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Gov. Sununu's proposed change

Point #	Proposed change	Point # in 7/5 Bernthal letter	IPCC Overview + Conclusions: Location of Change in Executive Summary	Location of Change in Overview + Conclusions Doc.
1	Improve discussion of natural sources + sinks	3, 6	p. i, l. 31-43	p. 4, l. 35-50
2	Carbon cycle - need range of values	6		p. 4. l. 35-50
3	Include Comprehensive Approach	7		p. 16, l. 10-23, 37-44
4	Include Natural sinks as potential means for stabilization of atmospheric CO_2	6		p. 4. l. 46-50
5	Additional Comment on uncertainties in underlying science	1, 2	p. ii, l. 20-27 p. ii, l. 43-52	
6	Too much focus on CO_2, augment discussion of other greenhouse gases	5		p. 17, l. 32-56 p. 18, l. 1-6

NATIONAL SCIENCE FOUNDATION
WASHINGTON. D.C. 20550

nsf

OFFICE OF THE
DEPUTY DIRECTOR

July 5, 1990

Professor Bert Bolin
Department of Meteorology
University of Stockholm
S10691 Stockholm
Sweden

Dear Bert:

My congratulations on the careful and thoughtful effort you have put into drafting both the IPCC executive summary and the overview and conclusions. I suspect that the meeting in Geneva was a useful preview for what to expect in Sundsvall! The draft documents that we recently received from the Secretariat incorporate many of the comments that the Drafting Committee raised in our meeting. We hope that careful consideration of the comments made in this additional iteration on the draft will save time and expedite consensus in the August plenary.

We have reviewed the draft documents as thoroughly as the tight deadline permits and offer both a reworked executive summary and detailed comments on the overview and conclusions. Some of the items in the enclosures reflect concerns about tone or policy implications and will require that substantive revisions be made, while others address typographical or stylistic problems which should improve readability and facilitate discussions in Sundsvall.

As you know, these documents will be used by ministers and heads of state to establish global policy on climate change and therefore they must be clear and convincing and flow logically for the lay reader. As I am sure you also realize, the documents still suffer from some redundancies and organizational problems, in large part a consequence of the Geneva additions and changes. In addition, the documents generally could use a thorough English-languange editing to sharpen the meaning, improve readability, and avoid problems in translation. To try to assist in this editorial process, we have offered extensive suggested revisions in the enclosures.

The primary purpose of this letter, however, is to highlight our key concerns and suggestions which warrant your attention. It is essential that the plenary documents clearly distinguish between what is known and what is projected or hypothesized. This was the task mandated to the IPCC. The three Working Groups have labored to strike a balance; that balance must be reflected in the plenary reports.

EXECUTIVE SUMMARY

Bolin accepted our proposed revised structure for the executive summary as well as many of the points that were made. The reworked version we sent to him

The executive summary must contain a careful statement acknowledging the significant uncertainties inherent in the underlying science. Our reworked executive summary contains the following statement regarding uncertainties, taken from page 2 of the WG I Policymakers Summary:

FB POINT #1 page ii lines 20-27

> There are many uncertainties in our predictions particularly with regard to the timing, magnitude and regional patterns of climate change, due to our incomplete understanding of the sources and sinks of greenhouse gases, clouds, oceans, and polar ice sheets.

The executive summary must strike a balance in its treatment of observed warming over the past 100 years and of the predicted warming. This can be accomplished by including the statement contained in the WG I Policymakers Summary (p. 30, last paragraph), as follows:

FB POINT #2 very similar language included page ii lines 43-52

> The size of the warming over the last century is broadly consistent with the predictions of climate models, but is also the same magnitude as natural climate variability. If the sole cause of the observed warming were the human-made greenhouse effect, then the implied climate sensitivity would be near the lower end of the range inferred from the models. The observed increase could be largely due to natural variability; alternatively this variability and other human-made factors could have offset a still larger human-made greenhouse warming.

There must be a more balanced presentation in the science summary of natural versus anthropogenic fluxes of greenhouse gases, notably CO2. As I mentioned in Geneva, we should not be afraid to place the entire story before the reader, especially since it may become essential to consider what steps might be taken to modify the "natural" CO2 cycle, should the situation turn out to be more serious even than we now expect. This can be done by including the following short paragraph:

FB POINT #3 These points are addressed, although not with this exact language in page i lines 31-43

> While the annual anthropogenic emissions of carbon dioxide are only about 4 percent of the total annual exchange of carbon dioxide by natural processes, they have been large enough to modify significantly the natural balance since pre-industrial times. Stabilization of atmospheric carbon dioxide concentrations can be achieved by either a 60-80% reduction in anthropogenic emissions, [or an increase in natural sinks by 2-3%.]

↑ not included in executive summary, but addressed on p 4, lines 48-49

OVERVIEW AND CONCLUSIONS

Scenarios

The Emission Scenarios A-D should be defined in a separate section at the beginning of the document. The explanation of how they were formulated should be taken from the WG III Policymakers Summary, Section 3.1. For example, for Scenario A:

FB Point #4 Appendix addresses all of these points

> Scenario A assumes that few or no steps are taken to limit greenhouse gas emissions. Energy use and clearing of tropical forest and the amount of biomass per hectare are low and fossil fuels, in particular coal, remain the world's primary energy source. The Montreal Protocol comes into effect but without strengthening and with less than 100 percent compliance. Under this scenario, the equivalent of a doubling of pre-industrial CO2 levels occurs, according to WG I, by around 2025.

The Business-as-Usual Scenario should be called Scenario A. At a minimum the designation should be "Scenario A (Business as Usual)."

Similarly, the Reference Scenario should be explained with regard to its purpose, with clarification that it is a scenario and not a plan, and reference made to the data on which it is based. The language should be drawn from the WG III Policymakers Summary, section 3.2.

Greenhouse Gases

FB Point #5

This draft continues to focus on CO2 to the virtual exclusion of other greenhouse gases, notably methane, so that the reader is left with the impression that CO2 reduction on the anthropogenic side, and reforestation on the natural side, are the only real options to consider. This does not reflect the conclusions of the AFOS report of WG III. To balance the presentation, lines 21 through 34 on page 17 need to be replaced with the following:

> Because the sources of other greenhouse gases, most notably methane, but also including nitrous oxide and ozone, are diverse and the quantitative importance of each of their sources is not well known at present, emissions reductions may prove difficult to achieve and the effectiveness of different control strategies may be hard to evaluate.

> Methane emissions arise primarily from agricultural, energy and waste management activities. Control strategies may include improved agricultural practices; use of low-emitting rice strains; and prevention, or recapture for energy recovery, of emissions from mine shafts, pipelines, and landfills.

Although all of the wording was not adopted, the tone of this section was changed in accordance with our request. Many of these phrases were used. See p 17, lines 32-56 p 18, lines 1-6

Natural Sources and Sinks of Greenhouse Gases

As stated earlier, the document must more explicitly discuss the natural sources and sinks of carbon dioxide, and uncertainties associated with the anthropogenic fluxes. The section (page 4, lines 22 to 30) needs to be expanded. This can most easily be accomplished by using Figure 1 (carbon cycle) on page 8 from Section 1 of the IPCC WG I scientific assessment, and the following text:

FB Point #6 Inserted verbatim on p 4, lines 35-50

The anthropogenic flux of carbon dioxide is about 6 Gt C per year from the combustion of fossil fuels, plus an additional 0.6 - 2.5 Gt C per year associated with tropical deforestation and changing land-use. These fluxes are much smaller than the natural exchange fluxes (about 200 Gt C per year) which occur between the atmosphere and the terrestrial biota and between the atmosphere and the oceans (Figure I). However, while the anthropogenic fluxes are much smaller than the natural fluxes, they have been large enough to modify significantly the natural balance since pre-industrial times. [Footnote: Scientific evidence for the anthropogenic character of these changes is noted in the Policymakers Summary of Working Group I. (Cite proper page and paragraph.)] Stabilization of atmospheric carbon dioxide can be achieved by a 60-80% decrease in the anthropogenic emissions of carbon dioxide or by an increase of about 2-3% in the natural sinks of carbon dioxide.

Comprehensive Approach

There must be further mention of the comprehensive approach to any possible solutions to the greenhouse gas problem. All greenhouse gases whose atmospheric concentrations are increasing should be considered together. This can be done through the concept of greenhouse warming potentials (GWPs). A short section, such as the following, needs to be inserted on page 15 line 35:

FB Point #7 addressed using much of this language including GWPs and comprehensive approach on p 16 lines 10-23 and 37-44

All greenhouse gases whose atmospheric concentrations are increasing because of human activities contribute to the enhanced greenhouse effect. Therefore, in view of the interrelationship among all greenhouse gases, their sources and sinks, when considering approaches to limit anthropogenic increases in radiative forcing it is essential to take a comprehensive approach to reductions in greenhouse gas emissions, i.e., all gases should be treated collectively (carbon dioxide, methane, nitrous oxide, CFCs, HCFCs, HFC, and ozone and its precursors). To evaluate possible policy options, it is useful to know the relative radiative effect (and, hence potential climate effect) of equal emissions of each of the greenhouse gases. Working Group I developed the concept of relative global warming potentials (GWPs) which take into account the differing times that gases remain in the atmosphere. Table x lists the GWPs for several key greenhouse gases, together with their 1990 emissions. (Table at the bottom of page 18 of WG I Policymakers Summary should be added here.)

In addition, the following short paragraph needs to be added to the legal issues summary immediately after the last bullet on page 28:

FB Point #8 not included

While it is recognized that the Convention is to be all-encompassing, the negotiating parties will have to decide whether greenhouse gases, their sources and sinks, are to be dealt with individually, in groups, or comprehensively.

I must stress that a considered response to these matters is essential if we are to have any hope of reaching consensus in Sundsvall. Please call if there is anything further that I can do to help, and good luck.

Best regards,

Fred

Frederick M. Bernthal

cc: Dr. N. Sundararaman

enclosures:
1) reworked executive summary
2) specific comments on overview and conclusions
   (to follow on July 6, 1990)

WMO

UNEP

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

OVERVIEW AND CONCLUSIONS

Climate Change: A Key Global Issue

DRAFT July 1990

(includes suggested US changes proposed in Bernthal letter of 7/5)

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FB pt #3

Sununu pt #1

EXECUTIVE SUMMARY

Science

<u>We are certain of the following</u>:

- there is a natural greenhouse effect which already keeps the earth warmer than it would otherwise be;

- emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases, carbon dioxide, methaNE, chlorofluorocarbons (CFCs) and nitrous oxide. These increases enhance the greenhouse effect, resulting on average in an additional warming of the Earth's surface. The main greenhouse gas, water vapour, will increase in response to global warming and further enhance it;

- the total increase of greenhouse gas concentrations attributable to human activities is at present equivalent to an increase of carbon dioxide since pre-industrial times (about 200 years ago) by about 50%.

<u>We calculate with confidence that</u>:

- atmospheric concentrations of the long-lived gases (carbon dioxide, nitrous oxide and the CFCs) adjust only slowly to changes of emissions;

FB Point #3

- the long-lived gases would require reductions in emissions from human activities of over 60% to stabilize their concentrations at today's levels; methane would require a 15-20% reduction;

- the human-caused emissions of carbon dioxide are small as compared to the natural carbon dioxide exchange bewtween the atmosphere on one hand and the terrestrial system and the oceans on the other. The latter were, however, in close balance before anthropogenic emissions began and the steady human-induced emissions into the atmosphere represent a significant disturbance of the natural carbon cycle.

<u>Based on current model results, we predict</u>:

- rate of increase of global mean temperature during the next century of about 0.3°C per decade (with an uncertainty range of 0.2 - 0.5°C per decade) assuming the IPCC Scenario A (Business-as-Ususal) emissions of greenhouse gases); this is a more rapid increase than seen over the past 10,000 years. This will result in a likely increase in the global mean temperature of about 1°C above the present value by 2025 (about 2°C

FB # 1,2

Sununu pt # 5

above that in the pre-industrial period), and 3°C above today's value before the end of the next century (about 4°C above pre-industrial). The rise will not be steady;

- that land surfaces warm more rapidly than the oceans, and higher northern latitudes warm more than the global mean.

- the oceans act as a heat sink and thus delay the full effect of greenhouse warming. The related (actual) temperature change is at any given time estimated to be between 50 and 80% of the committed change, i.e., the change when the climate system has reached equilibruim.

FB Point #1

* there are many uncertainties in our predictions particularly with regard to the timing, magnitude and regional patterns of climate change, espeically changes of precipitation. This is due to our incomplete understanding of sources and sinks of greenhouse gases and the responses of clouds, oceans and polar ice sheets to a change of the radiative forcing caused by increasing greenhouse gas concentrations.

* Over many thousands of years there have been significant changes in the atmospheric greenhouse gas concentrations and global climate, such as those that occurred during the Ice Ages. The mechanisms causing these are not yet well understood.

* <u>Our judgement is that:</u>

- global mean surface temperature has increased by 0.3 to 0.6°C over the last 100 years, with the five global-average warmest years being in the 1980's. The increase has not been smooth in time, nor uniform over the globe.

FB Point #2

- the size of the warming over the last century is broadly consistent with the prediction by climate models, but is also of the same magnitude as natural climate variability. Thus the observed increase could be largely due to this variability; alternatively this variability and other human factors could have upset a still larger human-induced greenhouse warming. The unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more.

Impacts

* Because of the lack of accurate estimates of the expected regional changes of climate, precise predictions of the

general conclusions can, however, be drawn.

* If no preventive measures to limit the further increase of man-induced emission of greenhouse gas (Scenario A Business as Usual), an average rate of global mean sea level rise of about 6 cm per decade is projected over the next century, with an uncertainty range of 3-10 cm per decade.
* Already a rise of sea level by 30-50 cm would affect the habitablity of low-lying coastal regions significantly and a one metre rise (possibly towards the end of next century as estimated in the Scenario A) would impact 360,000 km of coastline, render some island countries uninhabitable, displace tens of millions of people, threaten low-lying urban areas, flood productive land and contaminate fresh water supplies.

* Although studies have not yet conclusively determined whether on average global agricultural potential would increase or decrease, changes of climate would have important effects regionally. Decline in production might be expected in regions of high present-day vulnerability, where the ability to adjust is low.

* Some current forests will mature and decline in a climate, to which they are increasingly poorly adapted, while a potential for forests to grow might eventually develop elsewhere.

* Similarly other natural terrestrial ecosystems would be markedly influenced because the rates of climate changes are likely to be faster than the ability of some species to adjust.

* Enhanced carbon dioxide concentrations in the atmosphere might enhance growth of certain plants.

* Comparatively small changes of climate can cause large water resource problems. The availability of water and biomass might be significantly affected, positively or negatively, and both are major energy sources in many developing countries.

Response strategies

* A major dilemma of the issue of climate change due to increasing emission of greenhouse gases in the atmosphere is that actions may be required will before many of the specific issues that are and will be reaised can be analyzed more thoroughly by further research.

* The CFCs are already being eliminated to prevent their continued destruction of the stratospheric ozone layer. This is also an effective measure to slow down the rate of global warming. Every effort should be made to find replacements that have little or no greenhouse warming

potential or ozone depletion potential rather than the HCFCs and HFCs that are now being considered.

* Assuming a projected increase of the world population to about 8 billion by 2030, the present pglobal average emissions of carbon dioxide of about 1.45 tons of carbon per capita would have to be reduced to about 0.35 tons of carbon per capita in order to stabilize carbon dioxide concentration in th atmosphere.

* If the present rate of deforestation were reduced to about half of the present rare, this could reduce the rate of increase of carbon dixoide in the atmosphere by 5-15% compared with the present rate. Reforestation of 12 million hectars per year during the next 40 years would similarly slow down the rate of increase of carbon dioxide in the atmosphere during this period by 5-15%.

Roles of Industrialized and Developing Countries

* Industrialized and developing countries have a common responsibility in dealing with the problem arising from climate change. The former should take the lead in two ways:

    - to limit climate change by adapting their own economies in line with future agreements to limit emissions;

    - to cooperate with developing countries in international action, without standing in the way of the latter's development

* Sustainable development in industrialized as well as developing countries requires the progper concern for environmental protection as the necessary basis for continued economic growth. Environmental considerations must be systematically integrated into all plans for development. The right balance must be struck between economic growth and environmental objectives.

