Okpilak Glacier, Alaska. Left: June 1907. Right: August 5, 2004.

Decade of Change

the accelerating threat of global warming

By Katrina M. Verbrugge

At the time, the 1980s were the warmest decade on record. Subsequently, as climate change and global warming emerged into the public focus, governments around the globe ratified treaties including the Framework Convention on Climate Change in 1992 and created international scientific bodies such as the Intergovernmental Panel on Climate Change (IPCC).

Through the 1990s, these efforts did not prevent the decade from surpassing the 1980s as the hottest in record. Many realized early on that the FCCC was weak, and international discussion of nationally-binding reductions in greenhouse gases led to the creation of the Kyoto Protocol in 1997, which took effect in 2008 (1).

Despite international awareness of global climate change, including intergovernmental scientific investigation and treaties, the presence of global-scale warming and whether it poses a threat is still widely debated at the political level. Meanwhile, the past decade was hotter than each of the previous decades, and the trend does not appear to be slowing down (2).

The Science of Climate Change

The climate consists of the average of meteorological conditions that occur in a place or region, so changes tend to have a far reaching, long-term influence on various facets of life including water supply, agriculture, and human health. The Earth's climate and temperature is largely determined by the sun's radiation. Photons emitted by the sun, whose wavelengths of 0.3 to 0.8 microns, put them largely in the visible spectrum, strike the earth with a power of about 342 watts per square meter. About 30 percent is reflected back into space by clouds, snow and other surfaces so that about 240 watts per square meter are actually absorbed (1).

The Earth and atmosphere act like a black body radiator and emit energy back out into space in the infrared region of the electromagnetic spectrum. However, certain gases in the atmosphere absorb and re-emit infrared radiation, warming the Earth's surface. Water vapor, carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons, all considered "greenhouse gases," are minor atmospheric constituents, but they have a large warming effect through this absorption process that increases as their concentrations increase (1).

The rapid warming of the earth coincides with a rapid increase in atmospheric carbon dioxide levels inextricably tied to human activities including burning fossil fuels and deforestation. The IPCC's Fourth Assessment Report noted that the industrial activities have raised atmospheric carbon dioxide levels from 280 parts per million to 379 parts per million in the last 150 years. The past ten years have shown an average annual rate of increase of 2.04 ppm—more than double the rate in the 1960s. Human activities also contribute to an increase in atmospheric methane and nitrous oxide, leading the panel to conclude there is over a 90 percent probability that these greenhouse gases have caused the increase in temperature over the past 250 years (3).

Building Evidence

Scientists and organizations around the world, including the IPCC and the United State's National Oceanic and

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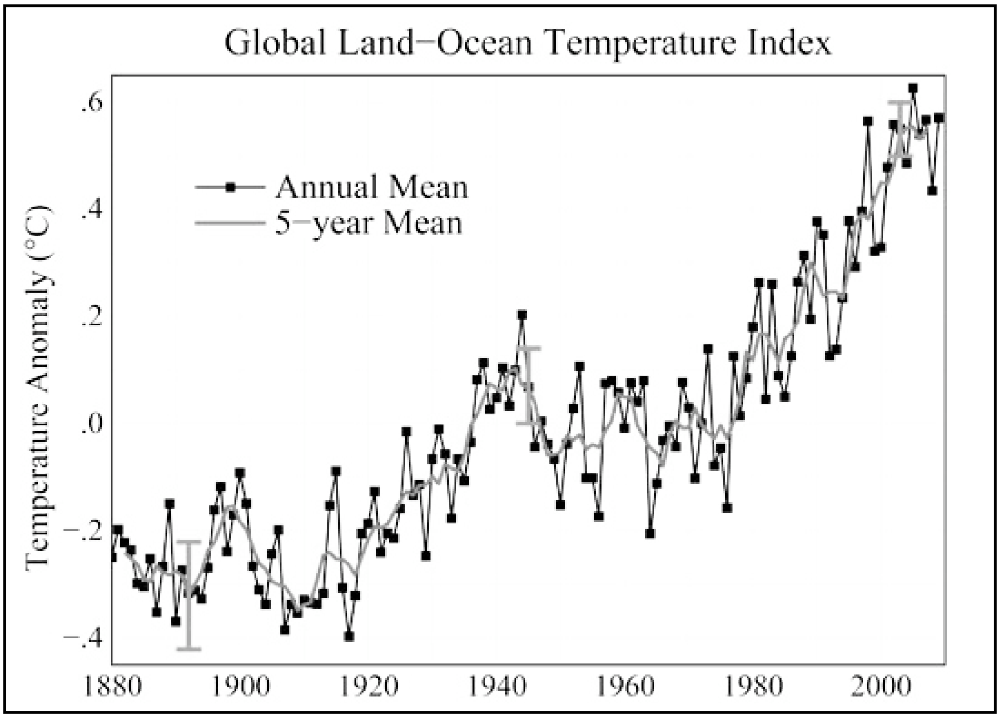

