satellites (ERBE: Barkstrom, 1984) also detected a reduction in short-wave radiation reflected from clouds to space during the same period, with a corresponding increase in long-wave radiation as more short-wave radiation reached the Earth's surface and was Wien-displaced to the near-infrared, consistent with a reduction in global cloud cover, especially at low altitudes and latitudes, and particularly in the 1990s.

At the time when Pinker reported, the ERBE outgoing-radiation data presented in Wielicki *et al.* (2002a, b) had not been corrected to allow for orbital decay.

After allowing for adjustments published by Wong *et al.* (2006), and combining ERBE values for latitudes 60N-60S with ISCCP FD 60N-90N and 90S-60S values, using surface-area weighting factors 0.866, 0.067 and 0.067 respectively, the ERBE data would imply that the global brightening from 1983-1999 was three-quarters of that indicated by the ISCCP data alone for 1983-2001.

Other observations confirm the fact of the global brightening, while disagreeing as to its magnitude. Solomon *et al.* (2007, at Table 3.5) compare tropical (20°S-20°N) top-of-atmosphere long-wave and short-wave radiative-fluxes for 1994-1997 with the fluxes for 1985-1989, citing the ERBE satellite data, which showed outgoing long-wave radiation increasing by 0.7 W m^{-2} and outgoing short-wave radiation decreasing by 2.1 W m^{-2} over the period.

Solomon also cites the ISCCP data as indicating that outgoing long-wave radiation increased by 0.5 W m^{-2}, while outgoing short-wave radiation decreased by 2.4 W m^{-2}.

The AVHRR Pathfinder gave an opposite result: but, as Solomon notes, "Calibration issues, conversion from narrow to broadband, and satellite orbit changes are thought to render the AVHRR record less reliable for decadal changes compared to ERBS."

Wild *et al.* (2007), focusing on changes in mean surface temperature over the land, concluded that the global dimming up to the 1980s was offset by the period of brightening (or at least the absence of dimming) thereafter, and that the rapid warming that followed the transition was attributable almost entirely to anthropogenic influences.

However, Pinker (at Figure 5A) shows a very slight dimming over land only from the 1980s onward. Though Wild makes a passing reference to Pinker, reliance is placed not upon satellite data but upon data from the Global Energy Balance archive and the Baseline Surface Radiation Network.

Wild focused solely on land surfaces. The absence of solar dimming, and the insignificant net brightening, over land after 1980, deduced from surface-station measurements, is consistent with the analysis of land-only satellite data in Pinker.

Solomon (*op. cit*: ch.3) concludes her discussion of clouds as follows:

> "In summary, while there is some consistency between ISCCP, ERBS, SAGE II and surface observations of a reduction in high cloud cover during the 1990s relative to the 1980s, there are substantial uncertainties in decadal trends in all datasets and at present there is no clear consensus on changes in total cloudiness over decadal time-scales."

However, the data indicate that from 1993-2001 there was a significant decline in cloud cover generally, not merely in high cloud cover. It is optically-dense clouds at low altitude and latitude that are most influential in global brightening or dimming.

Analysis and results

For clarity, the present analysis is confined to central estimates. Data and methods in Solomon are adopted where possible.

The global brightening of ~0.16 W m^{-2}/year reported by Pinker is equivalent to a surface solar radiative flux anomaly $\Delta F_{S,br} \approx 2.893$ W m^{-2} over the 18 years 1 month from 1983-2001. The consequent warming before temperature feedbacks is, at its simplest, the product of $\Delta F_{S,br}$ and the surface Planck pre-feedback climate-sensitivity parameter κ_S, whose value, implicit in Kiehl & Trenberth (1997), is the first differential of the Stefan-Boltzmann radiative-transfer equation where mean surface temperature T_S and surface radiative flux F_S are 288 K and 390 W m^{-2} respectively:

$$\kappa_S = \Delta T_S / \Delta F_S = T_S / (4F_S) \approx 0.185 \text{ K W}^{-1} \text{ m}^2. \quad (1)$$

Accordingly, the transient pre-feedbacks warming $\Delta T_{S,br}$ that would be expected to have arisen from the global brightening mentioned in Pinker was:

$$\Delta T_{S,br} = \Delta F_{S,br} \kappa_S \approx 0.5 \text{ K}. \quad (2)$$

Allowance must then be made for the amplifying influence of temperature feedbacks arising in response to the change in surface temperature. The feedback multiplier f, where b is the sum of all climate-relevant temperature feedbacks and where the upper-troposphere Planck parameter $\kappa_T = 3.2^{-1} \approx 0.313$ K W^{-1} m^2 (Solomon), is given by the amplification function in Bode (1945):

$$f = (1 - b\kappa_T)^{-1}. \quad (3)$$

At a doubling of atmospheric CO2 concentration, where the multi-model mean projected climate sensitivity $\Delta T_{S,2x}$ = 3.26 K (Solomon) and the CO2 radiative forcing $\Delta F_{2x} = 5.35 \ln 2$ (Myhre *et al.*, 1998, cited in Meehl *et al.*, 2001, and in Solomon), the implicit central estimate of f_{2x} is:

$$f_{2x} = \Delta T_{2x} / (\kappa_T \Delta F_{2x}) \approx 2.813. \quad (4)$$

With this central estimate of f_{2x}, we rearrange Eqn. (3) to derive the IPCC's implicit central estimate of the feedback-sum b_{2x}:

$$b_{2x} = (f_{2x} - 1)/(f_{2x} \kappa_T) \approx 2.063 \text{ W m}^{-2} \text{ K}^{-1}. \quad (5)$$

However, it is necessary to deduct the cloud feedback of 0.69 W m^{-2} K^{-1} (Soden & Held, 2006, cited in Solomon) from b_{2x}, since the observed global brightening will have reflected any cloud feedback effects. Thus,

$$b_{br} = b_{2x} - 0.69 = 1.373 \text{ W m}^{-2} \text{ K}^{-1}. \quad (6)$$

Then $$f_{br} = (1 - b_{br}\kappa_T)^{-1} \approx 1.752, \quad (7)$$

and $$\Delta T_{S,br} = \Delta T_{S,br} f_{br} = \Delta F_{S,br} \kappa_S f_{br} \approx 0.9 \text{ K}. \quad (8)$$

Accordingly, the IPCC's methodology implies that, in response to a global brightening of the magnitude reported by Pinker, pre-feedback and post-feedback warmings would be ~0.5 K and ~0.9 K respectively.

My distinguished colleague Dr. Joseph Boston has recently re-evaluated the ISCCP and ERBE data, and has concluded that the global brightening of 1983-2001 amounted to 0.106 W m^{-2} yr^{-1}, or 1.917 W m^{-2} in all, a more conservative value than the 0.16 W m^{-2} yr^{-1} found by Pinker, particularly since his change in surface radiative flux is on a net basis, requiring that the surface-albedo feedback, given in Soden & Held (2006) as 0.26 W m^{-2} K^{-1}, be deducted from the feedback-sum in Eqn. (6), so that $b_{br} \approx 1.113$ W m^{-2} K^{-1} and the feedback multiplier f_{br} in Eqn. (7) falls to 1.533. On that basis, the pre-feedback and post-feedback warmings would be ~0.35 K and ~0.55 K respectively.

In addition, anthropogenic warming would be expected to have occurred over the period. Table 1, again relying upon the methodology in Solomon, gives central estimates of the radiative forcings arising from observed increases in the concentrations of the major greenhouse gases from 1983-2001.

Greenhouse gas	1983	2001	Radiative forcing
Carbon dioxide	342 ppmv	370 ppmv	0.421 W m^{-2}
CFC-12	343 pptv	541 pptv	0.065 W m^{-2}
Methane	1630 ppbv	1775 ppbv	0.054 W m^{-2}
Ozone	Estimate	Estimate	0.048 W m^{-2}
Nitrous oxide	304 ppbv	312 ppbv	0.024 W m^{-2}
CFC-11	183 pptv	256 pptv	0.018 W m^{-2}
		Total forcing	$\Delta F_{T,gg} = 0.630$ W m^{-2}

Table 1. Radiative forcings arising from changes in the atmospheric concentrations of key greenhouse gases from 1983-2001, determined from functions given in Myhre et al. (1998) and cited in Meehl et al. (2001) and in Solomon. CFC concentrations are from Hartley et al., 1996. The ozone forcing is an estimate. The negative forcings from aerosol effects are omitted, since the measured surface radiative flux anomaly occasioned by the global brightening of 1983-2001 implicitly takes them into account. Forcings from minor halocarbons, land-use changes, and aircraft contrails are omitted as de minimis.

Since the forcings in Table 1 represent tropopausal changes in net radiative flux, it is the upper-troposphere value $\kappa_T = 3.2^{-1}$ K W^{-1} m^2 of the Planck parameter that is applicable. The feedback factor f_{br} remains appropriate, since the effects of anthropogenic forcings on the cloud feedback will also have influenced the measured change in surface radiative flux arising from global brightening over the period.

However, in the IPCC's methodology, the temperature change $\Delta T_{S,gg}$ that is projected to arise in consequence of greenhouse-gas forcings is not transient warming, as the observationally-derived $\Delta T_{S,br}$ is, but equilibrium warming: *i.e.*, the anomaly that would arise only after the climate had settled to a new equilibrium after the forcing. Thus, at equilibrium:

$$\Delta T_{S,gg} = \Delta F_{T,gg} \kappa_T f_{br} = \Delta F_{T,gg} \kappa_T (1 - b_{br} \kappa_T)^{-1}. \quad (9)$$

To determine transient temperature change $\Delta T_{S,eq}$, we introduce an additional term r to represent the ratio of transient to equilibrium warming. On the A2 scenario, Solomon projected ~0.2 K/decade *transient* warming in response to CO2 forcing for 2000-2010, all other anthropogenic influences being broadly self-canceling, but the observed increase in CO2 concentration was ~20 ppmv, implying *equilibrium* warming of 4.7 ln(388/368) ≈ 0.249 K, and hence a decadal transience ratio $r \approx 0.8$.

Over the entire 21st century (on IPCC scenario A2), with predicted transient warming of 3.4 K and CO2 concentration rising from a measured 368 to a projected 836 ppmv, the transience ratio r rises to 3.4 / [4.7 ln (836/368)] ≈ 0.9. Therefore, for periods ($10 \le y \le 100$) years, we take the approximation $r = r_y = 0.8 + (y - 10)/900$, so that $r_{18} \approx 0.81$ over the 18 years 1983-2001 and $r_{55} \approx 0.85$ over the 55 years 1950-2005. Taking $r = r_{18} \approx 0.81$:

$$\Delta T_{S,gg} = r \Delta F_T \kappa_T f_{br} \approx 0.3 \text{ K}, \quad (10)$$

and $$\Delta T_S = \Delta T_{S,br} + \Delta T_{S,gg} \approx 1.2 \text{ K}. \quad (11)$$

Accordingly, the methods in Solomon would lead us to expect total transient warming of ~1.2 K (Eqn. 11) over the period, or ~0.9 K based on Dr. Boston's re-evaluation of the global brightening. Of this warming, the greater part would be attributable to the naturally-occurring global brightening.

However, the linear regression trend on the HadCRU monthly global land and sea surface temperature anomalies indicates observed transient warming of only ~0.3 K. Even if the flux anomaly occasioned by the global brightening of 1983-2001 was only one-third of that which Pinker had reported, it would have caused ~0.3 K warming, approximately equal to the observed warming and consequently leaving little room for any contribution from anthropogenic influences.

Alternatively, even if temperature feedbacks were taken as net-zero rather than strongly positive, the warming arising even from Dr. Boston's more conservative value of the global brightening over the period would be at least equal to the global warming that was actually observed, again leaving little room for any anthropogenic contribution to warming.

It is possible that the global brightening from 1983-2001 was not as great as Pinker or Dr. Boston had found, or that the reported increase in radiative flux arising from the global brightening was to some extent offset by unreported factors, or that over so short a period the influence of long-acting temperature feedbacks may not have made itself felt (though this possibility is already implicit in the use of the transience ratio r, and, if the initial warming were small, long-acting feedbacks would also be small).

However, if the global brightening found by Pinker is correct, then the consequently-expected global warming of ~0.9 K is equivalent to that which would have arisen in response to a naturally-arising tropopausal radiative forcing of ~1.7 W m^{-2} over the 18-year period of study, compared with ~1.6 W m^{-2} from all anthropogenic causes in the 256 years 1750-2005:

$$\Delta F_{T,br} = \Delta T_{S,br} / (\kappa_T f_{br}) \approx 1.7 \text{ W m}^{-2}. \qquad (12)$$

Though it might be expected that in the sufficiently long term any transient global brightening would be canceled out, given the magnitude of the solar brightening from 1983-2001 it may be that no substantial net global dimming occurred from 1950-2005, the period during which Solomon concluded not only that anthropogenic warming exceeded natural warming but also that a substantial global dimming arose from anthropogenic emissions of particulate aerosols.

This proposition was tested by determining anthropogenic greenhouse-gas forcings from 1950-2005, using the functions in Solomon. The forcings are listed in Table 2.

Greenhouse gas	1950	2005	Radiative forcing
Carbon dioxide	305 ppmv	378 ppmv	1.148 W m^{-2}
CFC-12	20 pptv	541 pptv	0.172 W m^{-2}
Methane	1100 ppbv	1775 ppbv	0.281 W m^{-2}
Ozone	Estimate	Estimate	0.237 W m^{-2}
Nitrous oxide	287 ppbv	319 ppbv	0.102 W m^{-2}
CFC-11	10 pptv	248 pptv	0.060 W m^{-2}
		Total forcing	$\Delta F_{T,gg}$ = 2.000 W m^{-2}

Table 2. Radiative forcings arising from changes in the atmospheric concentrations of greenhouse gases from 1983-2001, determined on the same basis as Table 1.

To determine the warming that would be expected to have arisen over the 55-year period on the assumption that no net global brightening or dimming had occurred, it is again appropriate to omit the IPCC's strongly-negative forcing from anthropogenic particulate pollution and its strongly-positive forcing from the cloud feedback.

Where $\Delta F_{T,gg}$ = 2 W m^{-2} and, to reflect the longer period of study $r = r_{55} \approx 0.85$, Eqn. 10 determines that the warming to be expected from 1950-2005 in the absence of any global brightening or dimming would have been ~0.9 K.

However, if a global dimming of ~0.8 W m^{-2} had occurred from 1950-2005, consistent with the strongly-negative forcing from anthropogenic particulate aerosols posited in Solomon, the total radiative forcing $\Delta F_{T,gg}$ would fall to ~1.2 W m^{-2}. At the same time the feedback factor f_{2x} (Eqn. 3) rather than f_{br} (Eqn. 7) would be applicable, reinstating the IPCC's strongly-positive cloud feedback.

The two adjustments are broadly self-canceling, so that, even in the presence of a significant global dimming, warming implied by the IPCC's methodology would remain at ~0.9 K. This conclusion would suggest that any net global brightening or dimming over the 55-year period would have little or no effect on global mean surface temperature.

However, the linear-regression trend on the HadCRU global mean surface temperature anomalies from 1950-2005 was only ~0.65 K, raising the possibility that the IPCC's methodology may have led to an overstatement of climate sensitivity.

Since satellite observations were not available until the early 1980s, it is not reliably known whether there was any net global brightening or dimming over the 55-year period 1950-2005.

It is notable that linear regression on the global surface-temperature data for 2001-2008 shows the trend to be $dT_S/dt = -0.0120$ K yr^{-1}, producing a total change $\Delta T_S \approx -0.1$ K for the eight years. This may be an indication that cloud-cover forcing has switched from positive to negative, consistent with the long-term negative cloud-albedo radiative forcing adopted by Solomon. A reversal of this magnitude could represent the early years of a sustained long-term cooling trend comparable to that which occurred from 1877-1910, a 34-year period when the trend approached –0.01 K year^{-1} and greenhouse-gas concentrations were much lower.

Discussion

These results suggest that reliable worldwide measurement of changes in solar radiative flux reaching the Earth's surface is essential for the eventual determination of climate sensitivity, since the contribution of the naturally-occurring global brightening of 1983-2001 to warming over the period substantially exceeded observed warming. Even if the true global brightening were little more than one-half of that found by Dr. Boston or one-third of that reported by Pinker, it would be sufficient to account for all of the observed warming over the period, leaving little room for any anthropogenic contribution.

The surface brightening from 1983-2001 appears to have been real, substantial, and of natural origin. CO2 concentration has continued to rise near-monotonically until the present, but the monotonicity of its increase, set against the stochasticity of the fluctuations in global brightening and dimming, implies an absence of correlation and hence of causation between the former and the latter, at least on decadal timescales.

On the other hand, at least from 1983-2001, there is some agreement between the global brightening and the observed warming, suggesting a perhaps causative and certainly far from counter-intuitive correlation between the two.

The question arises whether Solomon was correct in listing direct and indirect aerosol forcings as being very strongly negative. If not, then the true magnitude of net anthropogenic forcings may be considerably greater than the values given in Solomon, while observed temperatures remain as before. If so, climate sensitivity may have been substantially overstated.

The question whether there were any non-anthropogenic changes in net surface flux from 1950-2005 is important. The natural brightening and dimmings that may be a significant cause of the stochasticity of the global temperature record may not necessarily cancel one another out even over long periods. However, in the absence of adequate satellite instrumentation before the early 1980s, that question cannot be definitively answered by climatologists today.

Yet the question might be answered more reliably in future – and quite inexpensively – by the deployment of standardized, automated, surface-mounted thermometers and pyranometers at locations all over the planet, reporting by satellite much as the Argo bathythermographs do for ocean temperature and salinity today. Solar pyranometers have been deployed in Japan for a century, and show a remarkably close, and possibly causative, correlation between changes in surface solar flux (expressed as hours of sunlight) and changes in surface temperature in the region (Soon, 2009), though data sources from other regions do not show similar correlations.

To some extent, the global brightening from 1983-2001 may have been caused by a decline in particulate aerosols resulting from environmental measures in Western nations to improve the quality of the atmosphere. However, particulate aerosols continue to be emitted in increasing quantities by nations such as China. If there had indeed been a clearing of the air sufficient to influence global temperatures, the warming from 1983-2001 might have been expected to continue thereafter: however, global temperature anomalies exhibit a small downtrend since late 2001.

Conclusions

Though Solomon concludes, with 90% confidence, that most of the "global warming" since 1950 was anthropogenic, use of the IPCC's own methodology implies that the warming of ~0.9 K arising from the naturally-occurring global brightening from 1983-2001 accounted for thrice the anthropogenic warming and thrice the total observed transient warming of those 18 years, and for ~40% more than the ~0.65 K warming observed from 1950-2005.

