

**STATEMENT OF
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**PROJECTED AND PAST EFFECTS OF CLIMATE CHANGE: A FOCUS
ON MARINE AND TERRESTRIAL ECOSYSTEMS**

**BEFORE THE
COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION
SUBCOMMITTEE ON GLOBAL CLIMATE CHANGE AND IMPACTS
UNITED STATES SENATE**

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Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to participate in this hearing on climate change and its effects on terrestrial and marine systems. My name is Tom Armstrong, and I am the Program Coordinator for the Earth Surface Dynamics Program at the U.S. Geological Survey (USGS). I also represent USGS and the Department of the Interior as a member of the U.S. Climate Change Science Program and the Climate Change Working Group of the Arctic Monitoring and Assessment Program.

The USGS strives to understand how the earth works and to anticipate changes in how the earth functions. To accomplish this, USGS science aims to understand the interrelationships among earth surface processes, ecological systems, and human activities. This includes understanding current changes in the context of pre-historic and recent earth processes, distinguishing between natural and human-influenced changes, and recognizing ecological and physical responses to changes in climate.

We conduct scientific research in order to understand the likely consequences of climate change, especially by studying how climate has changed in the past and using the past to forecast responses to shifting climate conditions in the future. My testimony today will address three major sets of challenges:

1. Distinguishing natural from human-influenced climate change;
2. Understanding ecological and physical responses to climate change, and predicting the related impacts of these responses on climate; and
3. Effectively conveying cutting-edge climate science to policy-makers, decision-makers, and the public.

I will conclude my testimony with a brief discussion of the state of our understanding of climate science and how this provides a roadmap to our future understanding of long-term climate change and its impact on people, natural resources, and the Earth.

Distinguishing natural from human-influenced climate change

In a statement on behalf of the Administration to the Senate in July, 2005, Dr. James R. Mahoney, now former Assistant Secretary of Commerce for Oceans and Atmosphere, and Director of the U.S. Climate Change Science Program, stated, “We know that an increase in greenhouse gases from the use of energy from fossil fuels and other human activities is associated with the warming of the Earth’s surface.” This statement underlies the growing public debate on climate change: are humans and their activities the driving force behind global warming? The scientific community is largely in agreement that human activity in the 20th and 21st centuries has enhanced greenhouse gas concentrations in the atmosphere, and these added gases have an effect on global temperatures and

climate. Climate change is also a natural, continuous, inevitable Earth process that is influenced by many forces, one of which is the concentration of both naturally-emitted and human-induced greenhouse gases in the atmosphere. Many other forces also control climate change, including cyclical changes in solar radiation, movement of the Earth's tectonic plates, oscillations in ocean temperatures and ocean currents, and the positions and magnitudes of meteorological entities such as high, low, and convergent zones. In fact, natural climate change has occurred on a regular basis on this planet for at least the last 800,000 years and possibly much longer. Paleoclimate research has shown that the Earth has experienced several episodes of global warming in this timeframe during which air temperatures and levels of CO₂ increased in ways comparable to the present day changes, although the ice record indicates that the current concentrations of CO₂ in the atmosphere are unprecedented during human existence. Understanding the science of natural variability in climate is essential to the formation of effective policy regarding the mitigation of or adaptation to climate change, both human and natural.

One of the major challenges facing the climate science community is distinguishing natural climate change from that imposed upon the natural system through human activities. This science must also develop an effective understanding of the consequences of the human-induced component. The science we conduct in order to understand both the human component of climate change and its potential impacts on the natural climate system is known as climatology; *paleoclimatology* looks into the prehistoric past of the Earth in order to determine how climate change occurred prior to human activity.

Through paleoclimate studies, scientists have been able to determine that climate changes

naturally, and that there indeed are natural climate cycles that have occurred regularly, and in a predictable fashion, over at least the last 800,000 years of Earth history.

By studying various parameters, or proxies, in the prehistoric record, such as tree-rings, ice-cores, and fossil pollen records, scientists at USGS and elsewhere have been able to develop a detailed record of climate change, including changes in temperature and atmospheric CO₂ concentrations over the last several hundred thousand years (Figure 1). This record shows that natural climate change predates human influence and is generally cyclical in nature, with long-term periods of global cooling and glaciation (40,000 to 50,000) years long, punctuated by shorter-term periods of global warming and deglaciation (10,000 to 15,000 years in duration). The general consensus among climate scientists is that we are within a new interglacial period with related global warming.

