CO2

GENERAL 7A

MEMORANDUM

TO T. K. Kett

FROM HENRY SHAW

DATE December 18, 1980

Attached is the "CO_2 Greenhouse Effect" technological forecast. I have added the items you suggested on 12/16/80. Pat McCall has not had a chance to review this draft. He will contact you directly if he has any comments.

Henry

Henry

HS/lw

Attachment

cc: P. P. McCall
H. C. Hayworth
H. N. Weinberg

H. N. WEINBERG
DEC 30 1980

Exxon Research and Engineering Company's Technological Forecast

CO_2 Greenhouse Effect

by
H. Shaw and P. P. McCall

Current Status

The build-up of CO_2 in the atmosphere has been monitored continuously at the National Oceanic and Atmospheric Administration's Observatory at Mauna Loa, Hawaii and periodically in other places since 1957. In addition to observing a trend between 1957-1979 that showed atmospheric CO_2 increasing from 315 to 337 ppm, Keeling and others also observed a seasonal variability ranging from 6 to 10 ppm between a low at the end of summer growing season (due to photosynthesis) and a high at the end of the winter (due to fossil fuel burning for heat, and biomass decay). There is little doubt that these observations indicate a growth of atmospheric CO_2 (See Figure 1). It is also believed that the growth of atmospheric CO_2 has been occuring since the middle of the past century i.e., coincident with the start of the Industrial Revolution. There is, however, great uncertainty on whether the atmospheric CO_2 concentration prior to the Industrial Revolution was 290-300 ppm or 260-270 ppm.

The relative contributions of biomass oxidation (mainly due to deforestation) and fossil fuel combustion to the observed atmospheric CO_2 increase are not known. There are fairly good indications that the annual growth of atmospheric CO_2 is on the order of 2.5 to 3.0 Gt/a of carbon and the net quantity of carbon absorbed by the ocean is similarly 2.5 to 3 Gt/a. Thus, these two sinks (atmosphere and ocean) can account for the total fossil carbon burned which is on the order of 5-6 Gt/a and does not allow much room for a net contribution of biomass carbon. Yet, highly respected scientists, such as Woodwell, Bolin and others have postulated a net biomass contribution to atmospheric CO_2 that range from 1 to perhaps 8 Gt/a of carbon. The rate of forest clearing has been estimated at 0.5 to 1.5%/a of the existing area. Forests occupy about $50 \times 10^6 km^2$ out of about $150 \times 10^6 km^2$ of continental land, and store about 650 Gt of carbon. One can easily see that if 1% of the worlds forests are cleared per year, then this could contribute 6.5 Gt of carbon to the atmosphere. Even if reforestation were contributing significantly to balancing the CO_2 from deforestation, the total carbon stored in new trees would be only a small fraction of the net carbon emitted. It should be noted, however, that the rate of forest clearing and reforestation are not known accurately at this time. If deforestation is indeed contributing to atmospheric CO_2, then another sink for carbon must be found and the impact of fossil fuel must be considered in the context of such a sink.

Figure 2, taken out of a recent DOE publication summarizes the fluxes and reserviors for the carbon cycle. Note that a deforestation flux of 0 to 2 Gt/a and a net flux to the oceans of 4 Gt/a are assumed. Thus, the carbon flux to the atmosphere is 6 Gt/a of fossil fuels, and 2 Gt/a deforestation, while 4 Gt/a returned to the ocean resulting in a 50% carbon retention rate in the atmosphere. One of the major objectives of the Exxon Research and Engineering Company project to measure CO_2 in the oceans using tankers is to clarify and quantify the role of the oceans as the ultimate sink for CO_2.

Projections of scientists active in the area indicate that the contribution of deforestation which may have been substantial in the past, will diminish in comparison to the expected rate of fossil fuel combustion in the future. A number of scientists have postulated that a doubling of the amount of carbon dioxide in the atmosphere could occur as early as 2035. Calculations recently completed at Exxon Research indicate that using the energy projections from the CONAES study and the World Energy Conference, a doubling of atmospheric CO_2 can occur at about 2060. If synthetic fuels are not developed, and fossil fuel needs are met by petroleum, then the atmospheric CO_2 doubling time would be delayed by about 5 years to 2065. It is now clear to most people working in the area that the doubling time will be much later in the future that previously postulated because of the decreasing rate of fossil fuel use.