If the data are in substance correct, it is also possible that the positive anthropogenic forcing over the period was offset to some extent by as-yet-unidentified negative forcings or temperature feedbacks. For instance, a temporary reduction in relative humidity associated with what may have been a cyclical reduction in cloud cover may have altered the sign of the water-vapor feedback. Cloud feedbacks may also be strongly negative rather than strongly positive (Spencer & Braswell, 2007). Temperature feedbacks in general may be somewhat net-negative (Lindzen & Choi, 2010), rather than strongly net-positive, as Solomon, citing Soden & Held (2006), find them.

It is also possible that, in the present condition of the atmosphere, climate sensitivity to atmospheric CO2 enrichment and to any other anthropogenic radiative forcings is substantially less than the estimates in Solomon. It was perhaps no mere coincidence that this natural cause of warming was coincident with the greater part of the only supra-decadal period of sustained and rapid warming observed since 1950.

Note that these results may require amendment when Dr. Boston is able to provide the meticulous re-analysis of the relevant satellite data that I have requested, for that analysis is beyond my competence.

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4. **In your testimony before the Select Committee, you claimed that there is much evidence in the scientific literature suggesting that the global warming over the last 30 years can be explained by forcing other than that from carbon dioxide.[6] Please provide a list of *peer-reviewed climate science journal articles* in which the authors argue that an alternate mechanism (i.e., not heat trapping due to greenhouse gases) is primarily responsible for the global warming over the last 30 years.**

The IPCC relies upon the "grey literature" for almost one-third of all its supposedly "scientific" references, and is not itself peer-reviewed in the accepted sense. Otherwise, for instance, the unfortunate "accelerating-warming" graph that appeared three times in the IPCC's 2007 report, and whose defects I mentioned in my testimony, would have been identified as misleading and would have been removed. I am delighted, therefore, that those on the Select Committee who raised the present question now seem to accept – unlike the IPCC – the desirability of studying the question of "global warming" exclusively by reference to the peer-reviewed literature rather than to the politicized and error-laded documents of the IPCC or to the various newspaper articles or propaganda leaflets of the environmental movement.

The references appended to my necessarily detailed answer to the Select Committee's previous question should provide a useful starting-point from which the Select Committee will be able to deduce that there is at least a statable case that there was a naturally-occurring global brightening from 1983-2001 and that, while there is some disagreement on the magnitude of the brightening, most authorities find it to have been substantial. Further references can be supplied if desired.

It is not, of course, necessary to demonstrate a particular natural cause of the by no means exceptional temperature fluctuations of the past 30 years: one has only to look at the proxy temperature record for the 11,400 years since the end of the last Ice Age to notice that, notwithstanding broadly constant carbon dioxide concentrations throughout the Holocene, temperature fluctuations well in excess of those observed today have occurred frequently. Indeed, in Central England, the temperature rose by 4 F° in the 40 years 1695-1735, well before the Industrial Revolution began; and 7500 of the past 11,400 years were warmer than the present. Given the evidence, it is baseless to assume that the major influence on global temperatures over the past 30-50 years must have been anthropogenic.

5. **What procedural flaws do you believe lend to the IPCC's errors? Do you agree with the IPCC's reliance on grey literature?**

In practice, "grey literature" – i.e. comments on climate science that are not peer reviewed – is all too often "green literature": i.e., literature compiled by pressure-groups with a vested interest in advancing the narrow, extreme and scientifically-unjustifiable point of view that the IPCC, by its founding document, is required to reflect regardless of the objective scientific truth.

"Peer review", as it is generally understood in science today, is the process by which the authors of a scientific paper submit their work to a learned journal of standing, whose Editors, if the paper appears on its face to have merit in that it adds new knowledge to the corpus of scientific advance and contains no manifest errors, appoint appropriately-qualified scientific reviewers, who then read the paper and make comments and suggestions for correction or clarification. The authors and reviewers of a scientific paper published in a learned journal are usually, but not always, scientifically qualified in the field appropriate to the subject-matter of the paper.

The reviewers' identities are, of course, known to the Editors, but are not necessarily known to the authors of the paper, to whom the Editors send the reviewers' comments and suggestions. The authors then revise the paper to take account of what the reviewers have said. Provided that the reviewers and Editors are satisfied that the reviewers' comments and suggestions have been fully and properly taken account in the authors' revisions, and that

[6] Unedited and unofficial hearing transcript of the House Select Committee on Energy Independence and Global Warming, May 6, 2010.

the paper as revised has merit, the Editors publish the paper. Otherwise, either the paper is rejected or further rounds of revisions may be required of the authors. Only when all revisions have been successfully completed is the paper published. Customarily, journals also publish the date on which the paper was received, the dates on which each subsequent revised draft was received, and the date on which the paper was finally accepted for publication.

Once the paper is published in a learned journal, if a scientist who reads it wishes to rebut it, the custom is that he sends a draft of his proposed rebuttal both to the journal and to the lead author of the paper. The lead author is then given the opportunity to draft a refutation to the rebuttal. Thereupon, if the Editors consider that the rebuttal and any refutation deserve to be published, they are published simultaneously in a subsequent edition of the journal.

The IPCC's four Assessment Reports (19990, 1885, 2001, and 2007) are the primary source relied upon by agencies of the US Government, such as the EPA, NRC, NAS, CCSP, etc. It is important to understand that, at least in the following respects, neither the IPCC's Reports nor those of the various taxpayer-funded scientific bodies who rely so heavily upon the IPCC's Reports are peer-reviewed in the accepted sense. In particular –

- The authors of the IPCC's Reports are chosen and appointed not by any scientific process but by governments.
- The IPCC has been known to interfere in the appointment of authors by taking careful steps to exclude eminent authors whose views are known to be at variance with the political stance of the IPCC. For instance, Professor Paul Reiter of the Institut Pasteur in Paris, one of the world's foremost experts on the epidemiology of malaria and yellow fever, was nominated to the IPCC by the United States Government to contribute to the sub-chapter of the IPCC's 2007 Fourth Assessment Report on climate change and vector-borne diseases. Professor Reiter suspected that the IPCC would do its best to exclude him and, accordingly, he obtained four copies of his nomination papers and sent them by registered mail, with proof of delivery, to four separate senior officials of the IPCC. As he had anticipated, the IPCC denied having received his nomination papers and refused to appoint him. However, he applied pressure and was eventually appointed a reviewer of the sub-chapter in question, discovering that the two lead authors were not malaria scientists. He later told the story to an investigating committee of the House of Lords in the United Kingdom.
- Authors who wish to contribute to the IPCC's scientific discussions are often excluded if the IPCC considers that they are likely to disagree with its political stance. When I wished to attend the Hawaii "scoping meeting" for the IPCC's 2013 Fifth Assessment Report early in 2009 to draw the IPCC's attention to some serious defects in its methodology that I had published in the scientific literature, I was peremptorily told that I should not be welcome because I "disagreed with the IPCC's position".
- The reviewers are appointed by the IPCC itself. Many of their comments and suggestions, therefore, tend to reflect the IPCC's political stance.
- The IPCC's authors are generally not permitted to work in their own environment and in their own way, free from political pressure or interference. Much of the drafting of the IPCC's reports is done by groups of authors at sessions held in exotic locations around the world. Some authors have reported that staff of the IPCC had intruded into scientific discussions and had pressured scientists into accepting various aspects of the IPCC's political stance. For instance, Professor Richard Lindzen of MIT testified before Congress to the effect that in IPCC sessions that he had attended the IPCC's staff had frequently applied pressure on participating scientists to accept the IPCC's contention that numerical modeling of the climate by complex (but error-prone) computer programs was a permissible alternative to observation, measurement, and calculation. The pressures to conform to the IPCC's political stance are real and considerable.
- The authors are permitted to ignore – and generally do ignore – the comments and suggestions made by the reviewers, particularly where what the reviewers say runs counter to the IPCC's political stance. This departure from the process generally recognized as peer review is particularly serious. For instance, in the sub-chapter on glaciers in the IPCC's 2007 Fourth Assessment Report, a scientifically-unqualified environmental campaigner whom a government had nominated to the IPCC wrote that the Himalayan glaciers would all have melted away by 2035. Various reviewers pointed out that the campaigner's absurd but alarming claim had no scientific foundation, but the campaigner simply overrode the reviewers and his draft was retained. When this error was exposed, the IPCC admitted that the correct year should have been not 2035 but 2350. The lead author of the sub-chapter in question also admitted that he had known the campaigner's statement to be scientifically unfounded, but that he had deliberately left the incorrect date in the published final version of the IPCC's 2007 report because, he said, it was the intention of the IPCC politically to influence governments.
- If the final draft of one of the IPCC's reports is not acceptable to the IPCC's staff in that it does not accord with the IPCC's political stance, the IPCC's procedures permit a single author to rewrite the final draft on

his own so as to make the Report "politically correct". This, too, is a very serious defect in the IPCC's process. For instance, the 1995 Second Assessment Report concluded, and stated on five separate occasions, that there was no discernible human influence on global temperature and that it was not clear when any such influence would become discernible. The IPCC's staff did not find this conclusion congenial. Accordingly a single author whose conformity to the IPCC's political stance – Dr. Ben Santer of the Lawrence Livermore National Laboratory – rewrote, and subsequently admitted that he rewrote, the final draft to remove all five "politically-incorrect" statement and to replace them with a single statement to the effect that a discernible human influence on global climate was now evident. To prevent this statement from appearing incongruous, Dr. Santer also found it necessary to make several hundred consequential amendments. The result was that the 1995 Report came to a conclusion precisely opposite to that which the scientists' final draft had drawn. This conclusion – the opinion of one man – has been the official conclusion of the IPCC ever since. Yet only a small minority of the 1995 Report's authors were told of Dr. Santer's revisions before the Report was published, and the final draft as revised by him was not subjected even to the attenuated and defective process of "review" normally followed by the IPCC.

- The IPCC's personnel, whether or not they have any scientific qualifications, are also permitted to tamper with the scientists' final drafts of the IPCC's reports. For instance, the final draft of the IPCC's 2007 Fourth Assessment Report was leaked to the *Sunday Telegraph,* a major Sunday newspaper in the United Kingdom, before publication. The newspaper revealed that the IPCC had revised its estimate of maximum global sea-level rise over the 21st century from 3 feet to less than 2 feet, with a central estimate of little more than 1 foot. This welcome news was widely reported around the world, but did not accord with the IPCC's political stance. Accordingly, the IPCC's staff altered the scientists' final draft of the IPCC's 2007 Report by inserting a new table of figures that had not appeared in the final draft. By the redeployment of four separate decimal points, it was made to appear that the observed contribution of the Greenland and Antarctic ice sheets to sea-level rise over the past 40 years had been ten times greater than that which had actually been measured. Whether or not this error was deliberate, the offending table was published in the final draft of the 2007 Report. On the day of publication, I noticed the error, reported it to four separate IPCC officials, and insisted that the table be removed or corrected. The IPCC's staff thereupon hastily corrected the error themselves, changed the units in which the table was denominated, retitled the table, moved it, and quietly posted up the corrected version on the IPCC's website, without openly declaring – as is the correct academic practice – that any change at all had been made.
- The final decisions on the principal conclusions in the IPCC's Reports, which are incorporated into a *Summary for Policymakers* in each Report, are taken not by scientific authors or reviewers but by political representatives of governments. This is a very serious defect of scientific process. For instance, the IPCC reached its decision in its 2007 Fourth Assessment Report to assign at least 90% confidence to its finding that most of the "global warming" that has occurred since 1950 was anthropogenic not by any scientific process of measurement, observation, or calculation conducted by scientists, but by a show of hands on the part of political representatives.
- Climate scientists, whether part of the IPCC process or not, are subjected to enormous pressures to agree to the IPCC's politicized, pseudo-scientific viewpoint. For instance, when Dr. Garth Paltridge, an eminent climatologist in Australia, first said publicly that he disagreed with the IPCC's central findings, within 24 hours the IPCC had contacted its point of contact in the Australian Government, which had in turn contacted the official body responsible for funding scientific research in Australia, which in turn contacted Dr. Paltridge and told him that if he ever again went public and expressed disagreement with any of the IPCC's conclusions he would never again receive any funding for scientific research.

For these reasons, the IPCC's Reports are in no way peer-reviewed in the generally-accepted sense of that term. In like manner and degree, the reports of the various scientific institutions upon which the US Government relies are also not peer-reviewed. The leading scientific institutions in the United States have substantially or absolutely relied upon the IPCC. In particular, they have appealed to the IPCC's "authority" in that they have adopted its principal conclusions in an insufficiently critical manner.

Key decisions of the IPCC were taken not by scientists but by scientifically-unqualified representatives of governments, or by environmental campaigners, or by campaigning journalists with no scientific qualifications. On any view, these government representatives and campaigners – however noble their reputations in their fields – have no reputations in the field of science, and, scientifically speaking, the IPCC should not have founded its position upon their decisions on the basis of their reputations. Even where the conclusions upon which the IPCC relies were drawn by scientists, the scientific method – whose essence is verification and scrutiny of scientific results, and not mere belief or acquiescence in those scientific results that are found politically expedient, socially congenial, or financially profitable – demands that the IPCC should take careful steps independently to verify that

the scientific conclusions on which it relies are justifiable, particularly where it is evident – or has become evident from comments received – that the conclusions in question are questionable.

The United States should withhold all further funding from the IPCC until it institutes a rigorous process of proper peer review of its own past as well as future work by independent scientists, and until it gives an undertaking that it will never again rely upon any sources other than peer-reviewed papers in the learned journals.

Not the least of the reasons why the IPCC is not functional is that the current chairman of its climate science panel is a railroad engineer now under investigation by the UK Charity Commission for having filed false accounts three years in a row for a charity of which he is the trustee. His defense is that he is financially inexperienced: yet he runs an 800-strong NGO in India. Key IPCC personnel should in future be appropriately qualified, and of unquestionable probity, and should not have any financial conflicts of interest.

6. **By its own admission, EPA has said that its Endangerment Finding for greenhouse gases relied on IPCC data and reports. In light of the errors revealed within the IPCC *Fourth Assessment Report*, how can this Congress and the current administration justify implementing legislation that will lead to fewer jobs and cost taxpayers more money?**

Article 1, Section 1 of the US Constitution says –

> "All legislative power herein granted shall be vested in a Congress of the United States, which shall consist of a Senate and House of Representatives."

Standing this clear wording, which is repeatedly amplified throughout the Constitution, the manifest intention of the Founding Fathers was to ensure that no laws were made for the people of the United States except by representatives whom the people themselves had elected and could remove at will. Accordingly, it is not clear to me that the US Congress has the right under the Constitution to transfer to the EPA or to any other "executive" agency the legislative power that the Constitution, in its opening words, vests in Congress alone.

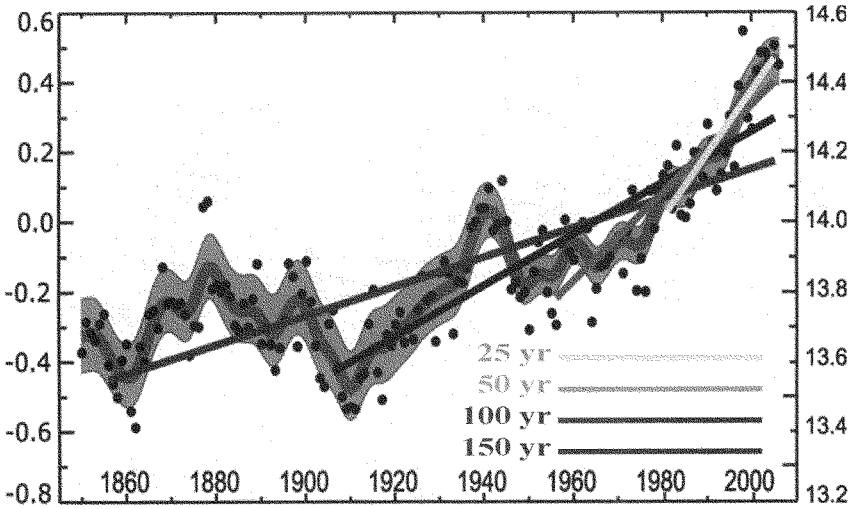
Arguably, therefore, the Clean Air Act is illegal: and it is certainly illegal for the EPA to introduce regulations selectively, targeting the largest businesses first and exempting businesses falling within the remit specified by Congress, and hence distorting the market in a manner not contemplated by Congress in the framing of the Act.

It is indeed apparent from a close study of the Technical Support Document produced by the EPA in defence of its proposed regime of Draconian regulation that the EPA has relied almost exclusively either upon the various reports of the IPCC or upon the documents of various US scientific bodies that have themselves relied almost exclusively upon the IPCC's reports. It is also apparent that the EPA has done little or nothing in the way of independently verifying whether the conclusions of the IPCC are robust. In this regard, I have direct evidence that the EPA is acting in bad faith.

One of the commentators on the EPA's Technical Support Document had mentioned that the following graph, reproduced three times in large scale and in full color in separate IPCC chapters, was gravely defective and misleading. The graph, which purports to show that the rate of "global warming" is itself increasing, relies upon a well-worn statistical fraud known as the "endpoint fallacy", by which multiple trend-lines with arbitrarily and capriciously chosen start-dates or end-dates are superimposed on a single stochastic dataset, in such a way that any desired conclusion as to the trend in the underlying data can be demonstrated.

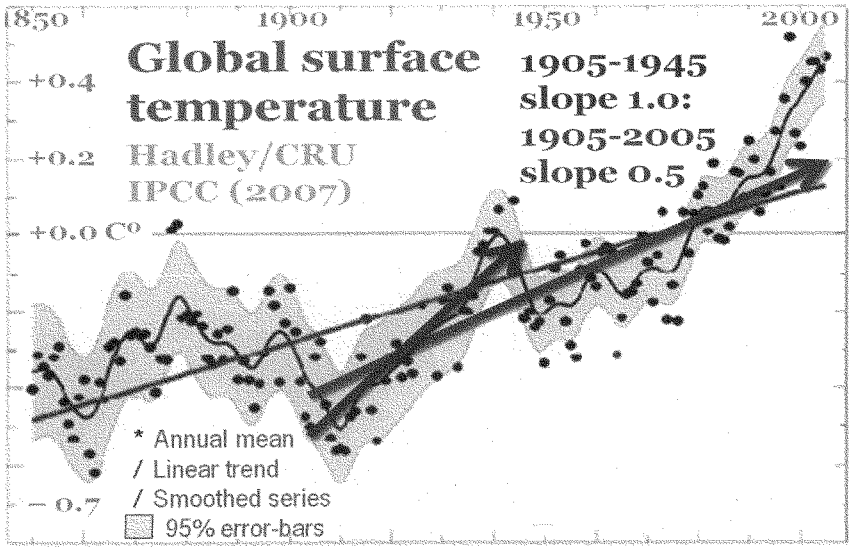
The EPA, even when the statistical fallacy had been carefully explained to it, decided willfully to adhere to its adoption and reproduction of the IPCC's grievously defective graph, inferentially either because its technical advisers were insufficiently literate in applied statistics to understand the nature and gravity of the defect or because it did not wish to cast any doubt whatsoever on the reliability, veracity, and competence of what was, in effect, the sole originating source of its entire "scientific" case, or both.