* The developing countries are rapidly increasing their emissions of greenhouse gases in striving for improving their living standards. Recognizing the poverty that prevails among the populations of developing countries, it is natural that achieving economic growth is given priority by them. Narrowing the gap between the industrialized and the developing world should provide a basis for full partnership of all nations in the world, which is essential for the development of a strategy to deal with the climate change issue.

Options

* The climate scenario studies of Working Group I and III

outline control policies on emission that would slow global warming from presently perhaps 0.3°C per decade to 0.1°C per decade.

* The potentially serious consequences of climate change give sufficient reasons to begin adopting response strategies that can be justified immediately even in the face of significant uncertainties. These include:

  - elimination of CFC emissions and careful assessment of the greenhouse gas potential of proposed substitutes,
  - improved energy end use efficiency,
  - improved forest management,
  - use of cleaner, more efficient energy sources with lower emissions of greenhouse gases,
  - review of agriculture practices.

* There is no single quick-fix technological option for limiting greenhouse gas emissions. A comprehensive strategy addressing all aspects of the problem and reflecting environmental, economic and social costs and benefits is necessary.

* Individual nations, or groups of nations, could initiate actions to stabilize and later reduce emissions and thus take the lead in the prevention of an accelerated increase of greenhouse gas concentrations in the atmosphere in order to prepare for international agreements. An important aim would be to define targets for cabon dioxide and other greenhouse gases.

* In the long term perspective, work should begin on defining criteria which would reflect the impacts of climate change and its costs on one hand and social and econoic cost on the other. This evaluation should take into account what might be an acceptable level of climate change on the one hand and an acceptable rate of economical and technological adjustments on the other hand.

* Consideration of measures for reducing the impacts of global climate change should begin as soon as possible, particularly with regard to disaster preparedness policies, coastal zone management and control measures for desertification, many of these being justified in their own right. Measures to limit or adapt to climate change should be as cost-effective as possible while taking into account important social implications. Limitation and adaptation should be considered as an integrated package.

* Environmental objectives can be achieved either through regulations or through market based economic instruments. The latter, through their encouragement of flexible selection of abatement measure, tend to encourage innvation and the development of improved technologies and practices for reducing emissions and therefore frequently offer the

possiblity of achieving environmental improvements at lower costs than through regulatory mechanisms. It is likely, however, that economic instruments wiill be applicable to all circumstances.

Future Work and International Cooperation

* The measures that may be necessary require a high degree of international cooperation, with due respect for national sovereignty of states. To assist in that process, international negotiations on a convention on climate change should start as quickly as possible. Key issues for negotiations will include the criteria, timing legal form and incidence of any obligations to control the net emissions of greenhouse gases, how to address equitably the consequences for all, any institutional mechanisms including research and monitoring that may be required, and in particular, the requests of the developing countries for additional financial resources and for the transfer of technology on a preferential basis.

* The IPCC recommends that research regarding the climate change issue in general, and the international economic implications in particular, be intensified.

* Because climate change would affect, either directly or indirectly, almost every sector of society broad global understanding of the issue will facilitate the adoption and the implementation of such response options as deemed necessary and appropriate. Further efforts to achieve such global understanding are urgently needed.

* The IPCC appeals to multilateral and bilateral finding organizations to assist developing nations in their efforts to take part in the international cooperation with regard to the climate change issue and to do so without awaiting the outcome of future negotiations on a climate convention. It further appeals on an urgent basis to governments for increased contributions to the ICC Trust Fund for future IPCC work.

I. Introduction

The consideration of the Final Report by the World Commission on Environment and Development by the UN General Assembly in 1987 brought the issue of a possible future man-induced climate change to world attention in the past decade and was discussed in a number of international fora. In 1988, in accordance with the decisions of the Tenth World Meteorological Congress, its Executive Council and the 14th session of the Governing Council of the United Nations Environment Programme (UNEP), the Executive Heads of the World Meteorological Organization (WMO) and UNEP invited all nations to take part in a more elaborate study of a possible man-induced climate change. The first meeting on such a study was held in Geneva in November 1988, in which 30 countries participated. The Intergovernmental Panel on Climate Change (IPCC) thus formed, and open to all countries, agreed on the following tasks (see reference 1):

1. assessment of available scientific information on climate change;

2. assessment of environmental and socio-economic impacts of climate change;

3. formulation of response strategies.

The Panel set up Working Group I on Science, Working Group II on Impacts and Working Group III on Response Strategies to carry out the three tasks listed above.

At its second meeting held in Nairobi in June 1989, IPCC established its Special Committee on the Participation of Developing Countries to promote, as quickly as possible, full participation by the developing countries in its activities. At this meeting, the Panel also responded to the request by the UN General Assembly to present its First Assessment Report in September 1990, to be available to the UN General Assembly later that year.

At its third session held in Washington D.C. in February 1990, IPCC responded to the request of the Noordwijk Ministerial Conference on Atmospheric Pollution and Climate Change to examine the feasibility of various options to stabilize and/or reduce emissions of carbon dioxide and other greenhouse gases. This work is now under way.

Due to the tight time schedule, the Working Groups and the Special Committee worked in parallel, with as much co-ordination as possible among them. The present report is an outcome of the deliberations by the Panel, its Working Groups and the Special Committee.

It should be emphasized that the issue of possible human-induced global climate change is very different from any other environmental issue. Climate change is a truly global problem, one that is of concern to all countries. Although the individual contributions to the emissions of greenhouse gases into the atmosphere vary from nation to nation and will vary in new patterns in the future, all countries will be influenced in one way or another, if climate change occurs. Joint actions by all countries will be required in order to limit or adapt to the consequences of potential global climate change.

The objective of IPCC has been to provide the scientific, technical and analytical basis for informed and intelligent policy choices. It is clear from the present overview, supported by the extensive reports of the working groups and their policymakers summaries, that some general conclusions can already be drawn, despite the remaining uncertainties. This First Assessment Report should therefore constitute a useful synthesis of our present knowledge and may serve as a basis for negotiations on how to deal with the issue. It is obvious that we are facing a very difficult issue, with no simple solutions.

The following overview of the IPCC First Assessment presents a synthesis of the most important conclusions that have been reached by the Working Groups, those that are judged to be of particular importance for policy analyses and the negotiations that will begin after the fourth IPCC plenary meeting in August 1990. The reader is referred to the complete reports of the Working Groups to address specific questions concerning the present analysis.

II. Scientific Issues

A. Atmospheric Concentrations of Greenhouse Gases

Although scientific uncertainties exist with regard to the likelihood and the character of human-induced climate change, we do know some things with considerable certainty. Working Group I has structured its policymakers summary to distinguish clearly between:

- what we know with certainty
- what we calculate with confidence
- what is predicted by current models
- what our best judgement is on matters that are more uncertain.

First it is stated that we are certain of the following:

- there is a natural greenhouse effect which keeps the Earth warmer than it would otherwise be.

- emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases: carbon dioxide, methane, chlorofluorocarbons (CFCs) and nitrous oxide. These increases will enhance the greenhouse effect, resulting on average in an additional warming of the Earth's surface.

Table 1 below summarizes the present and pre-industrial abundances, current rates of change and present atmospheric lifetimes of greenhouse gases influenced by human activities. Carbon dioxide, methane, and nitrous oxide all have significant natural and human sources, while the chlorofluorocarbons are only produced industrially.

TABLE 1

SUMMARY OF KEY GREENHOUSE GASES AFFECTED BY HUMAN ACTIVITIES

	Carbon Dioxide	Methane	CFC-11	CFC-12	Nitrous Oxide
Atmospheric concentration	ppmv	ppmv	pptv	pptv	ppbv
Pre-industrial (1750-1800)	280	0.8	0	0	288
Present day (1990)	353	1.72	280	484	310
Current rate of change per year	1.8 (0.5%)	0.015 (0.9%)	9.5 (4%)	17 (4%)	0.8 (0.25%)
Atmospheric lifetime (years)	50-200	10	65	130	150

ppmv = parts per million by volume; ppbv = parts per billion (thousand million) by volume; pptv = parts per trillion (million million) by volume.

Since the industrial revolution, the combustion of fossil fuels and deforestation have led to an increase of 26% in carbon dioxide concentration in the atmosphere. Methane concentrations have more than doubled because of rice production, cattle rearing, biomass burning, coal mining and ventilation of natural gas; fossil fuel combustion may have also contributed through chemical reactions in the atmosphere which reduce the rate of removal of methane. CFCs, which were not present in the atmosphere before their invention in the 1930s, are used as aerosol propellants, solvents, refrigerants and foam blowing agents. The total increase of all greenhouse gases due to human activities is at present equivalent to an increase of carbon dioxide since pre-industrial times of about 50%.

B. Emissions Scenarios

If considering at first a scenario (see the Appendix for a brief description of the scenarios developed by Working Group III) in which few or no steps are taken to limit greenhouse gas emissions (Scenario A or Business as Usual Scenario), the increase of greenhouse gas concentrations in the atmosphere would be the equivalent of a doubling of the carbon dioxide concentration by about 2025 and a quadrupling during the latter part of the next century although the scenario is quite uncertain beyond the middle of the next century. Estimated anthropogenic emissions in 1985 and those projected in 2025 in the Scenario A (Business as Usual Scenario) are given in Table 2 below:

TABLE 2

	1985	2025
Carbon dioxide (Gtc)	7.5	13
Methane (Tg)	350	550
Nitrous Oxide (Tg)	4	7
CFCs and HCFCs (Mt)	740	1900

It is interesting to note that national scenarios for the future (Reference Scenario of Working Group III) show a somewhat greater increase of carbon dioxide and methane emissions until 2025 than implied by the Business-as-Usual scenario.

FB Point #6

The net anthropogenic fluxes of carbon into the atmosphere are about 6 Gt per year from the combustion of fossil fuel, and an additional 0.6 - 2.5 Gt carbon per year associated with tropical deforestation and changing land use. These fluxes are much smaller than the natural exchange fluxes (about 200 Gt carbon per year) which occur between the atmosphere and the terrestrial biota and between the atmosphere and the oceans. The small variations of the atmospheric carbon dioxide concentrations since the last ice age show that the natural exchange was balanced within 0.5% each year and within 0.1% over periods of a decade or more, before man began disturbing the system significantly about 200 years ago. Stabilization of atmospheric carbon dioxide now requires a 60-80% decrease in its anthropogenic emissions or the increase of its terrestrial or oceanic sinks by 2-3%. No methods to achieve the latter are known.

FB pt #6

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FB pt #6

Sununu pt #2

FB pt #6

Sununu pt #4

C. Human-induced Climate Change

It is relatively easy to determine the direct effect of the increased radiative forcing due to increases in greenhouse gases. However, as radiative forcing begins to change, various natural processes act to amplify (through positive feedbacks) or reduce (through negative feedbacks) the change. The main feedbacks which have been identified are due to changes in atmospheric water vapour, clouds, sea-ice and the oceans.

The best tools we have which attempt to take the above feedbacks into account are mathematical models of the climate system which synthesise our knowledge of the physical and dynamical processes and allow for the complex interactions between the various components. However, in their current state of development, the descriptions of many of the processes involved are comparatively crude. As a result, considerable uncertainty is attached to these predictions of climate change, which is reflected in the ranges of values given below. Based on current model results, we predict, under the IPCC Scenario A (Business as Usual Scenario) emissions of greenhouse gases, a rate of increase of global mean temperature during the next century of about 0.3°C per decade (with an uncertainty range of 0.2-0.5°C per decade); this is greater than that seen over the past 10,000 years. This will result in a likely increase in global mean temperature of about 1°C above the present value by 2025 (about 2°C above that in the pre-industrial period) and 3°C before the end of the next century (about 4°C above that in the pre-industrial period). The projected temperature rise out to the year 2100, with high, low and best-estimate climate responses, is shown in Figure 1 below. Because of other factors which influence climate, we would not expect the temperature rise to be a steady one.

FIGURE 1

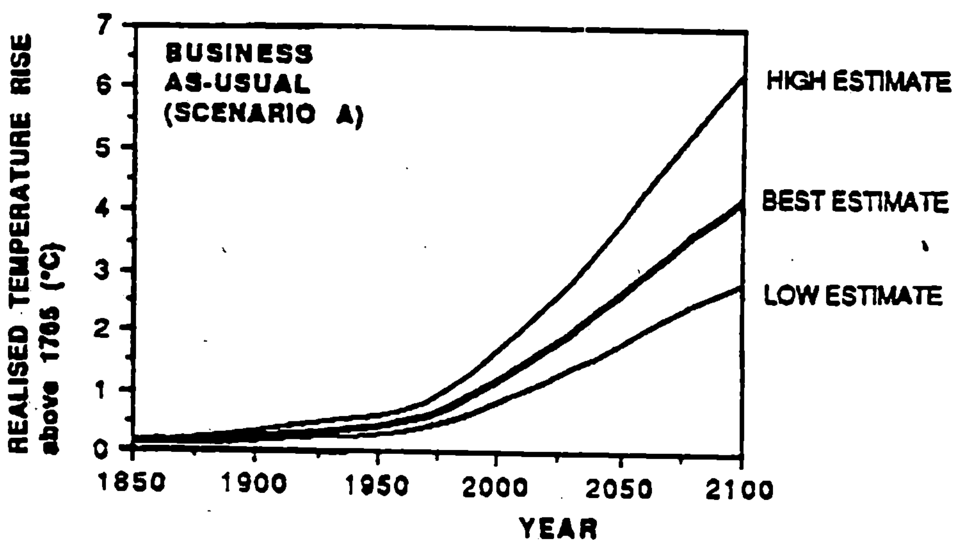


Figure 1 Calculated Realised Temperature Rise Since 1765: Scenario A (Business as Usual)

The temperature rise shown above is the realised tempera- ture. Due to the delaying effect of the oceans at any given time, we would also be committed to a further temperature rise which would progressively become apparent in the ensuing decades. Models predict that the realised temperature rise at any time is between 50 and 80% of the committed temperature rise.

It is important to recognize that a climate change caused by increased concentrations of greenhouse gases in the atmosphere would disappear only slowly even if all the human-induced emissions were stopped instantaneously. This is due to the fact that the life-times in the atmosphere of several of the major greenhouse gases with which we are concerned (carbon dioxide, nitrous oxide and the CFC-gases) range from about half a century to a few centuries. In practice, therefore, some climate change due to increasing amounts of greenhouse gases in the atmosphere may take many decades to reverse.

D. How Much Confidence Do We Have in Our Predictions?

There are many uncertainties in our predictions, particularly with regard to the timing, magnitude and regional variations of climate change. These uncertainties arise from our imperfect knowledge of:

- current and future rates of human-made emissions
- how these will change the atmospheric concentrations
- the response of the atmosphere, biosphere, and hydrosphere to these changed concentrations.

First, it is obvious that the extent to which climate will change depends on the rate at which greenhouse gases (and other gases which affect their concentrations) are emitted. This in turn will be dependent on various complex economic and sociological factors.

Second, because we do not fully understand the sources and sinks of the greenhouse gases, there are uncertainties in our calculations of future concentrations arising from a given emissions scenario. Furthermore, because natural sources and sinks of greenhouse gases are sensitive to a change in climate, they may substantially modify future concentrations. It appears that, as climate warms, these feedbacks will lead to an overall increase, rather than decrease, in natural greenhouse gas abundances. For this reason, climate change is likely to be greater than the estimates we have given.

Third, climate models are only as good as our understanding of the processes which they describe, and this is far from perfect. The ranges in the climate predictions given above reflect the uncertainties due to model imperfections; the largest of these is cloud feedback (those factors affecting the cloud amount and distribution and the interaction of clouds with solar and terrestrial radiation). Other uncertainties arise from the transfer of energy between the atmosphere and ocean, the atmosphere and land surfaces, and between the upper and deep layers of the ocean. The treatment of sea-ice and convection in the models is also crude. Nevertheless we have substantial confidence that models can predict at least the broadscale features of temperature change but not of changes in other climatic parameters (e.g., precipitation, soil moisture) and we are confident that existing reliability of the predictions can be improved by further research and increased computing capacity.

Furthermore, we must recognise that our imperfect understanding of climate processes (and corresponding ability to model them) could make us vulnerable to surprises; just as the human-made ozone hole over Antarctica was entirely unpredicted. In particular, the ocean circulation, changes in which are thought to have led to periods of comparatively rapid climate change at the end of the last ice age, is not well observed, understood or modelled.

E. Testing Predictions against Observations

It is of course essential to test model calculations against reality in order to validate the results.