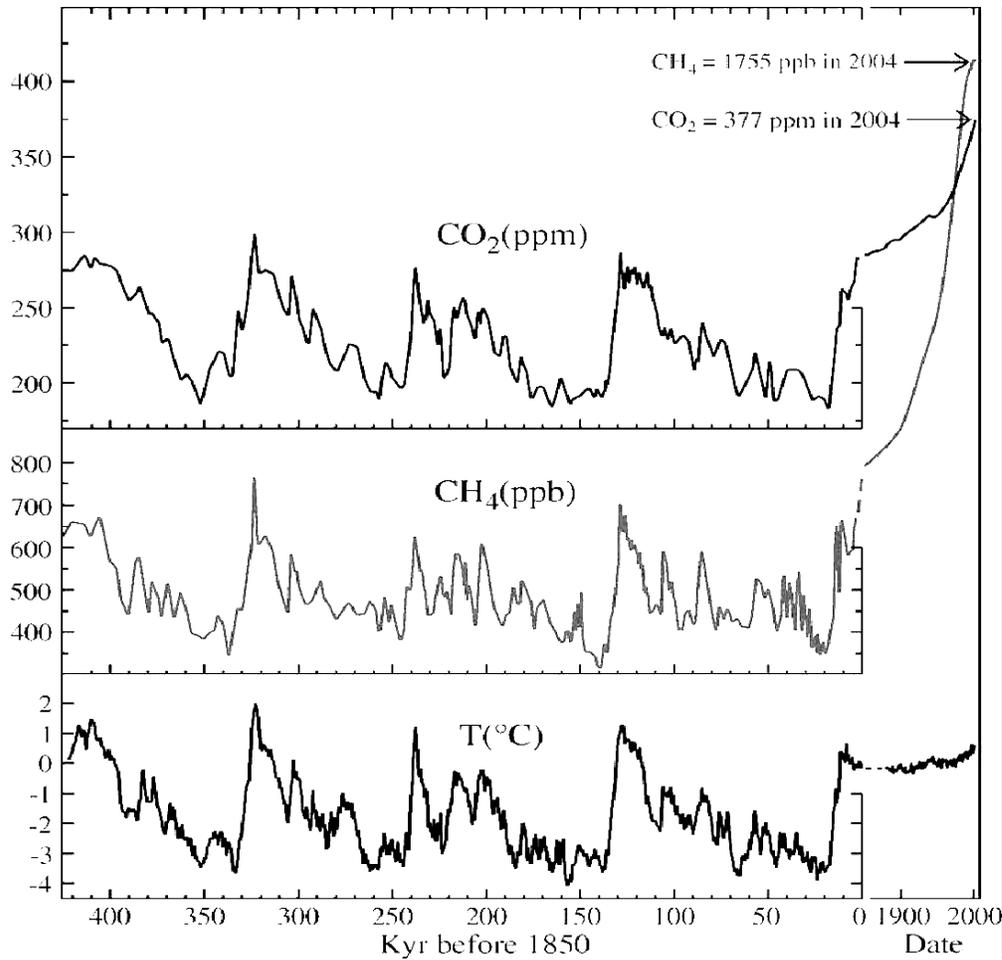


Figure 1. CO₂, CH₄ and estimated global temperature from Antarctic Ice core record (graph from Hansen, 2005)

Ecological and physical responses to climate change

A second set of very important challenges relates to developing a better understanding of how the earth and its physical and biological processes respond to climate change over the short-term and well into the Earth's future. Scientific research conducted over the past several decades reveals that climatic changes are part of a larger interactive system of changes in ecosystems, oceans, glaciers, atmospheric chemistry, and many other components. The geologic record provides information on how this complex system

has operated over time and clues to the potential causes of change. By looking back into the Earth's geologic record, scientists have been able to determine how ecological and physical systems and processes change, adapt, or terminate as climate changes; and how these responses can alter climate (known as a feedback mechanism). Many of these climate changes are gradual and continuous, with ecological and physical responses occurring over hundreds or thousands of years. Some of these climate changes are abrupt, spanning decades, with the resulting ecological and physical changes being short-lived but very dramatic.