The IPCC draws the stated conclusion from the defective graph that the rate of "global warming" has been inexorably increasing and that, accordingly, humankind must be to blame. Even if it were true that the rate of "global warming" is accelerating, it would be absurdly illogical to conclude that merely because "global warming" is accelerating one could – or must – ascribe the acceleration to the enterprises and industries of Man.



The IPCC's defective graph falsely purporting to show an inexorable increase in the rate of "global warming"

However, it is easy to demonstrate definitively that the technique relied upon by the IPCC to produce its bogus headline graph is defective. The following graph, which takes the same underlying global-temperature dataset, the Hadley/CRU dataset relied upon by the IPCC, and shows two arbitrarily-chosen trend-lines, shows that the rate of warming from 1905-1945 was twice as great as that from 1905-2005, indicating that the rate of "global warming" is slowing down, when the IPCC's different and equally-arbitrary choice of trend-lines purports to show that the rate of "global warming" is speeding up –



From 1905-2005 (red) the rate of "global warming" was half that from 1905-1945 (green).

Since we have deployed the same technique on the same dataset, but with a result that is precisely the opposite of that which the IPCC had reached, it is the technique itself that is defective, and the IPCC ought not to have relied upon it. Nor should the EPA have relied upon it. And, most certainly, the EPA should not have continued to rely upon the flagrantly defective IPCC graph after its attention had been explicitly drawn to the defect. Yet the EPA adhered to the defective graph and, in so adhering, demonstrated bad faith.

The key practical question in connection with the climate is whether any proposed measures to mitigate the anthropogenic emission of greenhouse gases will be cost-effective. I shall briefly consider the scientific dimension of that question.

Scientifically speaking, the question is how much future "global warming" will be forestalled if a given proportion of the world's current emissions of greenhouse gases is in future prevented. *Brevitatis causa,* this analysis is confined to emissions of carbon dioxide, and, except where indicated, is conducted on the basis that, *ad argumentum,* the IPCC is right to find that a doubling of atmospheric carbon dioxide concentration, expected sometime later in this century, will cause 3.26 ± 0.69 K (6 ± 1.25 F°) "global warming".

For the past 30 years, the relationship between CO_2 *emissions* and resultant CO_2 *concentration* has remained broadly constant at ~15 billion tons CO_2 per part per million by volume CO_2 concentration increase. Thus, currently the world is emitting ~30 billion tons/year CO_2. Consequently CO_2 concentration, now 388 ppmv, is rising by 2 ppmv/year. As noted in my testimony before the Select Committee, the equilibrium "global warming" that might arise from this increase in CO_2 concentration would be as below. This equation will be proved later, at Eqn. (15) –

$$\text{Annual warming forestalled} = (8.5 \pm 1.8)\ \ln[(388+2)/388] = 0.044 \pm 0.01\ \text{F°}.$$

We now consider a *reductio ad absurdum.*

- Suppose that all CO_2 emissions were to cease worldwide for an entire year, with the widespread death, disease, and destruction that would follow. As the above equation shows, the warming forestalled would be less than one-twentieth of a Fahrenheit degree.

- Suppose that the US accounts for as much as 20% of world CO_2 emissions. Shutting down all CO_2 emissions in the US for a year would forestall just one-hundredth of a Fahrenheit degree of warming.

- Suppose that the EPA's regulations would shut down as much as 10% of all CO_2 emissions in the US. Then, in each year, the emissions reductions mandated by the regulations imposed by the EPA would forestall one-thousandth of a Fahrenheit degree of "global warming" – a warming so small that it cannot be reliably discerned by any currently-available or foreseeable method of measurement.

- Suppose that the IPCC has overstated climate sensitivity to atmospheric CO_2 enrichment by as little as a factor of 2, rather than the factor of 4-5 suggested in Lindzen & Choi (2009, 2010), or Spencer (2010). If so, then the "global warming" of the 21st century would be below 2 K and would, on any view, be generally harmless and beneficial. In that event, full implementation of the EPA's regulations would forestall one-two-thousandth of a Fahrenheit degree of "global warming".

The very structure of the IPCC – with separate working groups considering mitigation of "global warming" by reducing emissions of carbon dioxide and adaptation to "global warming" by coping with its consequences as and if they occur – militates against proper consideration of the question whether mitigation or adaptation is likely to be more cost-effective.

Given the negligible warming that would be forestalled each year by even the fullest implementation of the EPA's regulations, and given the inevitably heavy economic cost of full implementation, it is very likely that focused adaptation to any consequences of "global warming" that might occur, as *and if* those consequences occur, will be orders of magnitude cheaper and more cost-effective than the attempted mitigation advocated by the EPA and targeted by its regulations.

Secondly, I am aware of declarations by governments such as that of China that they do not propose to impose upon themselves emissions-control policies anything like as onerous as those proposed by the EPA. If these

declarations are true and are given effect, then it is necessary to consider the likelihood that economic activities that now take place in the United States would – if they became unduly expensive or even impossible as a result of the EPA's imposition of its regulations – be transferred to less-regulated nations.

In this sense, the phrase "green jobs", recited with naive enthusiasm in certain quarters, may come to be regarded among the general population as a synonym for "mass unemployment". It would be the height of folly to continue closing down functioning and inexpensive methods of electricity generation, such as coal-fired stations, and to prevent new stations from being built, without having already developed affordable alternative sources of power.

It would be irresponsible merely to assume, vaguely, that somehow the new technologies will spring into being if only we stamp out the old. That way lies economic dislocation and environmental disaster.

Where, and to the extent that, the activities prevented by the EPA within its jurisdiction are merely transferred to less-regulated jurisdictions, even the minuscule forestalling of "global warming" that we have here demonstrated would not be achieved.

For these reasons, scientifically speaking one must conclude that the climatic implications of unilateral and full imposition of the EPA's regulations on the United States would be negligible. Even if all nations adopted such regulations, the impact on global temperatures would barely be discernible, even after a century.

The EPA has insufficiently considered that its regulations would have no discernible effect upon the climate, and has insufficiently considered the possibility that, unless its regulations were implemented worldwide (which they will not be), enterprises that are capable of removing themselves from the EPA's jurisdiction to less-regulated jurisdictions will be very likely to do so, rendering all of its attempts at regulation expensively otiose.

For the same reasons, scientifically speaking one must conclude that the financial cost of focused adaptation to any consequences of "global warming" that might occur would be very considerably less than that of implementing any approach which, like the EPA's regulations, is directed at reducing emissions of greenhouse gases rather than at focused adaptation.

Measures as far-reaching and potentially costly as those recommended by the EPA would only be justifiable if they were likely to have an appreciable effect on the climate, and if they were not likely to prove disproportionately more expensive than alternative measures that are readily available, such as focused adaptation.

I am conscious that the EPA's remit under the Clean Air and Clean Water Acts is confined to the assessment of risk to human health and to consequent regulation: however, in view of the fact, simply but definitively demonstrated above, that the maximum climatic effect of the EPA's proposed regulations would be immeasurably small, the health benefits of those regulations would also be immeasurably small.

In that event, an Agency acting reasonably would decline to regulate and, arguably, has no right under the Clean Air Act to regulate, since a "pollution" (in the form of slightly warmer weather) that is so small as to be immeasurable by any modern instrument cannot properly be held to fall within the scope of the Clean Air Act.

An Agency acting reasonably would have carefully considered –

- whether the regulations it proposed would have a sufficient climatic effect to be worthy of implementation;
- whether unilateral imposition of its proposed regulations would transplant American enterprises overseas, with a consequent nil benefit to the climate; and
- whether adaptation when *and if* necessary would be very substantially cheaper and more cost-effective than implementation of its proposed regulations.

However, the EPA has not considered any of these matters properly. In particular, it has not considered the question how much warming its proposed regulations would forestall, a question that should have been addressed in a quantitative analysis such as that which has been outlined here.

Accordingly, for this reason also the EPA has manifestly acted not only arbitrarily and capriciously but also in bad faith. The question arises whether the EPA has become too nakedly ambitious for America's good, and whether it should now be disbanded.

7. **The Climategate e-mails scandal reveals a troubling pattern of behavior among a group of scientists influential to the IPCC process and reports that have been issued thus far. The e-mails sent between scientists at the University of East Anglia's Climatic Research Unit show a pattern of data manipulation and secrecy that undermine the British academic body's credibility, and even demonstrate CRU researchers violating UK law by plotting to avoid Freedom of Information requests. For example:**

   From: Phil Jones, Date: Thu Jul 8 2004: 16:30:16

   I can't see either of these papers being in the next IPCC report. Kevin and I will keep them out somehow – even if we have to redefine what the peer-review literature is!

   (http://www.eastangliaemails.com/emails.php?eid=419&filename=1089318616.txt)

   Do these e-mails raise any concerns regarding scientific integrity? Do you condone this behavior?

Shortly after the Climategate emails were first revealed (the BBC having sat on them for six weeks because it could not bear to admit that the climate scientists in whom it had so naively and credulously placed its trust were incompetent and politically-motivated at best and corrupt at worst), a Professor of Physics from the US telephoned me, in tears, and said that he had been mentioned 71 times in the Climategate emails. The story he told was disfiguring. He had published a blameless paper drawing attention to the fact that, in a crucial respect, the computer games relied upon by the IPCC had failed to predict what was happening in observed reality. The Climategate emailers constituted so powerful a clique that they had succeeded in delaying the publication of his paper by a year until a dataset could be fabricated that purported to show a dozen other datasets to be wrong and a paper could be contrived, based on the fabricated dataset, apparently overturning the Professor's result. The gang had leaned upon the editor of a learned journal to delay publication of the Professor's paper so that their furtive and dishonest stratagem could be made to work. However, the two enquiries that have been held so far into the Climategate affair both found the emailers blameless.

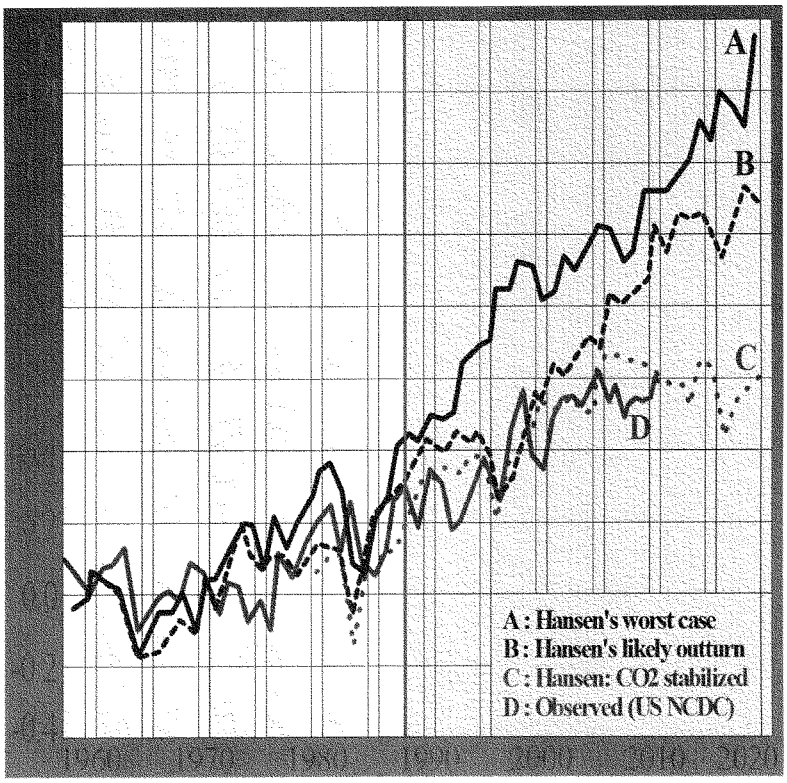
For many years, I had been following the output of many of the key Climategate emailers. I had suspected that they were connected, because their behavior exhibited a common pattern, characterized by several instantly-recognizable features. First, the emailers were thoroughly unpleasant people. The sheer nastiness of far too many of the Climategate emails is what first strikes anyone from outside who reads them for the first time. Secondly, they were ruthlessly unscrupulous, and did not care whom they trampled as they pushed their scientifically-nonsensical theories. Thirdly, they were dishonest, and had produced science that was demonstrably and often laughably bad, but had passed peer review because, in effect, the emailers owned and controlled the peer-review process as well as the major rent-seeking scientific pressure-groups, as their mistreatment of the Physics professor had demonstrated. Fourthly, their scientific errors all pointed relentlessly in the same direction: towards inventing a problem where there was no problem, and exaggerating it beyond all sense or reason where there was.

Here are some illustrations of the unsound science perpetrated by some of the Climategate conspirators –

- **Professor Phil Jones (University of East Anglia)** actively encouraged the other Climategate emailers to destroy scientific data so that other scientists would be prevented from verifying the emailers' results:

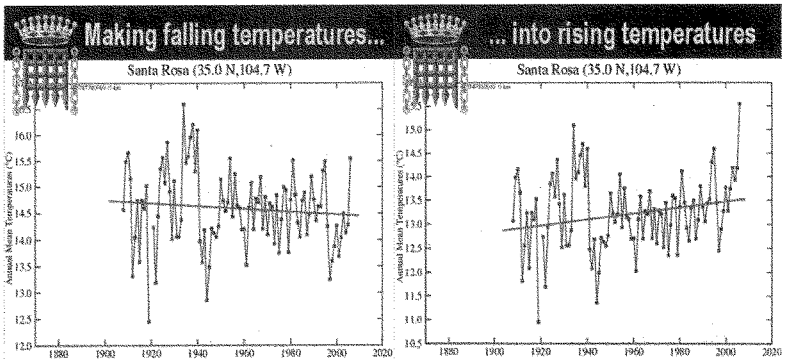
  "Mike, - Can you delete any emails you may have had with Keith re AR4 [the IPCC's *Fourth Assessment Report*]? Keith [Briffa] will do likewise. ... Can you also email Gene and get him to do the same? I don't have his new email address. We will be getting Caspar [Ammann] to do likewise."

- **Dr. James Hansen (NASA)** wrote in the British Marxist daily propaganda-sheet *The Guardian* that as a result of anthropogenic "global warming" sea level would rise by 75 meters [246 feet]. The IPCC's best estimate is 1 ft 5 in by 2100. Hansen also helped to get the "global warming" scare started by predicting before Congress in 1988 that global temperatures would rise far more rapidly than they have. Temperatures have in fact generally undershot Hansen's "CO_2 stabilization" case (C), in which he assumed (incorrectly) that as a result of drastic action by global governments carbon dioxide concentrations would have ceased to increase at all by 2000. In fact, CO_2 concentrations have continued to increase in a straight line at 2 ppmv/year, yet temperatures are in no way responding as rapidly as Hansen had alarmingly predicted: –



James Hansen's three 1988 predictions of "global warming" from 1988 to 2020, with observed warming in red. The observations are below Hansen's "CO_2 stabilization" case, with CO_2 concentration stabilized in 2000.

Hansen also supervises the NASA GISS global-temperature dataset, where it has been noticed that in several of the land-based stations the raw data have been adjusted in such a way as to turn falling trends into rising trends –

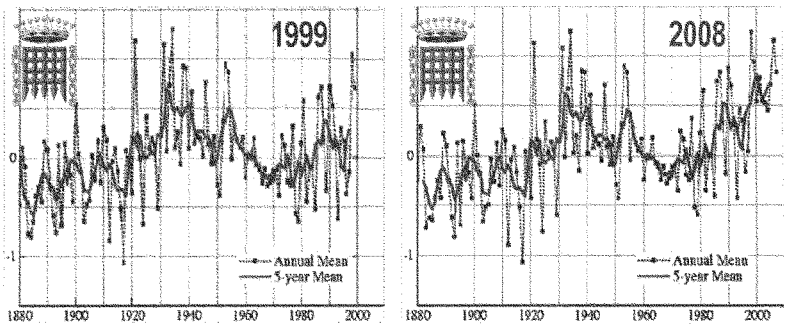


The raw temperature data (left) show cooling. The data after adjustment by GISS show warming, because data from the 1930s have been altered. The reason for this alteration of historical data is unclear and requires investigation.

The data tampering appears to have left the recent data unaltered, inferentially because independent satellite records prevent substantial alteration of terrestrial records. Instead, without apparent good reason, temperatures from the 1930s have been altered so as to reduce appreciably (by 2 F° in the above example) the values that were recorded in that era.

Two questions arise. First, does the adjustment of the temperature data by GISS apply only to a few stations, making little difference to the global trend? Secondly, has the adjustment of the data become greater over time, indicating *prima facie* that a systematic and unjustifiable bias has been introduced?

These questions may be simply answered by making a second comparison: this time between the GISS global dataset *after* data adjustment as it stood in 1999 and the same dataset *after* adjustment as it stood in 2008. Any difference between the earlier and later versions of the *adjusted* dataset would be *prima facie* evidence of a bias that would require further explanation before any reliance could be placed upon the dataset –



Bias over time: *The GISS global-temperature dataset, after adjustment, as it stood in 1999 (left) and in 2008 (right). The data peak in the 1930s has been reduced in the later version of the dataset, and the 1998 peak has been markedly increased, artificially increasing the warming rate over the period. I am grateful to Dr. Anthony Watts for making these graphs public.*

The data adjustments by GISS, therefore, are sufficient to affect the entire global database, and the comparison between the earlier and later versions of the *adjusted* global database over time shows that the adjustment that produces a warming bias has been increased over the years.

It is considerations such as these that cast doubt upon the reliability of the NASA GISS global-temperature dataset, and hence upon that of the very similar NOAA NCDC dataset. The Committee may wish to investigate this and other apparent defects and irregularities in the compilation of the official terrestrial global-temperature datasets, particularly in the period preceding the satellite temperature record that began in 1980.