<u>Description of potential impact on weather, climate, and land availability</u>

The most widely accepted calculations carried on thusfar on the potential impact of a doubling of carbon dioxide on climate indicate that an increase in the global average temperature of $3 \pm 1.5^{o}C$ is most likely. Such changes in temperature are expected to occur with uneven geographic distribution, with greater warming occuring at the higher latitudes i.e., the polar regions. This is due to the presumed change in the reflectivity of the Earth due to melting of the ice and snow cover (See Figure 3). There have been other calculations on a more limited scale by a number of climatologists which project average temperature increases on the order of $0.25^{o}C$ for a doubling of CO_2. These calculations are not held in high regard by the scientific community. Figure 4 summarizes the results presented in the literature on the possible temperature increase due to various changes in atmospheric CO_2 concentration.

The area of climate modeling was recently studied by a committee of the National Research Council, chaired by Jules G. Charney of MIT, and the conclusions are summarized in their booklet titled "Carbon Dioxide and Climate: A Scientific Assessment." This National Research Council study concluded that there are major uncertainties in these models in terms of the timing for a doubling of CO_2 and the resulting temperature increase. These uncertainties center around the thermal capacity of the oceans. The oceans have been assumed to consist of a relatively thin, well mixed surface layer averaging about 70 meters in depth in most of the general circulation model, and that the transfer of heat into the deep ocean is essentially infinitely slow. The Charney panel feels, however, that the amount of heat carried by the deep ocean has been underestimated and the oceans will slow the temperature increase due to doubling of atmospheric CO_2. The Charney group estimated that the delay in heating resulting from the effect of the oceans could delay the expected temperature increase due to a doubling of CO_2 by a few decades.

Along with temperature increase, other climatological factors that are expected to occur will include uneven global distribution of increased rainfall, and increased evaporation. These disturbances in the existing global water distribution balance will have dramatic impact on soil moisture, and in turn, on agriculture. The state-of-the-art in climate modeling allows only gross global zoning while some of the expected results from temperature increase of the magnitude indicated are quite dramatic. For example, areas that 4,000 to 8,000 years ago in the Altithermal period (when the global average temperature was some 2°C higher than present) were deserts, may in due time return to deserts. Conversely, some areas which are deserts now were formerly agricultural regions. It is postulated that part of the Sahara Desert in Africa was quite wet 4,000 to 8,000 years ago. The American Midwest, on the other hand, was much drier, and it is projected that the Midwest will again become drier should there be a temperature increase of the magnitude postulated for a doubling of atmospheric CO_2 (See Figure 5).

In addition to the effects of climate on the globe, there are some particularly dramatic questions that might cause serious global problems. For example, if the Antartic ice sheet which is anchored on land, should melt, then this could cause a rise in the sea level on the order of 5 meters. Such a rise would cause flooding in much of the U.S. East Coast including the state of Florida and Washington D.C. The melting rate of polar ice is being studied by a number of glaciologists. Estimates range for the melting of the West Antartica ice sheet from hundreds of years to a thousand years.

In a recent AAAS-DOE sponsored workshop on the environmental and societal consequences of a possible CO_2 induced climate change, other factors such as the environmental effects of a CO_2 growth rate on the less managed biosphere were studied. For example, the impact of a temperature increase and a higher atmospheric CO_2 concentration on weeds and pests was considered. The general concensus was that these unmanaged species would tend to thrive with increasing average global temperature. The effects of atmospheric CO_2 growth on the managed biosphere such as in agriculture would also tend to benefit from a CO_2 growth. It turns out that CO_2 can fertilize agriculture, provided the other key nutrients, phosphorous and nitrogen, are present in the right proportions. Agricultural water needs can be met by new irrigation techniques that require less water. In addition, with highest CO_2 and higher temperature conditions, the amount of water that some agricultural plants may need will be reduced. It is expected that bioscience contributions could point the way for dealing with climatological disruptions of the magnitude indicated above.

In terms of the societal and institututional responses to an increase in CO_2, it was felt that society can adapt to the increase in CO_2 and that this problem is not as significant to mankind as a nuclear holocaust or world famine. Finally, in an analysis of the issues associated with economic and geopolitical consequences, it was felt that society can adapt to a CO_2 increase within economic constraints that will be existing at the time. Some adaptive measures that were tested, for example, would not consume more than a few percent of the gross national product estimated in the middle of the next century.