We know from observations that the global mean temperature has increased between 0.3°C and 0.6°C, since the middle of last century and that most of this change has occurred primarily during two periods, i.e., the first four decades of this century and since 1975. Working Group I has carefully considered the criticism that local warming at observations sites within or in the vicinity of densely populated regions may explain some part of the observed change; such urban biases have largely been removed from the land record. Any residual bias will have a negligible influence on the global mean temperature, which is dominated by marine observations.

When trying to validate the model computations with the aid of these observations a further complication arises in that the global mean temperature has not been increasing steadily. A slight decline was observed in the Northern Hemisphere during the period 1949 - 1975. Such irregular variations of the global mean temperature by several tenths of a degree are to be expected due to internal interactions (e.g., between ocean and atmosphere) in the climate system. These natural variations further obscure any warming trend that may result from increasing amounts of greenhouse gases in the atmosphere.

The size of the warming over the last century is broadly consistent with the predictions of climate models, but is also of the same magnitude as natural climate variability. If the sole cause of the observed warming were the human-made greenhouse effect, then the implied climate sensitivity would be near the lower end of the range inferred from the models. The observed increase could be largely due to natural variability; alternatively this variability could have offset a still larger man-made greenhouse warming. The unequivocal detection of the enhanced greenhouse effect from observations is not likely much before the turn of the century, when the commitment to future climate change would have grown considerably larger than it is today.

F. Regional Patterns of Climate Change

Knowledge of the global mean warming is of limited use in determining the impacts of climate change, for instance on agriculture. For this we need to know changes of temperature and precipitation regionally and seasonally. Models predict that regional climate changes will be different from the global mean. For example, temperature increases in Southern Europe and central Northern America are predicted to be higher than the global mean, accompanied on average by reduced summer precipitation and soil moisture. In general, confidence in regional estimate is low, especially for the changes in precipitation and soil moisture. Therefore we cannot yet give reliable regional predictions at the smaller scales demanded for impacts assessments.

A completely different, and potentially useful way of predicting patterns of future climate is to search for periods in the past when the global mean temperatures were similar to those we expect in future, and then use the past spatial patterns as analogues of those which will arise in the future. Paleo-climatological information can provide useful insights into climate processes, and can assist in the validation of climate models. In addition, paleo-analogue scenarios are useful for sensitivity studies to evaluate regional impacts of climate change.

Changes in the variability of weather and the frequency of extremes will generally have more impact than changes in the mean climate at a particular location. With the possible exception of an increase in the number of intense showers, there is no clear evidence that weather variability, or the intensity or frequency of storms, will change in the future. However, with an increase in mean temperature, episodes of high temperatures will most likely become more frequent in the future, and cold episodes less frequent.

III. Environmental Impacts of Climate Change and Socio-Economic Consequences

A. Impact Sensitivity Of Projections

Because we are not yet able to foresee the likely changes of the regional distribution of climate with much accuracy we cannot predict specifically the probable impacts of regional changes. Quantitative assessments of the socio-economic implications of a climate change for specific regions and countries are also not yet possible. Our ability to make more precise assessments of the impacts of global change will only come gradually, as regional predictions of climate change become more reliable.

We can, however, analyze the sensitivity of the environment to a given change of climate and much of what is brought out in the report of the Working Group II should be interpreted in that way. Within the time available to it, Working Group II only had an opportunity to look at the effects associated with scale of change for Scenario A (Business as Usual Scenario).

What we can say with confidence is that the severity of the impacts will depend to a very large degree on the rate of climate change.

> **The Working Group II report concludes that the uncertainty of the regional predictions of climate change at present limits our possibility to assess quantitatively the impacts of such a change. For the time being we rely on sensitivity analyses for the assessment of the likely impacts, which should, however, yield clear qualitative views about the vulnerability of nations to such changes. The uncertainty about the spatial characteristics of regional and local changes of climate must not overshadow the earlier conclusion that a significant change of the global mean temperature is associated with both larger and smaller changes on the regional and local scale.**

A climate change will bring with it both positive and negative impacts, although the negative ones will dominate (cf Working Group II). It is likely that, to a greater or lesser extent, all countries will be affected either directly or indirectly by climate change.

B. Impacts Of Sea Level Rise

A warmer climate will induce a rise of the sea level, largely due to the expansion of sea water when being warmed and the melting of land glaciers. The response of the ice sheets over Greenland and particularly in the Antarctica is more uncertain, since both accumulation (due to change of snowfall) and melting is influenced by a change of climate.

The West Antarctic Ice Sheet is of special concern because a large part of it is grounded far below sea level. However, Working Group I concludes that "within the next century, it is not likely that there will be a major outflow of ice from the West Antarctica due directly to global warming".

Working Group I concludes that under the IPCC Scenario A (Business as Usual Scenario) emissions conditions, there will be an average rate of global mean sea level rise of about 6 cm per decade over the next century (with an uncertainty range of 3-10 cm per decade); this is three to six times faster than that seen over the last 100 years. The predicted rise is about 20 cm in global mean sea level by 2030, and 65 cm by the end of the next century (more detail is shown in Figure 2 below). There will be significant regional variations. Furthermore, even if greenhouse forcing is stabilized, there would still be a commitment to a continuing sea level rise for many decades and even centuries, due to lags in climate, ocean and ice mass responses.

FIGURE 2

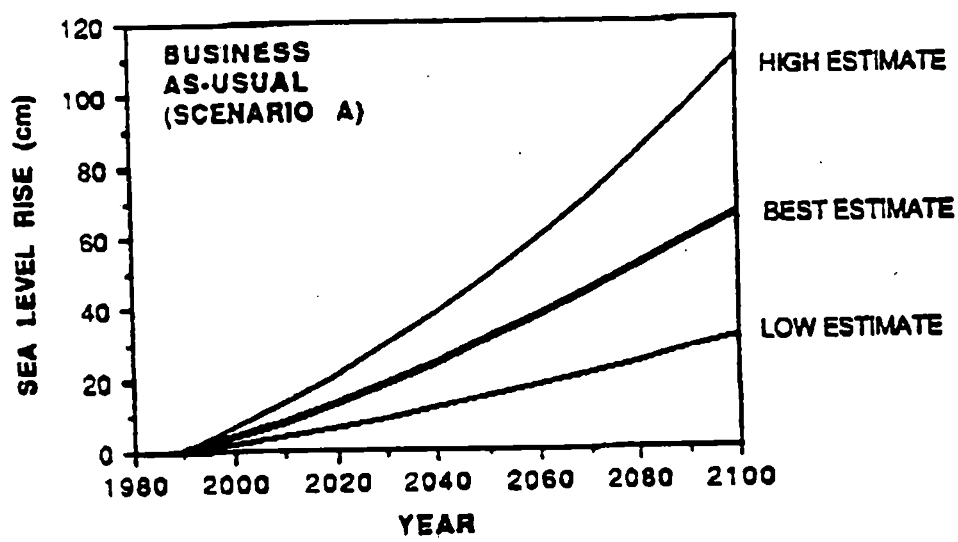


Figure 2. Calculated Sea Level Rise: Scenario A (Business as Usual)

These values are less than those given in earlier assessments, particularly the upper bounds. The lower values do not give rise to an immediate concern except in countries with extensive coastlal low-lying lands and for some island states. Working Group II recommends a more precise assessment of the risks to coastal areas and islands and to living resources caused by a 0.3-0.5 m rise of sea level which might be expected towards the latter part of the next century, if no preventive measures were taken.

A slowly rising mean sea level is not an immediate threat. Increased damage will more likely be experienced during storms, when short term variations of sea level induced by winds and by high waves would cause destructive flooding. Delta regions of major rivers are obviously vulnerable; these are also often heavily exploited for agricultural production.

The rise of sea level might threaten some low island and coastal zones by the middle of the next century. A one meter rise, which is at the upper end of the range of what might occur by the year 2100 as estimated under Scenario A (Business as Usual Scenario), would affect 360,000 km of coastline (Working Group III). In the absence of any adaptive measures, this would render some island countries uninhabitable, displace tens of millions of people, seriously threaten low-lying urban areas, flood productive land, contaminate fresh water supplies and destroy many coastal wetlands. The estimate made by Working Group III shows that the cost of protecting against a 1 m sea level rise (the maximum predicted by Working Group I) amount to $ 500 billion (cumulative to 2100 and undiscounted) or 0.04% of the world GDP.

C. Impacts on Land, Water and Ecosystems

Turning next to the more difficult question of impacts of climate change on land, water and ecosystems, a warmer climate may have many benefits, if precipitation is adequate and the rate of change is slow. However, if precipitation is inadequate or the rate of change is rapid, climate change could have many negative impacts on society, and especially ecosystems. Change in ecosystems could result in a loss of certain plant species.

It is likely, however, that the distribution of precipitation would change and that soil moisture could decrease in some regions. A change of the distribution of climatic zones would probably also occur and be associated with large regional local changes. Some ecosystems might well have difficulties to adjust in this process. The policymakers summary of Working Group II gives a more detailed analysis of the expected impacts in the case of Scenario A (Business as Usual Scenario). Some key features of these impacts as described by Working Group II have been extracted for the present overview.

> "Changes of climate would have an important effect on <u>agriculture</u>, including livestock. Studies have not yet conclusively determined whether on average, global agricultural potential would increase or decrease. Negative impacts could be felt at the regional level" and "there may be severe effects in some regions, particularly decline in production in regions of high present-day vulnerability, that are least able to adjust. These include Brazil, Peru, Sahel, S.E. Asia, Asian USSR and China." "Patterns of

agricultural trade could be altered by decreased cereal production in some of the currently high-production areas." Although not analyzed more specifically, the supply of food would become more vulnerable to disturbances caused by changes of climate in a world with a rapidly growing population.

"The rotation period of <u>forests</u> is long and current forests will mature and decline in a climate to which they are increasingly more poorly adapted. "Major forest-type zones and species ranges in the Northern Hemisphere could shift significantly as a result of climate change." "The most sensitive areas will be where species are close to their biological limits in terms of temperature and moisture", as "for example in semi-arid areas. Social stresses can be expected to increase and consequent damage to forest may occur. These increased and non-sustainable uses will place more pressure on forest investments, forest conservation and sound forest management."

"<u>Natural terrestrial ecosystems</u> would be markedly influenced because the rates of projected climatic change are likely to be faster than the ability of some species to respond. Flora and fauna would lag behind these climatic shifts and could find themselves in a different climatic regime. Major vegetation zones could face severe disturbances and disruptions, influencing plant and associated animal populations". "Species could disappear and lead to substantial reduction in biological diversity". "The socio-economic consequences of these impacts will be significant, especially for those regions of the globe where societies and related economies are dependent on natural terrestrial ecosystems for their welfare. Changes in the availability of food, fuel, medicine, construction materials and income are possible as these ecosystems are changed. Important fibre products could also be affected in some regions."

The <u>direct effects</u> of increased atmospheric concentration of CO_2 may increase plant growth, water use efficiency and tolerance to salinity, which could enhance the growth rates of certain crops and plants. It is not clear how this beneficial effect of CO_2 would be manifested in a farmer's field or in nature. The positive effects could be reduced by ecosystem feedbacks and by enhanced levels of air pollution.

"Relatively small climate changes can cause large <u>water resource problems</u>. In many areas, especially in arid and semi-arid regions and those humid areas where demand or pollution has led to water scarcity." While "many areas will have increased precipitation, soil moisture will decrease in other areas, particularly in those that are "already in marginal situations such as the Sahelian zone in Africa." Increased drought risk represents potentially the most serious impact of climate change on agriculture. "Future design in water resources engineering will need to take possible impacts into account when considering structures with life span to the end of the next century", but necessary analyses are uncertain at present because of the lack of adequate regional predictions.

"Global warming can be expected to affect the availability of water and biomass, both major energy sources in many developing countries. These effects are likely to differ between and within regions with some areas losing and others gaining water and biomass. Such changes in areas which lose water may jeopardise energy supply and materials for human habitation."

"The global areal extent and volume of elements of the terrestrial cryosphere (seasonal snow cover, near-surface layers of permafrost and some masses of ice) will be substantially reduced. These reductions, when reflected regionally, could have significant impacts on related ecosystems and social and economic activities. Compounding these impacts in some regions is that, as a result of the associated climatic warming positive feedbacks, the reductions could be sudden rather than gradual."

It is obviously difficult to judge how serious a climatic change might be to an individual nation, or to humankind as a whole, on the basis of the still largely qualitative findings as given in the Working Group II report.

Means to integrate more quantitatively the implications of these many possible impacts, both positive and negative, are needed. The possible impacts as briefly described call for careful consideration of the consequences of climate change in the development of plans for resource use and management.

D. Impacts on People

Changing climate could affect human settlement and change the geographical distribution of diseases in the world and stimulate a spread of epidemic diseases. The IPCC recognizes the views as expressed by Working Goup II, that

"The most vulnerable human settlements are those especially exposed to natural hazards, e.g. coastal or river flooding, severe drought, landslides, severe wind storms and tropical cyclones. The most vulnerable populations are in developing countries, in the lower income groups, residents of coastal lowlands and islands and of semi-arid zones and grasslands."

"A greater number of heatwaves could increase the risk of excess mortality. Changes in precipitation and temperature could radically alter the patterns of vector-borne and viral diseases by shifting them to higher latitudes and thereby putting large populations at risk." "This could initiate migrations of people, in turn leading to disruptions of

settlement pattern and social instability in some areas."

IV. Reducing Emissions of Greenhouse Gases

A. Scope of the Problem

As pointed out above, anthropogenic emissions of greenhouse gases have given rise to an increase in their atmospheric concentrations in such a manner that their present integrated radiative forcing effect is equivalent to a concentration of carbon dioxide in the atmosphere of about 150% of the pre-industrial concentration. Half of this increase has occurred in less than the last 25 years. Before enquiring what measures to limit future emissions might be justified, it is important to recognize the very major efforts that are required to slow down or to halt climate change.

It is important to clarify first the relative importance of the different greenhouse gases in bringing about a climate change. We need to understand the difficulties that will be encountered in efforts to reduce their emissions and thereby to slow down their rates of increase or ultimately to stabilize their atmospheric concentrations.

Working Group I and III have presented relative contributions to the additional forcing (heating) of the atmosphere during the period 1765 - 1990, 1980 - 1990, and their predicted contributions for the period 2000 - 2025 under Scenario A (Business as Usual Scenario), in percent. These are shown in Table 3 below.

TABLE 3

	1765-1990	1980-90	Scenario A (BaU) 2000-25
Carbon dioxide	61	55	63
Methane	23	15	17
CFC	12	24	7
HCFCs	0	0	8
Nitrous Oxide	4	6	5

(Ozone may be an important contributor, but its effects are difficult to quantify and have not been included above.)

The recent (1980 - 1990) reduction in the proportion of forcing change due to carbon dioxide is primarily due to the very rapid increase in the role of the CFC-gases as forcing agents. Because of the Montreal agreement on limiting the use of CFC-gases, the relative contribution of carbon dioxide will increase throughout the 21st century according to Scenario A (Business as Usual Scenario).

B. Contribution by Sector

For later analysis of possible measures to be implemented it is of interest also to give the relative contributions to the enhanced radiative forcing during the decade of the 1980s and the projected distribution for the period 2000 -2025 by sector (see Table 4 below).