- **Dr. Ben Santer (Lawrence Livermore National Laboratory)** was the Climategate emailer responsible for the rewriting of the principal conclusions of the 1995 IPCC *Second Assessment Report* so as to produce a conclusion opposite from that of the scientists who had delivered to the IPCC's bureaucracy their final draft of the report. The scientists had concluded, and had stated their conclusion plainly on five separate occasions in the final draft, that there was no detectable anthropogenic signal in the global temperature record, and that "global warming" could not (a point later effectively confirmed by Lord Hunt's Parliamentary answer to my question mentioned earlier in this letter) –

    - **"None of the studies cited above has shown clear evidence that we can attribute the observed [climate] changes to the specific cause of increases in greenhouse gases."**

    - **"No study to date has positively attributed all or part [of observed climate change] to anthropogenic causes."**

- **"While none of these studies has specifically considered the attribution issue, they often draw some attribution conclusions, for which there is little justification."**

- **"Any claims of positive detection of significant climate change are likely to remain controversial until uncertainties in the total natural variability of the climate system are reduced."**

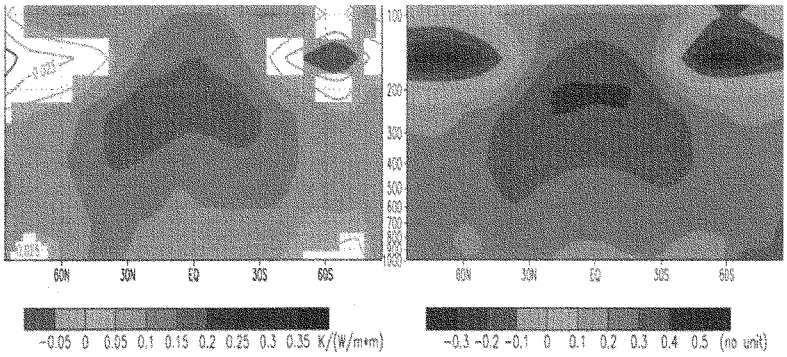
- **"When will an anthropogenic effect on climate be identified? It is not surprising that the best answer to this question is, 'We do not know.'"**

Yet, remarkably, the "procedures" of the IPCC permitted – and, indeed, facilitated – a rewrite by just one scientist on whom the bureaucracy could absolutely rely to come up with the result it wanted: Dr. Santer. He deleted all five of the inconvenient truths that the world's scientists had incorporated into their final draft of the 1995 Report, and, after making hundreds of consequential amendments throughout the text, inserted the following entirely opposite conclusion –

- **"The body of ... evidence now points to a discernible human influence on global climate."**

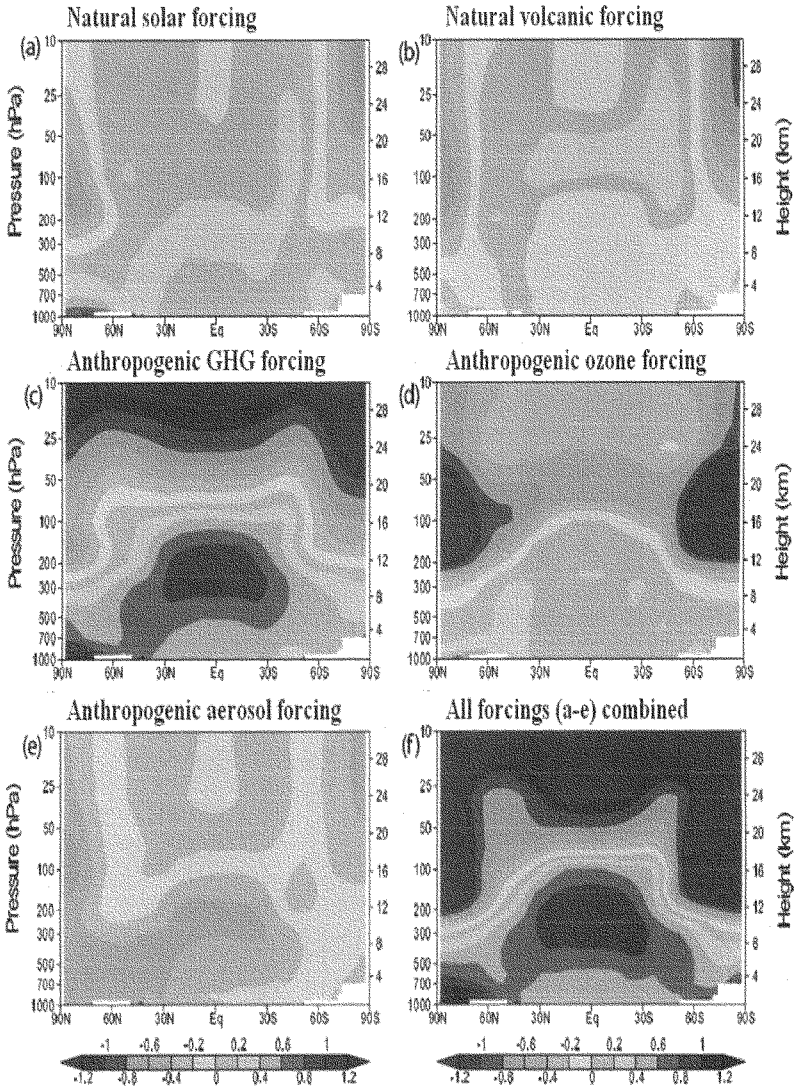
It points to no such thing, or the scientists would have said so. Yet that – the opinion of one man, which was shown to only a handful of the thousands of participating scientists before publication of the 1995 *Second Assessment Report* that set their work at nought, has been the official line ever since, regardless of the considerable body of science to the contrary. The much-vaunted scientific "consensus" is, therefore, essentially one man's view.

Dr. Santer has also been responsible for rearranging the science that relates to the crucial question of temperature change in the tropical upper troposphere. In the 2001 *Third Assessment Report,* as the following altitude-vs.-latitude plots of computer-model-predicted temperature change demonstrate, it was predicted that the atmospheric fingerprints of solar and anthropogenic greenhouse forcings should be broadly identical in the troposphere, with doubling or tripling of the tropical surface warming rate at altitude in the tropics (the tropical upper-troposphere "hot-spot") –



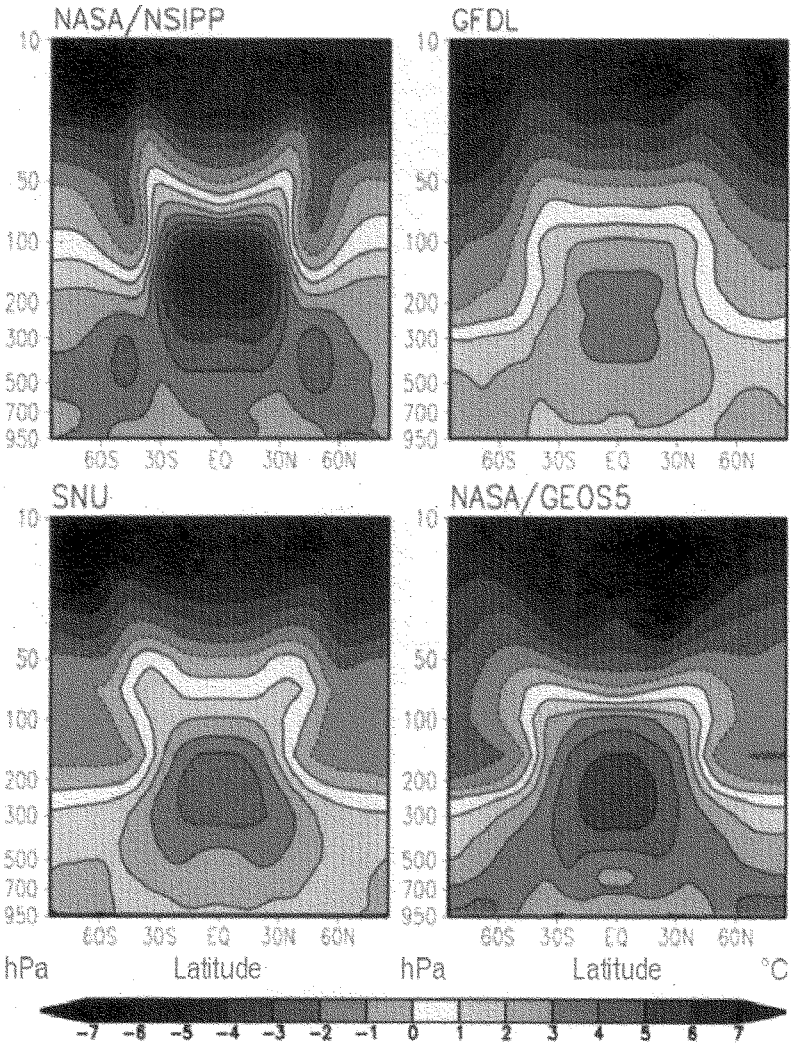
Computer-predicted fingerprints of temperature change by latitude (x axis) and altitude (y axis: hPa) for solar forcing (left) and anthropogenic greenhouse-gas forcing (right). ***Source:*** *IPCC (2001).*

However, by the 2007 IPCC report, Dr. Santer had updated a paper of 2000 in which he predicted that solar forcing, in panel (a) at top left below, would lead to a near-uniform distribution of temperature change throughout the tropical troposphere, with no warming differential between the surface and the mid-troposphere (i.e., no "hot-spot"), while anthropogenic greenhouse-gas forcing, in panel (c) at middle left, would exhibit a strong "hot-spot" in the tropical upper troposphere, with warming at close to thrice the surface warming: a pattern so dominant that it would persist even when five separate forcings were combined, in panel (f) at bottom right. The IPCC adopted Dr. Santer's result as its own –



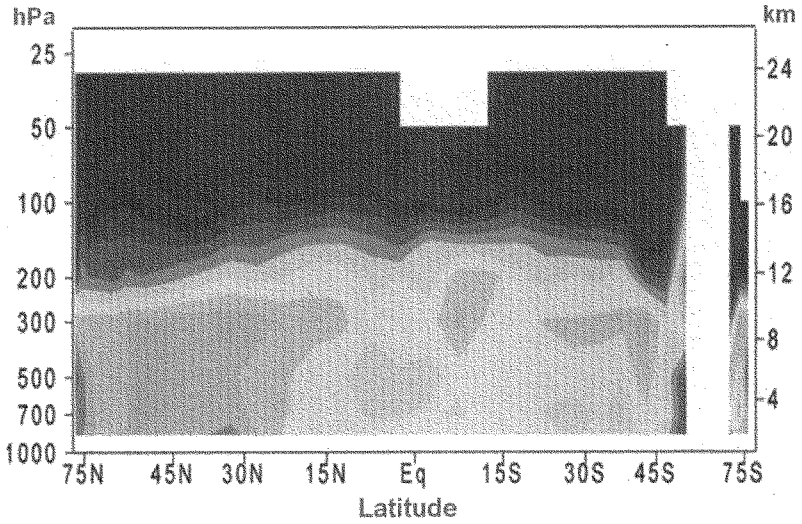
Modelled zonal mean atmospheric temperature change (C°/century, 1890-1999) from five distinct forcings (a-e), and from all forcings combined (f). Altitude is in hPa (left scale) and km (right scale) vs. latitude (abscissa). ***Source:*** *IPCC (2007, after Santer, 2003).*

Indeed, all of the models on which the UN relies predict that most of the atmospheric warming that arises from greenhouse-gas enrichment of the atmosphere will occur about six miles up in the tropical upper troposphere. At that altitude, the warming rate is predicted to be 2-3 times that at the tropical surface (Lee *et al.*, 2007) –



Zonal mean equilibrium temperature change (°C) at CO_2 doubling (2x CO_2 – control), as a function of latitude and pressure (hPa) for 4 general-circulation models. All show the projected fingerprint of anthropogenic greenhouse-gas warming: the tropical mid-troposphere "hot-spot" is projected to warm at twice or even thrice the surface rate. ***Source:*** *Lee et al. (2007).*

Four of the UN's computer models, shown above, predict the "hot-spot's" presence. However, the model-predicted tropical upper-troposphere "hot-spot" does not occur in reality, as Figure 8 shows. It has not been observed in 50 years of radiosonde and drop-sonde measurements. It has not been observed in 30 years of satellite observations. It has not been observed at all. It is not there (HadAT, 2006) –



Altitude-vs.-latitude plot of observed relative warming rates in the satellite era. The greater rate of warming in the tropical mid-troposphere that is projected by general-circulation models is absent in this and all other observational datasets, whether satellite or radiosonde. Altitude units are hPa (left) and km (right). ***Source:*** *Hadley Centre for Forecasting (HadAT, 2006).*

In a lecture given in 2008, Professor Lindzen of MIT concluded from the absence of the "hot-spot" that –

> "... A doubling of CO_2 leads to surface warming of from about 1.5-3.5 C. By contrast, the observed warming over the past century or so amounts to only about 0.6-0.8 C (not all of which need be due to increased greenhouse gases). ... Using basic theory, modelling results and observations, we can reasonably bound the anthropogenic contributions to surface warming since 1979 to a third of the observed warming, leading to a climate sensitivity too small to offer any significant measure of alarm ...".

In short, the absence of the model-predicted "hot-spot" requires us to divide the UN's climate-sensitivity estimates by *at least 3*. Lindzen's result is in line with that of Scafetta & West (2008), who attribute more than two-thirds of the past half-century's "global warming" to the Sun.

Douglass *et al.* (2008) analyzed a dozen different radiosonde and satellite tropical-troposphere datasets, and concluded that the "hot-spot" that Santer and hence the IPCC had determined was the characteristic signature or fingerprint unique to anthropogenic greenhouse warming was not present in any of them. This result was a grave threat to the IPCC's contention that recent warming must be attributed chiefly to anthropogenic factors. So important was this issue that the US Climate Change Science Program devoted its first lengthy report to a discussion of the discrepancy, concluding that it was possibly attributable to uncertainties in measuring upper-troposphere temperatures. In short, the theoretical computer models that predicted the actually-absent "hot-spot" were preferred to the real-world data.

Dr. Santer swung into action again. First, he and his fellow Climategate emailers conspired with journal editors to prevent publication of the Douglass *et al.* paper for a year, so that a new dataset could be fabricated with the objective of showing that – contrary to all the other datasets – the tropical upper-troposphere "hot-spot" might perhaps be present after all. Dr. Santer and various fellow-emailers then set about writing a paper unfairly excoriating Professor Douglass and his colleagues for having displayed error-bars on their graphs of model predictions that were too narrow, given that some of the models had only been run once.

Repeatedly in the Climategate emails, Dr. Santer snidely condemned Professor Douglass and his colleagues for having perpetrated a "fundamental statistical error", which he, Dr. Santer, had heroically

pointed out in a rebuttal paper that – thanks to the delay he and his conspirators had occasioned in the publication of Professor Douglass' paper – appeared almost at the same date as theirs.

However, as is so often the case when the venomous stridency of the Climategate conspirators in condemning diligent researchers who dare to disagree with them reaches a painful pitch of screeching, the bluster conceals the fact that the "fundamental statistical error" is simply irrelevant to the question in hand. The truth is that the models are so unreliable that the error-bars applicable to their outputs are so wide as to be meaningless: Dr. Douglass and his colleagues could, with perfect justification, have omitted them altogether from their paper without in any way undermining the strength of its conclusion, which was that all tropical-temperature datasets obtained by real-world *measurement* rather than by the expensive guesswork that is climate *modeling* showed that the model-predicted characteristic fingerprint of anthropogenic "global warming" in the form of the tropical upper-troposphere "hot-spot" is simply absent in observed reality.

In this crucial respect, the Douglass paper is fatal to the IPCC's theory. By questionable methods, as has done before, Dr. Santer has attempted to rescue the situation for the IPCC: but all the datasets except that which appears to have been brought into being specifically for Dr. Santer's paper (and which had not been published in any peer-reviewed journal before Dr. Santer found it expedient to rely upon it) show that the IPCC is wrong. Whatever caused the "global warming" that ceased in the late 1990s, it was not Man.

- **Dr. Michael Mann (Pennsylvania State University)** is right at the heart of the Climategate conspiracy, judging by the number of emails to and from him on the file released by the whistleblower at the University of East Anglia. His chief contribution to the unsatisfactory science behind the "global warming" scare was his strange graph of 1998/9 purporting to abolish the medieval warm period, when temperatures worldwide were warmer than the present. His "hockey-stick" graph was reproduced six times at large scale and in full color in the 2001 IPCC report, and was even adopted as the IPCC's logo for a few years until it was comprehensively debunked and discredited in the peer-reviewed literature. This graph and the unfortunate methodological and statistical errors without which it could not have been contrived are considered later in this letter, in response to the Select Committee's specific question on this topic. The Attorney-General for the State of Virginia is currently investigating whether criminal offenses have been committed in connection with the fabrication of Dr. Mann's "hockey-stick" graph.

- **Dr. Susan Solomon (lead author, IPCC 2007 report),** another figure integral to the Climategate nexus, wrote a paper in 2009 in which she maintained that, as a result of humankind's influence, "global warming" would continue for thousands of years. However, based on the A2 emissions scenario of the IPCC that comes closest to today's real-world emissions of carbon dioxide, it is simple to demonstrate that most of "global warming" that is projected to occur this century will have occurred by 2100, leaving approximately 1 F° of warming "in the pipeline" that might emerge later:

Equilibrium warming from 368-836 ppmv CO2:	4.7 ln(836/368)	3.9 K
– Transient warming predicted to 2100 (Scenario A2):		3.4 K
= Warming "in the pipeline":		**0.5 K (<1 F°)**

As is often the case with the climate-extremist viewpoint, a little math soon puts the scare in perspective. It would scarcely be problematic if less 1 F° of warming "in the pipeline" were to occur over the timescale of thousands of years envisaged by Dr. Solomon. Let us prove the above result, since the Select Committee has been kind enough to express interest in my workings:

What is the difference between *transient* and *equilibrium* climate sensitivity? To make the imagined "threat" of anthropogenic "global warming" sound far more serious than it is in reality, papers such as that by Solomon *et al.* follow the UN's climate panel in suggesting, without explicit quantification, that once the concentration of CO_2 has become elevated significant increases in atmospheric temperature will be "locked in", and, worse, that further increases in temperature will occur for hundreds or even thousands of years even after the concentration of CO_2 has ceased to rise and has become stable.

For this element of the scare to work, it is essential to conceal from the general reader just how small is the difference between *transient* climate sensitivity (the warming that occurs initially in response to a perturbation of a presumed pre-existing equilibrium in the climate) and *equilibrium* climate sensitivity (the final warming once the climate has settled, after perturbation, to a new equilibrium.

A little simple arithmetic is sufficient to demonstrate that, even on the basis of the flagrantly-exaggerated climate sensitivity imagined by the UN's climate panel, the difference between transient and equilibrium climate sensitivity must be very small.