Major Programs Underway

The DOE which is acting as a focal point for the U.S. government in this area is considering two reports to the scientific community and to the policy makers. The first one, summarizing five years of study is due in 1984, and the second one in 1989. The current plan is to spend approximately 10 years of research and assessment prior to recommending policy decisions in this area which impact greatly on the energy needs and scenarios for the U.S. and the world. The national program on CO_2, environment and society is summarized in Figure 6.

Projections on When General Concensus Can be Reached

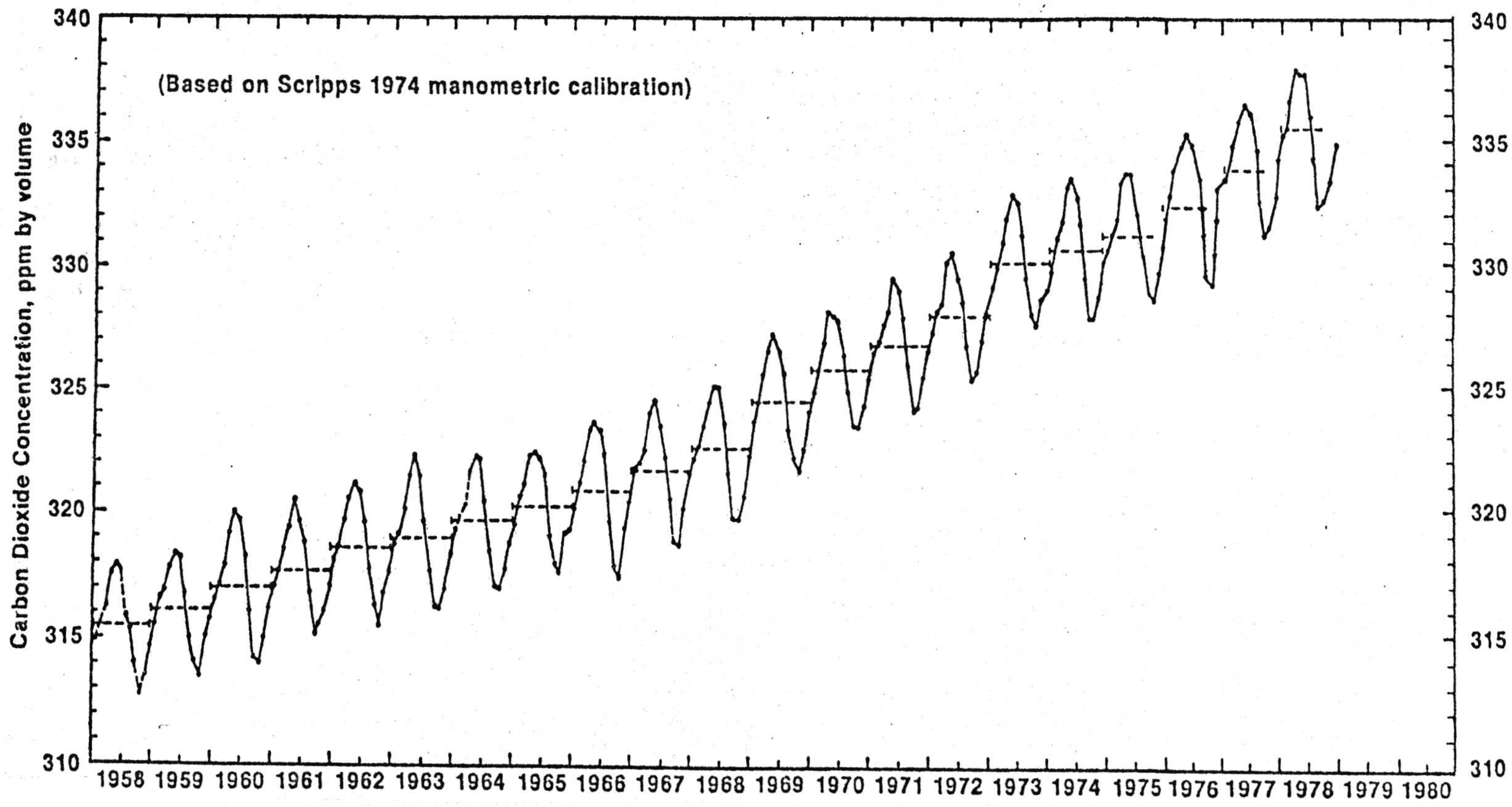
It is anticipated by most scientists that a general concensus will not be reached until such time as a significant temperature increase can be detected above the natural random temperature fluctuations in average global climate. The earliest that such discreet signals will be able to be measured is after the year 2000. However, depending on the actual global energy demand and supply, it is possible that some of the concerns about CO_2 growth due to fossil fuel combustion will be minimized if fossil fuel use is decreased due to high price, scarcity, and unavailability. Figure 7 illustrates the behavior of the mean global temperature from 1850 to the present contained within an envelope scaled to include the random temperature fluctuations.

