United States
Environmental Protection
Agency

Research and Development

Atmospheric Sciences
Research Laboratory
Research Triangle Park NC 27711

EPA/600/S9-86/016 Dec. 1986

EPA

Project Summary

EPA Workshop on Global Atmospheric Change and EPA Planning: Final Report

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The earth's climate is warming due to "greenhouse" gases, stratospheric ozone modifications caused by chlorofluorocarbons, and tropospheric ozone modifications caused by carbon monoxide and methane. Consensus among scientific researchers as to the causes, probable magnitudes, and timing of the changes has led to a call for assessment of policy options and impacts.

This workshop was organized to begin collaborations among EPA research and policy personnel, and climate researchers. EPA policy makers described their needs and working methods. Eight technical papers, presenting the state of the science, were given by non-EPA climate researchers. In addition to typical discussion and dialogue, a panel of policy makers and scientists discussed the impact of the projected global climate change on EPA planning. EPA responses to climate problems were suggested.

This Project Summary was developed by EPA's Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Expanding industrial and agricultural growth are leading to greater and greater emissions of many compounds that are changing the earth's atmosphere and climate. The changes are broadly classified as:

- warming of the climate caused by increasing concentrations of "greenhouse" gases;
- modifications of stratospheric composition and ozone chemistry caused by the introduction of compounds, especially the chlorofluorocarbon gases, that contribute to ozone depletion; and
- modifications of tropospheric chemistry mainly caused by increasing levels of carbon monoxide and methane.

The emissions include carbon dioxide from fossil fuel combustion, carbon monoxide from automobile and combustion sources, methane from agricultural sources, nitrous oxide from fertilizers, and Freons from industrial processes.

The Global Atmospheric Change and EPA Planning workshop was designed to initiate active collaboration among EPA research and policy personnel and non-EPA climate researchers. The workshop served as a forum for scientific leaders in the climate research field to impress upon the decision makers the extent to which they understand the problems and believe that actions are needed. EPA decision makers had the opportunity to begin an on-going dialogue with climate researchers and to develop a better understanding of the relevance of this field to EPA control policies and methodologies.

Conclusions

A. Climate Modification Processes

There is reliable evidence that the climate of the earth is far from constant.

The most fundamental factors influencing climate are: the solar constant (i.e., the energy flux at the earth's orbit) and orbital variations that influence the latitudinal distribution of the energy input. There is evidence that suggests that major climate swings between glacial and interglacial periods have occurred every 120,000 years, and it is believed that orbital variations may have been the triggers for these large changes in climate although changes in CO_2 concentrations are also implicated.

The composition of a planet's atmosphere influences its global temperature. Gases that absorb radiation in the IR-region can influence the global temperature by intercepting some of the outgoing energy and re-radiating it back to the surface, thus warming the surface. This is called the "greenhouse" process and the gases are described as greenhouse gases. In addition to the direct greenhouse effect of IR-absorbing gases, there are major positive feedback processes that determine climate sensitivity to long-term changes. For example, greenhouse warming causes an increase in atmospheric water vapor, which leads to more greenhouse effect, which leads to more warming. Climate change is, therefore, discussed in terms of an initial forcing function and the positive and negative feedback processes that increase or decrease the initial change. Thus, the direct effect of doubling the carbon dioxide (CO_2) over pre-industrial concentrations is estimated to be a temperature rise of 1.2°C because of increased IR-radiation absorption (the direct effect); currently the total multiplicative feedback processes are estimated to increase the initial effect by factors of 3 to 4, leading to a total temperature rise at equilibrium of 3.2-4.8°C (the total direct and indirect effect).

B. The Dynamic Nature of the Atmosphere

The atmosphere is in continuous motion and is coupled to the oceans and the biosphere; in addition, the atmosphere's composition is a result of both long-term and short-term chemical cycles. The abundance of trace gases in the global atmosphere is the result of the interaction between sources and sinks. For the majority of the trace gases, the two major sink processes are reaction with hydroxyl radicals (HO) in the troposphere and photolysis by short wavelength ultraviolet (UV) radiation in the stratosphere. Hydroxyl radicals are produced in the troposphere by a chemical cycle involving the oxidation of methane (CH_4), carbon monoxide (CO), other hydrocarbons, and aldehydes. Its primary source in the troposphere is the photolysis of ozone (O_3), as well as the reaction of hydroperoxy radicals (HO_2) with nitric oxide (NO). A major source of HO_2 radicals is the photolysis of aldehydes (such as formaldehyde), which are products of all organic oxidation including methane. Methane and CO are the primary consumers of HO in the troposphere.