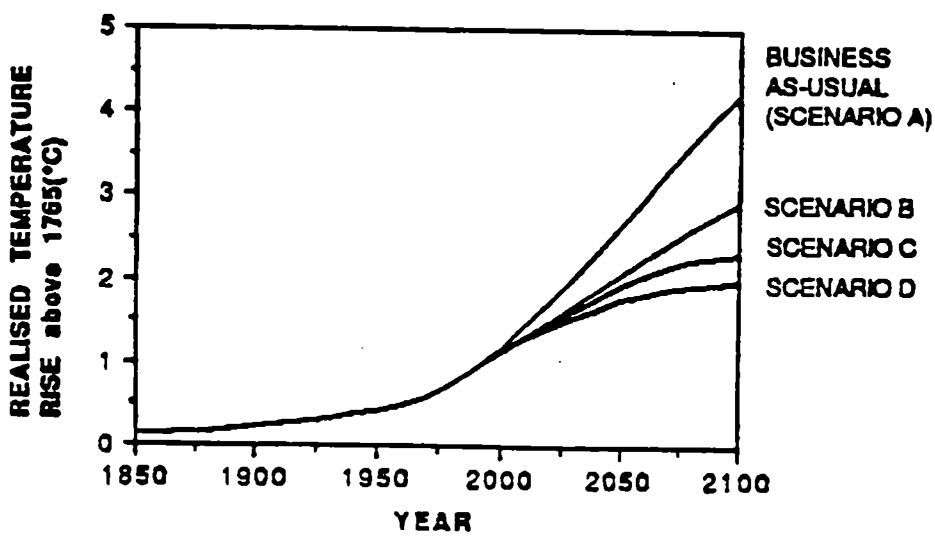
TABLE 4

Sector	Contribution during the 1980s (percent)	Contribution 2000-2025 (percent)
Energy	46	[65]
CFCs	24	[3]
Forestry	18	[15]
Agriculture	9	[14]
Other	3	[3]

C. Climate Change under Controlled Emissions

Under the other Working Group III emission scenarios which assume progressively increasing levels of controls, rates of increase in global mean temperature are projected to be about 0.2°C per decade (Scenario B), just above 0.1°C per decade (Scenario C) and about 0.1°C per decade (Scenario D). Further details are shown in Figure 3 below. Sea level rise by the end of the next century will be between 50% and 70% of Scenario A (Business as Usual Scenario).

FIGURE 3



Only the best estimate of the temperature rise is shown in each case. There is approximately a plus or minus 50 percent uncertainty associated with each of these curves.

D. Limitations on Emissions of Greenhouse Gases

Point #7

All greenhouse gases whose atmospheric concentrations are increasing because of human activities contribute to the enhanced greenhouse effect. It is therefore essential to take a comprehensive approach to reductions in the greenhouse gas emissions, i.e., all such gas emissions (carbon dioxide, methane, nitrous oxide, CFCs, HCFCs, HFC, and ozone and its precursors) should be treated collectively. For this purpose, Working Group I has developed the concept of relative global warming potentials which take into account the relative effectiveness of the different gases as well as the differing times that these gases remain in the atmosphere. Still, the projections of the forcing (heating) due to likely future emissions as given by Scenario A (Business as Usual Scenario) show the expected dominating role of carbon dioxide.

Atmospheric concentrations of the long-lived gases (carbon dioxide, nitrous oxide and the CFCs) adjust only slowly to changes in emissions. Continued rates of growth in emissions of these gases reduces the options for future generations to stabilize at any particular level of concentration. The longer emissions continue to increase at present day rates, the greater reductions would have to be for concentrations to stabilize at a given level. <u>The long-lived gases would require immediate reductions in emissions from human activities by more than 60% in order to stabilise their concentrations at today's levels; methane would require a 15-20% reduction.</u>

There are other technical criteria which may help policymakers to decide, in the event of emissions reduction being deemed necessary, which gases should be considered. Does the gas contribute in a major way to current, and future, climate forcing? Does it have a long lifetime, so earlier reductions in emissions would be more effective than those made later? And are its sources and sinks well enough known to decide which could be controlled in practice? Table 5 below illustrates these factors.

FB pt #7

Sununu pt #3

FB pt # 5

Sununu pT # 6

TABLE 5

GAS	MAJOR CONTRIBUTOR?	LONG LIFETIME?	SOURCES KNOWN?
Carbon dioxide	yes	yes	yes
Methane	yes	no	semi-quantitatively
Nitrous oxide	not at present	yes	qualitatively
CFCs	yes	yes	yes
HCFCs,etc	not at present	mainly no	yes
Ozone	possibly	no	qualitatively

1. Chlorofluorocarbons

FB Point #5

The assessment by Working Group I clearly shows that the CFC-gases are far more effective per kilogramme emitted in heating the atmosphere than any of the other greenhouse gases in today's atmosphere.

The CFCs are already being eliminated to prevent their continued destruction of the stratospheric ozone layer. This action is also an effective measure to slow down the rate of predicted global warming. The CFCs will probably be partially replaced by HCFCs and HFCs, which are weaker greenhouse gases, but every effort should be made to find other replacements which have little or no greenhouse warming potential or ozone depletion potential.

2. Methane, nitrous oxide and ozone

Because the sources of methane, nitrous oxide and ozone are diverse and the quantitative importance of each of their sources are not well known at present, emissions reductions may prove difficult to achieve and the effectiveness of different control strategies hard to evaluate.

Methane emissions arise primarily from agriculture, energy and waste management activities. Nitrous oxide emissions arise primarily from agricultural and forestry-related activities. Tropospheric ozone is predicted to increase due to increased emissions of carbon monoxide, hydrocarbons and nitrogen oxides released mainly by transportation and industrial activities.

Improved monitoring techniques are needed to quantify these emissions and assess the effectiveness of control strategies.

FB# 5

3. Carbon dioxide

Available data indicate that carbon di[illegible]el combustion and deforestation are major and [illegible]of emissions. Carbon dioxide emissions from [illegible]t present 5.5 - 6.0 billion tons of carbon a[illegible]in 1980 from deforestation and changing land use were 0.6 - 2.5 billion tons of carbon annually. Thus, present total anthropogenic emissions are at least 6.5 - 8.5 billion tons of carbon annually. At the current world population of 5.2 billion, current per capita annual carbon emissions are around 1.1 tons from fossil fuel and 0.35 billion tons from deforestation and changing land use.

Sununu pt #6

The emissions due to fossil fuel burning are, however, very unevenly distributed among regions of the world as shown in Table 6:

TABLE 6

Carbon Emissions from Combustion of Fossil Fuels

Year: 1985

	Billion tonnes of carbon per year	Tonnes of carbon per capita & year	Tonnes of carbon per GNP
Global Totals	**5.15**	**1.06**	**23.3**
North America	**1.34**	**5.08**	**19.7**
Western Europe	**0.85**	**2.14**	**18.2**
OECD Pacific	**0.31**	**2.14**	**12.3**
Centr. Planned Europe	**1.33**	**3.19**	**27.9**
Africa	**0.17**	**0.29**	**35.1**
Centr. Planned Asia	**0.54**	**0.47**	**82.8**
Latin America	**0.22**	**0.55**	**28.6**
Middle East	**0.13**	**1.20**	**16.0**
South & East Asia	**0.27**	**0.19**	**39.1**

It is difficult to deduce accurate values for the carbon dioxide emissions due to deforestation and changing land use. It seems clear, however, from the reports by Working Groups II and III that the net emission of carbon dioxide from the tropics due to deforestation amounted to about 1.7 GtC pa (range 0.6-2.5) in 1980. The average emissions per capita in the tropical countries is about 1 ton of carbon per year while some with more intense exploitation of their forests account for a per capita emission that is comparable to that of industrial countries due to fossil fuel emissions.

On the basis of the various emissions scenarios, we project the per capita anthropogenic emissions to the year 2070, assuming that the global population is 10 billion at that time, we arrive at the figures in the following table for the per capita emissions.

TABLE 7

Scenario	CO_2 (TC/capita)	Methane (T/capita)
Scenario A (Business as Usual)	1.8	0.08
Scenario B	0.8	0.05
Scenario C	0.5	0.04
Scenario D	0.3	0.03

Noting that, only under Scenario D is the carbon dioxide concentration stabilized by 2100, and then at a level about 50% above pre-industrial, it is clear from the figures in Table 5 that reducing the rate of change of climate as in Scenarios B and C would be very challenging, even with successful replacement of CFCs by gases with less greenhouse warming potential. To embark on stabilization as occurs in Scenario D after 2050 would clearly be very challenging.

It is important in this context also to compare the possible importance of reducing the rate of deforestation and expanding reforestation. We note first that, at present, the total emissions of carbon dioxide due to human use of the terrestrial ecosystems are about 25% of the total anthropogenic emissions of carbon dioxide into the atmosphere. A major decrease of the rate of deforestation would contribute significantly to slowing down the rate of carbon dioxide increase in the atmosphere, but not stop it.

It has been proposed that a major programme for reforestation should be initiated. The Noordwijk Ministerial Declaration in

November 1989 requested the IPCC to evaluate the effects of an annual net increase in reforestation of 12 million hectares. Working Group I has calculated roughly the transfer of carbon from the atmosphere into the terrestrial biosphere that thereby would be achieved. If such a policy would be maintained for a period of 40 years an area as large as about 50% of the total area of the United States would have been reforested. By 2030, i.e. 40 years from now, 25 to 40 billion tons of carbon would have been sequestered into the terrestrial biosphere. This is about 10% of the emissions of carbon dioxide into the atmosphere that is expected during these periods of time due to fossil fuel burning according to the Busines-as-Usual and the Reference Scenario of Working Group III. The practical difficulties of implementing such a policy have not been analysed by Working Group III.

A reduction of the rate of increase of carbon dioxide in the atmosphere by 5-15% could be achieved if the present rate of deforestation would be reduced to about half of the present rate. In tropical countries this would also contribute to maintaining biological diversity. A major program of reforestation as considered by the Noordwijk Ministerial Conference in November 1989 would play some role in slowing down the rate of increase of carbon dioxide in the atmosphere, but would at most reduce it by 5-10%, if fossil fuel use would continue to increase in accordance with Scenario A (Business as Usual Scenario).

V. Response Strategies for Dealing with Potential Climate Change

The scientific assessment of a possible human-induced climate change, the environmental and socio-economic consequences of such a change, and the difficulties we encounter in attempting to slow down or halt it call for the development of strategies that deal with both the short- and long-term issues. The great diversity in the situation of different countries and their responsibilities for combatting climate change will have to be taken into account in such development. It is clear that this is not going to be a simple undertaking.

With time, we will learn more from further research and monitoring activities, and from experience with implementing limitation/adaptation measures. To take maximum advantage of such growing knowledge and experience, a flexible and progressive approach to addressing climate change is required.

Working Group III has addressed the issue of formulating response strategies. The following subsections are extracts from the policymakers summary of that Working Group.

A. Main Findings of Working Group III

1) Climate change is a global issue; effective responses would

require a global effort which may have a considerable impact on humankind and individual societies.

2) Industrialized countries and developing countries have a common responsibility in dealing with problems arising from climate change.

3) Industrialized countries should take the lead and have specific responsibilities on two levels:

a) Major part of emissions affecting the atmosphere at present originates in industrialized countries where the scope for change is greatest. Industrialized countries should adopt domestic measures to limit climate change by adapting their own economies in line with future agreements to limit emissions;

b) To co-operate with developing countries in international action without standing in the way of the latter's development by contributing additional financial resources, by appropriate transfer of technology, by engaging in close co-operation concerning scientific observation, by analysis and research, and finally by means of technical co-operation geared to forestalling and managing environmental problems.

4) Emissions from developing countries are growing and may need to grow in order to meet their development requirements and thus, over time, are likely to represent an increasingly significant percentage of global emissions. Developing countries should, within the limits feasible, take measures to suitably adapt their economies.

5) Sustainable development requires the proper concern for environmental protection, as the necessary basis for continuing economic growth. Continuing economic development will increasingly have to take into account the issue of climate change. It is imperative that the right balance between economic and environmental objectives be struck.

6) Limitation and adaptation strategies must be considered as an integrated package and should complement each other to minimize net costs. Strategies that limit greenhouse gases emissions also make it easier to adapt to climate change.

7) The potentially serious consequences of climate change on the global environment give sufficient reasons to begin by adopting response strategies that can be justified immediately even in the face of significant uncertainties.

8) A well-informed population is essential to promote awareness of the issues and provide guidance on positive practices. The social, economic and cultural diversity of nations will require tailored approaches.

Because a large, projected increase in world population will be a major factor in causing the projected increase in global greenhouse gases, it is essential that global climate change strategies include strategies and measures to deal with the rate of growth of the world population.

Working Group III has also identified measures at the national, regional and international levels as applicable which, while helping to address the issue of climate change, can yield other benefits in the shorter term.

B. Limitation of Net Emissions from the Energy Sector

The energy sector plays a vitally important role in economic well-being and development for all nations. At the same time, because energy production and use accounts for about one half of the radiative forcing from human activities, energy policies need to ensure that continued economic growth occurs in a manner that, globally, conserves the environment for future generations.

However, there is no single, quick-fix technological option for limiting greenhouse gas emissions from energy sources. A comprehensive strategy is necessary which deals with improving efficiency on both the demand and supply sides as a priority and emphasizes technological research, development, and deployment.

Achieving even a 20% reduction in CO2 from current emission levels would require major changes in global energy markets, plans, and infrastructure, with intervention by governments. Maintaining emissions reductions would require continued technological improvements, structural changes in the global economy, and changes in the proportion of carbon-based fuels utilized over the whole of the next century.

In the energy category, Working Group III especially noted that:

- Improved energy efficiency reduces emissions of carbon dioxide, the most significant greenhouse gas, while improving overall economic performance and reducing other pollutant emissions and increasing energy security;

- Use of cleaner energy and safer sources and technologies reduces carbon dioxide emissions, while reducing other pollutant emissions that give rise to acid rain and other damaging effects.

Working Group III recognizes the particular difficulties which will be faced by countries, particularly developing countries, whose economy is heavily dependent on production and/or export of fossil fuels, as a consequence of actions taken by other countries to limit or reduce energy related greenhouse gas emissions. These difficulties should be taken into account when elaborating international strategies.

Various potential options have been identified for reducing greenhouse gas emissions from energy systems. The most relevant categories of options appear to be:

- efficiency improvements and conservation in energy supply, conversion, and end use;

- fuel substitution by energy sources which have lower or no greenhouse gas emissions;

- reduction of greenhouse gas emissions by removal, recirculation or fixation;

- management and behavioural changes (e.g. increased work in homes through information technology) and structural changes (e.g. modal shift in transport).

The technical potential for energy efficiency savings in a number of these options ranges from 15 to as much as 60% (see the policymakers summary of Working Group III).

The challenge to policy makers is to enhance the continual diffusion of technological options into the market place, to encourage behavioural and operational changes, and to address the broader issues outside the energy sector in order to capture more of the technical potential that exists.

The feasibility of achieving reductions through adoption of a particular option depends on more than its technical potential alone. Important additional factors are its economic potential (economic efficiency and cost effectiveness) and its market potential (the likelihood of consumer acceptance, reflecting attitudes to risk and non-monetary costs).

C. Limitations of Net Emissions from Agricultural and Forestry Activities

Agriculture, forestry and other human activities are also responsible for substantial quantities of greenhouse gas emissions.

About 9 percent of anthropogenic greenhouse gas emissions can be attributed to the agricultural sector. Limitation of emissions from this sector presents a challenge because the processes by which greenhouse gases, in particular methane and nitrous oxide, are released in agricultural activities are not well understood. In addition, response options in the agricultural sector must be designed to ensure maintenance of food supply.

In the short term, reductions can be achieved through improved livestock waste management, altered use and formulation of fertilizers, and other changes to agricultural land use, without affecting food security.

Forestry practices and other human activities associated with land use, such as biomass burning and landfills, account for about 18 percent of anthropogenic greenhouse gas emissions. The forest crisis is rooted in the agricultural sector and in the human need for employment and income. Deforestation will be stopped only when the natural forest is economically more valuable for the people who live in and around the forests than alternative uses for the same land. Useful steps might include:

- o Improved forest management and, where feasible, expansion of forest areas as possible reservoirs of carbon;

- o Possible key elements of a world forest conservation protocol could be identified in the context of a climate convention process;

- o Use of forest products and wood could be strengthened and improved through measures such as substituting a portion of fossil energy sources by wood or other sustainable managed biomass;partial replacement of high energy input materials by wood; further recycling of forest products; and, improved efficiency of use of fuel wood.

D. Limitation by Phasing Out CFCs under the Montreal Protocol

CFCs represent a very important source of greenhouse gas emissions and account for about 25% of the total contributions to the enhanced radiative forcing for the period of the 1980s. Phasing out of CFCs under the Montreal Protocol would remove some of the most powerful and long-lived greenhouse gases, while also protecting the stratospheric ozone layer.

The CFCs are already being eliminated to prevent their continued destruction of the stratospheric ozone layer. This action is also an effective measure to slow down the rate of predicted global warming. The CFCs will probably be partially replaced by HCFCs and HFCs, which are weaker greenhouse gases, but every effort should be made to find other replacements which have little or no greenhouse warming potential or ozone depletion potential.

E. Measures for Adapting to Global Climate Change

In addition to the limitation options discussed above, Working Group III developed options for adapting to potential climate change with respect to coastal zones and resource use management. These options include:

- o Developing emergency and disaster preparedness policies and programs.