First, we recall that equilibrium climate sensitivity, at its simplest, is a logarithmic function of the proportionate increase in CO_2 concentration. In passing, we shall overlook the fact that use of a logarithmic function will lead to an overstatement (and perhaps a considerable overstatement) of climate sensitivity: a radiative-decay function allowing for eventual CO_2 saturation would be less inappropriate. The IPCC uses a logarithmic function, which implies an equation of the form –

$$\Delta T_{S,eq} = c \ln(C/C_0) \quad \text{K} \tag{13}$$

where the term in parentheses is the proportionate increase in CO_2 concentration, and c is an appropriate coefficient. We need to find the UN's central estimate of that important coefficient, which is nowhere made explicit in the 1600 pages of its 2007 climate assessment.

On page 798 of the UN's 2007 report, it is stated that the central estimate of equilibrium climate sensitivity $\Delta T_{S,eq}$ to a doubling of atmospheric CO2 concentration is $\Delta T_{S,eq} = 3.26 \pm 0.69$ Kelvin. From this value, noting that by a strange coincidence the IPCC's given standard deviation 0.69 is approximately equal to the logarithm of 2, we may derive the central climate-sensitivity coefficient c –

$$c = (3.26 \pm \ln 2) / (\ln 2) \approx 4.7 \pm 1. \tag{14}$$

So now we have our equation to convert any given change in CO_2 concentration directly to what the IPCC would predict, as its central estimate plus or minus one standard deviation, would be the consequent change in global mean surface temperature, after allowing for the amplifying effect of all temperature feedbacks –

$$\begin{aligned} \Delta T_{S,eq} &\approx (4.7 \pm 1) \ln(C/C_0) \quad \text{K} \\ &\approx (8.5 \pm 1.8) \ln(C/C_0) \quad \text{F°} \end{aligned} \tag{15}$$

It is astonishing that this equation nowhere appears as simply as this in the IPCC's 2007 *Fourth Assessment Report,* and does not appear at all in the *Summary for Policymakers,* which is the only part of the report that most politicians and journalists read. It is almost as though the IPCC did not want people to be able to calculate easily and quickly the warming effect that the IPCC predicts in response to changes in CO_2 concentration. We shall shortly see why not.

Next, we visit page 790 of the 2007 report and discover that the UN's central estimate of the atmospheric CO2 concentration in 2100, on Scenario A2, is 836 parts per million by volume. Since we know that the concentration in 2000 was 368 ppmv, we can swiftly calculate the UN's central estimate of the equilibrium increase $\Delta T_{S,eq}$ in global mean surface temperature over the whole of the 21st century (remarkably, the UN does not provide any central estimate of this value) –

$$\Delta T_{S,eq} = c \ln(C/C_0) \approx 4.7 \ln(836/368) \approx 3.9 \text{ K}. \tag{16}$$

Now we go to the *Summary for Policymakers,* where we find, at Table SPM-3, the predicted central estimate of *transient* global surface temperature increase in the 21st century, again on Scenario A2 –

$$\Delta T_{S,tr} \approx 3.4 \text{ K}. \tag{17}$$

The difference between the central estimates of the equilibrium ($\Delta T_{S,eq}$) and transient ($\Delta T_{S,tr}$) climate sensitivities is accordingly no more than 0.5 C°, or comfortably below 1 F°. This simple calculation removes the central plank in the thesis of Solomon *et al.* – namely, the suggestion that even after stabilization of atmospheric CO_2 emissions there will be an unspecified and implicitly large locked-in further increase in global mean surface temperature occurring over the subsequent millennium.

On reviewing the simple steps in this calculation, we note that most of the intermediate values that led to the final result are simply not reported in the 2007 report of the UN's climate panel. Yet these values are central to an understanding of whether or not there is, even in theory, a "climate crisis". Inferentially, the arithmetical obscurantism that pervades the report is far from accidental: it is designed precisely to hinder calculations such as that which we have just performed, for such calculations swiftly demonstrate that the

problems darkly hinted at in the text, and subsequently luridly cited in papers such as that of Solomon *et al.*, are too small to be significant.

Why does the IPCC not provide the simple function at Eqn. (15) for the benefit of policymakers? There is a simple, and devastating reason why not. Even if, *ad argumentum*, the IPCC were right in imagining that the warming in response to a doubling of atmospheric CO_2 concentration were as extravagantly great as 3.26 K, or close to 6 F°, the truth is that we can do remarkably little about it.

As noted earlier, we are only adding 2 ppmv/year CO_2 to the atmosphere. That value has remained broadly constant for a decade and is, if anything, declining a little, perhaps in response to worldwide economic recession. If, therefore, we were to shut down the entire global carbon economy for a year, with all the death, disease, destruction, and disaster that such a widespread and profound economic shutdown would cause, Eqn. (15) allows us to calculate immediately the amount of "global warming" we should be able to forestall, assuming 388 ppmv CO_2 in the atmosphere today and a 2 ppmv/year growth rate –

$$\Delta T_{S,eq} \approx 8.5 \ln[(388+2)/388] \approx 0.044 \text{ F°} \qquad (18)$$

At that rate, it would take half a century of total worldwide economic inactivity to reduce global temperature by just 1 F°, and only then if China, India, Indonesia, Russia, Brazil, South Africa, and other emerging nations could be persuaded to cut off their economic growth just as they are beginning to take the opportunity to lift their populations out of poverty.

It is fanciful in the extreme to assume that alternative technologies will become available in time totally to replace fossil fuels whose combustion emits carbon dioxide, and still more fanciful to assume that destroying the cheapest form of electricity generation, and therefore the fastest method of lifting the world's poorest nations out of their poverty and hence of stabilizing those populations, will be a net creator of so-called "green jobs".

For present purposes, though, it is necessary only to say that Solomon and other members of the Climategate clique who have gloomily foretold thousands of years of "global warming" as a result of Man's activities are severely exaggerating the problem – if, that is, there is a problem at all.

- **Dr. Kevin Trenberth (author of a much-cited 1997 paper on the Earth's radiation budget)** is another active member of the Climategate clique. One of the emailers' many unpleasant habits is to rubbish any learned paper that threatens the supposed "consensus" view. An important paper demonstrating that the "consensus" is very probably very wrong is that of Lindzen & Choi (2009). The authors of that paper found the simplest method yet of directly *measuring* – rather than merely of modeling – the atmospheric changes that allow the true warming effect of CO_2 and other greenhouse gases to be simply and reliably determined.

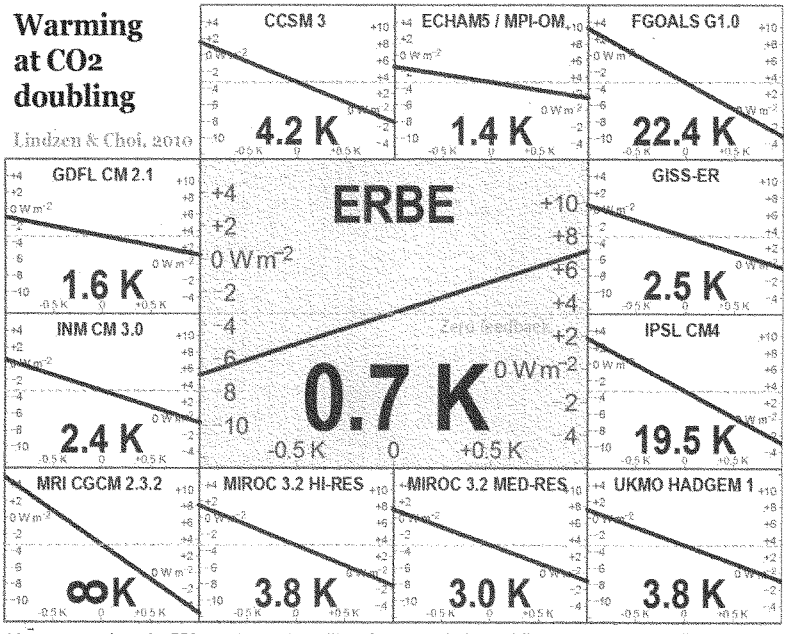
  Lindzen and Choi decided to examine two closely-related datasets: the observed changes in sea-surface temperature and the observed changes in outgoing radiation at the top of the atmosphere. The two researchers chose sea-surface temperatures to remove the contaminating effects of the urban heat-island effect, which has been shown to distort land-based temperature measurements. They selected 13 periods over the past two decades during which sea-surface temperatures rose or fell by at least 0.1 K (~0.2 F°) over a few months, so as to exclude the effects of statistical noise. They then observed how outgoing radiation changed over each period, and scatter-plotted changes in outgoing radiation compared with change in sea-surface temperature. They also forced 11 of the IPCC's computer models with the observed changes in sea-surface temperature, to see what consequent changes in outgoing radiation the models had been told to predict.

  The results indicated that, although the "consensus" theory reflected in the IPCC's documents held that warmer temperatures at the surface would cause a reduction in outgoing radiation because additional greenhouse-gas concentrations would retain some of the radiation in the atmosphere, in truth more outgoing radiation escaped to space, so that very little remained in the atmosphere to cause "global warming". From these observations, Lindzen and Choi concluded that the "global warming" to be expected from a doubling of atmospheric CO_2 concentration would be between one-third and one-sixth of the IPCC's central estimate.

  Dr. Trenberth and his Climategate colleagues acted swiftly and with characteristic venom. They published a viciously-expressed rebuttal paper written in language so impolite intemperate that it should never have

passed peer review – except that the Climategate faction largely controls the peer review process. As with Santer's mean-spirited attack on Professor Douglass' paper, so Trenberth and his colleagues inflated inconsequential statistical infelicities in Lindzen and Choi's paper into a major issue. Patiently, Lindzen and Choi rewrote their paper to address the minor points raised by Trenberth and other Climategate conspirators, and concluded that the IPCC's central estimate of the warming to be expected from a doubling of atmospheric CO_2 concentration was a fourfold to fivefold exaggeration, rather than a threefold to sixfold exaggeration.

Based on the revised scatter-plots of the outputs of the 11 IPCC models and of the real-world observations by the ERBE and CERES satellites (center panel), the stark difference between what the models predict and what real-world observations demonstrate is painfully clear –



Measurements from the ERBE and CERES satellites show a result that is different in essence as well as in degree from the outcomes predicted by 11 of the models relied upon by the IPCC in its 2007 report. The models all show positive feedbacks amplifying the initial warming caused by additional CO_2 concentrations, while the measurements (center panel) show that there is a significant increase in outgoing radiation at the top of the atmosphere in response to an increase in sea surface temperature, so that temperature feedbacks in the climate system will be negative. This result suggests that the warming to be expected from a doubling of CO_2 concentration would be not the 3.26 K (5.9 F) imagined by the IPCC in its 2007 assessment report but just 0.7 K (1.3 F). ***Source:*** *based on Lindzen & Choi (2010).*

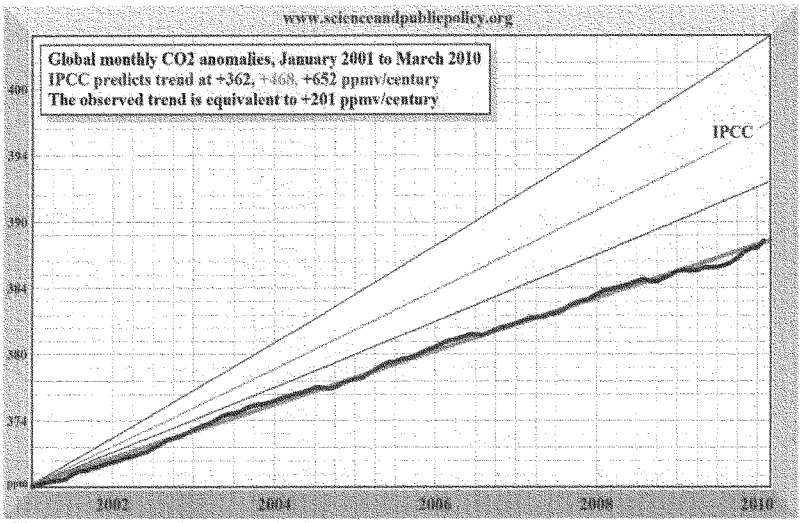
Though there are uncertainties in the measurements, and though Lindzen and Choi's result cannot be said to be definitive until improved measurements are proven reliable, they have provided what will be perhaps the most reliable method of obtaining a reliable estimate of climate sensitivity once better measurements are available. Their result, upheld after the unconstructive and impertinently-expressed attack by Trenberth and other Climategate conspirators, is potentially fatal to the IPCC's central contention.

➢ **Tom Karl (director of the NOAA's National Climatic Data Center)** is another active member of the Climategate clique. We have already described how he failed to admit, when specifically asked by the ranking Minority member of the House Energy and Commerce Committee, that there had been global cooling for the best part of a decade, and how his less than honest conduct before the Committee was

subsequently exposed by the use of his own NCDC global-temperature dataset, which clearly demonstrated the small decline in global temperature that has occurred in the first decade of the 21st century.

Mr. Karl also seems to be behind the NOAA's response to my testimony last year before the House Energy and Commerce Committee. Less than honestly, that response, which in breach of normal courtesies was not copied to me by the Committee staff, takes me to task for putting before the Committee a graph showing that atmospheric CO_2 concentration has been rising for the past decade in a straight line at ~2 ppmv/year towards ~570 ppmv (with something of a slowing in the past couple of years), while the IPCC (on the A2 scenario) predicts an exponential acceleration towards 836[730, 1020] ppmv. I say "less than honestly" because the NOAA submission makes much of the statement that (on some unspecified scenario) the IPCC currently predicts a 1.7 ppmv/year CO_2 concentration increase rather than 2 ppmv/year. Since the last IPCC report was published in 2007, and CO_2 concentration had been rising at 2 ppmv/year for several years already, it is difficult to know on what basis the IPCC could have made such a prediction (if it did so), still less on what basis NOAA regarded that prediction as credible enough to serve as a basis for challenging my graph.

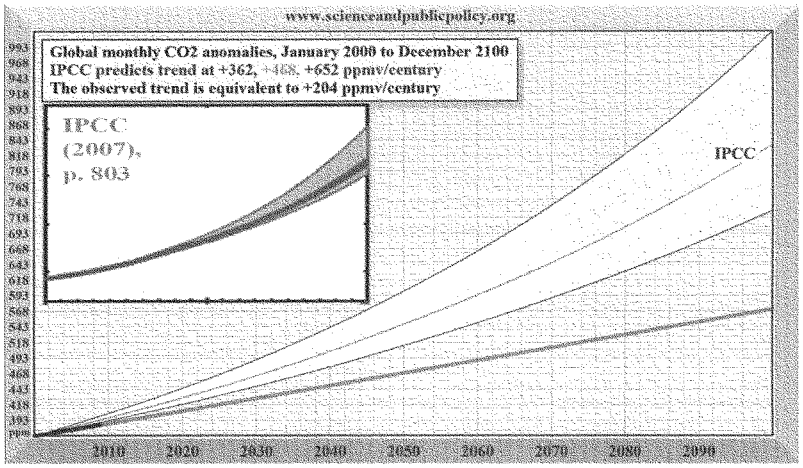
Perhaps the simplest way to demonstrate the point is visual. First, here is my graph:



CO_2 concentration (monthly deseasonalized data: dark blue curve) is rising in a near-straight line, well below the IPCC's projected range (pale blue region). The deseasonalized real-world data are shown as a thick, dark-blue line overlaid on the least-squares linear-regression trend. There is no sign of the exponential (i.e. ever-accelerating) rate of growth the IPCC predicts. Instead, for almost a decade CO2 has grown in a straight line at just 2 ppmv/year. If anything, the rate of growth is decelerating a little. ***Data source:*** *NOAA.*

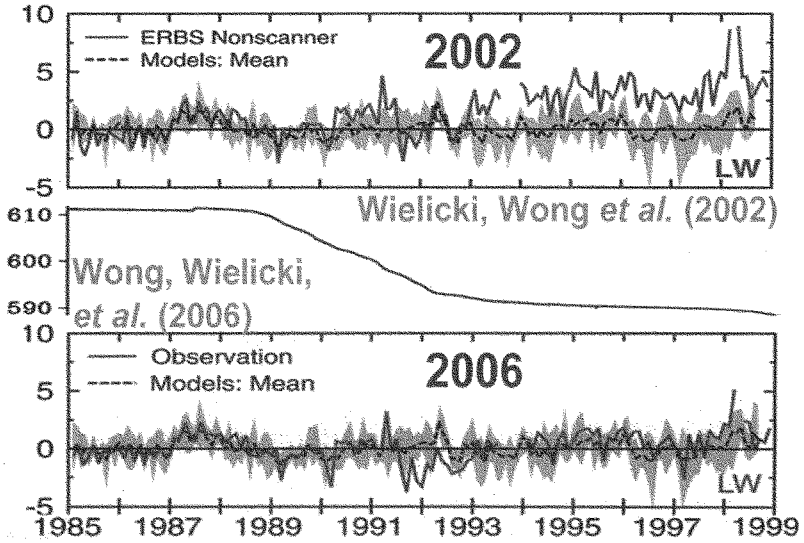
The graph is constructed thus. The raw data, in dark blue, are overlaid on the thick pale blue straight line that is the least-squares linear-regression trend on the data. The two are almost coincident. The pale-blue region above the data curve is the series of exponential curves that commence at the starting-date of the graph and continue towards 730, 836, and 1020 ppmv respectively. These are the IPCC's lower, central, and upper estimates based on the A2 emissions scenario, the closest scenario to today's actual emissions. A2 is essentially an exponential scenario, so exponential curves are appropriate.

To show the extrapolation of the exponential curves to the values the IPCC predicts for CO_2 concentration in 2100, the exponential curves representing the IPCC's projections are carried forward to that year on the following graph, with a visual verification (inset curve) taken from page 803 of the IPCC's 2007 report. –



The IPCC's projections (pale blue zone) carried forward to 2100, reaching 730, 836, and 1020 ppmv respectively, with the linear trend on the actual data heading for just 570 ppmv at present. The terracotta curve on the inset graph is taken from IPCC (2007), p. 803, with the aspect ratio adjusted to conform to that of the main graph. The close similarity of the two graphs can be clearly seen.

Finally, NOAA/Mr. Karl say that I drew inappropriate conclusions from the visible discrepancy between the model-predicted and actually-observed outgoing long-wave radiation as measured by satellites –



Outgoing long-wave radiation (ERBE: W m^{-2}, 1985-1999) as predicted by models (black dashed curve) against measured outgoing radiation (solid red curve). Upper panel: not corrected for orbital decay in the satellites. Lower panel: after correction. Center panel: mean altitude of ERBE satellites (km), showing the orbital decay.