The most common stratospheric photolysis process is for molecular oxygen (O_2) to photolyze into atomic oxygen (O). The O atom most often reacts with O_2 to produce ozone (O_3). Ozone also absorbs UV-radiation and photolyzes to produce O and O_2 again. This cycle recurs many times and converts light energy into heat in the upper stratosphere. This absorption of UV radiation limits the amount of short wavelength, high-energy light that reaches the earth's surface. Such wavelengths can cause skin cancer and promote rapid smog formation.

The dynamic processes and chemistry of the atmosphere are so complex and interactive that mathematical simulation models are the only tools available to comprehend the processes. Because of the complexity, models must often simulate only one aspect of the problem, using simple or average descriptions for the other aspects. For example, one-dimensional models tend to have complex chemistry and no horizontal atmospheric transport. Still, these models predict the average concentrations in the hemisphere fairly well. More complex and costly two-dimensional models also predict concentrations as a function of latitude as well. These models have to make assumptions about how transport occurs and different assumptions lead to somewhat different predictions of the temporal and spatial distributions of the O_3.

C. Increasing Emissions

Carbon dioxide concentrations have increased from 315 ppm in 1958 to more than 340 ppm in 1985, a very considerable increase. Researchers, using samples from ice cores, have determined that pre-industrial CO_2 concentrations were about 225 ppm, and in the last glacial period, the values were even lower. Part of the source of this increase in CO_2 is from the combustion of fossil fuel. Man's activities are injecting abou 5 gigitons per year into the atmosphere about 50% of this material appears t remain in the atmosphere, the rest go ing into the oceans and the biosphere Chlorofluorocarbon (CFC) concentra tions are increasing at about 3% pe year. Nitrous oxide (N_2O), which had northern hemispheric concentration o 301 ppb in 1980, is increasing at abou 0.5 ppb per year. Methane (CH_4) is th most abundant atmospheric hydrocar bon, and in 1980 its concentration wa 1.65 ppm in the northern hemisphere Its concentration has also been show to be increasing at rates between 0.! and 2% per year, and the rate itself ha been increasing. Near the surface, i rural areas of Europe and the centra and eastern U.S., the summertime con centration of O_3 may have increased b 6-12 ppb since the 1940s. There is reli able evidence for an increase in ozon in the middle troposphere over Europ during the past 15 years, and weake evidence for a similar increase ove North America and Japan.

D. Implications for Climate and Atmophere

Increasing the concentrations of IR absorbing gases can cause an increas in the earth's average global tempera ture. Three independently develope global climate models predict a total cli mate sensitivity of about 4°C for a dou bling of CO_2 concentrations over prein dustrial times or for a combination o some increase in CO_2 and increases i other greenhouse gases such a methane, ozone, chlorofluorocarbons and nitrous oxide. Although CO_2 is th greenhouse gas that is increasing th most, other trace gases (Freons, N_2O CH_4, and O_3) also have a major green house effect. If present trends continue their combined concentrations will lea to an equivalent effect of doubling th CO_2 concentration by the 2030s instea of the actual doubling of the CO_2 con centration that was predicted to occu sometime around 2070. Analysis of ob servations over the last 100 years sug gests that the average global tempera ture has increased 0.3-0.5°C. Mode simulations of the changes in emission and concentrations over this same pe riod also predict similar increases. Be cause of uncertainties in the model in puts and formulations, however, it i not possible to ascribe, in a scientifically rigorous manner, the increase in globa temperature to the increases in the greenhouse gases.

