COMMITTEE ON SCIENCE AND TECHNOLOGY

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
U.S. HOUSE OF REPRESENTATIVES

HEARING CHARTER

A Rational Discussion of Climate Change: the Science, the Evidence, the Response

Wednesday, November 17th, 2010
10:30 am
2325 Rayburn House Office Building

Purpose

On Wednesday, November 17, 2010 the Subcommittee on Energy and Environment of the House Committee on Science and Technology will hold a hearing entitled: "A Rational Discussion of Climate Change: the Science, the Evidence, the Response". The Subcommittee will receive testimony on the basic science underlying how climate change happens; the evidence and the current impacts of climate change; and the actions that diverse sectors are taking today to respond to and prepare for a changing climate.

Witnesses

Panel 1

- **Dr. Ralph Cicerone** is the President of the National Academy of Sciences. Dr. Cicerone will explain the basic science, including the fundamental physics, underlying how climate change happens. He will also discuss the role of the National Academy of Sciences in advancing climate science and informing the public on the issue.

- **Dr. Heidi Cullen** is the CEO and Director of Communications at Climate Central. Dr. Cullen will discuss the basic science of climate change, including the fundamental chemistry, the causes of production of greenhouse gases; and the expected impacts on the climate.

- **Dr. Gerald A. Meehl** is a Senior Scientist in the Climate and Global Dynamics Division at the National Center for Atmospheric Research. Dr. Meehl will discuss the basic physics underlying how climate change happens and how the physics is incorporated into the development of the climate models.

- **Dr. Richard Lindzen** is the Alfred P. Sloan Professor of Meteorology in the Department of Earth, Atmospheric, and Planetary Sciences at Massachusetts Institute of Technology. Dr. Lindzen will discuss how greenhouse gas emissions resulting from human activities will only minimally contribute to warming. He will also discuss the limitations in the global climate models and the problems with the positive feedbacks built into the models.

Panel 2

- **Dr. Benjamin Santer** is an Atmospheric Scientist in the Program for Climate Model Diagnosis and Intercomparison at the Lawrence Livermore National Laboratory. Dr. Santer will discuss the evidence of climate change; how well the science validates that climate change is happening; and the computational climate models, including how the various climate data sets are utilized and analyzed.

- **Dr. Richard Alley** is the Evan Pugh Professor in the Department of Geosciences and an Associate of the Earth and Environmental Systems Institute at Pennsylvania State University. Dr. Alley will describe the effects of climate change on ice dynamics and explain how changes in levels of carbon dioxide in the atmosphere have led to a rise in global temperatures.

- **Dr. Richard Feely** is a Senior Scientist at the Pacific Marine Environment Laboratory of the National Oceanic and Atmospheric Administration (NOAA). Dr. Feely will discuss the current science and understanding of ocean acidification, the factors that contribute to the acidification process, and the resulting impacts.

- **Dr. Patrick Michaels** is a Senior Fellow in Environmental Studies at the Cato Institute. Dr. Michaels will discuss the rate of greenhouse-related warming; the Endangerment Finding by the Environmental Protection Agency; and scientific integrity.

Panel 3

- **Rear Admiral David Titley** is an Oceanographer and Navigator for the United States Department of the Navy, Department of Defense. RADM Titley will discuss the impacts of climate change on U.S. Navy missions and operations, the national security implications of climate change, and the role of the U.S. Navy's Task Force Climate Change.

- **Mr. James Lopez** is the Senior Advisor to the Deputy Secretary at the Department of Housing and Urban Development. Mr. Lopez will discuss the impacts of climate change on vulnerable populations and communities; HUD's proposed Sustainable Communities Initiative; and how the Department is working to improve the coordination of transportation and housing investments to ensure more regional and local sustainable development patterns, more transit-accessible housing choices, and reduced greenhouse gas emissions.

- **Mr. William Geer** is the Director of the Center for Western Lands for the Theodore Roosevelt Conservation Partnership. Mr. Geer will discuss the threat of climate change to hunting and fishing; its impacts on fish and wildlife; and how the Theodore Roosevelt Conservation Partnership is responding to the impacts of climate change.

- **Dr. Judith Curry** is the Chair of the School of Earth and Atmospheric Sciences at Georgia Institute of Technology. Dr. Curry will discuss how uncertainty in data and conclusions is evaluated and communicated. She will also discuss how this uncertainty should be incorporated into decision-making efforts.