- o Assessing areas at risk from sea-level rise and developing comprehensive management plans to reduce future vulnerability of populations and coastal developments and ecosystems as part of coastal zone management plans.

- o Improving the efficiency of natural resource use, research on control measures for desertification and enhancing adaptability of crops to saline regimes.

A programme could begin now to enable developing countries to implement coastal zone management plans by the year 2000. The programme would provide for training of country experts, data collection and technical assistance and co-operation.

F. Implementation Measures

Working Group III also considered several priority areas which must be addressed in order to adequately implement limitation or adaptation responses. These "implementation mechanisms" represent the primary vehicles through which national, regional and international responses to climate can be effected.

1. Public Information and Education

A well informed global population is essential for addressing and coping with an issue as complex as climate change. Because climate change would affect, either directly or indirectly, almost every sector of society, broad global understanding of the issue will facilitate the adoption and implementation of such response options as deemed necessary and appropriate. The dissemination of information also represents a powerful economic instrument for ensuring that markets accurately take into account potential consequences and/or opportunities of climate change.

2. Technology Development and Transfer

The development and transfer of technologies is vital to any effort to address global climate change. The development of new technologies may provide the means by which societies can meet their energy, food, and other needs in the face of changes in global climate, while at the same time minimizing emissions of greenhouse gases.

Technological development, including improvement and reassessment of existing technologies, is needed to limit or reduce anthropogenic greenhouse gas emissions; absorb such gases by protecting and increasing sinks; adapt human activities and resource use and management to the impacts of climate change; and detect, monitor and predict climate change and its impacts.

There is a need for the rapid transfer of technology to the developing countries on a preferential basis, of technologies for addressing climate change. Developing countries are of the view that transfer of technologies on a non-commercial basis is necessary and that specific bilateral and multilateral agreements should be established to promote this. Some other countries where technologies are not owned by the government believe that transfer of technologies would be a function of commercial negotiations. The issue of intellectual property rights also presents a case where international opinion is mixed.

3. Economic Mechanisms

It is important that any potential measures to limit or adapt to global climate change be as economically efficient and cost-effective as possible, while taking into account important social implications.

In general, environmental objectives can be achieved either through regulations requiring the use of a specific technology or attainment of specified goals, or through economic instruments such as emissions fees, subsidies, sanctions, tradeable permits, or a comprehensive approach that might address all greenhouse gases. Market based economic instruments encourage limitations in emissions by those who can achieve them at least cost. Careful and substantive analysis of the implications of such instruments is needed.

Economic instruments, through their encouragement of flexible selection of abatement measures, frequently offer the possibility of achieving environmental improvements at lower cost than regulatory mechanisms. Unlike many regulations, they tend to encourage innovation, efficient use of resources and the development of improved technologies and practices for reducing emissions. Economic mechanisms also have the potential to provide the signals necessary for more environmentally sensitive operation of markets. It is unlikely, however, that economic instruments will be applicable to all circumstances.

4. Financial Mechanisms

Both the industrialized and developing countries recognize that in order that the developing world can play its full part in the international response to climate change, the industrialized countries will need to support them through adequate financial mechanisms.

Financial resources channelled to developing countries would be most effective if focused on those activities which contribute both to limiting greenhouse gas emissions and promoting economic development. Areas for cooperation and assistance could include:

- o Efficient use of energy resources and the use of fossil fuels with lower greenhouse gas emission rate or non-fossil sources;
- o Rational forest management practices and agricultural techniques which reduce greenhouse gas emissions;
- o Facilitating technology transfer and technology development;

- Establishing and upgrading regional environmental research centres to assist regions with common cultures and environmental problems to develop indigeneous technology and expertise and to conduct environmental education programmes to tackle those problems in a manner appropriate for the region;

- Measures which enhance the capacity of developing countries to develop programs to address climate change, including research and development activities and public awareness and education;

- Participation by developing countries in international fora on global climate change, such as the IPCC.

5. Legal Measures

The measures noted above would require a high degree of international cooperation, with due respect for national sovereignty of states. To assist in that process, international negotiation on a framework convention on climate change should start as quickly as possible after the completion of the IPCC First assessment Report. This, together with any additional protocol(s) that might be agreed upon, would provide a firm basis for effective cooperation to act on greenhouse gas emissions and to adapt to any adverse effects of climate change.

The framework convention should recognize that developing nations will have to achieve an improved level of economic development in order for them to participate meaningfully in global warming response. Consequently the framework convention should be structured in such a way as to encourage actions which serve to narrow the "poverty gap" and should recognize a minimum level of economic development below which response options will not be expected.

The framework convention should, at a minimum, contain general principles and obligations. It should be framed in such a way as to gain the adherence of the largest possible number and most suitably balanced range of countries while permitting timely action to be taken.

Working Group III compiled a list of possible elements for a framework convention. The Working Group considered in some detail the key issues that would need to be considered in negotiating such a convention; these include:

- the political imperative of striking the correct balances (a) between the arguments for a far-reaching, action-oriented convention and the need for urgent adoption of a convention so as to begin tackling the problem of climate change; and (b) among the risks of inaction, the costs of action and current levels of scientific uncertainty;

- the extent to which specific obligations, particularly on the control of emissions of greenhouse gases, should be included in the convention itself, possibly as annexes, or be the subject of a separate protocol(s);

- the timing of negotiation of protocol(s) in relation to the negotiations on the convention;

- the introduction as appropriate of sound scientific bases for establishing emission targets (such as total emission levels, per capita emissions, emissions per GNP, emissions per energy use, climatic conditions, past performance, geographic characteristics, fossil fuel resource base, carbon intensity per unit of energy, energy intensity per GNP, socio-economic costs and benefits or other equitable considerations);

- the extent to which specific goals with respect to global levels of emissions or atmospheric concentrations of greenhouse gases should be addressed;

- whether obligations should be equitably differentiated according to countries' respective responsibilities for causing and combatting climate change and their level of development;

- the need for additional resources for developing countries and the manner in which this should be addressed, particularly in terms of the nature, size and conditions of the funding, even if detailed arrangements form the subject of a separate protocol;

- the basis on which the promotion of the development and transfer of technology and provision of technical assistance and co-operation to developing countries should take place, taking into account considerations such as terms of transfer (preferential or non-preferential, commercial or non-commercial), assured access, intellectual property rights, the environmental soundness of such technology, and the financial implications;

- the nature of any new institutions to be created by the convention (such as a Conference of the Parties, an Executive Organ, as well as other bodies), together with their functions, composition and decision-making powers, e.g., whether or not they should exercise supervision and control over the obligations undertaken;

- the criteria, timing, legal form and incidence of any obligations to control the net emissions of greenhouse gases.

VI. Strategies for the future

A. The major dilemmas

The conclusions of Working Group I show clearly that the scientific community agrees on the climate changes that could occur if the present build-up of greenhouse gas emissions continues into the next century as projected by both the Scenario A (Business as Usual Scenario) and the Reference Scenario of Working Group III. Working Group II envisages potentially far-reaching environmental consequences of such changes. This threat to the global environment and its implications for countries and the peoples of the world must be weighed against the costs and other socio-economic implications for limiting, and/or adapting to, any adverse effects of climate change. It is, therefore, essential to address a few fundamental questions in this context.

The developed countries have emitted most of the greenhouse gases into the atmosphere that now cause us concern. The developing countries are rapidly increasing their emissions in striving for improving their living standards, particularly by increasing their use of fossil fuels as the prime source of energy. Cheap energy has in the past contributed substantially to the rapid increase of the standards of living in industrialized countries. They possess the knowledge and the human and financial resources to develop the necessary means to combat climate change. Recognizing the poverty that prevails among the populations of developing countries, it is natural that fight against poverty and achieving economic growth is given priority by them. Narrowing the existing economic, scientific and technological gap between the industrialized and the developing countries is a prerequisite for a full partnership of all nations of the world in the development of a strategy to deal with the climate change issue.

A rapidly increasing world population will mean greater demands for resources in general and energy in particular. Management of the world's natural resources is also closely linked to the climate change issue. It is obvious, that all these and other global issues have to be addressed simultaneously.

The climate change issue is a long term, evolutionary issue. We are not able to foresee its long term consequences very well yet nor will we be able to do so soon. However, scientific data indicate that at present the atmospheric concentrations of carbon dioxide and methane are on their way to reaching values well outside the range that has prevailed for more than 100,000 years. It seems prudent, then, to consider that an unlimited growth in the concentrations of greenhouse gases in the atmosphere is not acceptable. Although stabilization of the greenhouse gas concentrations in the atmosphere is ultimately a necessity, we cannot as yet determine at what levels they should be stabilized or the costs of such stabilization.

In order to develop a strategy for the future, a great deal more work needs to be done. The report of Working Group III spells out the work required to assess both the social and economic costs of climate change as well as the costs and consequences of the measures required to limit climate change.

International agreements are necessary in order both to promote well-balanced international development of the world economy and to safeguard the global environment. This applies particularly when confronted with as complex and global an issue as that of climate change. If individual countries can optimize their benefits by letting other countries share their costs (i.e. pay for pollution) without they themselves taking the necessary precautions (reducing pollution), the economy of the total system becomes unstable and a catastrophic development may occur ("the law of the commons"). We must also recognize the vast differences in economic strength between the players on the international scene, i.e., the nations and the large multinational companies in the world. The fundamental question becomes: How can a sustainable and improving future for the developing countries i.e., for three quarters of humanity, as well as for the industrial countries, be achieved faced with the potential threat of climate change?

It is also clear that specific proposed preventive actions will have widely varying effects on different countries. At present fossil fuels account for 80 - 85% of the primary energy supply in the world, but different countries are very differently dependent on their use. Producers and users of fossil fuels will experience restrictions on the emissions of greenhouse gases into the atmosphere very differently.

Many developing countries have extensive plans for using fossil fuels to meet their increased energy demands for development. The infrastructure of most countries to a large extent has been based on a fossil-fuel driven transport system.

Deforestation is in part an expression of the need to expand agriculture or of the dependance on forest products for export. Measures to limit methane production in wet-land agriculture may imply major changes of traditional management practices with unpredictable consequences for the farmers involved. Any plan for combatting man-induced climate change must carefully consider these and many other concerns that will be faced by the world's countries. It is not surprising that controversies arise about as complex an issue as the present one, in particular when the detailed understanding of the likely problems is as yet incomplete. A major dilemma is that actions may be required well before many of these specific issues can be resolved.

B. Elements of a strategy and an action programme

The complexity of the problem as outlined above based on the detailed reports of the IPCC Working Groups, means that agreements on necessary actions will not be easy to reach. Working Group I has concluded that "the longer emissions continue to increase at present day rates, the greater reductions would have to be for concentrations to stabilize at a given level".

> **The IPCC emphasizes that, because of the very long response times of the atmosphere, climate and society, despite scientific uncertainties in the magnitude and timing of climate change, it would be prudent to initiate negotiations on a framework convention on climate change as soon as possible.**

1. Actions That Could Be Taken Now

It is clear from the report of Working Group III that there are a number of actions which would be beneficial for other environmental reasons and which would cost comparatively little or even in some cases be associated with savings. These deserve attention now. An action program to take advantage of such possibilities has been called a "no regrets policy" defined as a policy of taking "measures in the shorter term which while helping to tackle climate change also yield other benefits". Measures of this kind considered by Working Group III are summarized in a previous section of this overview. Economic analyses are needed to confirm and to better understand the other benefits that such measures might yield.

> **IPCC confirms that such measures would, if widely used, significantly slow down the further increase of greenhouse gas concentrations in the atmosphere. Options for such measures at the national, regional and international levels include:**

- **CFC controls to include resticted use of greenhouse active alternatives,**
- **use of safe and clean energy sources with lower emissions of greenhouse gases,**
- **improved energy end use efficiency,**
- **improved forest management and where feasible expansion of forest areas,**
- **review of agricultural practices aiming at reduced greenhouse gas emissions.**

More elaborate descriptions of these are given in earlier sections of this report.

> **IPCC further believes that individual nations, or groups of nations, should consider actions to stabilize emissions in order to reduce the rate of increase in net global emissions and thus limit acceleration of greenhouse gas concentrations in the atmosphere. Such initiatives may accelerate progress towards international agreements.**

2. Need for A Phased Strategy in The Longer Term

Anticipating the outcome of negotiations for general agreements on a convention, it is important to explore how long term targets and policies can be defined.

Because existing information is inadequate to understand what rate of change of greenhouse gas emissions, and potentially, of climate might be acceptable, there is a need for a phased approach.

> **The IPCC considers that it is essential to increase work on defining criteria which would reflect the impacts of climate change and their costs on the one hand, and the costs and practicalities of net reductions in emissions and/or adaptation to climate change on the other. Such criteria would be evolutionary; they should take into account what might be an acceptable level of climate change and reflect the changes in our scientific and economic understanding and technological capabilities.**

In the light of the importance of understanding better the economics of the greenhouse gas issue,

> **the IPCC recommends that research on the international economic implications of the global climate issue be intensified, with particular regard to the specific circumstances of individual countries as well as the broad generic differences between industrialized and developing countries. Governments may consider developing mechanisms by which the international market can find optimal means to recognize the implicit climate change cost of human activities without hampering sustainable development, and in this regard, should fully evaluate social and economic consequences of such mechanisms.**

Working Group III also emphasizes in this context the importance of public information and education.

> **IPCC supports the view that because climate change would affect, either directly or indirectly, almost every sector of society, and also because important policy responses will have to be developed against a background of uncertainty, broad global understanding of the issue will facilitate the adoption and the implementation of such response options as deemed necessary and appropriate. Further efforts to achieve this understanding are urgently needed.**

VII. The Special Circumstances of the Developing Countries

It is obvious that the impact on and the participation by the developing countries in the further development of a future strategy is essential. The IPCC has addressed this specific issue by establishing a Special Committee on the Participation of Developing Countries. This subsection summarizes the findings on the issue.

Although emissions of greenhouse gases are increasing in developing countries, where about 75% of the world population lives, they currently emit only about 25% of the world total. Their per capita emission is about a tenth of that in the industrialized world.

Industrialized countries and developing countries have a common responsibility in dealing with the adverse effects of climate change, taking into account not only the past and present responsibility of the industrialized world in the accumulation of greenhouse gases but also the present technological, human and financial capacities of the industrialized countries. An acceptable standard of living in the developing countries needs to be achieved before a developing country can be expected to participate fully in addressing issues related to climate change. Industrialized nations should assign high priority for reduction of their own emissions of greenhouse gases as well as financial support of actions within the developing world to reduce future emissions. Such support should emphasize meaningful ecnomic development which leads to increased viability and sustainability of development within developing nations. In this context,

a) Industrialized countries should take the lead and have specific responsibilities on two levels:

i) To adopt domestic measures to limit greenhouse gas emissions by adapting their own economies in line with relevant future international agreements;

ii) To cooperate with developing countries in international action without standing in the way of the latter's development by contributing additional financial resources, by appropriate transfer of technology, by engaging in close cooperation concerning scientific observation, by analysis and research, and finally by means of technical cooperation geared to forestalling and managing environmental problems;

b) Emissions from developing countries are growing and need to grow in order to meet their development requirements. Thus, over time, they are likely to represent an increasingly significant percentage of global emissions. Developing countries should, within the limits feasible, take measures to suitably adapt their economies.

Against this background, IPCC requested its Special Committee to identify factors inhibiting the full participation of the developing countries in IPCC and recommend remedial measures where possible. The Committee stresses that full participation includes not only the physical presence at meetings but also the development of national competence to address all issues of concern such as the appreciation of the scientific basis of climate change, the potential impacts on society of such change and evaluations of practical response strategies for national/regional applications.

The factors identified by the Special Committee are:

*insufficient information;
*insufficient communication;
*limited human resources;
*institutional difficulties;
*limited financial resources.

On some of these factors, the IPCC Working Groups have developed policy options which are to be found in their respective reports. The Special Committee itself has made a number of specific recommendations including the development of specific programmes of action; these are to be found in its report. The implementation of the recommendations and appropriate policy options will require commitment of financial resources and mechanisms.

Financial resources channelled to developing countries would be most effective if focused on those activities which contribute both to limiting greenhouse gas emissions and/or adapting to any adverse effects of climate change, and promoting economic development. Areas for cooperation and assistance could include:

- o Efficient use of energy resources and the use of fossil fuels with lower greenhouse gas emission rate or non-fossil sources;
- o Rational forest management practices and agricultural techniques which reduce greenhouse gas emissions;
- o Facilitating technology transfer and technology development;
- o Measures which enhance the capacity of developing countries to develop programs to address climate change, including research and development activities and public awareness and education;
- o Participation by developing countries in international fora on global climate change, such as the IPCC.