Future Scenarios and Their Consequences For Exxon

A number of future energy scenarios have been studied in relation to the CO_2 problem. These include such unlikely scenarios as stopping all fossil fuel combustion at the 1980 rate, looking at the delay in doubling time and maintaining the pre-1973 fuel growth rate. Other studies have investigated the market penetration of non-fossil fuel technologies such as nuclear, and its impact on CO_2. It should be noted, however, that a new technology in a competitive scenario would need about 50 years to penetrate and achieve roughly half of the total market. Thus, even if solar or nuclear were to be considered viable alternatives, these would not really displace fossil fuel power generation for the next 50 years or so, and CO_2 growth would have to be estimated based on realistic market displacement of the fossil fuel technologies. All of these studies tend to give a range of deviations on the order of 50 years, indicating a CO_2 doubling time that might be as early as 2035 (for a fossil fuel growth rate of 4.3%), to a doubling time occuring by about 2080 resulting from scenarios which assumed fossil fuel growth rates of 1 to 2%. Synthetic fuels will cause minor perturbations on the projected atmospheric CO_2 growth rates in the next century.

FIGURE 1

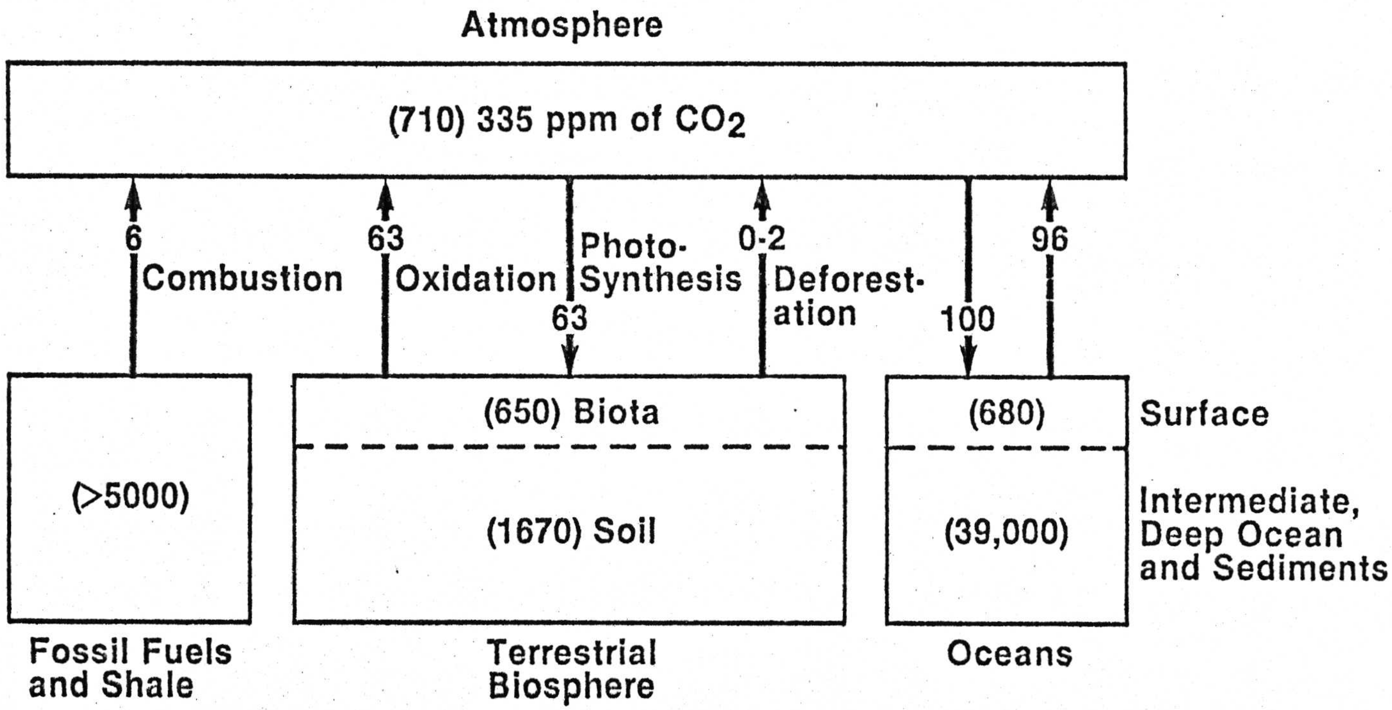
Trend in Atmospheric CO_2 Concentrations at Mauna Loa (Hawaii)



