Climate Change: A History of Environmental Knowledge

J. Donald Hughes

When I entered the storage facility of the U.S. National Ice Core Laboratory (NICL),[1] at the foot of the Rocky Mountains west of Denver, I experienced the coldest temperature I had ever felt: minus -36°C (-33°F). There, on shelves filling a large but increasingly inadequate space of 1,540 cubic meters (55,000 cubic feet), lay thousands of silvered cylindrical sleeves containing sections of cores of ice taken from the ice sheets of Antarctica and Greenland, and from mountain glaciers: an archive of the history of the Earth's climate and atmosphere. Many cores were drilled from ice surface to bedrock, some approaching 4 kilometers (2.5 miles) in length, so that one core is represented by thousands of cylindrical ice segments on the shelves. Looking at one of them removed from its sleeve, I could see layers, one above the other, each representing the annual snowfall of a year many centuries in the past. Using electrical conductivity, visual counting, and stable isotope analysis, these layers can be dated exactly—more accurately than a method such as radiocarbon allows—and they represent unbroken records stretching back farther than 450,000 years in Antarctica.[2] I was amazed to see a disk of ice from Greenland that had not melted for a quarter-of-a-million years. Glaciers are fast melting all over the Earth, so an archive like this one is very precious.[3] In the future, it might become impossible to collect such a library of ice.

Archival records of the history of climate change extend back through time for hundreds of thousands of years, but the knowledge of these archives and the ability to interpret them is a scientific development of the 19th through early 21st centuries. Through theoretical propositions, experimentation, study of proxy records, historical documents, and computer models that simulate the past and potentially the future with increasing accuracy, climatic scientists have achieved a general consensus on the process of climate change that is useful to historians as they develop interpretations of the changing relationships of human societies to the environment.

The tenor of scientific discourse about climate change in the decades from the second quarter of the 19th century, when the concept was first proposed, to the present has changed considerably. This discourse exhibits three major periods,[4] each of which is characterized by a different phase of scientific effort and its relationship to society. Briefly put, they are a period of hypothesis, a period of gathering evidence and testing hypotheses, and a period of controversy over the application of apparent scientific consensus. Of course, all three of these aspects of science continued throughout recent history: theories have been developed and tested all along, but these periods do seem to follow an emergent dialectic, and the public debate on the relationship between science and society has unmistakably intensified in the most recent decades.

---

[1] NICL is a joint program funded by the U.S. Geological Survey and the National Science Foundation. It is located in the Denver Federal Center, west of Denver, Colorado. Scientific aspects of NICL'S work are coordinated by a Science Management Office in the Climate Change Research Center at the University of New Hampshire.

[2] Richard B. Alley, *The Two-Mile Time Machine: Ice Cores, Abrupt Climate Change, and Our Future* (Princeton: Princeton University Press, 2000).

[3] Ben Orlove, Ellen Wiegandt, and Brian H. Luckman (eds.), *Darkening Peaks: Glacier Retreat, Science, and Society* (Berkeley and Los Angeles: University of California Press, 2008).

[4] Spencer R. Weart, *The Discovery of Global Warming: Revised and Expanded Edition* (Cambridge, MA: Harvard University Press, 2008). This author is indebted to Weart's groundbreaking work.

Initial Development of Theories

The first period, from around 1825 up to about 1945, was characterized by the development of major theories of the causation of climatic change. As evidence was found for past ice ages, the idea that climate is not constant came to be accepted over the course of the 19th century.

Following Joseph Fourier and John Tyndall, the Nobel prize-winning Swedish physicist and chemist, Svante Arrhenius, noted that atmospheric gases such as methane, carbon dioxide, and water vapor created a heat barrier in the upper atmosphere, which he characterized as the "greenhouse effect." Arrhenius speculated on the effect of worldwide industrial combustion on global heating[5] and thought the higher temperatures would be beneficial to humanity, possibly preventing a new ice age.

Others noted that worldwide cooler temperatures followed major volcanic eruptions, probably due to the reflectivity of sulfur dioxide and aerosols injected into the atmosphere. For example, Mount Tambora in Indonesia erupted in 1815, apparently causing 1816 to be the "year without a summer," with snows in June in Europe and North America, crop failures, and famine. After the cataclysmic explosion of Krakatoa in 1883, average world temperatures briefly dropped by 1.2°C (2.2°F). These episodes, however, lasted only a few months or years. The idea that increased levels of pollution might cause cooling in a similar way but over a longer period of time by shielding the Earth's surface from solar radiation was suggested by Guy Callendar.[6]

The influence of solar variations on climate became a subject of speculation; in the mid-19th century, an eleven-year cycle of sunspot numbers was noticed. Edward Maunder, following Gustav Spörer, correlated longer periods of minimum sunspot activity with cooler episodes such as the Little Ice Age. Milutin Milankovitch theorized the effects of variations in the Earth's orbit around the Sun on insolation, or the amount of solar radiation on the Earth's surface, and climatic variations.[7] Milankovitch's predicted variations do seem to correspond roughly with past ice ages. Interestingly, they suggest that the Northern Hemisphere should have been cooling slowly over the last decades rather than rapidly warming, as has been observed.