It was recognized that cooperation and assistance for adaptive measures would be required, noting that for some regions and countries, adaptation rather than limitation activities are potentially most important.

The IPCC concludes that the recommendations of the Special Committee need not and should not await the outcome of future negotiations on a climate convention. It appeals to the multilateral and bilateral funding organizations to implement the recommendations. It further appeals to the governments for continuing and increased contributions to the IPCC Trust Fund on an urgent basis.

VIII. Future IPCC Activities

Periodic reassessments of the climate change issue will be necessary while the process of developing agreements on international actions continues.

IPCC points out that there is no need to establish new international mechanisms or programmes and that, in general, future work of IPCC should rely more extensively on the climate-related research and monitoring capabilities and expertise of existing international organizations and their programmes. Close liaison should be maintained with all relevant programmes, and particularly the World Climate Programme, to ensure that maximum inputs from them are made to the IPCC assessments. In this context, IPCC calls for increased financial support and other assistance in kind for national activities that contribute to such programmes.

Further, the programmes of research and monitoring will require unprecedented international co-operation and inter-agency co-ordination, with programmes such as the World Climate Research Programme of WMO and ICSU, World Climate Impacts Programme of UNEP, the International Geosphere Biosphere Programme of ICSU and the relevant programmes of OECD playing vital roles.

A. Science and Impacts

Another full new assessment of the science and impacts of climate change will probably not be required until 1995. Nevertheless, first revisions in areas of major quantitative progress and greatest uncertainty should be made by 1992. In addition, an ad hoc capability should be established to respond to scientific and socio-economic impacts questions which may arise from negotiations for a convention on climate change.

B. Response Stategies

With respect to the further development of response options, there is a pressing need to increase the participation of the developing and Eastern European countries in such development. Analyses of the economic consequences of response options and their relative effectiveness in promoting efforts to limit or adapt to climate change is a major theme that needs to be addressed. Also, efforts at collecting information on current and future sources of greenhouse gas emissions, limitation and adaptation strategies and relevant technology development programmes need to be initiated and strengthened.

C. Special Circumstances of the Developing Countries

Programmes of action should be formulated, without awaiting the outcome of the planned negotiations on actions to address climate change, to promote more effective participation by the developing countries in IPCC and other climate-change-related activities. Such programmes should be specific with regard to action items, implementation schedules and identification of requisite resources and institutions.

Reference 1: Report of the First Session of the WMO/UNEP Intergovernmental Panel on Climate Change, IPCC-1, Geneva, 9-11 November 1988.

FIGURE A.2

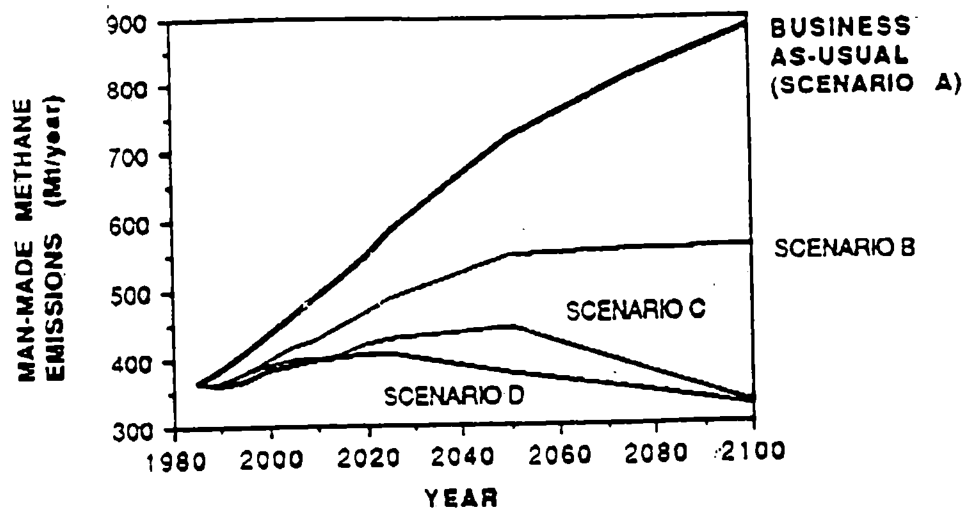


Figure A.2. Projected Man-Made Methane Emissions (ME/Year)

Figure A.2 is consistent with Table 2.

Scenario B (Low Emissions Scenario) assumes the energy supply mix of fossil fuels shifts towards natural gas, large efficiency increases are achieved, deforestation is reversed and emissions of CFCs are reduced by 50% from their 1986 levels. This results in an equivalent doubling of carbon dioxide by about 2040.

Scenario C (Control Policies Scenario) assumes a shift towards renewable energies and safe nuclear energy takes place in the latter part of the next century, CFC-gases are phased out and agricultural emissions (methane and dinitrogen oxide) are limited; an equivalent doubling of carbon dioxide will occur in about 2050.

Scenario D (Accelerated Policies Scenario) assumes a rapid shift to renewable energies and safe nuclear energy takes place early in the next century, stringent emission controls in industrial countries and moderate growth of emissions in developing countries. This scenario stabilizes equivalent carbon dioxide concentrations at about twice the pre-industrial levels towards the end of the next century.

Under the Reference Scenario which deals only with CO_2, global emissions of CO_2 grow from 5.15 billion tonnes carbon (BtC) in 1985 to 7.30 BTC in 2000 and 12.43 BTC in 2025. Primary energy demand more than doubles between 1985 and 2025 with an average growth rate of 2.1%. The per capita emissions in the industrialized countries increase from 3.1 tonnes carbon (TC) in 1985 to 4.7 TC in 2025; for the developing countries, they rise from 0.4 TC in 1985 to 0.8 TC in 2025. This scenario was developed from the National Case Studies and other data submitted to the Energy and Industry Subgroup (EIS) of Working group III.

DRAFT OVERVIEW AND CONCLUSIONS

List of acronyms and chemical symbols

BaU	Business as Usual Scenario. Same as Scenario A ofWorking Group III
Bt	Billion (1000 million) tonnes
BTC	Billion (or 1000 millions) tonnes Carbon
CFCs	Chlorofluorocarbons
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
EIS	Energy and Industry Subgroup of Working Group III
GHG	Greenhouse Gas
GDP	Gross Domestic Product
GNP	Gross National Product
GtC	Gigatonnes (10^9 tonnes) carbon
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
IPCC	Intergovernmental Panel on Climate Change
ICSU	International Council of Scientific Unions
Mt	Megatonnes (10^6 tonnes)
N_2O	Nitrous oxide
NGOs	Non-Governmental Organizations
NOx	Nitrogen oxides
O_3	Ozone
OECD	Organization for Economic Cooperation and Development
pa	per annum
ppm	part per million
TC	Tonnes Carbon
Tg	Teragrams (10^{12} grams)
UN	United Nations
UNEP	United Nations Environment Programme
WMO	World Meteorological Organization

FB

Point #4

APPENDIX

EMISSIONS SCENARIOS

Scenario A (Business as Usual Scenario) assumes that few or no steps are taken to limit greenhouse gas emissions. Energy use and clearing of tropical forests continue and fossil fuels, in particular coal, remain the world's primary energy source. The Montreal Protocol comes into effect but without strengthening and with less than 100 percent compliance. Under this scenario, the equivalent of a doubling of pre-industrial CO_2 levels occurs, according to Working Group I, by around 2025.

Working Group III has developed three other scenarios. All of these four scenarios assume the same global economic growth rates taken from World Bank projections, and the same population growth estimates taken from UN studies. The anthropogenic emissions of carbon dioxide and methane from these scenarios are shown in the Figures below.

FIGURE A.1

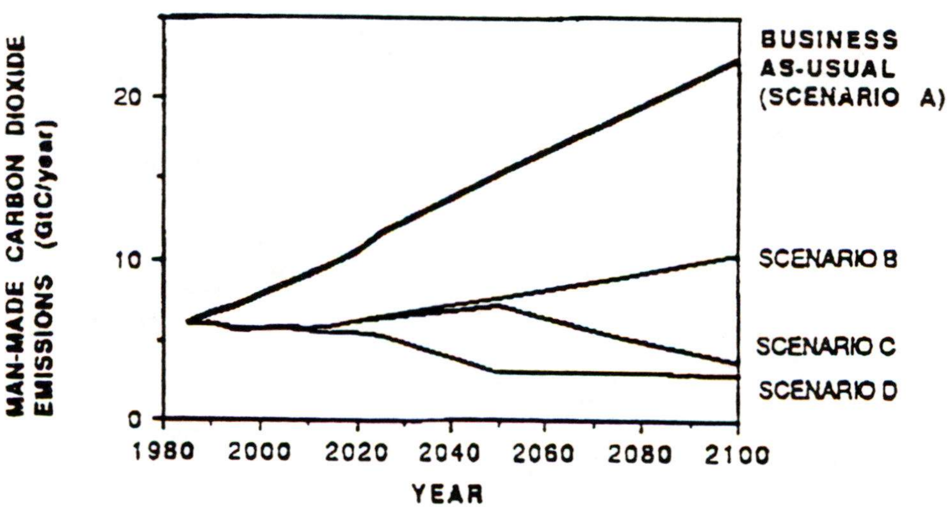


Figure A.1. Projected Man-Made CO_2 Emissions (GEC/Year)

Significant Upcoming Meetings/Events

AUGUST

Aug. 24-25	Open-Ended Orientation Meeting of the Special Committee on Developing Country Participation, Intergovernmental Panel on Climate Change. Sundsvall, Sweden
Aug. 27-30	Fourth Plenary, Intergovernmental Panel on Climate Change (IPCC), Sundsvall, Sweden

SEPTEMBER

xxx	IMF/World Bank Conference, Washington, D.C.
Sept. 3-14	U.N. Conference on Least Developed Countries, Paris
Sept. 6	Opening of Regional Environment Center, Budapest
Sept. 6-7	DOD Conference on our Nation's Defense and the Environment, Washington, D.C.
Sept. 18-19	U.S.- EC Environment Bilaterals, Brussels
Sept. 19-21	TFAP Steering Committee, Rome
Sept. 24-26	Organizational Meeting of Government Representatives to Prepare for Negotiations on a Framework Convention on Climate Change, Geneva
Sept. 24-28	FAO Committee on Forestry, Rome
Sept. 27-29	Prepcom for Second World Climate Conference, Geneva
Sept.-Dec.	U.N. General Assembly, New York

OCTOBER

Oct. 10-16	ESCAP Ministerial Conference on the Environment in Asia and the Pacific (Prepcom 10-13, Ministerial 15-16)
Oct. 15-16	Ministerial Conference on Environment and Development in Asia and the Pacific, Economic and Social Commission for Asia and the Pacific (ESCAP), Bankok
Oct. 4-6	International Workshop "Global Warming: the Problem and the Economic Response," (held under aegis of Italian Government), Rome
Oct. 19-21	Executive Committee for Montreal Protocol Financing Mechanism, Montreal
Oct. 29-Nov. 3	Technical Portion, Second World Climate Conference, Geneva

NOVEMBER

Nov. 6-7	Ministerial Portion, Second World Climate Conference, Geneva
Nov. 13-29	9th ITTO Council Session, Yokohama

DECEMBER

Dec. 10-14	TFAP Advisors Meeting, Helsinki
XXX	IPCC/OECD Workshop on Economic Instruments (tentative)

1991

Jan. 30-31	OECD Environmental Ministerial, Paris
Feb. 1	Joint OECD Environment/DAC Ministerial, Paris
Feb. 4-8	Negotiations on a Framework Climate Convention, Washington, D.C.
Feb. 20-21	Pacific Rim Conference on Sustainable Development, Seattle
March	Second Prepcom Meeting, 1992 UNCED

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Thurs 4pm

CLIMATE CHANGE POLICY PROSPECTUS

4th IPCC Plenary (Sundsvall, Sweden Aug. 26-?)

Agenda:

- o Approve final IPCC report ("Policymakers Summary")
- o Future workplan of IPCC (and structure of IPCC?)

Issues:

- o Science (Bernthal letter to Bolin of 7/5/90):
  - -- Uncertainties;
  - -- Natural vs. anthropogenic fluxes;
  - -- Comprehensive approach (sources and sinks)
  - -- "Emissions Scenarios"
- o Legal issues--comprehensive approach
- o Extraneous material (e.g. "tragedy of the commons"; world poverty, etc. etc.) Possible remedy: Chairman's introduction.
- o Material for IPCC summary to be drawn directly from Working Group summaries?
- o Publication of Working Group I (Science) Report (Bernthal letter to Bolin of 8/3/90)
- o Key, "fall-on-sword" issues for U.S.?

UNEP-WMO Preparations for Convention Negotiations (Geneva, Nairobi)

Agenda:

- o Organizational meeting on conduct ("means and modalities") of negotiations (Sept. 24, Geneva)
- o U.S. hosts first negotiation, Feb. 4-8 1991 (location? cost? U.S. role?)

Issues (procedural and substantive):

- o Format & procedure in negotiations (previous similar negotiations tightly controlled by UNEP D-G Tolba)

- o Level of negotiators; U.S. negotiator? Chair? Secretariat?
- o Structure of convention: Strictly framework (per Geneva Convention on stratospheric ozone) or other?
- o The "slippery slope": U.S. to date has agreed only to convention provision for subsequent consideration of protocols, but has U.S. implicitly agreed to a "comprehensive" protocol?

Second World Climate Conference (Oct. 29-Nov. 7):

Agenda:

- o Scientific meeting, including IPCC report
- o Political ("Ministerial" meeting)--Noordwijk-II

Issues:

- o U.S. representative at ministerial--level??
- o Draft resolution for ministerial meeting

Forestry Convention

Issues:

- o Separation from IPCC negotiation
- o How to be handled by USG?

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*Through January 20, 1989

6 July 1990

The Honorable D. Allan Bromley
Assistant to the President for Science and Technology
The White House
Washington, D.C. 20506

Dear Allan,

As you are aware, the Carnegie Commission on Science, Technology, and Government was established in 1988 to seek ways in which the branches of the U.S. government can encourage and better use the contributions of the nation's scientists and engineers.

In early June the Commission convened a workshop to examine "International Environmental Organizations: The Science and Technology Dimensions." This meeting was designed to study, in depth, the institutional issues raised at the recent "White House Conference on Science and Economics Related to Global Change."

Workshop participants took particular note of the June 1992 United Nations ministerial Conference on Environment and Development to be held in Brazil. As a result, the co-chairs of the workshop have prepared a letter, attached here, which recommends three near-term actions by the U.S. government. These are:

1) appointment of a Special Ambassador for the 1992 Brazil Conference to oversee the complex U.S. efforts required to be successful at the meeting;
2) appointment of a Presidential Commission (or comparable body) for the Conference to synthesize data and concepts for the U.S. position; and
3) appointment of a Public Advisory Committee to the Special Ambassador to enhance dialogue among industry, universities, and citizens with the government on issues relating to the Conference.

The workshop participants believe that such actions could greatly facilitate the process of analysis and consultation needed to organize a unified U.S. position for this important meeting and to relay recommendations to the President for consideration. We understand that the Office of Science and Technology Policy is working with the Council on Environmental Quality, the Department of State, and other agencies in the preliminary preparation for Brazil. Thus, we bring the suggested actions to your attention. If the Workshop participants are correct, it would be desirable to take actions, in concert with the Congress, before the end of 1990, so that the mechanisms can be most effective.

Our Carnegie group would be pleased to meet with you and other officials to share detailed views relating to this matter.

Respectfully yours,

William T. Golden

William T. Golden   Joshua Lederberg

6 July 1990

Mr. William T. Golden
Dr. Joshua Lederberg
Co-Chairmen, Carnegie Commission
on Science, Technology, and Government
10 Waverly Place
New York NY 10003

Dear Bill and Josh,

As co-chairmen of the meeting, we are pleased to report a successful Workshop of the Carnegie Commission on the subject of "International Environmental Organization: The Science & Technology Dimensions" at The Rockefeller University, June 4-6, 1990. The detailed findings of the Workshop will be conveyed to you later this summer.