It will be seen that even after correction in 2006 for orbital decay the very substantial ocean warming of 1998 caused by the Great El Niño of that year caused a very much greater emission of radiation than the models would have predicted. It was on the basis of this observation that Lindzen & Choi (2009, 2010 *op. cit.*) decided to investigate the relationship between changes in sea-surface temperature and corresponding

changes in outgoing radiation. The adjustment for orbital decay reduces the IPCC's overstatement of climate sensitivity – the warming effect of CO_2 and other greenhouse gases – from sevenfold to fivefold, but the overstatement remains, and remains substantial. That is the central point.

I have thought it right to spend a little time providing the background to some of the tricks and data tampering to which several of the Climategate emailers have resorted, by way of illustrating how it is that quite a small number of manifestly ill-intentioned scientists in high positions, working – as we can now prove – in concert, have been able to capture and control the climate debate, and to influence governments unduly.

The implications for the credibility of science are profound. Until the "global warming" scare, the public had thought that scientists were largely free from political ambition, and were diligent researchers merely getting on with their work. Now, as the climate continues to fail to respond as predicted by the climate extremists, the public are taking the increasingly cynical – and substantially correct – view that powerfully-placed scientists, businessmen, media, politicians, and academics are forming a coalescence of financial vested interests with the aim of taxing and regulating the citizen for the mutual profit of the governing class at the expense of the governed.

The conduct of all of the scientists I have named here, and of many others I could have named, falls well below the minimum standards of academic probity, impartiality, and honesty. I am asked whether I condone the deceptions and manipulations and data destructions organized by the Climategate clique. The answer is No.

8. **[with q.12] What recommendations would you make to regain public trust in the climate science discipline? What should climate scientists do to regain the public's trust in their work? What should they do to ensure transparency and accountability in the climate science community, especially as we look towards the development of the upcoming IPCC's Fifth Assessment Report?**

Science has become what economists call a monopsony: there is only one paying customer – the taxpayer. As Professor Lindzen has testified before the Senate, everyone these days is reclassifying himself as a climatologist for the sake of getting the substantial and too-available taxpayer funding that is available for often half-baked "Save-The-Planet" research. In short, the profits of doom are enormous and, while they remain easily available, climate science will remain dishonest. Remove the cash incentive to over-predict catastrophe and much of the nonsense will stop. Then, and only then, will confidence in climate science be restored.

To bring climate scientists to heel, then, the first step is to make it plain to them that the gravy-train has tipped into the gulch. Make it plain that all special programs for "global warming" research will be terminated at once, and will not be resumed unless and until global mean surface temperature, taken as the least-squares linear regression on the global satellite temperature data, shall have risen by 2 F° above what it was in January 2001.

The UN's climate panel is not the only organization that has made it clear that warming of up to 2 K (3.6 F°) would, on balance, be beneficial. Therefore, it would be good for the planet not to prevent a resumption of the "global warming" that ceased in the mid-1990s, so that, if and when "global warming" resumes, we shall get the benefit of it. Indeed, there is no particular reason to believe that warming of more than 3.5 F° would do more harm than good: but it is widely agreed that a rise of up to 2 F° would fall well within the "net-beneficial" range.

How long will it take for global temperatures to rise by 2 F°, even on the assumption that the IPCC has not exaggerated the "global warming" to be expected in response to increases in CO_2 concentration? We adopt the ever-useful Eqn (15) to tell us the answer, taking today's concentration of 388 ppmv CO_2 and increasing it by 100 ppmv to represent half a century of emissions growth at the past decade's rate of 2 ppmv/year –

$$\Delta T_{S,eq} \approx 8.5 \ln[(388 + 100)/388] \approx 2 \text{ F}^\circ \qquad (18)$$

Of course, it is possible that, with the rapid growth of carbon dioxide emissions in China and other third-world countries, concentrations in the atmosphere may begin to rise over the coming decades. In that event, and always provided that the IPCC has not exaggerated the warming from CO_2 as the literature increasingly suggests it has, the world may reach 2 F° in less than 50 years. In any event, the 2 F° warming is not going to arrive anytime soon, so there will be plenty of time to monitor the situation. What Eqn. (18) shows is that, contrary to the relentless propaganda of the climate extremists, there is in fact no hurry. We have time to begin to see who is right long before anything but good will come of rising temperatures worldwide.

In general, too much policymaking these days is on the hoof – hasty decisions taken by over-pressured politicians leaned upon mercilessly by well-funded single-issue lobby groups who have long learned that telling the politicians

that immediate action to avert some imagined catastrophe. As Schulte (2008) has pointed out, however, of 539 papers in the peer-reviewed literature containing the phrase "global climate change", not one provides any evidence of any catastrophe arising from Man's influence on the climate.

A further step towards the restoration of some sort of credibility for climate science would be for the US to cease to fund, contribute to, or participate in the IPCC. That discredited, over-politicized, and self-serving body no longer deserves support and – though this is not in the gift of the United States alone – it should be disbanded forthwith. At the very least, the United States should insist that the founding document of the IPCC be revised to make it plain that the IPCC is obliged to consider all scientific points of view carefully and not, as at present, to take for granted that Man's influence on the climate will be catastrophic, and should also insist on the changes in IPCC procedures for peer review that I have described in the answer to an earlier question.

9. It has been acknowledged that certain sets of primary data have been intentionally destroyed and other sets of data are not shared within the scientific community. Do you believe that sharing of primary data sets will lead to more transparency in scientific work and is a step towards climate scientists being held more accountable?

Yes. It is a disgrace, and ought to have merited instant dismissal, that Professor Jones refused to share his data and methods with other scientists on the *stated* ground that he did not want to give them the chance to find fault with his research. It is fundamental to the operation of the scientific method that scientists – especially when they are in receipt of over-generous funding for questionable research at taxpayers' expense – should be compelled to share with other scientists, and with the taxpayers, the data and methods for which the taxpayers so generously provide.

Perhaps the most certain way to ensure that in future the operations of climate science are more transparent and hence less prone to the corruption and data-tampering that I have outlined in answers to earlier questions is to make it plain to the editors of all learned journals in climate and related fields -- indeed, in science generally – that if they do not have a sufficiently rigorous policy of insisting that all data, programs, and results are fully and publicly archived with the journal so that they are available to all then they will not be regarded as competent journals and the United States will take no note of their contents.

The Climategate emailers, when discussing how to do down one of the eminent scientists whose conclusions demonstrated the falsity of the notion of catastrophic "global warming", discussed at some length how desirable it was to their rebuttal paper published in a journal that did not require archiving of data, programs, and results. Therefore, in future the full and public disclosure of all relevant material supporting papers published in the journals must become the iron and universal rule, not the occasional and commendable exception.

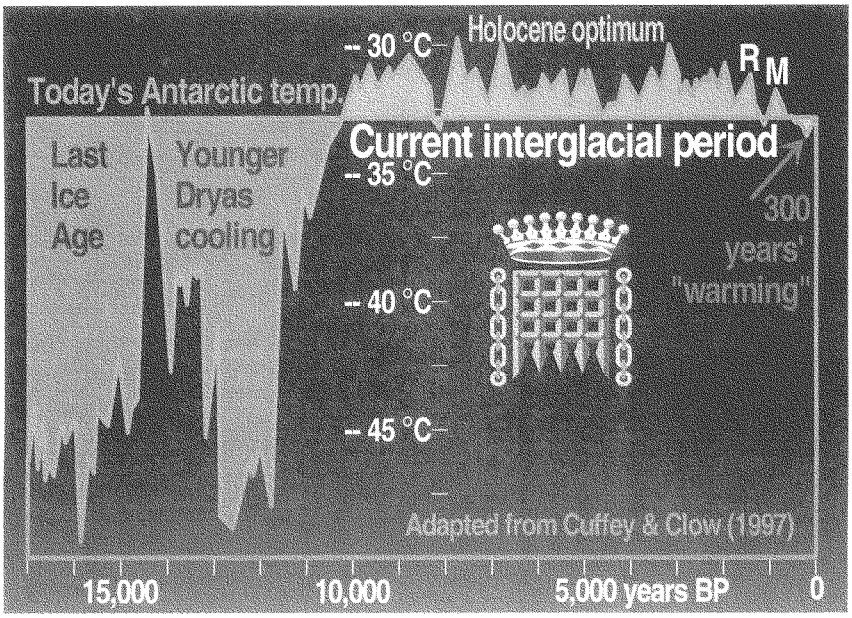
10. Can you address the Medieval warming period and why temperatures were much higher in recent pre-industrial time periods? Are you able to model why such periods took place?

The Vostok ice cores show that in the past 650,000 years the correlation between greenhouse gases and temperature was close. Al Gore said in his sci-fi comedy horror movie that whenever CO_2 changed, temperature changed. However, it was in fact the temperature that changed first, and CO_2 that followed 800-2800 years later. The latter change cannot have caused the former. Carbon dioxide was arguably a temperature *feedback:* as temperature increased, warming the atmosphere, CO_2 was outgassed from the oceans, amplifying the warming to some extent. However, some other natural factor, nothing to do with CO_2, must have triggered the changes.

For 7500 of the past 11,400 years, global temperatures were warmer than the present. There is, therefore, nothing exceptional about the absolute magnitude of today's temperatures worldwide. Nor is there anything unusual about the rate of change in temperatures. As we have seen earlier, the warming of the 26 years 1976-2001, at 0.16 K/decade, was exactly parallel to (and not, as Dr. Holdren had falsely attempted to claim, substantially greater than) two previous periods of warming at exactly that rate – 1860-1880 and 1910-1940.

In the two earlier periods, CO_2 concentration simply did not rise fast enough – even on the IPCC's exaggerated estimate of the warming effect of CO_2 – to cause the rapid temperature changes. Therefore, we know that some natural cause must have been at work. One possibility is that the rapid rises in temperature over all three periods were caused by the positive phases of the Pacific Decadal Oscillation, an influential pattern of ocean currents. Certainly, the most recent positive phase of the PDO commenced in 1976, just as global temperatures began to rise sharply. For the past few years, the PDO has been in its negative phase, and global temperatures (despite Dr. Karl's best attempts not to admit the fact before Congress when questioned) have been falling a little.

Furthermore, in the 40 years 1695-1735, temperatures in central England (a reasonable proxy for global temperatures) rose by 4 F°, while in the 100 years 1906-2006 global temperatures rose by little more than 1 F°. Once again, natural factors must have been at work to cause the rapid rise in temperatures over the earlier 40-year period, which preceded the onset of the Industrial Revolution. From these and many similar observations, it is necessary to deduce that CO_2 was not and is not the principal driver of climate.



"Global warming" in perspective: *The recent 300-year period of "global warming", nearly all of which cannot have been anthropogenic, is insignificant in comparison with the Holocene climate record. Throughout much of the past 10,000 years, including the Minoan, Roman (R), and Medieval (M) warm periods, global temperatures were up to 5 Fahrenheit degrees warmer than the present. Today's temperatures are not unprecedented.* ***Source:*** *based on Cuffey & Clow (1997), with adjustment of aspect ratio for clarity.*

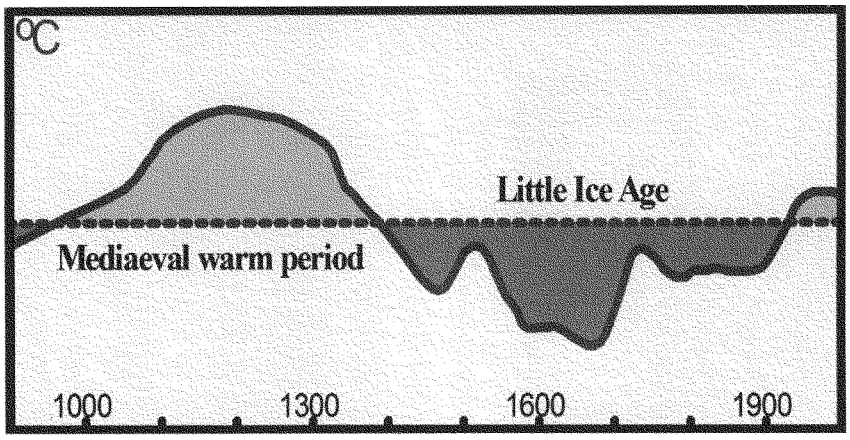
Unfortunately, the IPCC has made a determined effort artificially to abolish the medieval warm period, inferentially with the intention of making it appear, falsely, that today's global mean surface temperatures are unprecedented in recent history.

By focusing the debate exclusively on the medieval warm period, the IPCC has succeeded in drawing public attention away from the Roman and Minoan warm periods and, above all, from the Holocene Climate Optimum.

It is only when one examines the reconstructed temperature record for the whole of the 11,400 years since the end of the last Ice Age (see the graph above) that the very small warming of the past 300 years (during 270 of which we cannot have exerted much influence over the climate) is put into its proper perspective.

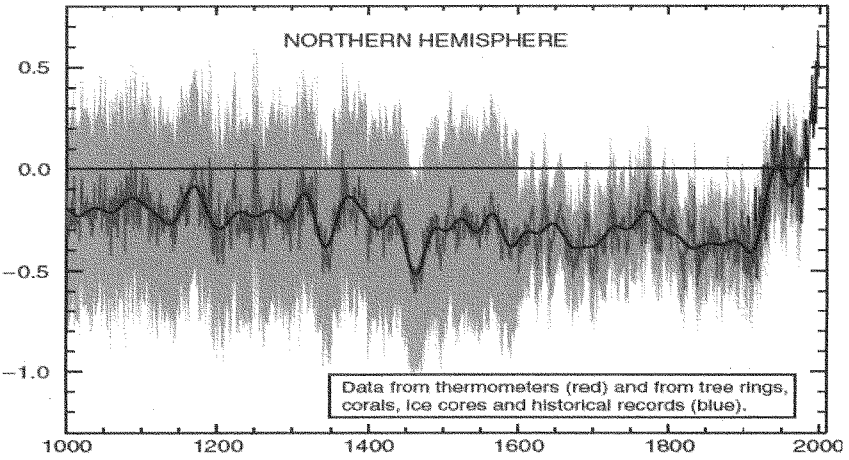
Let us, however, play the IPCC's game and concentrate on the medieval warm period, the most recent of the four great warming periods of the Holocene era.

The IPCC's 1990 report shows the existence of the Medieval Warm Period quite clearly –



Medieval warm period? *Yes. This drawing of a graph in the IPCC's 1990 report shows it clearly.*

However, by the time of the IPCC's 2001 report the warm period had been eradicated by a computer model that produced the following graph, which appeared six times in large scale and in full color in the report and was then adopted as the iconic symbol of the IPCC itself –



Medieval warm period? *Not any more: the UN purported to abolish it in its 2001 assessment report. The above graph appeared six times, in full color, and at large scale, in the 2001 report, the only graph to be so favored.*

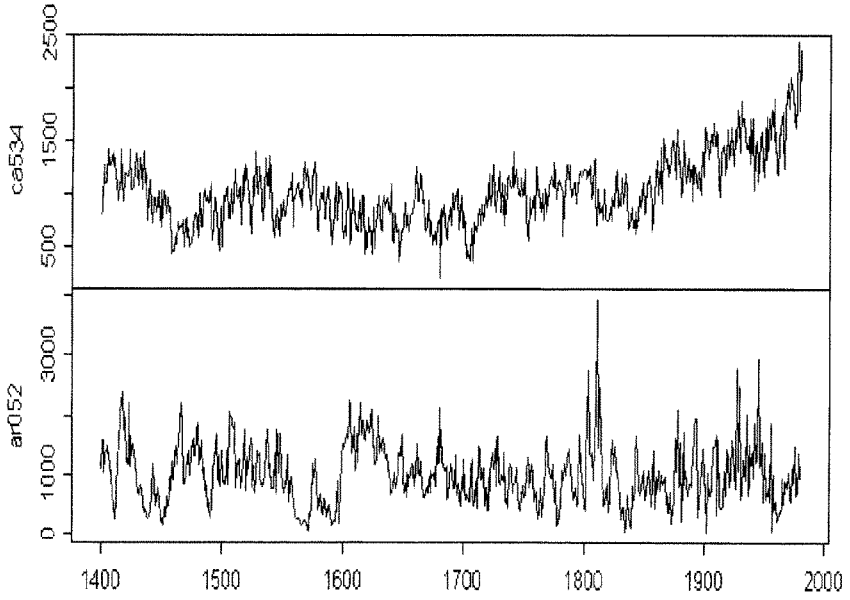
The IPCC notoriously abolished the medieval warm period in its 2001 report, having explicitly acknowledged its existence in its 1990 report. Its justification for the purported abolition was questionable. The unique prominence that it accorded to the 2001 graph suggests a political rather than a scientific motive. The graph is taken from a paper in *Nature* (Mann *et al.*, 1998-1999) that relied upon a number of abuses of sound statistical practice. The paper drew heavily upon bristlecone-pine proxies for pre-instrumental temperature change, even though a previous UN report had explicitly recommended against the use of such proxies on the ground that the width of the tree-rings is influenced not only by temperature change but also by changes in precipitation, and most notably by changes in atmospheric CO_2 concentration.

Recent attempts by Mann *et al.* to revive the unsound graph regrettably suffer from the same central defect as the original: removing the bristlecone proxies and a further defective outlier (the Tiljander proxy) from among the proxy datasets clearly shows that the medieval warm period was real, and appreciably warmer than the present day.

The unsatisfactory statistical methods in Mann *et al.* were thoroughly exposed by McIntyre & McKitrick (2003, 2005). In all material respects, the findings of McIntyre & McKitrick were powerfully endorsed by a detailed investigative study by three statisticians at the instigation of the US House of Representatives (Wegman, 2005).

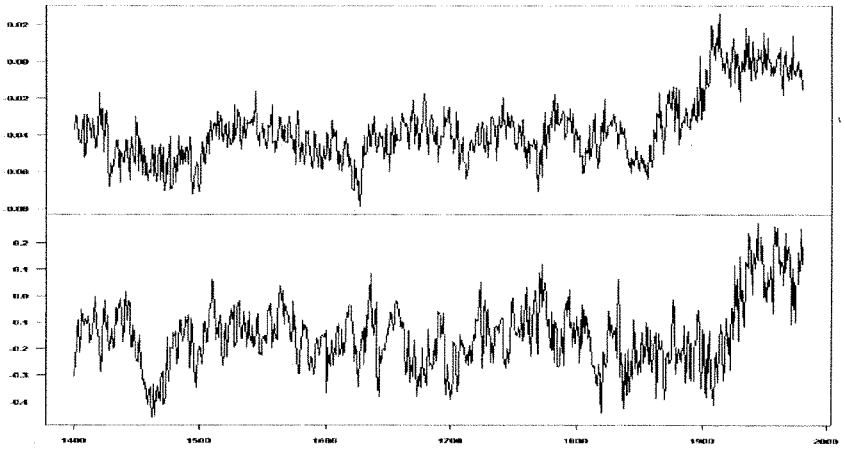
It is of particular concern that the compilers of the now-discredited graph upon which the UN unwisely placed such undue weight in its 2001 report were extremely reluctant to release their computer programs and data. *Nature* failed to require them to produce the data; and it was only after numerous requests by McIntyre and McKitrick that Mann *et al.* eventually parted with the information necessary to allow a proper, independent, academic review of the graph that the UN had been so willing to accept without any real peer review.