Year

FIGURE 2

Exchangeable Carbon Reservoirs and Fluxes

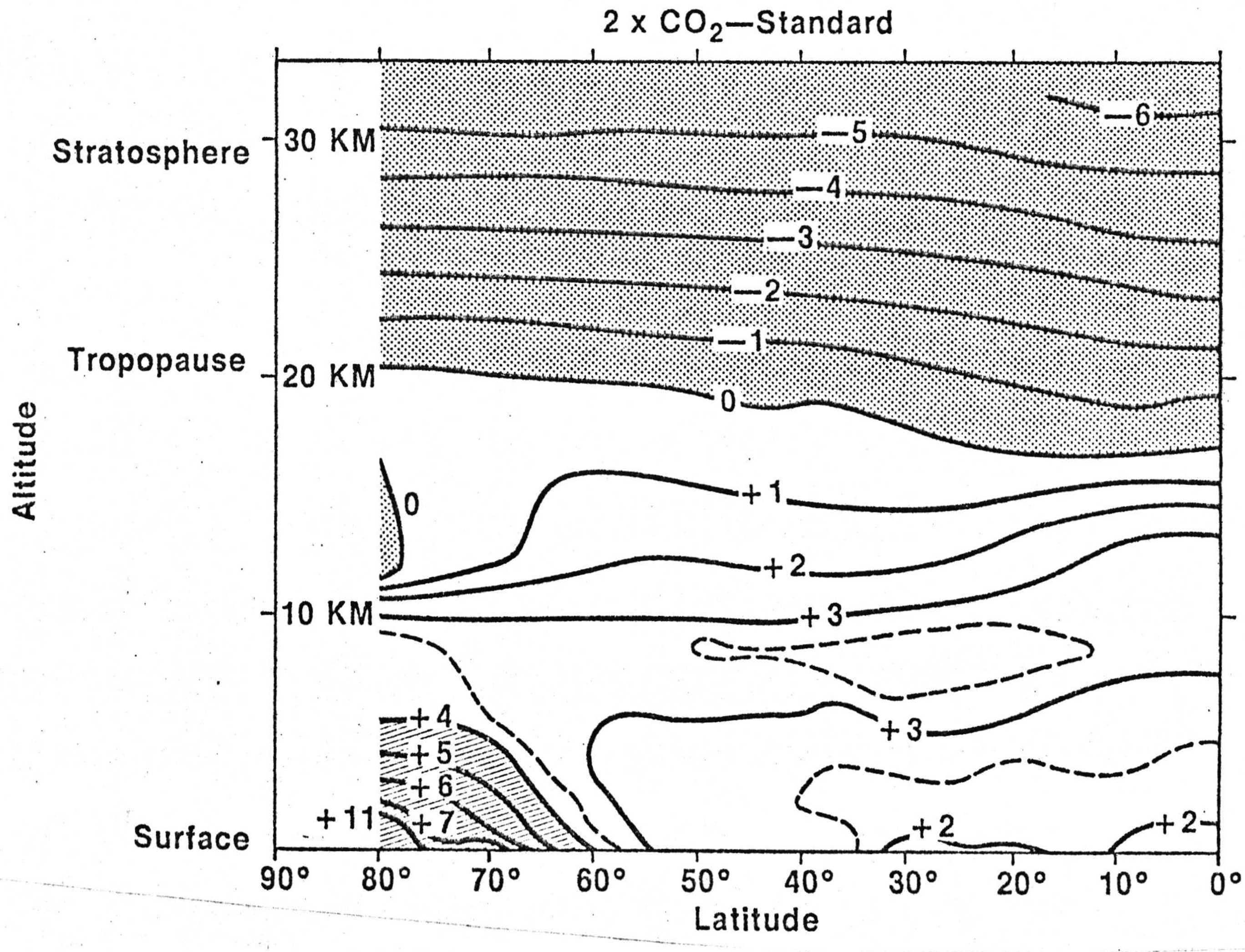


( ) = Size of Carbon Reservoirs in Billions of Metric Tons of Carbon

Fluxes (arrows) = Exchange of Carbon Between Reservoirs in Billions of Metric Tons of Carbon per Year

FIGURE 3

Temperature Change (°C) Due to Doubling CO_2 Concentrations



---- Decrease in Temperature

FIGURE 4

Estimates of the Change in Global Average Surface Temperature Due to Various Changes in CO_2 Concentration. Shading Shows Present Range of Natural Fluctuations.