During the course of our discussions, an important issue emerged that calls for early consideration. Our attention was drawn to the UN Conference on Environment and Development to be held in Brazil in June, 1992. Major recent studies have provided convincing evidence that the linkage between environment and development is now so compelling that the two very complex and important topics often need to be considered together. Decisions of lasting significance with regard to international institutions and decision-making processes bearing on both the quality of the global environment and the strategies for economic growth could be made in connection with the Conference.

The UN has appointed an outstanding Secretary General, Maurice Strong of Canada, for the Conference and established a Preparatory Committee to develop the agenda and supporting papers. A demanding schedule of international and regional meetings has been set by the Preparatory Committee for the next two years. Several scientific organizations in the United States (for example, the American Association for the Advancement of Science, American Association of Engineering Societies, Social Science Research Council, Consortium of Social Science Associations, the Council of Scientific Society Presidents, and Sigma Xi) have banded together to elicit and integrate the views of the scientific community in this country on these issues. There has been a call from the recent ministerial-level conference in Bergen, Norway, supported by influential scientists from many nations, for a "Science Summit" on environment and development that would be held only a few months before the 1992 Brazil Conference.

Our Workshop members agreed that it is a matter of prime importance that the United States be well prepared for the Brazil Conference. Several of the attendees were involved in similar preparatory work for other UN conferences, such as that on the Environment held in Stockholm in June, 1972, and on Science and Technology for Development held in Vienna during

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August 1979. The strong and persuasive national position developed by the United States was a factor in the success at Stockholm. An experienced delegation coped well with the contentious problems faced in Vienna. Our Workshop participants were unanimous in the conviction that lessons from the past show that more activity in regard to the Brazil Conference is desirable, both within the government and in its interactions with the outside community. Several actions should be considered, as a matter of urgency, to assure a dynamic and creative participation by our country. We recommend the following:

1) The President should appoint a Special Ambassador to work with the Secretary of State and other high level officials to oversee policy planning and development of a unified U.S. government position for the Conference on Environment and Development. This Special Ambassador should be provided with adequate funds and staff to support careful preparation of papers outlining options for the U.S. position. To be effective, the initial papers should be in hand no later than 1 September 1991. Accordingly, the Ambassador should be appointed by the fall of 1990, this year.

2) The President and the Congress should establish a Presidential Commission (or comparable body) on the UN 1992 Conference on Environment and Development to provide and help synthesize a wide range of data and views from governmental and nongovernmental sources in order to assist the State Department and other federal agencies involved in the planning process. To assure an appropriate diversity of perspectives, the President and Congress should appoint individuals from the Congress, the Executive Branch, industry, labor, environmental organizations, the scientific and engineering community, and other professionally expert and concerned groups to serve on the Commission. Selected members of the Commission would later serve as members of the U.S. delegation to the Conference and would thus be well-prepared to represent the U.S. position. For the 1972 Stockholm Conference, Senator Howard H. Baker, Jr. of Tennessee served as chairman of the comparable advisory group. Having a distinguished and knowledgeable sitting member of the Congress lead the group worked exceptionally well.

3) The Secretary of State in consultation with appropriate federal officials[1] should appoint a larger Public Advisory Committee to work with the Ambassador in preparing for the Conference. The Committee would serve to assure broad public dialogue in the U.S., through regional conferences and other means, on the issues the Conference will address.

* * * * * * * * * * * * *

1 These include the Assistant to the President for Science and Technology, the Chairs of the Councils of Economic Advisors and Environmental Quality, the Secretary of Energy, the Secretary of the Treasury, the Administrator of the Environmental Protection Agency, the Administrator of the Agency for International Development, the Under Secretary of Commerce for Oceans and Atmosphere, and the Director of the National Science Foundation.

We urge you to bring these considered recommendations to the attention of the President, key White House officials, the Secretary of State, and such other individuals in the executive and legislative branches whom you feel must be informed now. We note that the steps recommended are ones that traditionally have been taken by the U.S. government in preparing itself for world conferences of major potential significance, such as the 1972 Stockholm Conference and the 1979 Vienna Conference.

As agreed at the Workshop, this letter has been prepared in consultation with Harvey Brooks, Rodney W. Nichols, Walter A. Rosenblith, and H. Guyford Stever, members of the Commission and its international steering group who participated in the Workshop, and has their full agreement. A list of all the Workshop participants is attached.

We join in commending you for your initiative in bringing the participants of our Workshop together and look forward to discussing with you our conclusions on a range of issues during the months ahead.

Sincerely yours,

Jesse H. Ausubel Thomas F. Malone

cc. Workshop participants

"International Environmental Organization: The S&T Dimensions"
Workshop, The Rockefeller University, New York, NY
June 4-6, 1990

Participants:

John F. Ahearne, Sigma Xi
Jesse H. Ausubel, Carnegie Commission on Science, Technology, and Government
D. James Baker, Joint Oceanographic Institutions
Richard E. Benedick, World Wildlife Fund/ The Conservation Foundation
Harvey Brooks, John F. Kennedy School of Government, Harvard University
William C. Clark, John F. Kennedy School of Government, Harvard University
Richard E. Hallgren, American Meteorological Society
Philip W. Hemily, National Research Council
John A. Knauss, National Oceanic and Atmospheric Administration
J. W. M. La Riviere, Institute for Hydraulic & Environmental Engineering, Netherlands
Jeffrey Laurenti, UN Association of America
James R. Mahoney, National Acid Precipitation Assessment Program
Thomas F. Malone, St. Joseph's College
Rodney W. Nichols, The Rockefeller University
William A. Nitze, Environmental Law Institute
John S. Perry, National Research Council
Peter H. Raven, Missouri Botanical Garden
Walter A. Rosenblith, Massachusetts Institute of Technology
H. Guyford Stever, Carnegie Commission on Science, Technology & Government
Peter S. Thacher, World Resources Institute
Mary Martha Treichel, National Research Council
Gilbert F. White, University of Colorado
Robert M. White, National Academy of Engineering
Anne V.T. Whyte, International Development Research Centre, Canada

Withdrawal/Redaction Sheet
(George Bush Library)

Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
01a. Memo	From Ede Holiday to John Sununu Re: U.N. Conference on Environment and Development (2 pp.)	8/9/90	P/5	

Collection:

Record Group: Bush Presidential Records
Office: Chief of Staff, White House Office of
Series: Sununu, John, Files
Subseries: Issues Files
WHORM Cat.:
File Location: Global Warming 1990 (1 of 2) [4]

Open on Expiration of PRA
(Document Follows)
By JP (NLGB) on 10/28/05

Date Closed: 12/20/2004	**OA/ID Number:** 29157-004
FOIA/SYS Case #: 1998-0004-F[1]	**Appeal Case #:**
Re-review Case #: 2005-0426-S	**Appeal Disposition:**
P-2/P-5 Review Case #:	**Disposition Date:**
AR Case #:	**MR Case #:**
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THE WHITE HOUSE

WASHINGTON

August 9, 1990

MEMORANDUM FOR GOVERNOR SUNUNU

FROM: EDE HOLIDAY

SUBJECT: U.N. Conference on Environment and Development

The first of four preparatory meetings for the June 1992 U.N. Conference on Environment and Development in Brazil has begun in Nairobi. The meeting has as its goals resolving all outstanding organizational questions and establishing the agenda of the conference. In response to my July 27 memo regarding the conference (attached at Tab A), you raised questions regarding U.S. ability to manage the conference and our internal preparations for it.

Management and Direction of the Conference

The Secretary General of the conference is Maurice Strong, a Canadian who was pushed for the post by the State Department, but whose early actions indicate that he may take a more liberal approach than State had anticipated. The Nairobi preparatory meeting is being attended by representatives of approximately 100 nations, with all nations meeting as a committee of the whole.

The U.S. positions for the Nairobi meeting have been prepared by a mid-level PCC led by State and are reflected in the scope paper attached at Tab B. State will present general U.S. goals and objectives for the conference, which were summarized in my July 27 memo. In developing the U.S. objectives, position papers have been prepared on the full range of issues that could be addressed by the conference working groups, although no substantive discussions are expected to occur at the Nairobi meetings and only organizational issues resolved.

U.N. planners have proposed that the work of the conference be divided among two working groups -- one dealing with atmospheric protection, land resources, biological diversity and biotechnology, the other dealing with water, wastes and toxic chemicals. State will propose that the conference and the working groups not address environmental issues that are already being handled elsewhere or that will be handled in other fora (such as climate change or forestry). (There is clearly strong sentiment to have agreements or conventions on several of these issues ready for signing in Brazil, however.) If State's proposal is adopted, the first working group would have very little to do. A third "cross-cutting" working group to deal with issues such as legal and financial mechanisms may be proposed by

U.N. planners, but State intends to oppose this concept and to suggest that such matters be dealt with as each discrete substantive issue arises. If the State proposal is accepted and only environmental issues not being addressed elsewhere are to be dealt with by the conference, these "untouched" issues will have to be identified clearly.

With no reports back yet from Nairobi, it is difficult to assess how much influence the U.S. is having over the organizational process for the conference and how much influence we will have as substantive discussions begin. The PCC has not focused on any strategy for maximizing the U.S. role. Continued participation in the preparatory meetings and working group sessions through high-level U.S. representatives and close consultation with other developed nations (that may be equally concerned about the conference becoming a north-south battleground) offer the best routes for steering the conference in an acceptable direction.

U.S. Preparations for the Conference

As noted above, State has led U.S. preparatory efforts for the conference through a mid-level interagency PCC. The PCC views itself as the best continuing forum for preparations. Its intent is to review the organizational structure of the conference following the meetings in Nairobi, enlisting technical expertise on the various issues within the conference preparatory working groups and soliciting ideas, based on the particular strengths or interests of the U.S., that could be pushed within the groups. As plans for the conference become clearer and decisions on substantive positions must be made, State would propose elevating the composition of the PCC to assistant or under secretary level. State also anticipates that Buff Bohlen will continue to lead the U.S. delegations to future meetings.

A range of alternatives have been suggested for raising the level of U.S. preparations:

A higher-level PCC could immediately be tasked with overseeing preparations.

Allan Bromley's DPC Global Change Working Group could be given the assignment.

A new ambassadorial-level position, vested with responsibility for the conference (and perhaps for the framework climate change convention negotiations), could be created.

The issue could be placed within the soon-to-be-formed Environmental Policy Review Group (EPRG), which could establish a task force or review the work of the PCC.

As this seems to be exactly the type of situation and issue for which the EPRG is being created, we recommend the final alternative.

Withdrawal/Redaction Sheet
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Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
01b. Memo	TAB "A": Memo from Ede Holiday to John Sununu Re: U.N. Conference on Environment and Development (2 pp.)	7/27/90	P/5	

Collection:

Record Group: Bush Presidential Records
Office: Chief of Staff, White House Office of
Series: Sununu, John, Files
Subseries: Issues Files
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(b)(9) Release would disclose geological or geophysical information

AC HAS SEEN

THE WHITE HOUSE

WASHINGTON

July 27, 1990

per HHS What are the plans suggested? What does the working group suggest? AHC 7/31

MEMORANDUM FOR GOVERNOR SUNUNU

THE CHIEF of STAFF has seen

FROM: EDE HOLIDAY

SUBJECT: U.N. Conference on Environment and Development

The first of four planned preparatory meetings for the U.N. Conference on Environment and Development, scheduled for June 1992 in Brazil, will be held from August 6 through 31 in Nairobi. The conference is the follow-up to the 1972 Stockholm Conference on the Human Environment, which produced a landmark declaration of principles for international environmental protection. State is now internally developing suggested U.S. proposals for the work of the conference -- preparing a non-binding declaration of principles; defining a general 20-year international environmental agenda (avoiding specific targets and timetables); examining revisions to the U.N.'s environmental processes; and establishing a coordinated information network with greater emphasis on education (which State sees as a U.S. strength).

The critical issue is whether the conference independently delves into issues being negotiated in separate international fora, such as climate change or forestry. State proposes that the conference not duplicate such efforts, although it could provide a setting for signature of conventions or agreements on these issues. Another issue is the participation of non-governmental organizations (NGOs) in the conference. State likes the Bergen Conference model, in which NGOs participated in a parallel process leading to a non-binding, laundry-list "agenda for action." At State's request, CEQ has begun an outreach process to solicit NGO views on their involvement in the conference.

The Nairobi meetings will be predominantly organizational, focusing on logistical matters, such as the conference's location. The U.S. delegation will be led by Curtis "Buff" Bohlen, the new Assistant Secretary of State for Oceans, Environment and Science. Preparations for the meeting are currently being handled through a State-led, low-level interagency working group.

There are concerns that the conference will devolve into a north-south battle, with less developed countries demanding financial assistance and preferential technology transfers. Given the timing of the conference vis-a-vis our 1992 elections and its potential for damage, we need to begin paying more attention to the management and direction of the conference and consider raising the profile of U.S. preparations.

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Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
01c. Paper	TAB "B": Scope paper, 1992 UN Conference on Environment and Development, Meeting of the Preparatory Committee (6 pp.)	7/11/90	P-5	

Collection:

Record Group: Bush Presidential Records
Office: Chief of Staff, White House Office of
Series: Sununu, John, Files
Subseries: Issues Files
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SCOPE PAPER
1992 UN Conference on Environment and Development
Meeting of the Preparatory Committee
August 6-31, 1990, Nairobi

Background

The 1992 UN Conference on Environment and Development will mark the twentieth anniversary of the landmark Stockholm Conference on the Human Environment. The Stockholm Conference issued a declaration of principles that continue to guide our approach to environmental protection today; the Conference also established the UN Environment Programme (UNEP) to coordinate international work on the environment. The U.S. was a primary sponsor of the Stockholm Conference and played a pivotal role in its success.

The 1992 Conference will be held in June, 1992, in Brazil; the Secretary General of the Conference is Maurice Strong (Canada). An organizational meeting in March, 1990, in New York established a Preparatory Committee, chaired by Ambassador Tommy Koh (Singapore). The first of four Prepcom sessions will be held in Nairobi, August 6-31; these Prepcom sessions will set the agenda and focus of the Conference itself.

The Conference will address the full range of specific environmental issues, as well as cross-cutting issues such as information systems, legal mechanisms, technology transfer and financial assistance.

U.S. Goal for the 1992 Conference

The Conference offers an excellent opportunity to shape a new, well-defined, practical and comprehensive approach to environmental action and cooperation as we enter the 21st century. Our overarching goal for the Conference is to promote improved cooperation and more effective actions to protect the environment in a manner fully integrated with economic and development strategies.

U.S. Objectives for the 1992 Conference

The 1992 Conference also offers an opportunity to take stock of national and international efforts in the twenty years since the Stockholm Conference, identifying the gaps, and planning how best to fill them. Future activities should build on those already under way, maintaining a basic continuity of effort while incorporating needed adjustments. Working through the Prepcom, the U.S. should pursue the following general objectives for the Conference:

- Agreement on a non-binding declaration of principles (perhaps related to sustainable development) (along the lines of the Stockholm Declaration of Principles)

- Definition of an international environmental agenda for the next twenty years to address the most critical environmental and related development issues. This should be done primarily through the identification and ranking of environmental issues, rather than the elaboration of targets and timetables for detailed actions and should include a coordinated research and management strategy.

- Establishment of an effective, coordinated information network, to encourage the integration of environmental considerations at all levels of decision-making and to ensure the broadest participation possible.

- Recommendation of measures to strengthen international and national environmental programs, focussing on the institutional, economic, financial and human resources dedicated to the environment.

- Examination, and, as necessary, revision of the ways in which the international system addresses environmental issues, leading to a more effective and efficient division of labor among UN system agencies dealing with these issues.

- Signature of conventions on discreet environmental issues to be prepared outside the prepcom process (e.g. framework Convention on Climate Change, Forestry Convention, etc.)

<u>The Prepcom Process</u>

The two-year process of preparing for the Conference will largely determine the results of the Conference. Therefore, it is essential that the preparatory process be based on clear objectives (preferably tracking those outlined above), with well-defined tasks and well-orgainized working groups. Throughout this process, US reps should keep in mind the following guidelines:

- Environment and development should be integrated in all Prepcom activities and should not be examined on separate tracks. The central focus of the Working Groups should be on the environment.

- Form should not drive substance: the Conference should have clear objectives and the Prepcom and Working Group agendas and schedules should be set to best respond to those objectives.

- Issues being addressed in other international fora should not take up scarce Prepcom resources; rather, ongoing work should be integrated into the Prepcom process. This might be accomplished through status reports, or structured reporting schedules (a reporting process should be set up during the Nairobi meeting). Such would allow the Prepcom to take advantage of ongoing but as yet incomplete work without duplicating efforts.