The photolysis of chlorofluorocarbons in the stratosphere results in the release of chlorine that acts as a catalyst in shortening the O_3 formation chain reaction and ultimately lowering the stratospheric O_3. Stratospheric O_3 absorbs short wavelength UV-radiation and thus filters such radiation from the earth's surface. Lower O_3 results in more UV-radiation in the troposphere and at the surface, as well as cooler stratospheric and warmer tropospheric temperatures. At the same time, the increase in tropospheric gases such as CH_4 and NO_x results in increases in O_3 in the troposphere. The British have been measuring total column O_3 at Halley, Antarctica (76°S) since the International Geophysical Year in 1956. In 1957, the values were 310-320 Dobson Units (DU) in the springtime. Now values are 40% lower in October (antarctic spring). In the winter at Halley, there is no sunlight; in the spring, the sun returns. It is speculated that during the dark, very cold winter, CFCs accumulate, and when the sun does reach the upper stratosphere for the first time in the spring, the CFCs undergo rapid reaction and destroy the O_3. As the CFCs are consumed, O_3 levels gradually increase to higher values, but by autumn the level is still 5-10% lower than it was 10 years ago.

Increased emissions of CO and CH_4 can, through complex photochemical interactions, result in a decrease in the average tropospheric HO concentration. Estimates suggest that HO concentrations were as much as 30% higher in 1860 than now. Projections of emissions patterns suggest that in 2035, HO concentrations will have decreased another 20-30%. Not only will many trace gases (including some toxics) survive longer in such conditions, so will CH_4, which contributes to the greenhouse effect. Longer survival in the troposphere also means a greater concentration in the stratosphere through tropospheric-stratospheric coupling and transport.

Preliminary modeling studies of urban smog formation have shown that increased UV-radiation and global temperature may cause a significantly enhanced potential for smog formation. The combined effects appear to be additive in some scenarios, resulting in e.g. a 40% increase in O_3 in the Nashville urban area.

Climate changes may have a variety of impacts on the acid rain problem. For example, increased air temperatures will lead to a larger demand for electricity for air conditioning and, hence, to increased SO_2 emissions, and to a more rapid oxidation of the SO_2 and NO_x to sulfate and nitrate ions. Also, altered precipitation patterns and changed cloud cover can potentially change the importance of aqueous phase oxidation and long range transport processes, as well as the impacts on aquatic systems and forests.

Recommendations

1. Implicit recommendations were derived consistent with the following four general types of responses to these problems:
   - Understanding—We can continue to develop the basic science and measurement programs needed to determine the magnitude and timing of environmental effects.
   - Preventing—Many scientists believe that climate change cannot be prevented: too much material is already in the air and only lags in the system (such as ocean turnover) are delaying the changes; the changes will happen eventually.
   - Limiting—There are questions about the quasi-irreversibility of the systems that suggest that options to limit the changes are difficult. The long lifetimes of some of the species mean that if emissions stopped now, it would require 30-50 years for conditions to be restored to those of pre-industrial times. On the other hand, a "wait and see" approach implies very significant changes will occur when the system lags catch up with the emissions input. Actions can be taken to limit the emissions of some of the critical species, for example, noncritical uses of Freons.
   - Adjusting—We can adjust to the existence of the situation by accounting for its existence in our activities. This means that decision makers at all levels should begin to consider the impact of the probable changes in their policies and strategies. There have been very few policy impact analyses comparable with the level of scientific modeling work done in the last few years.
2. One of the challenges that EPA should address is that of devising an observational strategy and supporting validating studies to give the policy and scientific community a good model for the continental U.S.
3. In the short term, EPA can build understanding and institutional capability. Furthermore, EPA should undertake additional analyses to assure that agency actions do not inadvertently speed up the rate of change. In the long term, EPA should use climate scenarios in long-range transport models; conduct synergistic experiments (e.g., involving the impact of CO_2, increased UV-radiation, and acid rain) on forests, crops, lakes, and materials for the world of the year 2020; and we should begin to develop a risk methodology for the global environment.

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The complete report, entitled "EPA Workshop on Global Atmospheric Change and EPA Planning: Final Report," (Order No. PB 86-244 639/AS; Cost: $22.95, subject to change) will be available only from:
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