During this first period, however, the investigation of the magnitude and direction of climatic change was hindered by lack of evidence. Speculation about the possible effects of global warming, if it were to occur, emphasized positive outcomes such as improving weather and agricultural conditions, especially in northern latitudes.

Accumulating Evidence

The second period, from about 1945 to 1975, was a time of testing some of these hypotheses through a successful search for manifold new evidence. Governments granted money for such studies beginning with the International Geophysical Year of 1957-58. Roger Revelle and Hans Suess, attempting to establish the role of oceans in absorbing carbon dioxide, inspired Charles Keeling to establish remote stations on Mauna Loa in Hawai'i and in Antarctica to monitor the

---

[5] Svante August Arrhenius, "On the Influence of Carbonic Acid in the Air Upon the Temperature of the Ground," *Philosophical Magazine*, 41, 1896, pp. 237-276.

[6] Stephan Harding, "The Long Road to Enlightenment," *The Guardian*, January 8, 2007, online at: http://www.guardian.co.uk/environment/2007/jan/08/climatechange.climatechangeenvironment.

[7] Milutin Milankovitch, *Canon of Insolation and the Ice-age Problem* (Jerusalem: Israel Program for Scientific Translations, 1969).

concentration of CO_2 in the atmosphere. Keeling's measurement resulted in the discovery of the "Keeling Curve," which showed that CO_2 is steadily increasing. From this data, Revelle and Suess made an ominous conclusion: "Human beings are now carrying out a large-scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future."[8]

Satellites began to measure temperatures on the surface and in the atmosphere, and to provide detailed information on changes in solar irradiance; stratospheric chemistry, including ozone depletion such as the Ozone Hole over Antarctica; temperature; precipitation; clouds and water vapor; wind velocity; ocean currents and surface temperatures, including El Niño; sea level; vegetation and desertification; coastal configuration; volcanoes; snow cover; sea ice; glaciers and ice sheets; and human activities, such as fires and the growth of cities.[9]

Climate scientists braving difficult weather drilled ice cores in Greenland and Antarctica, revealing evidence of past concentrations of atmospheric gases, temperatures, dust, pollutants, and radioisotopes.[10] For example, it became possible to plot long-term temperature variations and changes in carbon dioxide concentration on the same time scale, and to note that they follow patterns that are remarkably similar. In a chart of these two curves, a relatively regular, approximately 100,000-year cycle is prominent, although it also appears that the climate has occasionally changed rapidly in very short time periods. The most recent decades have shown a divergence in which the level of carbon dioxide has risen more rapidly than temperature.

Sea and lake bottom cores were added to the ice core archives after Harold Urey and Cesare Emiliani's seabed discoveries that revealed ancient climate changes. Many studies of coral reef stratigraphy, malacology, dendrochronology, and other long-term archives also represented extended natural cycles, rapid climate variations, and the apparent recent influence of human-induced change. This period was also an anomalous phase of declining temperatures in the Northern Hemisphere, possibly connected with rapidly increasing levels of pollution. Although it proved to be only a temporary pause in the overall warming trend from about 1850 to the present, it reduced the level of concern about global warming.

Consensus and Resistance

In the third period, from 1975 up to the present, climate scientists generally agreed that global warming is occurring and that it is caused, to a major extent, by human activities. The need to take action to mitigate it by measures such as reducing emissions of greenhouse gases emerged as an issue in national and world politics.

Computer modeling became more sophisticated and indicated that an increase in atmospheric carbon dioxide would lead to warmer temperatures. The computer models suggested that the effects of these changes, should they continue, will vary in different regions of the Earth's surface but could include rising temperatures, changing patterns of precipitation, an elevation of sea level with flooding of islands and coastal zones, disruption of freshwater flows by removal of ice, and stresses on agricultural crops, forests, and wildlife, including coral reefs and fish as a result of

---

[8] Roger Revelle and Hans E. Suess, "Carbon Dioxide Exchange between Atmosphere and Ocean and the Question of an Increase of Atmospheric CO_2 During the Past Decades," *Tellus*, 9, 1957, pp. 18-27.
[9] R.J. Gurney, J.L. Foster, and C.L. Parkinson (eds.), *Atlas of Satellite Observations Related to Global Change* (Cambridge: Cambridge University Press, 1993).
[10] Willi Dansgaard, *Frozen Annals: Greenland Ice Cap Research* (Odder, Denmark: Aage V. Jenkins Fonde, 2004), p. 54; Alley, *The Two-Mile Time Machine*, 2000, pp. 18-19.