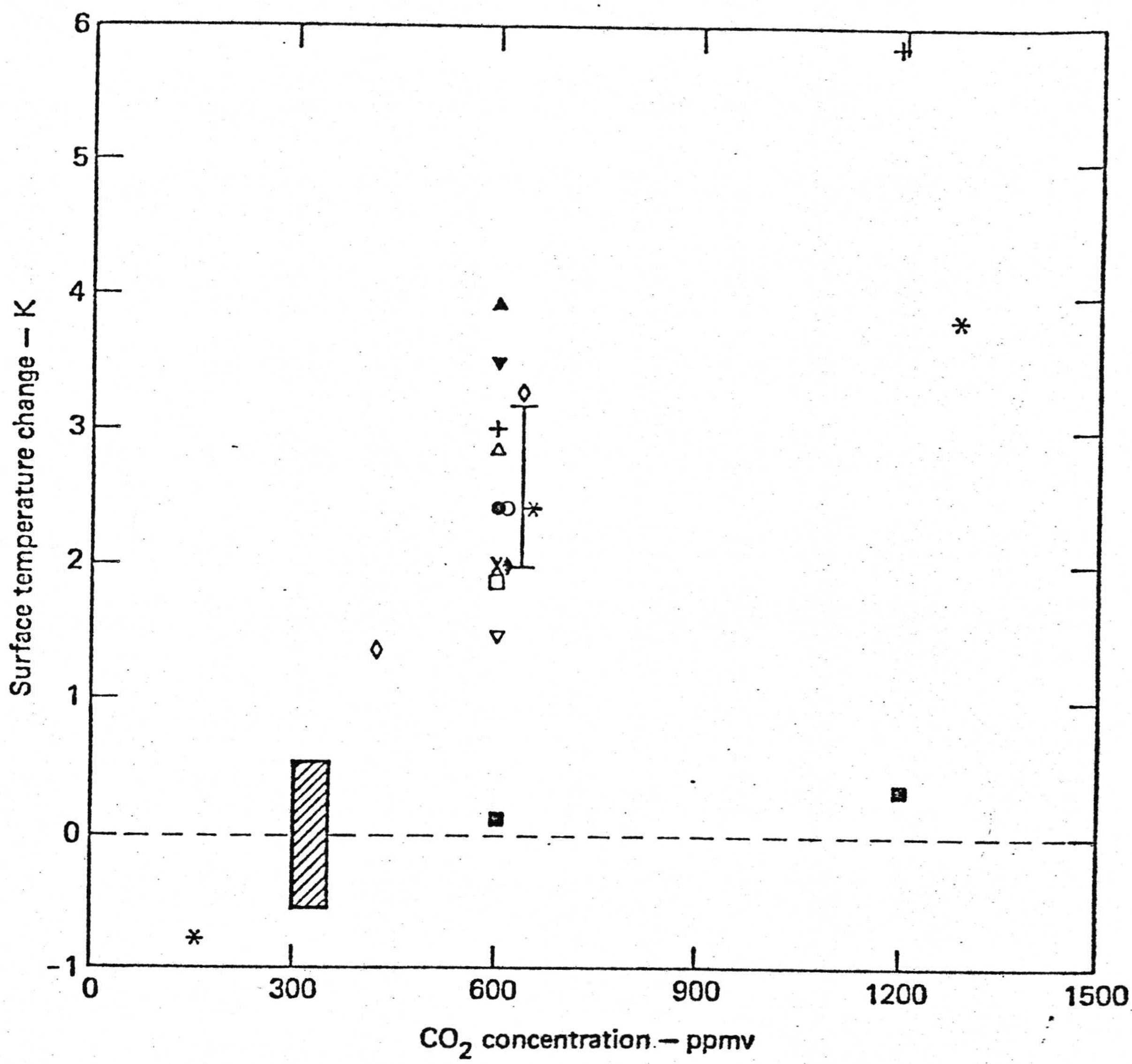


FIGURE 5

The Altithermal Period

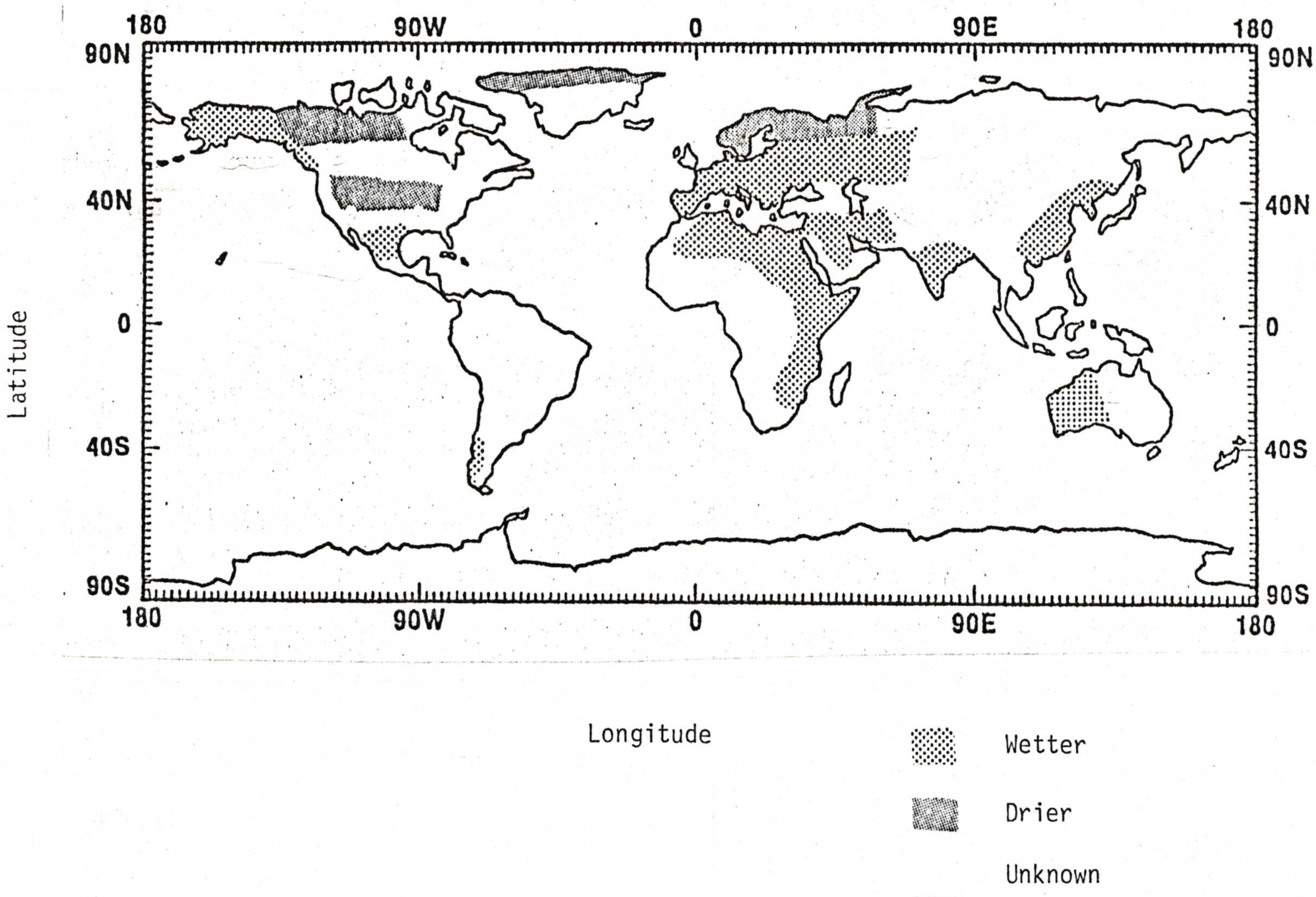


FIGURE 6