Background

Human society is shaped by the climate in fundamental ways, and so for many decades researchers around the world have been working to understand how humans are affecting the climate, the impacts of these changes, and how society can mitigate and prepare for these effects. Since human settlement began, climate has influenced what we wear, the food that we eat, where we live, and how we build our houses. And despite our greatest technological advances, climate still affects how and where we live our lives today, as well as our economy and national security. Various sectors, from agriculture to transportation, rely on climate certainty. Climate change has increased uncertainty in many sectors; therefore, many decisions with significant economic impacts will have to be made with greater levels of associated risk. Advancements in climate science may reduce uncertainty in climate dependent sectors, thus better informing decisions that impact the quality of our lives.

Climate and Weather

Climate can be defined as the product of several meteorological elements[1] in a given region over a period of time. In addition, spatial elements such as latitude, terrain, altitude, proximity to water and ocean currents affect the climate. We experience climate on a daily basis through the weather. The difference between weather and climate is a measure of time—weather consists of the short-term (minutes to months) changes in the atmosphere. Weather is often thought of in terms of temperature, humidity, precipitation, cloudiness, brightness, visibility, wind, and atmospheric pressure. Weather is what conditions of the atmosphere are over a short period of time, and climate is how the atmosphere "behaves" over relatively long periods of time. In most places, weather can change from minute-to-minute, hour-to-hour, day-to-day, and season-to-season. Climate, however, is the average of weather over a period of years to decades. Generally, climate is what you expect, like a very hot summer in the American Southwest, and weather is what you get, like a hot day with pop-up thunderstorms.[2]

The Science

Climate can be influenced by a variety of factors, including: changes in solar activity, long-period changes in the Earth's orbit, natural internal processes of the climate system, and anthropogenic (i.e. human-induced) increases in atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases (GHGs).[3] As described above, "climate" is the long-term average of a region's weather patterns, and "climate change" is the term used to describe changes in those patterns. Climate change will not have a uniform effect on all regions and these differing effects may include changes to average temperatures (up or down), changes in season length (e.g. shorter winters), changes in rain and snowfall patterns, and changes in the frequency of intense storms. The scientific community has made tremendous advances in understanding the basic physical processes as well as the primary causes of climate change. And researchers are developing a strong understanding of the current and potential future impacts on people and industries.

Throughout Earth's history, the climate has changed in dramatic ways. What makes this point in time different from the past is the human influence on this change and the rate at which this change is occurring. Volumes of peer-reviewed scientific data show that CO_2 concentrations in the atmosphere have increased substantially since industrialization began. Fossil fuel use has become an increasingly important part of our lives, and as a result, CO_2 concentrations have increased approximately 30% since pre-industrial times.[4] And the current level of CO_2 in the atmosphere is the highest in the past 650,000 years.[5] According to the National Academies, there is strong scientific consensus that these increases in CO_2 concentrations intensify the greenhouse effect, and this effect plays a critical role in warming our planet.[6]

---

[1] Meteorological elements such as temperature, humidity, atmospheric pressure, wind, rainfall, and atmospheric particle count.

[2] *See* < http://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html >.

[3] In addition to long-term climate change, there are shorter term climate variations. This so-called climate variability can be represented by periodic or intermittent changes related to El Niño, La Niña, volcanic eruptions, or other changes in the Earth system.

[4] *See* < http://www.wpro.who.int/NR/rdonlyres/33FA546E-7813-4E51-BA89-48759FF45360/0/climate_factsheet.pdf >.

[5] Michael Hopkin, *Greenhouse-Gas Levels Highest for 650,000 Years:Climate Record Highlights Extent of Man-Made Change*, NATURE NEWS. Published Online. (24 Nov 2005). doi:10.1038/news051121-14.

[6] National Research Council, AMERICA'S CLIMATE CHOICES: ADVANCING THE SCIENCE OF CLIMATE CHANGE (2010).

Greenhouse Effect

Greenhouses work by trapping heat from the sun. The glass panels of the greenhouse let in light but keep heat from escaping. This causes the greenhouse to heat up, much like the inside of a car parked in sunlight. Greenhouse gases in the atmosphere behave much like the glass panes in a greenhouse. Sunlight enters the Earth's atmosphere, passing through the blanket of greenhouse gases. As it reaches the surface, the Earth's land, water, and biosphere absorb the sun's energy. Once absorbed, this energy is eventually transmitted back into the atmosphere through physical processes such as heat conduction, convection, and evaporation. Some of the energy passes back into space, but much of it remains trapped in the atmosphere by the greenhouse gases, causing the Earth to heat up.

As a basis for discussion about GHGs and their influence on the climate, it should be noted that there is a natural, non-anthropogenic greenhouse effect, which Joseph Fourier discovered more than 150 years ago. Fourier argued that "the atmosphere acts like the glass of a hothouse because it lets through the light rays of the sun but retains the dark rays from the ground".[7] This is a major simplification in describing the greenhouse effect, but it does provide insight into why the Earth's surface is considerably warmer than it would be without an atmosphere.