increases in oceanic temperatures and acidity. Data collected during this time has confirmed that unprecedented warming is indeed occurring. Among other observed phenomena, most glaciers and ice sheets are seen to be retreating. Spokespersons such as Stephen Schneider and James Hansen popularized the fact that climate science was moving toward a new consensus that global warming is an observable process, has been in considerable part caused by human activities in recent decades, and is likely to have significant impacts that are predominantly negative.[11] Though the Intergovernmental Panel on Climate Change (IPCC), established in 1988 by the United Nations, has been carefully conservative in structure and cautious about evidence, it nevertheless concluded that predominant scientific opinion predicted higher temperatures leading to threatening effects such as a rising sea level.[12] International discussions in Rio (1992), Kyoto (1998), and Copenhagen (2009) showed a recognition of the importance of the new environmental knowledge and the need for action to counter global warming. But political pressure dominated the negotiations, and the commitment of nations to follow up with needed actions—even those agreed upon—was unclear.

As awareness of the likelihood of climate change spread among the general public and economic measures to reduce carbon emissions gained support, determined opposition to efforts to halt or mitigate global warming emerged on at least three fronts. A few scientists pointed out problems with evidence and models used in prediction. This was to be expected considering that such critique is part of the process of scientific inquiry. Bona fide scientific critique is positive, because it leads to open discussion, further investigation, and testing of hypotheses. In the case of global warming, the weight of scientific opinion moved toward the conclusion that global warming is occurring, and that at least a major proportion of the cause is assignable to human activities.

A second source of opposition to the idea that the danger of climate change merited major interventions to alleviate it came, and continues to come, from the industries whose activities cause it, and therefore who might have to bear the cost of the efforts to counter it. This includes petroleum and coal companies, other fossil fuel industries, and automobile manufacturers. They have engaged in advertisements against the idea of global warming, seized on or sponsored studies that questioned it, and have even created false front organizations that claim objectivity but have in fact engaged in tendentious campaigns designed to sow doubt about the reality of global warming and the idea that human activities are an important cause of it.[13] Recently they have publicized the results of espionage intended to discredit the work of the IPCC, which has since been exonerated.[14] Not all business organizations have resisted the findings of climate science; some of them see a benefit to be involved in the development of environmentally friendly technology, genuinely, or at least to gain the public appearance of "greenness."

A third group active in opposing programs to mitigate global warming is political, composed of right-wing organizations that fight the role of governmental intervention on principle. These

---

[11] M.D. Mastrandea and Steven Schneider, "Probabilistic Integrated Assessment of 'Dangerous' Climate Change," *Science*, 304, 2004, pp. 571-574; James Hansen, et al., "Earth's Energy Imbalance: Confirmation and Implications," *Science*, 308, 2005, pp. 1341-4135.

[12] Bert Bolin, *A History of the Science and Politics of Climate Change: The Role of the Intergovernmental Panel on Climate Change* (Cambridge: Cambridge University Press, 2007).

[13] James Hoggan, *Climate Cover-up: The Crusade to Deny Global Warming* (Vancouver: Greystone Books, 2009).

[14] Raphael G. Satter, "'Climategate' Investigation VINDICATES Scientists, Finds Research Reliable, *Huffington Post*, July 7, 2010, online at: http://www.huffingtonpost.com/2010/07/07/climategate-investigation_0_n_637622.html.

organizations fear that reduction of the emission of greenhouse gases will require regulation on national and international levels, and they use questioning of global warming and the role of humankind in causing it as a way of resisting the extension of government control.

Who are the people who will suffer first and most from the bad effects of global warming? It will not be the rich and the holders of capital. They will have the resources to build defenses or move out of the way. It is the common people, the workers, and the poor people of the Earth who will find themselves in the way of disasters they cannot escape. Affluent cities and nations may build dikes to keep out rising seas, but the people of poverty-stricken countries like Bangladesh and the Maldives will have the choice to flee or drown. In New Orleans, the poorest and blackest neighborhoods suffered most from hurricane Katrina. If deserts become dryer and threaten to expand, we of the American Southwest will subsidize water developments as long as it is possible, but the herders and farmers of the African Sahel will find their environments too degraded to support life. Those who are most responsible for global warming will suffer from it, but they will suffer last and least. Where can we find environmental justice?

The history of the recognition of global warming and its implications for human society is an illustrative case of the interaction between the growth of scientific knowledge and the interests of competing political and economic entities. Science can inform us of the relative (not absolute) certainty of continued human-induced global warming and its probable effects. It can evaluate possible measures intended to forestall negative changes, or at least to lessen their magnitude, as well as courses of action intended to enable human societies to cope with the negative effects of the likely changes. But the decisions as to what measures will be implemented will be made by governments and corporations that historically have demonstrated a pattern of acting in accord with what they see as their own short-term interests. Thus far, they have ignored the common good of humans and the Earth in the long term.