It is worth demonstrating one or two of the statistical abuses that led to the false abolition of the medieval warm period. One startling abuse was the disproportionate weight given to temperature proxies that provided Mann *et al.* with the "hockey-stick" profile they desired, in comparison with the lesser weight given to proxies that demonstrated the presence of the medieval warm period. An instance –



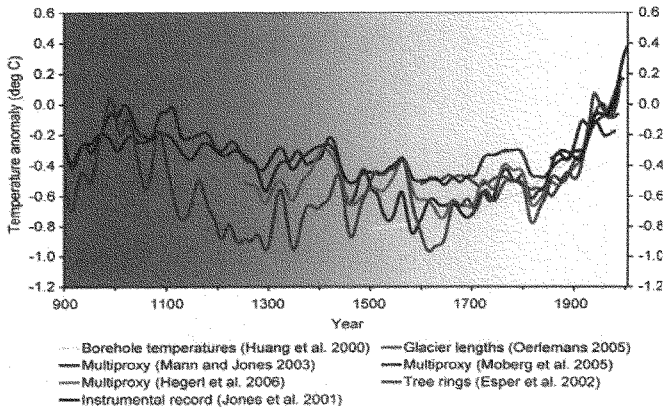
In the compilation of the UN graph purporting to abolish the medieval warm period, the upper data, showing the present day to be warmer than the previous 600 years, was given 390 times the weight of the lower data, showing the Middle Ages as warmer than the present. ***Source:*** *McKitrick, R.: testimony before the Australian Parliament, 2005.*

The computer model which was used to generate the defective UN graph was tuned to generate data curves showing the present day to be warmer than at any time over the past 600 years, regardless of whether the graph were based on genuine temperature proxies or on random red noise –



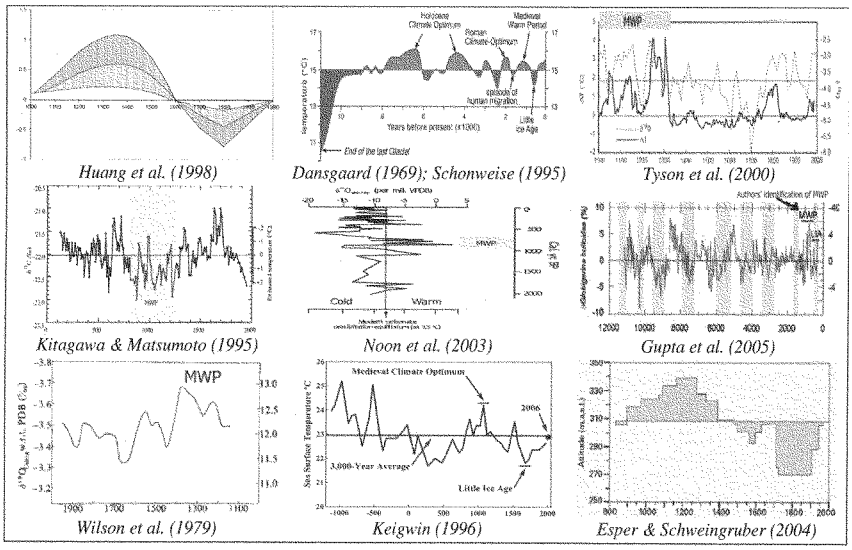
The computer model that generated the UN's graph that "abolished" the medieval warm period generates "hockey-sticks" that show today's temperatures as warmer than for 600 years, with the post-1900 temperature increase serving as the blade of the hockey-stick. Remarkably, the model generates "hockey-sticks" even if, instead of the genuine temperature-proxy data (upper panel), random red noise (lower panel) is used. ***Source:*** *McKitrick, R., testimony before the Australian Parliament, 2005.*

The EPA, in the Technical Support Document that it has prayed in aid as justification for its "endangerment" finding in respect of CO_2 and five other greenhouse gases, disregards the overwhelming majority of the papers in the scientific literature, and also denies history by finding that there was no medieval warm period –



Notwithstanding official attempts either to eradicate the medieval warm period altogether or to show that it was not as warm as the present, in the past 25 years at least 670 scientists from 391 institutions in 40 countries have contributed to peer-reviewed papers in the learned literature establishing that the medieval warm period was real. Their distribution estsablishes that the warming was global. Many – if not most – find the Middle Ages were warmer than the present.

Here are graphs from a few of these papers –



The medieval warm period is as well established in the scientific literature as it is in the historical record.

It was only after the UN's use of the defective graph had been challenged that a suspicious spate of papers supporting Mann *et al.* in their attempted abolition of the medieval warm period appeared in the scientific literature. However, the Wegman report showed that most of the authors of these papers had previously been co-authors with Mann himself. This incident illustrates a central difficulty. Many of the scientific journals have declared prejudices in favour of the "official" position on climate change: therefore, they are far more indulgent of authors who support the "official" position than of skeptics.

This declared bias among the journal editors allows supporters of the "official" position to knock down any skeptical paper by dashing off a quick rebuttal, which is eagerly printed after a minimum of scrutiny. Then the IPCC, which claims to operate by reviewing the literature, can concentrate on the rebuttals rather than the skeptical papers that question its position.

At any rate, the IPCC, in its anxiety not to admit its mistake in attempting so prominently to abolish the medieval warm period in 2001, failed – and continues to fail – to take any account of the overwhelming majority of papers in the literature that demonstrate that the medieval warm period was real, global, and appreciably warmer than the present.

Most of the papers in the literature that suggest there was no medieval warm period do so on the basis of computer modeling. By contrast, most of the papers that find the Middle Ages warmer than the present do so on the basis of measurements.

The saga of the IPCC's questionable attempt to abolish the medieval warm period illustrates in microcosm one of the central defects in the IPCC's approach: its undue reliance upon modeling, too often to the extent of subordinating real-world measurement to expensive, defective, and in any event necessarily ineffective computerized guesswork.

We conclude that today's temperature is not exceptional. It was warmer than today in the medieval, Roman, and Minoan warm periods and during the Holocene climate optimum; it was up to 7 F° warmer than the present in each of the four previous interglacial warm periods; and 12.5 F° warmer than the present throughout most of the past 600 million years. Yet Earth did not fry and the oceans did not acidify.

11. All of the climate research seems to be focusing on the previous 100 years and examining the recent rise in atmospheric CO_2 levels. Given the incredible complexities associated with the global climate, is it possible that this timeframe is not adequate? How can one overcome the lack of accurate data dating back before 1800?

This perceptive question one of the central difficulties in climate science: the data, even today, are simply inadequate to support the often extreme conclusions that are being drawn from them. The reason why research into global temperatures tends to concentrate chiefly on the last couple of centuries is that before the Central England Temperature Record was established in 1659 there was no reliable regional instrumental record of temperature change anywhere, still less a global record.

The global instrumental record was only compiled from 1860 onwards, and – as the Climategate scandal has revealed – it has been tampered with. Much of the original data have been lost or (if the Climategate emailers meant what they said in some of their emails) deliberately destroyed to prevent verification of what has been done to the data. In a number of regions – such as Australia and New Zealand, as well as the US global historical climatological network as a whole – there is disturbing evidence that temperatures in the early part of the 20th century have been rewritten at lower values, without any adequate explanation or excuse, inferentially with the aim of making the 20th-century warming rate seem a great deal steeper than it actually was.

The global temperature record only became reliable in the early 1980s, when the first well-calibrated satellite measurements became available. However, even with the satellite measurements a degree of uncertainty remains, as we have seen when considering the various records of changes in outgoing radiation and in cloud cover.

Before the instrumental record began, the position was still less satisfactory. We now have to rely upon what are called "proxy temperature reconstructions", where climate scientists analyze the greenhouse-gas concentrations or isotopic ratios of air trapped in layers of Antarctic or Greenland ice going back hundreds of thousands of years, or the varying widths of tree-rings, or the strata visible in speleothems (stalagmites and stalactites), or the shells of tiny foraminifera in the oceans, or the sediments at the bottom of lakes, or the variations in the extents of glaciers.

All of these proxy records are subject to large uncertainties, and also to subjective interpretation by scientists making use of them. For instance, the tree-rings from bristlecone pines are widely used as temperature proxies, but are unsatisfactory because it is not only changes in CO_2 concentration that widen them: in addition, increased rainfall or warmth or both will widen the tree-rings.

Likewise, the mere recession of glaciers does not necessarily indicate unprecedented warming. Nor, of course, does the mere fact of the warming indicated by glacial recession tell us anything about the cause of the warming, which, as we have estsablished, may very well have been chiefly of natural origin.

For instance, many Alpine glaciers are receding, but as they fall back they reveal medieval mountain passes, forests, and even an entire silver-mine that were overrun by the advance of the glaciers as recently as the end of the medieval warm period. Many Andean glaciers are also receding, but the evidence is that for most of the Holocene all but the very highest peaks were ice-free (Polissar *et al.*, 2006).

In truth, the vast majority of the world's 160,000+ glaciers, most of them in Antarctica, have never been visited or measured by Man, so we have no sound scientific basis for the oft-stated conclusion that all or most of the glaciers are "threatened" by "global warming".

Furthermore, though the paleoclimate has a place in helping us to understand the present and future climate, its value is often more limited than its protagonists are willing to admit.

The central question to which we need the answer – and on which there is no "consensus" (not that science is or was or ever could be done by mere head-count: to suggest that a supposed "consensus" matters is to perpetrate the shopworn Aristotelian logical fallacy of the *argumentum ad populum*, or headcount fallacy) – is not on whether increased CO_2 concentration causes warming (it does), nor on whether its concentration in the atmosphere is rising (it is), nor on whether we are responsible for the increase in concentration (we are), but on the quantitative question *how much* warming the foreseeable doubling of today's concentration can be expected to cause.

The paleoclimate can shed some light on this question. For instance, in the neoproterozoic era, some 750 million years ago, mile-high glaciers came and went, twice, at sea level and at the equator, as geological researchers in

Australia, southern Africa, Thailand, and Sweden have reported. However, we also know that at that era the dolomitic rocks (containing 44% CO_2) were first deposited: and that dolomitic rock will not precipitate out of the ocean, involving not only the superabundance of oceanic calcium ions but also the magnesium ions, unless the partial pressure of CO_2 above the ocean is at least 300,000 ppmv, or more than 720 times its present concentration. Though the Sun was 5% less bright than today, and though more of the sunlight than today would have been reflected back to space by increased albedo, it is highly unlikely that glaciers could have come and gone at the equator and at sea level with 300,000 ppmv CO_2 in the air, if CO_2 had anything like as large a warming effect as the IPCC would like us to imagine.

However, the further back we look in geological time the more difficult it becomes to draw definitive conclusions. If we cannot safely draw definitive conclusions about today's climate, then *a fortiori* we cannot draw definitive conclusions about earlier climates whose true states we can only infer, in a strictly limited degree, by paleoclimate proxy data.

To settle the most urgent question in climate science today – *how much* warming will a given increase in the concentration of CO2 really cause? – we shall have to concentrate on improving today's methods of measuring and recording what goes on in the real climate. All previous climates are too inaccessible to us to give us the definitive answers we need.

How, then, can we improve current measurements of the climate to overcome the limitations imposed by the lack of sound, comprehensive data even in our own era? First, it is necessary to understand the limitations on forecasting the future evolution of a complex, non-linear, mathematically-chaotic object such as the climate. As Lorenz demonstrated in 1963, in a chaotic object such as the climate the slightest perturbation in the value of just one of the parameters that defines the object at some chosen starting point can cause bifurcations in the future evolution of the object, and those bifurcations – though in principle predictable – cannot in practice be reliably predicted over the very long term unless the values of the millions of defining parameters of the object are known to a precision that – in the climate, at any rate – is and will forever be unachievable. Even if we had the capacity to obtain all of the necessary real-time data fast enough to make use of them in a computer model, to make a reliable forecast for more than a few weeks ahead would require computing power greater than anything currently foreseeable, as well as so much time that, to get next year's weather right, we should have to run the program from now till eternity.

Computer models, therefore, cannot tell us the answers we seek, not least because *we* tell *them*. The supplementary material supplied with the IPCC's 2007 report reveals that five of the 23 computer models on which the IPCC so heavily and imprudently relies are *pre*-programmed with the IPCC's own declared central estimate of the radiative forcing in response to a CO_2 doubling – i.e. $\Delta F_{T,2x} \approx 5.35 \ln 2 \approx 3.71$ W m^{-2}. If we are telling the computers what values to assume, they cannot tell us what values are right.

The IPCC and its adherents often claim that the models are telling us significant things because, if we do not pre-program them with the very high warming effect of CO_2 in which the IPCC would like us to believe, they cannot reproduce the "global warming" of 1975-2001. This notion is, of course, nonsense: as we have already seen, the warming rate of those 26 years was no greater than the warming rates of the 20 years 1860-1880 and of the 30 years 1910-1940, and yet we know we could not have caused those two previous periods of rapid warming, because the rate at which we were adding CO_2 to the atmosphere was manifestly insufficient. So we know that those two periods of warming were naturally caused. That, at least, raises the question whether the third period was also naturally caused: and we have already examined in some detail one mathematically-plausible natural explanation for much of that third period of warming. Therefore, we cannot assume that the influence of Man's CO_2 emissions is the only possible explanation for that warming.

With that necessary background, we must accept that the limitations on what we can learn about the evolution of today's climate from palaeoclimate research require us to direct most of our research efforts to today's climate. What measurements in today's climate would give us the best opportunity to determine correctly the true amount of "global warming" to be expected from any given increase in CO_2 concentration?

We can now take it that satellite measurements of global temperature change are respectably accurate. However, there are only two sets of global satellite temperature data available – those from the University of Alabama at Huntsville, under the formidable John Christy and Roy Spencer, and from Remote Sensing Systems, Inc. The United States would be doing the world a further great service if it were to ensure that a third global temperature monitoring satellite system were made available, to ensure the secure continuance of the satellite temperature monitoring program. The intercalibration of successive generations of temperature monitoring satellites is a

complex and highly specialist art: for secure and reliable future temperature measurement, it will be necessary to ensure that enough trained analysts with the necessary specialist knowledge and skills are available.

The landmark paper by Lindzen and Choi, referred to in an earlier answer, which carefully compares changes in sea surface temperature to changes in outgoing radiation at the top of the atmosphere, provides a simple and elegant method of coming as close as we can, given the known limitations I have already outlined, to measuring anthropogenic warming effects directly. The authors of that great paper would be the first to concede that there remain considerable uncertainties in the measurement both of sea surface temperatures and of outgoing radiation.

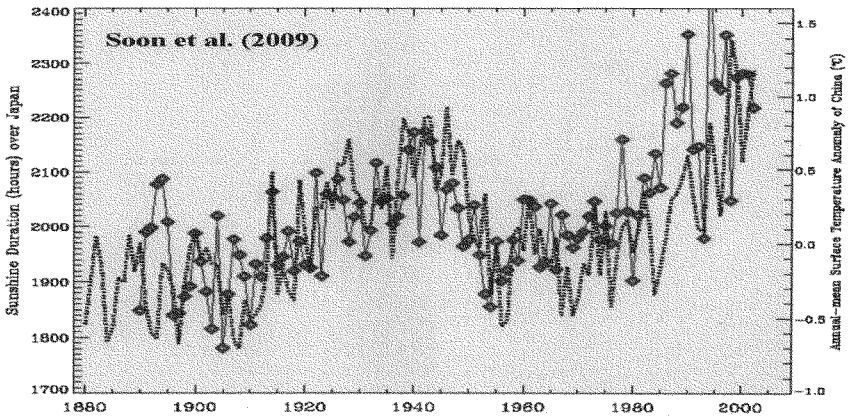
However, sea surface temperatures are now quite reliably monitored by the 3300+ automated bathythermograph buoys of the ARGO project, which, however, requires continuous maintenance if it is to continue to deliver reliable data. Some 800 of the buoys have to be replaced every year. In the long term, this project – if it can be maintained – will tell us much about changes temperature and salinity of the world's oceans.

Can the satellite measurements of outgoing radiation be improved? This is certainly an important priority, because it is the rate of change in outgoing radiative flux per unit change in surface temperature that is the key climate sensitivity parameter that tells us how much warming any past changes in greenhouse-gas concentrations has brought about. The ERBE and CERES satellites have done well: but a new generation of satellites will give us the additional confidence necessary to refine and confirm or deny the results obtained by Lindzen and Choi on the basis of the technologies now available.

It will also be important to improve measurements of changes in cloud cover. All of the IPCC's assessment reports have admitted that clouds are perhaps the greatest source of uncertainty and unreliability in climate projections. At present the International Satellite Cloud Climatology Project is providing some interesting data, as are other satellites: but no one is yet content that we are able adequately to capture, for instance, such subtleties as changes in cloud cover at different latitudes and altitudes, which have different implications for warming or cooling the Earth.

One need not rely solely upon satellites to determine the effects of changing cloud cover on surface temperature change. Pyranometers mounted at the surface, that continuously monitor the hours of sunlight incident upon the instruments, can produce some revealing results: for it is clouds, of course, that are the chief reason why the flux of sunlight actually striking the surface of the Earth changes, at least over the short term and possibly over the long.