Several scientists built on Fourier's greenhouse theory by recognizing the importance of the selective absorption of some of the minor constituents of the atmosphere, such as CO_2 and water vapor. Swedish chemist Svante Arrhenius conducted an extensive analysis of the greenhouse effect. [8] Arrhenius calculated the temperature increase caused by the greenhouse effect as a function of the atmospheric concentration of "carbonic acid"[9], latitude, and season. The values Arrhenius obtained for the warming of the atmosphere are very much in agreement with what are now being obtained using complex climate models. Further research in the 1930s showed that, due to the more extensive use of fossil fuels, the atmospheric concentration of carbon dioxide was increasing, and the first projection of the atmospheric CO_2 concentration was made in the late 1950s.[10] As these scientific findings were coming to light, operational data collection programs were initiated for measuring atmospheric CO_2 in Scandinavia, Mauna Loa, Hawaii and at the South Pole.

Carbon dioxide (CO_2) is a greenhouse gas (GHG) that traps the sun's radiation within the troposphere, i.e. the lower atmosphere. It has accumulated along with other man-made greenhouse gases, such as methane (CH_4), chlorofluorocarbons (CFCs), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). GHGs are an important part of our atmosphere because they keep Earth from having an inhospitably cold surface temperature. [11]That said, if the greenhouse effect becomes stronger, through increased concentrations of GHGs and water vapor, it could make the Earth warmer than human civilization and its surrounding ecosystem has currently adapted to. Even a small additional warming is predicted to cause significant issues for humans, plants, and animals.

---

[7] Joseph Fourier, *Remarques Générales Sur Les Températures Du Globe Terrestre Et Des Espaces Planétaires*, 27 ANNALES DE CHIMIE ET DE PHYSIQUE p.136–67 (1824). *and* Joseph Fourier, *Mémoire Sur Les Températures Du Globe Terrestre Et Des Espaces Planétaires*, 7 MÉMOIRES DE L'ACADÉMIE ROYALE DES SCIENCES p.569–604 (1827).

[8] Svante Arrhenius, *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground* 41 PHILOSOPHICAL MAGAZINE p.237-276 (1896). *and* ELISABETH T.CRAWFORD, ARRHENIUS: FROM IONIC THEORY TO THE GREENHOUSE EFFECT (Science History Publications) (1996).

[9] Carbonic acid is a byproduct of carbon dioxide when dissolved in water.

[10] Roger Revelle and Hans E. Suess, *Carbon Dioxide Exchange Between Atmospheric and Ocean and the Question of an Increase of Atmospheric CO2 during the Past Decades*, 9 TELLUS p.18-27 (1957).

[11]*See* < http://www.epa.gov/climatechange/glossary.html >.

The Scientific Process: Uncertainty, Consensus, and Peer Review

Climate science, like all science, is an iterative process of collective learning: data are collected; hypotheses are formulated, tested, and refined; theories are constructed and models are built in order to synthesize understanding and to generate predictions; and experiments are conducted to test these hypotheses, theories, and models. New observations and refined theories are incorporated throughout this process, and predictions and theories will be further supported or refuted. Confidence in a theory grows if it is able to survive this rigorous testing process, if multiple lines of evidence converge in agreement, and if competing explanations can be ruled out.

The scientific community uses a highly formalized version of peer review to validate research results and improve our understanding of the relevance of these results. Through this process, only those concepts that have been described through well-documented research and subjected to the scrutiny of other experts in the field become published papers in science journals and accepted as current scientific knowledge. Although peer review does not guarantee that any particular published result is valid, it does provide a high assurance that the work has been carefully vetted for accuracy by informed experts prior to publication. The overwhelming majority of peer-reviewed papers about global climate change acknowledge that human activities are substantial contributing factors.

Science is based on observations and therefore uncertainty is inherent to the scientific process. Uncertainties about climate change will never be completely eliminated by scientific research, but science can enable decision makers to make informed choices in the face of risks.[12]

The Evidence

There are numerous effects that can result from climate change. Some effects are already being felt today, and some are projected by scientists to occur in the future. Scientifically documented evidence of climate change includes:

Sea Level Rise. The global sea level rose about 17 centimeters (6.7 inches) in the last century. The rate in the last decade, however, is nearly double that of the last century.[13]

Global Temperature Rise. The major comprehensive global surface temperature reconstructions, which use a wide variety of data sources from satellites to weather stations, show that Earth has warmed since 1880.[14] Most recorded warming has occurred since the 1970s, with the twenty warmest years having occurred since 1981 and with all ten of the warmest years occurring in the past twelve years.[15] Even though the 2000s witnessed a solar output decline resulting in an unusually deep solar minimum in 2007-2009, surface temperatures continue to increase.[16]

Warming Oceans. The oceans have absorbed much of the increased heat, with the top 700 meters (about 2,300 feet) of ocean showing warming of 0.302 degrees Fahrenheit since 1969.[17]

---

[12] National Research Council, AMERICA'S CLIMATE CHOICES: ADVANCING THE SCIENCE OF CLIMATE CHANGE p.15 (2010).