A National Program on Carbon Dioxide, Environment and Society

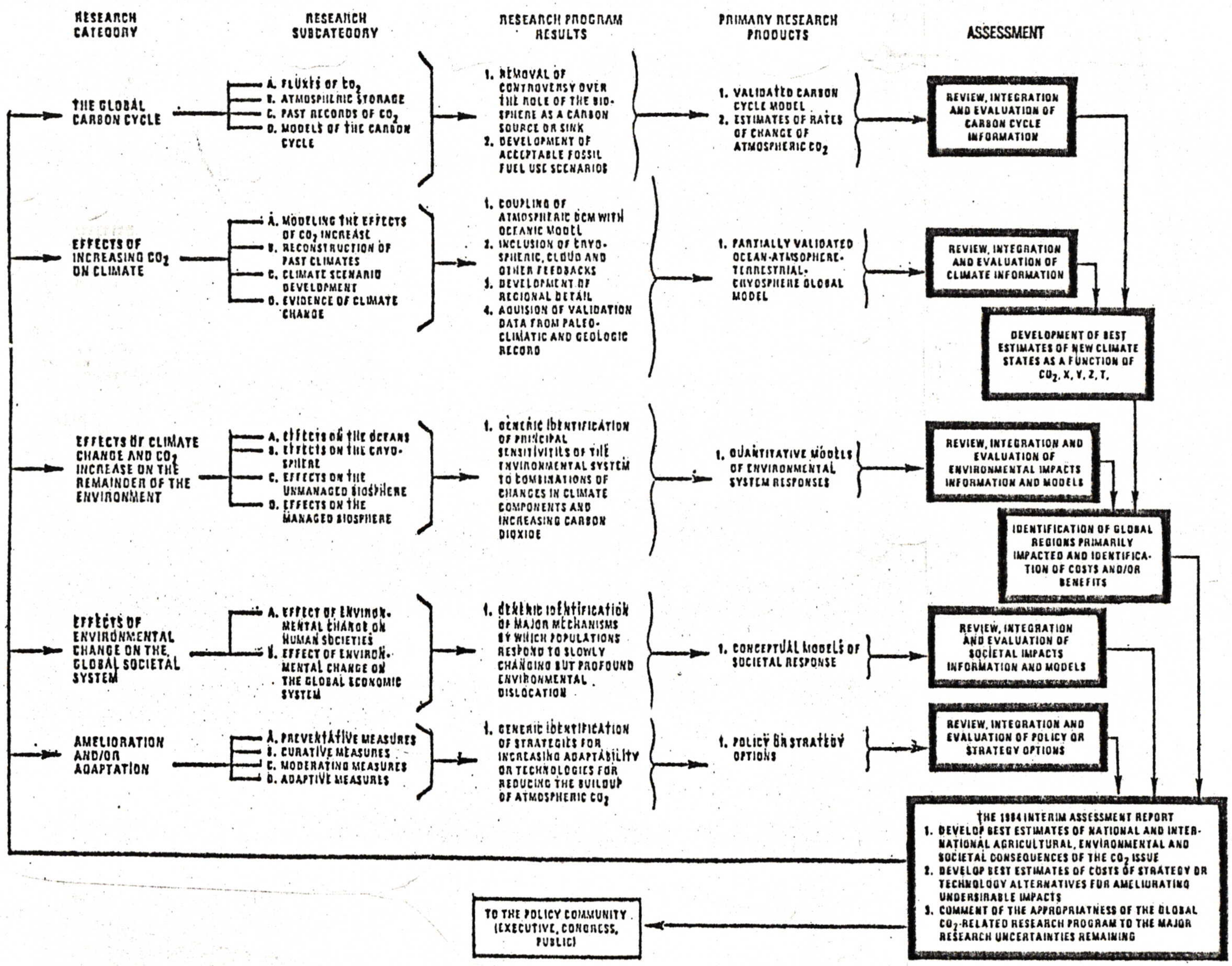


FIGURE 7

Range of Global Mean Temperature From 1850 to the Present with the Projected Instantaneous Climatic Response to Increasing CO_2 Concentrations.