My distinguished colleague Dr. Willie Soon, of the Harvard-Smithsonian Institute for Astrophysics, who has done much work on the complex connections between changes in solar radiative flux and changes in climate, has compiled the following interesting graph, which shows an apparent – and by no means counter-intuitive – correlation between changes in the number of hours of sunlight measured by surface-mounted pyranometers at various places in Japan over the past 100 years: probably the best long-run record of its kind that we have –



Sunshine hours over Japan (red curve: left axis) compared with annual-mean surface temperature anomalies in the region (blue curve: right axis). ***Source:*** *Dr. Willie Soon, Harvard-Smithsonian Institute for Astrophysics (personal communication).*

In most regions of the world, such excellent correlations do not appear in the data: however, in most regions, the length and reliability of the pyranometer record are not as good as they are in Japan. Dr. Soon's graph demonstrates how important it is to establish whether (and, in due course, why) centennial-scale net increases or decreases in solar flux reaching the surface, chiefly moderated by changes in cloud cover, are occurring. If, for instance, there has been a net reduction in cloud cover over the 20th century, then it could – on its own – have been sufficient to account for much, if not all, of the observed warming over the period. Though we cannot now hope to reconstruct past changes in global cloud cover, we shall not be able to determine climate sensitivity reliably in the future unless we become able to measure these changes to a precision that is not presently available, but is theoretically achievable – without too much expense – by the installation of standardized and automated side-by-side thermometers and pyranometers at land and, if possible, ocean locations worldwide, reporting their position, status, and measurements directly via satellite much as the Argo temperature bathythermographs do in the oceans today.

The potentially major influence of changes in cloud cover, at least over the short term, is all too evident from our earlier discussion of the measured changes in cloud cover from 1983-2001, and of the substantial influence that those changes may have had on global temperatures over the period. That is why an Argo project for measuring the effect of changes in cloud cover on changes in solar flux reaching the Earth's surface is a priority.

Uncertainties also remain in the measurement of changes in temperature at altitude, which is performed partly by satellites and partly by balloon-borne radiosondes or drop-sondes. In view of the discrepancy between model-predicted and actually-observed changes in upper-tropospheric temperatures, and given the major importance for the determination of climate sensitivity that a correct measurement of upper-troposphere temperature change will have, it will be important to task new satellites to address the problem, and also to co-ordinate, standardize, and improve the international gathering of temperature and other climate data by the use of sondes.

I am conscious that I have outlined a long and quite costly list of expenditures at a time when austerity is inevitable. However, it would be very much cheaper to determine climate sensitivity reliably over the next half-century by proper measurements of the parameters that our previous researches have shown are of the greatest importance than to waste any more time or money on the vast computer models which, even if we were able to provide them with reliable enough information to describe the past and present climate properly, will forever be unable to answer the central question about how much warming a given increase in CO_2 concentration may be expected to cause. That question can only be properly answered by measurement. It cannot be answered at all by modeling.

And it would certainly be cheaper to spend a decade or two improving our capacity to measure the vital characteristics of today's climate, and hence to determine climate sensitivity to a reasonable precision, than to spend trillions on selectively shutting down the economies of the West in the specious name of Saving The Planet, when it is arguable that the planet does not need to be saved, and it is certain that our present climatic information is wholly inadequate to allow the principal alarmist conclusions of the IPCC to be reliably made.

I am also conscious that very nearly all of the key satellite and other measurements and analyses of the climate that are germane to the debate about the climate are generously provided to the world by the United States, and I should like to thank your great nation for this further and characteristic example of her generosity in the interest of the wider world.

12. ***[formerly q. 13]*** **Given the EPA's heavy reliance on IPCC climate science, much of which has been called into question, do you think the U.S. government should conduct a full scale investigation into the state of climate science and the certainty thereof?**

Yes. The IPCC's approach to the climate question is incurably defective, since it is a political and not a scientific body, which Sir Maurice Strong – a Canadian bureaucrat – set up a quarter of a century ago with the specific and stated intention that it should provide the basis for the establishment of a world government. The UN and its officials have a lamentable record in championing democracy. In effect, the UN too often behaves as a dictators' club. Its draft Copenhagen Treaty dated September 15, 2009, envisaging a world government with absolute powers over the economies as well as environments of all nations, including the power to set the rules of all markets, so that the free market would become a mere memory, does not mention the words "democracy", "ballot", or "vote" anywhere in its 186 pages.

The IPCC, therefore, is fatally *parti pris*. It makes not the slightest attempt at objectivity. As noted above, its founding document actually requires it to assume that "global warming" is a global crisis, rather than to check whether or to what extent there is a problem. It excludes from its deliberations those who disagree with it. Its senior officials are corrupt. It has an overwhelming financial and political vested interest in pursuing the climate-extremist viewpoint to the exclusion of all other scientific opinion and in increasingly open defiance of scientific results and data that it finds uncongenial.

Let us recall some instances of the IPCC's behavior.

- **Glaciergate:** The IPCC's 2007 *Fourth Assessment Report* said that the Himalayan glaciers would all be gone by 2035. In fact, the (non-peer-reviewed) source for this assertion had used the year 2350. Nevertheless, 2035 was what appeared in print. In effect, the IPCC was saying that within little more than 25 years all of the Himalayan glaciers would be gone.

  Several of the IPCC's own "reviewers" [note that the IPCC's documents are not peer-reviewed in any accepted sense of that term] pointed out that the data 2035 for the extinction of the Himalayan glaciers seemed incorrect. However, the authors of the sub-chapter in question merely overrode the reviewers (one of many fundamental respects in which the IPCC's procedures are contrary to true peer review), and reasserted the nonsensical figure.

  The figure was widely challenged in the public forum after publication of the IPCC's 2007 report, but the chairman of its climate-science panel, a multi-millionaire railroad engineer whose only relevant publications are in the soft "science" of ecology rather than in the mathematics, physics, or chemistry of climate, treated anyone who criticized the figure as a "flat-earther", and refused to allow the manifestly incorrect figure to be corrected. Meanwhile, the glaciologists in his own country, India, were expressing bafflement at the notion that all of the Himalayan glaciers might disappear in little more than a quarter of a century. They had the advantage of 200 years' records, going back to the days of the British Raj, and they knew that – except in areas of local geological instability – the glaciers were coming and going much as they always had (Prof. M.I. Bhat, Indian Geological Survey, personal communications, 2006-2010).

  Eventually, in the aftermath of Climategate, the IPCC admitted in a surly fashion that the Himalayas would still have their glaciers for hundreds of years, adding that this was the only mistake in the 1500 pages of its science report. In passing, there were many more, and more fundamental, mistakes, in particular in the IPCC's method for determining the amount of warming to be expected from increases in greenhouse-gas concentrations.

  Once the IPCC had admitted its "single" mistake, and not until then, the lead author of the chapter in question, admitted he had known that "2035" should have read "2350", but added that he had left the incorrect value in the text because "I wanted to influence governments".

  In those words lies the incurable problem with the IPCC. It is, first and foremost, political. It is no longer in the least capable – if it ever was – of providing objective, dispassionate advice to the governments who so expensively subsidize its officials' junketings to all the most fashionable resort hotels around the world. It has no intention of providing impartial advice. It is there to enrich and empower itself by pretending that the non-problem of "global warming" is a real problem.

- **Trendlinegate:** When I confronted the railroad engineer who runs the IPCC's climate-science panel with the bogus and thrice-repeated headline full-color graph purporting to demonstrate that the rate of "global warming" was itself increasing, with Man as the culprit, he said that the point I was raising was "very deep", but – although he himself was relying upon the graph in his presentations – he simply did not have the scientific or mathematical knowledge to understand, still less to answer, what I was talking about. When I asked him to get back to me within 48 hours to let me know whether I had misunderstood something, he failed to contact me – then or ever. Instead, he began making speeches in which he attacked me, by name, for having dared to criticize the IPCC. If that is the "openness" and "transparency" which the IPCC claims, I am less than impressed.

- **Greenlandgate:** When I reported to four officials of the IPCC, on the day of publication of its 2007 report, that its bureaucracy had inserted into the scientists' already-complete final draft a new table of figures that overstated tenfold the true observed contribution of the Greenland and Antarctic ice-sheets to sea-level rise,

not one of the officials responded. Nor was there any public announcement that an error had been found and corrected. Instead, the officials quietly moved, relabeled, and corrected the table, changing the units of measurement to provide further concealment, and then furtively posted up the new version of the report on the IPCC's website, two days after publication, without telling anyone that the originally-published version had been altered.

- **Mosquitogate:** As noted earlier, when the United States Government nominated Professor Paul Reiter of the NIH and the Institut Pasteur to be the lead author of the sub-chapter on "global warming" and malaria in the 2007 IPCC report, four separate officials of the IPCC pretended that they had not received Professor Reiter's nomination papers, when in fact he could prove they had all received them.

- **Modelgate:** As we have seen, Professor Richard Lindzen of MIT, who attended the discussions that led to the 2001 IPCC report, said in testimony before Congress that the IPCC's bureaucrats had continually circulated throughout the scientific discussions, putting undue pressure on the scientists to accept the IPCC's central contention that computer models (long proven to be ineffective for reliable long-run projection of future climate states) were a reasonable and proper way to approach the climate problem.

- **Hurricanegate:** Dr. Christopher Landsea, an expert on hurricanes, reported to the IPCC that his lead author, the Climategate emailer Kevin Trenberth, had been appearing on a public platform saying that hurricanes would become more frequent and more intense because of "global warming", when the evidence did not support that contention. When the IPCC's bureaucracy took no action, Dr. Landsea resigned.

Everyone who has come into contact with the IPCC has similar stories to tell. The IPCC is irreformable and should be ignored, defunded and, preferably, disbanded. It is a costly luxury that can no longer be afforded.

It is precisely because the IPCC is irremediably prejudiced, and because the learned journals that were once the home of true scientific research can no longer be trusted to present all sides of the climate question fairly by the selection of papers in their pages, and because scientists who believe that "global warming" is a global crisis are unwilling (and unable) to debate those who do not, that an independent enquiry at national level into the climate question is now essential. I respectfully recommend that the following steps be now taken, either by the United States Government or at least by one or other House of Congress –

Judicial Commission on "global warming" science and economics

A Royal Commission on "global warming" science and economics should be appointed under a senior Justice. Advocates should be heard on either side of the case, to examine and cross-examine the science and economics of "global warming" with all the evidential rigor of a court of law. The IPCC's process lacks rigor. So, regrettably, do the peer-reviewed journals, now that the Climategate emailers have been revealed as cynically tampering with the process. Given the very high levels of expenditure demanded by a host of "global warming" profiteers, it is essential that the US Government should not merely abdicate in the face of pressure from the IPCC, from other governments, or from its own scientific vested-interest groups such as the NAS, the NRC, and the AAAS. It must find out for itself whether or not a "bandwagon effect" has come about as a result of the very substantial funding for "global warming" research that has recently become available.

It is for these reasons that I advocate the appointment of a Judicial Commission. In any other forum than a formal, quasi-judicial proceeding, it will not prove possible systematically to subject the "official" line to real, independent, competent scrutiny. Not a penny more of US taxpayers' money should be squandered on "global warming", and no cap-and-trade Bill should even be considered, let alone passed, unless and until a thorough and genuinely independent enquiry has been held, and has given access to those to whom the IPCC has sullenly, relentlessly, and deliberately denied a fair hearing.

The remit of the Judicial Commission would be to decide –

- Whether and to what degree the IPCC has exaggerated climate sensitivity to CO_2 or other greenhouse gases (for this is the central question in the entire climate debate, and there is no consensus as to the answer);
- Whether and under what conditions, if any, the IPCC's imagined consequences of the present rate of atmospheric CO_2 enrichment will be beneficial or harmful (for at least half a century, even on the IPCC's own analysis, they are likely to be beneficial);

- Whether and under what conditions, if any, mitigation of "global warming" by reducing carbon emissions will be cheaper and more cost-effective than adaptation as, and if, necessary (almost every economist, other than Stern, considers that adaptation would be cheaper by orders of magnitude than attempted mitigation);
- Whether and under what conditions any emissions-trading scheme can make any appreciable difference to the CO_2 concentration in the atmosphere, and whether and to what degree, if any, any such difference would affect global surface temperature (in practice, not one of the measures so far advocated to mitigate "global warming", including the current US Administration's proposals for cap and tax, would make any measurable difference to global temperatures).

Other climate-change measures

Pending the report of the Judicial Commission, the United States should immediately –

- De-fund climate research exceeding pre-"global-warming" levels until it is 2 F° warmer than in 2001;
- Halt all US contributions to the IPCC and to the UN Framework Convention;

In any event, the US should immediately –

- Commission enough fossil-fueled and nuclear generating stations to meet demand;
- Legislate to curtail the activities of environmental lobbies opposing new fossil-fueled generating stations;
- Cease to subsidize wind-farms, on environmental and economic grounds;
- Cease to subsidize any environmental or "global-warming" pressure-groups at taxpayers' expense;
- Forbid public authorities to make any "global-warming"-related expenditure;
- Relate NASA/NOAA funding to the accuracy of their forecasts;
- Ban blatantly inaccurate "global warming" propaganda, such as Al Gore's movie, in schools;
- Abolish the EPA, and return environmental lawmaking to Congress, where it belongs;
- Divert a proportion of the billions now wasted on the non-problem of "global warming" towards solving the world's real environmental problems.

Conclusion

I hope that the Select Committee will allow me to end with a few words of caution. Certain members of the Committee have adopted a generally frivolous, trivializing approach to the matters that the Select Committee was established to address. They have attempted to politicize science. That way lies great danger, not least for those foolish enough to think that, merely because they have politicized and poisoned much else that perhaps ought not to have been dragged into the political arena, they can get away with politicizing objective scientific truth.

It is time to end that pointless and futile Christmas game. Know this: as global temperatures continue to fail to rise anything like as fast as the climate extremists of the IPCC have so confidently and yet so baselessly predicted, it is already becoming increasingly difficult to prevent a skeptical electorate from discerning the scientific truth, which will become inexorably clearer with each year that passes, however much Mr. Karl and his colleagues may try to deny, complicate, or conceal the abject failure of global temperatures to match up to the IPCC's foolish, excessive, and alarmist predictions.

The United States economy is fragile, the currency a fiction, and the Treasury bankrupt (I do not crow: the United Kingdom is in the same case). Now is not the time to inflict upon the American people the largest and least justifiable increases in their cost of living that any government has ever imposed in human history. Even if Hon. Members of the Committee genuinely believe (for whatever reasons, whether scientific or merely political) that the IPCC is broadly correct about the supposed menace posed by the natural trace gas CO_2, elementary and decisive economic calculations demonstrate that the suggestion of the climate-extremist faction that we must act now or doom the planet are entirely without foundation. We can well afford to wait, and, even if "global warming" is a problem, no – repeat no – damage will come to the planet even if we wait up to half a century before taking any further steps to shut down the economies of the West in the name of addressing the supposed problem.

It is now time for the Administration to put aside forever the foofaraw of pusillanimous, pork-barrel whigmaleeries that is the cap-and-tax legislation. The scarce and dwindling resources of your nation are sorely needed for other and more pressing matters. Energy security is one such matter. Some Hon. Members of the Committee have spoken and acted as though the only way to achieve energy security were to do without energy. By contrast, what is the policy of China, now the world's largest emitter of carbon dioxide? China is adding the equivalent of the total carbon emissions of the United Kingdom to her electricity grid *every year*, and proposes – according to the annual statistical communiqués of the dictatorship in Peking – to continue to do so until at least 2030. That policy is

correct. And how is China addressing energy security? Not by condemning her population to continuing poverty, but by going quietly around the world doing binding bilateral deals with suppliers of raw materials of every kind, including the fossil fuels that will long provide for the vast majority of her rapidly-growing energy needs.

With respect, the Committee should now learn from the Chinese regime, which is rightly determined that its people shall not be imprisoned in poverty by shortages either of fossil fuels or of other raw materials.

My final recommendation, therefore, is that once the distractions of the mid-term elections are out of the way the Select Committee should reconstitute itself as the Strategic Resources Committee, should abandon all discussion of the now-dead issue of "global warming" unless and until global mean surface temperatures shall have risen by at least 2 F° over their value in 2001 on a linear-regression basis, and should instead concentrate on ensuring that reliable and affordable supplies of all commodities and raw materials necessary to the function of a modern and growing US economy will be available to the nation's industries and enterprises in future.

The Committee could do worse than to start by removing the regional and national bureaucratic blockades on the now urgently-needed construction of at least 150 fossil-fueled and nuclear generating stations. Already, one of the world's largest aluminum smelters has had to close down in the US because the national grid cannot supply it with enough electricity. Yet, as far as I know, the Committee has not yet addressed the urgent and immediate threat to energy security demonstrated by this regrettable closure, and posed by the sinister and undemocratic activities of lavishly-funded environmental-extremist groups whose first concern is not the environment but the economic destruction, selectively and exclusively, of the free West in general and of the United States in particular.

The funding of these environmental-extremist groups should be investigated with particular care. How much of that funding is in fact sovereign wealth from nations not friendly to the United States? To the Chinese regime in particular, with her growing population and rapidly-developing economy, the principal objective of economic activity has long been the securing of substantial forward supplies of raw materials. If she could knock the West out of competition for finite natural resources, she could secure those resources for herself at a far lower price than she could otherwise obtain.

Pursuit of natural resources was, for instance, the chief reason why China trumped up an excuse to invade Tibet, over which she had no conceivable legitimate claim. The present Administration, in a move apparently co-ordinated with the previous but politically-similar Government in the UK, seems to have decided quietly to recognize China's brute-force hegemony over Tibet. That move was perhaps unwise, and may even encourage further ambitions of territorial expansion on China's part, not so much for *lebensraum* as for treasure. The vast and mountainous plateau of Tibet is rich in copper, lithium, and other minerals, which the Chinese are now rapaciously extracting and shipping out on the newly-built railroad from Lhasa into China.

It is time that these and other hard strategic realities of the new world economic order were properly considered – or, indeed, considered at all – by the Select Committee. Energy security does not lie in the rampant and enforced reduction of energy consumption by the enterprises of the United States that a narrow political faction is senselessly and cruelly demanding, but instead in intelligent and far-sighted planning for the extraction of new resources wherever they can be found and safely and profitably developed.

What sense does it make, for instance, to flare off (with a huge "carbon footprint", not that that matters) enough natural gas to power and heat the whole of Europe every day from the oilfields on the North Slope of Alaska, when the addition of a gas pipeline from the frozen north to the ice-free ports of southern Alaska, following the corridor of the existing oil pipeline so that the environmental impact would be negligible, would allow the gas to be shipped daily to Europe rather than extravagantly and foolishly wasted?

It is real, hard, practical, down-to-earth questions like this that the Committee should surely address in future. The "global warming" question certainly does not need to be addressed now, and arguably does not need to be addressed ever. Security of energy and resources does need to be addressed now. If the Committee is willing to take up the new and more vital purpose that I here propose – securing the resources that America needs for her continuing economic development – then it will have made a great contribution to the future prosperity of your nation. If America remains prosperous, she has the chance to remain free. If she remains free, the rest of the world has the chance remain or become free. If America fails, freedom fails. If the Committee continues on its present misguided course, be warned: America will fail, and those Hon. Members who would not act on this warning will be held to account by the electorate for that purposeless failure.

Monckton of Brenchley

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