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▲ **Figure 1.** This graph shows the change in surface temperature globally, relative to 1951-1980 averages. The grey line shows temperatures averaged over 5 years, clearly exhibiting the long term trend of increasing temperature. The 2000s included the hottest periods on record.

Atmospheric Administration, continuously publish results solidifying the conclusive evidence of several important climate change indicators. The surface thermometer record, or measurements of temperature taken around the globe, shows that the global average temperature of the earth rose 0.4-0.8 °C in the last century. While this is the most direct measurement of a warming trend, weaknesses including incomplete global coverage and inconsistencies in measurement times make additional indicators necessary (1).

The glacial record, which shows an accelerating decrease in glacier length, coincides with the increase in atmospheric carbon levels at the start of the industrial revolution (4). Simultaneously, the Greenland and Antarctic ice sheets have decreased in mass (5). Data from NASA's Gravity Recovery and Climate Experiment show Greenland lost 36 to 60 cubic miles of ice per year between 2002 and 2006, while Antarctica lost about 36 cubic miles of ice between 2002 and 2005 (6).

Additionally, sea levels rose about 6.7 inches in the last century, but the rate of increase nearly doubled in the 2000s (7). The warming climate causes the water to expand, and the melting ice on land flows into the sea raising the levels even more (1). The oceans are also warming, with the top 2,300 feet showing a 0.302 °F increase since 1969 (8).

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Forecasting the Future

While many of these measuring techniques have been reliable and present for many decades, the 2000s brought an increasing reliance on computer modeling systems. Often called General Circulation Models (GCMs), they simulate the Earth's climate. The models are tested by comparing their output to the Earth's actual climatic behavior over a known time period. Once established, they are used to study various hypothetical scenarios, and predict the climate if current trends continue (1).

The National Center for Atmospheric Research recently released the Community Earth System Model (CESM), a more advanced climate model that will play an important role in the IPCC's Fifth Assessment Report. The new software incorporates additional atmospheric chemicals, while also allowing more advanced simulation of the carbon cycle and of the interaction between marine ecosystems and greenhouse gases. The collaborative scientific effort continuously updating this type of software allows otherwise impossible experimentation with the atmosphere and climate (9).

The IPCC's Fourth Assessment Report included forecasts using these predictive models for a variety of scenarios, including a constant atmospheric carbon level and different rates of increase in these levels. Overall, the net costs of climate change predicted are significant, though the effects on individual regions will vary. Models have predicted increased flooding in Europe and Asia, which could lead to a rising death rate from diseases and coastal erosion. Additionally, crop productivity in many areas along with a decrease in freshwater availability could present a severe threat to many populations, especially in developing countries in Asia and Africa. For example, the report projected that by 2020 between 75 and 250 million people in Africa will be exposed to increased water stress while agriculture simultaneously decreases by 50 percent. In an already suffering region, this could have devastating effects (3).

