Changing Climate

Report of the Carbon Dioxide Assessment Committee

Board on Atmospheric Sciences and Climate
Commission on Physical Sciences,
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Annex 2
Historical Note

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The issue of carbon dioxide and climatic change has now been on the research agenda for more than a century. Indeed, by the 1980s it has acquired quite a distinguished scientific provenance. In the 1860s J. Tyndall began suggesting that slight changes in atmospheric composition could bring about climatic variations. The first precise numerical calculations about how much increased carbon dioxide concentrations would influence the Earth's surface temperature were made by Svante Arrhenius (1896, 1908). He estimated that a doubling of atmospheric CO_2 concentrations would produce a global warming of about 4-6°C. At the same time, T. C. Chamberlin (1899) was developing theories that the large variations in the Earth's climate, including periodic glaciation, could be attributable to changing carbon dioxide concentrations. C. F. Tolman (1899) provided the first major insights into the critical role of the oceans in the global distribution of carbon dioxide.

By the early decades of this century, there was a lively debate among scientists on the direction of future CO_2 concentrations. Some, like Arrhenius (1908), built their conception of future development on the expectation that the atmosphere is gaining in CO_2 under the present regime of "evaporating" our coal mines into the air. Others, like C. Schuchert (1919), stressed the volcanic origin of much CO_2 and worried that the ultimate extinction of the Earth's "plutonic fires" would bring in train the depletion of atmospheric CO_2 and the extinction of life. "Life and its abundance at any time are conditioned by the amount of this gas (CO_2) present in the atmosphere."

In his classic work, Elements of Physical Biology, A. J. Lotka (1924), stimulated by a general interest in the history of systems in the course of irreversible transformations, also explored the carbon cycle. Lotka offered one of the first eloquent formulations of the CO_2 issue:

> ...to us, the human race in the twentieth century [this phenomenon of slow formation of fossil fuels] is of altogether transcendent importance: The great industrial era is founded upon, and at the present day inexorably dependent upon, the exploitation of the fossil fuel accumulated in past geological ages.

> We have every reason to be optimistic; to believe that we shall be found, ultimately, to have taken at the flood this great tide in the affairs of men; and that we shall presently be carried on the crest of the wave into a safer harbor. There we shall view with even mind the exhaustion of the fuel that took us into port, knowing that practically imperishable resources have in the meanwhile been unlocked, abundantly sufficient for all our journeys to the end of time. But whatever may be the ultimate course of events, the present is an eminently atypical epoch. Economically we are living on our capital; biologically we are changing radically the complexion of our share in the carbon cycle by throwing into the atmosphere, from coal fires and metallurgical furnaces, ten times as much carbon dioxide as in the natural biological process of breathing. . .[T]hese human agencies alone would. . .double the amount of carbon dioxide in the entire atmosphere. . . .

Lotka estimated a doubling time of 500 years, based on continued usage of coal at 1920s levels. If he had used the logistic ("Lotka-Volterra") equations for which he was to become famous to calculate future emissions as a result of human activities, Lotka would have given a doubling time in the middle of the twenty-first century.

V. I. Vernadski (1926) was among the first to show the extent to which the Earth, its atmosphere as well as its hydrosphere and landscapes, is indebted to living processes, to the biota. The theoretical ecologist V. A. Kostitzin (1935) dealt extensively with the circulation of carbon in his monograph "Evolution de l'atmosphere, circulation organique, epoques glaciares." Kostitzin provides a general review of available information and some of the theories concerning the circulation of oxygen, carbon, and nitrogen and discusses the long-term changes in their abundance in the atmosphere and soil. He reviews the theories in light of a simple model, incorporating a system of linear and quadratic differential equations, one of the early formal attempts to model the cycles. In his concluding remarks Kostitzin warns against confusing the relative short-term stability of nature with the absolute, but misleading, long-term stability of mechanical systems "which does not, in fact, exist, either in mechanics or in biology."

By 1938 G. S. Callendar was focusing directly on the industrial production of carbon dioxide and its influence on temperature. He went on (1940, 1949) to speculate that a 10% increase in atmospheric CO_2 between 1850 and 1940 could account for the observed warming of northern Europe and northern America that had begun in the 1880s. G. Plass, of the Aeronutronic Division of the Ford Motor Company, was responsible during the 1950s for the development of surface energy balance approaches to climate sensitivity that yielded the first "modern" estimates of global surface temperature response to increased CO_2. R. Revelle and H. E. Suess, in the opening of their often-cited 1957 paper, dramatically emphasized the significance of the rise in atmospheric CO_2: "Human beings are now carrying out a large-scale geophysical experiment...." They also pointed out for the first time that most of the CO_2 produced by the combustion of fossil fuels would

stay in the atmosphere and would not be rapidly absorbed by the ocean. Revelle was instrumental in incorporating accurate and regular measurements of the concentration of CO_2 into the program of the International Geophysical Year (IGY).

Meanwhile, the potential societal significance of climatic change had not gone unrecognized. J. von Neumann (1955), noting the effects of increasing atmospheric CO_2, anticipated that deliberate human modification of climate would become a major issue in world affairs.

> The most constructive schemes of climate control would have to be based on insights and techniques that would also lend themselves to forms of climatic warfare as yet unimagined... [U]seful and harmful techniques lie everywhere so close together that it is never possible to separate the lions from the lambs. This is known to all who have so laboriously tried to separate secret, "classified" science or technology (military) from the open kind; success is never more--nor intended to be more--than transient, lasting perhaps half a decade. Similarly, a separation into useful and harmful subjects in any technological sphere would probably diffuse into nothing in a decade. . .After global climate control becomes possible, perhaps all our present involvements will seem simple. We should not deceive ourselves: once such possibilities become actual, they will be exploited. It will, therefore, be necessary to develop suitable new political forms and procedures.

Broader public concern with the implications of rising CO_2 content of the atmosphere probably dates to a conference on the topic sponsored by The Conservation Foundation in March 1963. Conference participants included Plass and C. D. Keeling, who was responsible for the continuous monitoring program of atmospheric CO_2 begun at Mauna Loa in Hawaii and at the South Pole in 1957 during the IGY. The report of the conference states in part:

> It is known that the carbon dioxide situation, as it has been observed within the last century, is one which might have considerable biological, geographical and economic consequences within the not too distant future. . .It is estimated that a doubling of the carbon dioxide content of the atmosphere would produce an average atmospheric temperature rise of 3.8 degrees (Celsius). This could be enough to bring about an immense flooding of the lower portions of the world's land surface, resulting from increased melting of glaciers. . . .

The report goes on to recommend special emphasis on continuation of the CO_2 monitoring program and more exact quantitative knowledge of the biosphere, themes that have been maintained over the past two decades. The Conservation Foundation report also concluded:

> There is a need for a watchdog. The effects of the continuing rise in atmospheric CO_2 while not now alarming are likely to

become so if the rise continues. A committee of the National Academy of Sciences, National Research Council, might be charged with exploring the problem....

The CO_2 issue was subsequently raised as a national concern in Restoring the Quality of Our Environment, the Report of the Environmental Pollution Panel of the President's Science Advisory Committee, in 1965. Since that time, the CO_2 issue has been included in most lists of potentially serious environmental problems.

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