Some examples of responses and feedbacks to climate change include:

- The temperature of the United States has increased by an average of less than 1 degree Celsius during the past 56 years, with much variation among regions. For example, Alaska has experienced an average warming of 4 degrees since 1950, more than 4 times the U.S. average of 1 degree.
- The higher the latitude, the greater the increase in temperature. Of particular concern are the rapid changes occurring in northern latitudes, where temperature changes have been greater than elsewhere on the globe. Permafrost is thawing and has the potential of releasing significant amounts of carbon dioxide to the atmosphere and nutrients to the coastal ocean. Decreasing ice cover is exposing coastlines to rapid erosion and the Arctic Ocean to accelerated warming. The USGS and the U.S. Forest Service are initiating a multi-agency, multi-disciplinary research and monitoring effort to track and understand these changes in the Yukon River Basin in Alaska and northwest Canada. The Yukon Basin will serve

as a benchmark landscape for interpreting and responding to rapid climatic, hydrologic, and ecological changes occurring in Northern latitudes.

- Decreased cloud cover in the northern latitudes related to climate change correlates to decreased snow levels, less solar reflection, and thus greater melting of snow, glacial ice and permafrost. This creates an additional feedback mechanism where more melting leads to greater atmospheric water vapor, which in turn leads to a warmer atmosphere.
- Over the last 50 years, climate change in the northeast (Maine and New Hampshire) and mountain-west (Washington and Oregon) of the United States has led to between 8 and 17 percent declines in annual winter snow pack. The physical response to this decline includes decreased recharge of the ground-water systems, decreases in surface-water flows, increased stress to public water systems, changes in the timing of river ice-outs, and significant impacts on the spawning environments for fish such as Pacific and Atlantic salmon.

The effective conveyance of climate science to policy-makers, decision-makers, and the public

Scientists must relay relevant information, analyses, and conclusions to policymakers, resource managers, and the general public as a whole. Besides global warming, other ecological and physical consequences of climate change may include strong storms, sea-level rise, droughts and floods. If scientists can better inform decision-makers about what to expect from climate change, this will effectively enhance the development of

short- and long-term strategies for protecting the public welfare and maintaining healthy and viable ecosystems and natural resources. For instance, studies conducted by USGS and others are showing that sea-level rise will continue to impact coastal zones throughout the world. Present and future resource managers will need to take into consideration this scientific conclusion when developing an adaptive management strategy for restoration and long-term stewardship of land, water, and biological resources.

Scientific findings related to climate change must be delivered in a timely manner so that decision-makers are informed by the most relevant, up to date, objective information possible. Furthermore, scientists must provide this information with very accurate estimates of uncertainty so that conclusions and recommendations drawn from scientific studies can be properly evaluated. The U.S. Climate Change Science Program, of which USGS and the Department of the Interior are members, is actively involved in developing a more effective decision support strategy for all interested stakeholders.

The Future of Climate Change

Understanding the paleoclimate history- where we look at climate information well beyond the 50 to 100 year instrumental record- is important because it provides us a natural climate baseline from which to work. The instrumental record provides us only a momentary glimpse of the entire picture of past and future climate change. We need to understand what has happened in the past in order to forecast future short and long-term

climate trends. Once the baseline has been established we can then begin to distinguish the human-induced factors that must be considered. This information then allows us to validate model predictions of past climate change and use that information to develop better-constrained models to forecast the effects of future climate change, and related ecological and physical responses and feedbacks.

For all of the information we have gathered, and for all of the understanding of climate change that we have developed, the climate science community continues to strive towards development of a consensus on the long-term climate future for our planet.

Given our current scientific understanding of climate change, the following are areas in which USGS science can make a valuable contribution:

- Determining the baseline physical, chemical, and ecological conditions of the Arctic and Subarctic. Without new baseline data and monitoring infrastructure, our ability to determine what changes are occurring in northern latitudes, and our capacity to help society develop cost-effective adaptations to those changes, will may be greatly diminished.
- Developing decision support systems for the impact of sea-level rise. Current research concludes that sea level rise will continue. Since sea-level rise is already having impacts on some ecosystems and human communities, decision support systems will be critical tools for planners to anticipate levee construction or relocation of shoreline infrastructure.

- Focusing attention on the potential changes in the most vulnerable regions and systems (e.g., polar regions, coastal zones, and the tropics), and assessing regional impacts of long-term climate change.
- There might be surprises: critical thresholds in Earth and biological systems may be abruptly reached that have long-term or even permanent consequences.
- Adaptation strategies can minimize negative impacts of natural climate change, as well as the impacts of human-induced climate change; mitigation may work to quell human-induced climate change and variability.
- Although possibly successful, mitigation of natural changes may very likely lead to unforeseen additional problems unless the system under study is extremely well understood.

Thank you, Mr. Chairman, for the opportunity to present this testimony. I will be pleased to answer questions you and other Members of the Subcommittee might have.