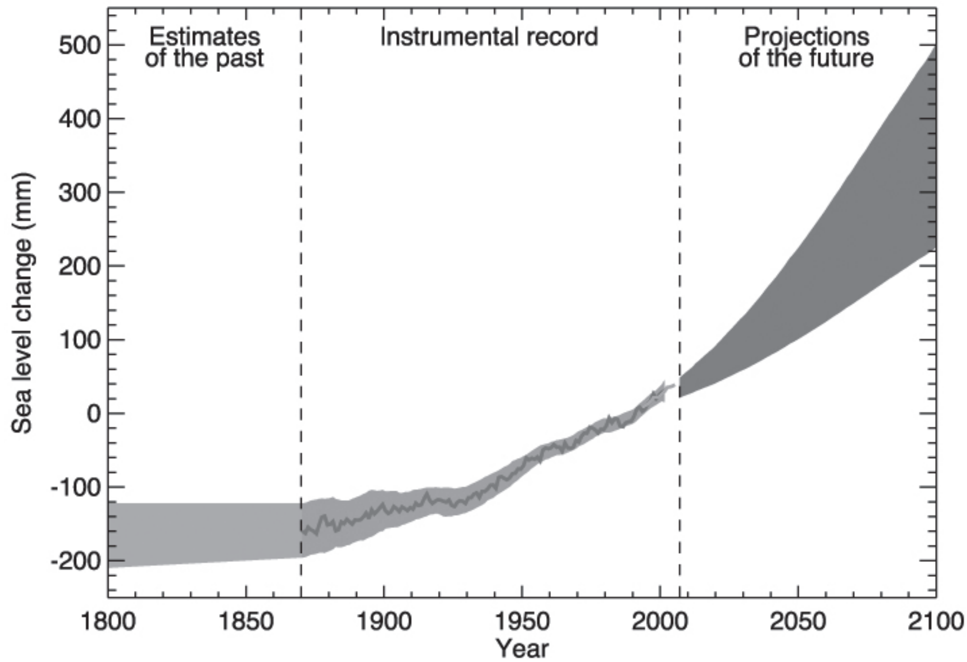
Political Challenges

Addressing the obvious changes before the predicted implications come into full force requires a complex interplay of science and policy. Although the consequences of allowing climate change to proceed at its current rate or faster are dire, the short-term economic implications of political action complicate steps to impede or reverse the changes. For example, fossil fuels account for about 80 percent of the energy supply in the world, and no current alternatives could replace this huge source of energy cheaply or quickly (1). Imposing restrictions on emissions or fuel source could have a huge monetary cost for an incredibly large percent of industries.

Trying to address the problem from the other end, by capturing or reducing the culprit gases post-emission comes with similar economic consequences. In the United States, forests offset about 20 percent of fossil fuel carbon emissions. Increasing this "carbon sink" by just 10 percent would require planting trees on one third of current croplands (10).

A continued uncertainty in the political and public spheres about climate change complicates progress further on a national scale, and disagreement between or among developed and developing nations impedes progress on an international scale. However, slow movement in the first half of the decade to address the issue has been very gradually shifting to a more aggressive approach internationally.

The Kyoto Protocol came legally into force in 2005 following Russia's November 2004 ratification. The Protocol's first mitigation period began in 2008 and concludes in 2012, with a required overall reduction in emissions of 5.2 percent below 1990 levels. Industrialized countries have differing emission requirements, while developing countries have no requirements at all. While the bulk of the political negotiations occurred in the 2000s, only the next decade can show whether any progress has been made toward the Protocol's goals and whether it represents a step towards an effective long-term response to climate change (1).



▲ **Figure 2.** This graph shows the recorded and projected sea level changes. Even the lowest projected rise could present serious consequences to humanity through flooding and disease in addition to further affecting the global climate.

Looking Forward

The last decade has provided additional evidence of accelerating global climate change and forecasted potential effects of the global-scale warming. Despite scientific consensus, numerous factors including economic concern, international disagreement, and continued uncertainty make public policy difficult to implement. Only time will show whether current measures mitigate greenhouse gas emissions to slow the rate of climate change. Unfortunately, with time, more of the deleterious effects of climate change will surface as well. In order to truly address the mounting threat, there must be an increase in interdisciplinary work between fields like science, economics, and politics; if not, uninhibited human activities will change our world unrecognizably within our lifetimes. H

> *"In the United States, forests offset about 20 percent of fossil fuel carbon emissions. Increasing this carbon sink by just 10 percent would require planting trees on one third of current croplands"*

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