[13] J.A. Church and N.J. White, *A 20th Century Acceleration in Global Sea Level Rise*, 33 GEOPHYSICAL RESEARCH LETTERS (2006).

[14] *See* < http://www.ncdc.noaa.gov/cmb-faq/anomalies.html >.

[15] T.C. Peterson ET.AL., *State of the Climate in 2008*, 90 SPECIAL SUPPLEMENT TO THE BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY p.S17-S18 (2009).

[16] I. ALLISON ET.AL., THE COPENHAGEN DIAGNOSIS: UPDATING THE WORLD ON THE LATEST CLIMATE SCIENCE, (UNSW Climate Change Research Center, Sydney, Australia) (2009).

[17] Levitus ET.AL., *Global Ocean Heat Content 1955–2008 In Light of Recently Revealed Instrumentation Problems*, 36 GEOPHYSICAL RESEARCH LETTERS (2009).

Shrinking Ice Sheets. The Greenland and Antarctic ice sheets have decreased in mass. Data from NASA's Gravity Recovery and Climate Experiment show Greenland lost 150 to 250 cubic kilometers (36 to 60 cubic miles) of ice per year between 2002 and 2006, while Antarctica lost about 152 cubic kilometers (36 cubic miles) of ice between 2002 and 2005.[18]

Declining Arctic Sea Ice. Both the extent and thickness of Arctic sea ice has declined rapidly over the last several decades.[19]

Glacial Retreat. Glaciers are retreating almost everywhere around the world — including in the Alps, Himalayas, Andes, Rockies, Alaska, and Africa.[20]

Extreme Weather Events. The number of record high temperature events in the United States has been increasing, while the number of record low temperature events has been decreasing, since 1950. The U.S. has also witnessed increasing numbers of intense rainfall events.[21]

Ocean Acidification. The carbon dioxide content of the Earth's oceans has been increasing since 1750, and is now increasing at a rate of approximately 2 billion tons per year. This has increased ocean acidity by about 30 percent.[22]

The Response

Scientific research is also invested in developing ways to respond and adapt to climate change, in addition to developing technologies and policies that can be used to limit the magnitude of future changes to the climate. The issues of mitigating, adapting, and responding to the impacts of climate change are currently being explored through global collaborative input from a wide range of experts, including physical scientists, engineers, social scientists, public health officials, business leaders, economists, and governmental officials. Demand for information to support climate-related decisions has grown as people, organizations, and governments have moved ahead with plans and actions to reduce greenhouse gas emissions and to adapt to the impacts of climate change. Today, however, the nation lacks comprehensive, robust, and credible information systems to inform climate choices and evaluate their effectiveness.

Scientific research plays a role in guiding the nation's response to climate change by:

- projecting the beneficial and adverse effects of climate changes;
- identifying and evaluating the likely or possible consequences, including unintended consequences, of different policy options to address climate change;
- improving the effectiveness of existing options and expanding the portfolio of options available for responding to climate change; and
- developing improved decision-making processes.

[18] *See* < http://climate.nasa.gov/evidence/ >, < *http://www.giss.nasa.gov/research/news/20100121/* > *and* <*http://science.nasa.gov/headlines/y2009/01apr_deepsolarminimum.htm* >.

[19] L. Polyak ET.AL., HISTORY OF SEA ICE IN THE ARCTIC *In* PAST CLIMATE VARIABILITY AND CHANGE IN THE ARCTIC AND AT HIGH LATITUDES, U.S. Geological Survey, Climate Change Science Program Synthesis and Assessment Product 1.2. chapter 7 (2009). *and* R. Kwok and D.A. Rothrock, *Decline in Arctic sea ice thickness from submarine and ICESAT records: 1958-2008*, 36 GEOPHYSICAL RESEARCH LETTERS (2009).

[20] *See* < http://nsidc.org/sotc/glacier_balance.html > *and* < http://www.geo.unizh.ch/wgms/mbb/sum08.html >.

[21] *See* < http://lwf.ncdc.noaa.gov/extremes/cei.html >.

[22] C.L. Sabine ET.AL., *The Oceanic Sink for Anthropogenic* CO_2, 305 SCIENCE p.367-371 (2004),; Copenhagen. *Also see* < http://www.pmel.noaa.gov/co2/OA/>.