- Given the important contribution of public participation and citizen involvement, greater participation for all NGOs is needed at all stages of preparatory work for the Conference.

Preparatory Structure

The Prepcom currently has two Working Groups; a third has been suggested to deal with legal and other cross-cutting issues. The US believes that, generally, cross-cutting issues, such as legal and financial mechanisms, should be considered topic by topic, in the Working Groups, to keep the focus on actions needed to address the particular environmental issue under discussion. We should, therefore, oppose the establishment of a separate Working Group to deal with cross-cutting issues.

The Working Group structure, as set during the March organizational session, is:

Working Group I:
(1) protection of the atmosphere (climate change, depletion of the ozone layer, transboundary air pollution)
(2) protection and management of land resources (deforestation, desertification, drought)
(3) biological diversity
(4) environmentally sound management of biotechnology

Working Group II:
(1) protection of the oceans, seas and coastal areas, including their living resources
(2) fresh water resources
(3) environmentally sound management of wastes and toxic chemicals

A brief summary of US positions with respect to each issue area is attached as Tab A.

It should be recognized that these groupings of Working Group issues are random and without substantive justification. Given the US guidelines, WGI would do little other than track work being done in other fora; this is not likely to be acceptable.

Nairobi Prepcom Session

The Nairobi meeting should be used to identify work being done in other fora and set reporting or tracking schedules for such work. More importantly, the Working Groups should identify specific problems within an issue area that are not being covered elsewhere, determine what the 1992 Conference might do to address such problems and develop appropriate work programmes. This work will be cursory at best but is essential if the Prepcom and Conference is to have the information necessary to identify gaps and recommend action. In light of the objectives, the work programmes could include:

--defining the problem
--assessing the scientific understanding of the problem
--assessing the social, cultural and economic impacts of the problem
--identifying possible response strategies, including a discussion of appropriate mechanisms, e.g. national, regional or multilateral
--assessing the capability of existing resources, institutions and mechanisms (scientific, information, legal, financial, managerial, etc) to address the problem

drafted:S/P:CDawson
7/11/90

cleared: OES/E:RSmith
IO:JBecker
L/OES:SBiniaz

SECOND WORLD CLIMATE CONFERENCE
Geneva, 29 October-7 November 1990

13 July 1990

DRAFT MINISTERIAL DECLARATION

PREAMBLE

1. We, the Ministers from countries representing the world community met in Geneva, Switzerland, from 6 to 7 November 1990 at the Second World Climate Conference.

2. Our Meeting following the IPCC Report is a demonstration of our intention to take active and constructive step in the global response to the global climate change issue. It is also the expression of our will to fully contribute to the preparation for the 1992 UN Conference on Environment and Development.

3. Ever since the dawn of history, man's life on earth has been largely dependent on the environmental processes which we call weather and climate. The world climate system consists of a delicately balanced combination of many interactive components which include the atmosphere and the biosphere, as well as the land, sea and ice surfaces.

4. Climate has varied in the past. But the temperature increase which is predicted to occur in the decades to come due to the increasing accumulation of the greenhouse gases in the atmosphere has not been encountered in the last 100,000 years at least; nor has the past rapidity of change been as fast as that predicted. The greenhouse gases result from a host of human activities such as the burning of fossil fuel, deforestation, mining operations and waste management.

5. Recognising that climate change is a common concern of mankind United Nations General Assembly's Resolution 43/53 urged the intergovernmental and non-governmental organisations and scientific institutions, to treat climate change as a priority issue, and to co-operate in research and action-oriented programmes so as to increase the understanding of the causes and effects of climate change.

6. The World Climate Programme undertaken jointly by the World Meteorological Organisation, the International Council of Scientific Unions with the co-operation of its Scientific Committee on Oceanic Research, and UNESCO and its International Oceanographic Commission and UNEP have endeavoured during the last decade to promote a quantitative understanding of climate, and predictions of global and regional climate changes on all time scales and on their potential impacts. Through its three major projects the study of Tropical Ocean and Global Atmosphere, the Global Energy and Water Cycle Experiment, and the World Ocean Circulation Experiment, the World Climate Research Programme has succeeded in providing valuable information on the causes, processes and some of the effects of climate change.

7. The Intergovernmental Panel on Climate Change (IPCC) established by U.N.E.P. and W.M.O. has undertaken to study the problem of climate change including global warming. Through the work of its various working groups and their sub-groups the I.P.C.C. has produced a comprehensive report on the causes and effects of climate change. It has also proposed strategies to delay, limit or mitigate the impact of climate change, and at the request of United Nations General Assembly has proposed the elements for inclusion in a convention on climate.

DEFINITION OF PROBLEM AND RISKS

8. Global warming poses environmental threat of a magnitude the world has never known before. Human activities which have lead to the emissions of greenhouse gases into the atmosphere have so far committed the Global Commons to an irreversible warming so far. In order to stem an unprecedented global warming likely to lead to serious environmental consequences such as a rise in sea level of about 20 cm by the year 2030 and 65 cm by the end of the next century urgent action should be taken now. Carbon dioxide has been responsible for over half the enhanced greenhouse effect in the past and is likely to remain so in the future. It is therefore important that emissions of greenhouse gases especially CO_2 and other long lived greenhouse gases be reduced as soon as possible. This is urgent because changes in emission rates of these gases lead to a slow rate of change in their concentration in the atmosphere. If action is delayed, it will take much longer and much greater reductions at greater economic sacrifice to stabilize concentrations at today's levels. The long lived gases (CO_2 and N_2O) would require at least 60% reductions in emissions, and methane 15-20 % reduction in emissions in order to stabilise their concentrations in the atmosphere at today's levels. The other gases of concern, namely the CFC are addressed under the Montreal Protocol on Substances that Deplete the Ozone Layer.

GLOBAL STRATEGY

9. We consider therefore that a global response must be decided and implemented without further delay based on the best available knowledge such as those resulting from the IPCC assessment.
Recognizing that the principle of equity should be the basis of any global response to the climate change phenomena industrialized countries, which are responsible for most of the observed increase in the greenhouse gases' concentration in the atmosphere must take the lead, commit themselves to immediate action and provide resources and assistance to developing countries to help them in addressing climate change in a way compatible with their development needs. [To this end the industrialized countries will support developing countries with new, additional and specific contributions.] [To this end there is a need to negotiate the necessary support needed by developing countries] [To this end there is a need to provide the necessary support, including additional and specific financial assistance to the developing countries]

ACKNOWLEDGMENT OF THE CONCLUSIONS OF LONDON CONFERENCE ON THE MONTREAL PROTOCOL

10. [Short text to be included after the conclusions of the London Meeting]

ENDORSMENT OF THE CONCLUSION OF THE SCIENTIFIC PART OF SWCC

11. We are highly appreciative of the work done by IPCC.

We accept and are highly appreciative of the conclusions and recommendations of the scientific part of the Second World Climate Conference as presented in the annex 1 of this Declaration. Their implementation should be strongly supported by governments.

THEREFORE:

I. ROLE OF SCIENCE IN IMPROVING OUR UNDERSTANDING, CAPACITY OF PREDICTION AND OUR RESPONSE TO CLIMATE CHANGE

12. We reaffirm that, in order to reduce uncertainties, to increase our ability to predict (including early identification of as yet unknown climate-related problems) and to design scientifically sound response strategies, there is a need to strengthen both national and international activities in research, monitoring, and data and information exchange related to climate change.

13. Recognizing that climate changes are of a complex interdisciplinary character, we urge the full participation of scientists dealing with the atmosphere, the oceans and land, as well as with the physical, chemical and biological processes needed for a deeper understanding of climate issues. Given the intrinsically global nature of climate and climate research, we stress the need to strenghten international cooperation. The magnitude of the problem being addressed is such that no nation can undertake it alone. It is imperative therefore, that, to the extent feasible, national research programmes on climate be planned in such a way that they form integral parts of international research programmes. We urge that special resources to sustain such programmes are made available to less developed countries in order to insure their full participation in the international research effort and the response strategies based upon the results.

14. We stress that special efforts be directed to key areas of uncertainty, including:

the role of clouds, ocean and greenhouse gases; ecosystem responses to global change; effects of land-use changes in the hydrological cycle; climate changes on a regional scale and the socio-economic and cultural dimensions and impacts of climate change.

15. We consider that research programmes must be accompanied by long-term monitoring programmes so designed as to provide continuous and comprehensive coverage of climate-influencing variables as well as those useful in detecting climate change. We agree that long term governmental commitments are necessary to sustain these monitoring programmes. We ask further-more that obstacles to the free flow of relevant data and information be removed.

16. We reaffirm that there is no need to establish new international coordination mechanisms, but rather urge all countries and relevant organizations to contribute through their national efforts and to increase financial support and assistance in kind on a sustained basis to important existing programmes such as the World Climate Programme including the WMO/ICSU World Climate Research Programme, the ICSU International Geosphere-Biosphere Programme, and the climate-related components of programmes of WMO, UNEP, Unesco and its IOC and FAO. We further urge that these programmes be better supported in order to continue to strengthen their interdisciplinary approach, to include the participation of all nations, and to increase coordination in order to achieve still greater efficiency.

II. POLICY TARGET FOR URGENT POLICY ACTION

(Precautionary measures)

17. In order to achieve sustainable development, we must base ourselves on the precautionary principle. Environmental measures must anticipate, prevent and attack the causes of environmental degradation. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

18. We note that a mechanism is being set up by WMO and UNEP to undertake the necessary intergovernmental negotiations on global warming.

(Stabilization and reduction of greenhouse gases)

19. We recognise the fundamental need to conserve the global climate, and protect it from anthropogenic interference. Taking into account that the increase of greenhouse gas concentrations in the atmosphere threaten the natural variability of climate, we agree that the ultimate global objective should be to stabilize and reduce those concentrations.

20. We stress, as a first step, the need to stabilize, while ensuring stable development of the world economy, emissions of greenhouse gases not controlled by the Montreal Protocol. We note with appreciation the unilateral commitments of some industrialised countries to stabilize emissions at present level or reduce them by the year 2000.

21. We agree that stabilization of greenhouse gas emissions should be achieved by industrialized countries by the year [2000] and should be set at [present] emission levels.

22. We urge industrialized countries to establish greenhouse gases reduction programmes aiming at achieving at least 20% reduction of their current contribution to global warming potential, possibly by the year 2005 and in any case not later than the year 2010;

23. We recommend that the specifications of the obligation to stabilize and reduce greenhouse gases emissions be realized in the form of separate Protocols to the Climate Convention. Some of these protocols could be negotiated concurrently with the framework convention.

(Economic situation of certain countries)

24. We recognize that developing countries with, as yet, relatively low energy requirements, which can reasonably be expected to grow in step with their development, may have targets that accommodate that development. We also recognize that additional financial resources [will] [may] have to be made available to developing countries to enable them to limit their net emissions of greenhouse gases while ensuring a steady development of their economies;

(Fund (Climate Fund))

25. We recommend that existing institutions for development and financial assistance including the World Bank and other Multilateral Development Banks, Bilateral Assistance Programmes, the relevant United Nations organisations and specialized agencies, and scientific and technological organisations should give greater attention to climate change issues within their environmental and other relevant programmes by providing expanded funding including concessional funding. In addition, regional and subregional co-operation should be reinforced and funded so as to address and implement the required action at that level.

26. We commend that consideration should be given to the need for funding facilities including a clearinghouse mechanism and a possible new international fund and their relationship to existing funding mechanisms, both multilateral and bilateral. Such funding should be related to the implementation of the climate convention and associated protocols. In the meantime the donor community is urged to provide assistance to developing countries to support immediate actions addressing climate change without waiting for the Convention.

27. We recommend that additional resources should progressively, be mobilized to help developing countries take the necessary measures to address climate change consistent with their development needs.

28. We recommend further that the scope of resources needed be assessed. Such assessments should include *inter alia* country studies and the capabilities of existing institutions and mechanisms to meet the financing needs identified, similar to the approaches developed under the Montreal Protocol.

29. We recommend that, initially, international funding be directed towards

(i) conducting research and monitoring;

(ii) promoting public awareness, education and institutional and manpower development.

(iii) promoting efficient use of energy, including appropriate end use technologies, increasing the use of non-fossil fuels and switching to energy sources with lower greenhouse gas emissions, and the use of renewable energy sources;

(iv) increased financial support for forest protection and forest management improvement, for example through the Tropical Forestry Action Plan (TFAP), the Plan of Action to Combat Desertification, the International Tropical Timber ORganization (ITTO) and other relevant international organizations;

(v) arranging for technology transfer to and technology development in developing countries;

(vi) assisting developing countries in planning how to address problems posed by climate change;

(vii) supporting developing countries to enable their full participation in international meetings on the subject of climate change.

The use of financial resources could subsequently be extended inter alia to major energy sources with little or no environmentally damaging characteristics and for steps to reduce other global man-made emissions of greenhouse gases due to human activities.

(Economic instruments)

30. We recognise that an environmentally sound development must include policies which will achieve a sustainable energy system and take the environmental costs and benefits of energy fully into account. We are convinced that promoting energy efficiency is the most cost effective immediate measure for reducing energy-related emissions of atmospheric pollutants, in particular CO2.

31. We recommend that new policies at national level be established making extensive use of economic instruments in order to increase energy efficiency and reduce energy consumption.

Such instruments could include:

(i) taxes on environmentally damaging activities and energy inefficient product

(ii) emission trading (tradeable permits/allowances)

(iii) reduction or, wherever possible, elimination of subsidies to energy intensive and other activities that induce climate change

(iv) other measures such as emission changes and fees deposit refund systems and fiscal incentive

Such action should in particular affect energy prices with the aim to reflect environmental costs and benefits and provide incentives to reduce energy consumption. They should also modify production and consumption pattern and encourage production and use of energy efficient technologies.

(Technology development)

32. We agree that technological breakthrough in a wide range of fields covering energy, industry and other sectors related to the emission and absorption of CO2 and other greenhouse gases is the key element of any long-term strategy that deals with climate change in a way that meets the goal of sustainable development. To this end, we urge all countries, the industrialized countries in particular, to intensify their individual efforts and international cooperation in technology development concerning, inter alia, low-energy and low-GHG production processes and products (e.g. chlorofluorocarbon substitutes with little or no global warming potential), and CO2 fixation and reutilization.

(Transfer of technology)

[Alternative 1]

33. We urge that relevant technology be utilized by all sectors in all countries to the full extent possible. We recognize that there are great disparities in energy efficiency, even among the industrialized countries, and further urge all countries, industrialized and developing, to identify and take effective measures to remove barriers to the dissemination of the best available technology. This requires, in the case of developing countries, effective measures to aid their efforts in meeting the specific needs arising, to a great extent, from their lack of human and financial resources and other elements necessary for the continuous development and dissemination of the most appropriate technology. The East European countries, which are currently suffering the consequences of inefficient use of energy and other resources, also require special attention. To this end, we also urge all industrialized countries and relevant international institution to step up their contributions to the effective transfer and dissemination of relevant technology in ways that fully address the constraints that all these countries face.

[Alternative 2]

33. We consider important that this expansion of development employ appropriate and environmentally sound technology in order that the problem of global warming and climate change not be exacerbated. Consequently, the transfer and development of such technologies must assume a high priority. It will be important for the industrial nations to respond to this priority and assign sufficient resources to assure technological development and establishment of mechanisms for successful transfer.

(<u>Forestry</u>)

34. We <u>recognize</u> that the conservation of the world's forests is of crucial importance for global climatic stability, particularly having regard to the important contribution of forest destruction to global warming through the emission of carbon-dioxide, methane and other trace gases.

We stress the need to reduce the rate of deforestation and to enhance the potential of the world's forests as a sink for greenhouse gases, through vigorous programmes of reforestation and afforestation.

We <u>endorse</u> the target included in the Noordwijk Declaration of achieving net global forest growth of 12 million hectares per year, through conservation of existing forests and through agressive programmes of reforestation and afforestation.

We <u>call</u> on all countries to:

(i) Adopt clear objectives for the conservation, reforestation and sustainable management of forests in national development plans.

(ii) Amend national policies to minimize forest loss and their human disturbance associated with public and private development projects (e.g. roads, dams, resettlement projects, mining, logging).

(iii) Integrate forest management solutions with policies on environment, agriculture, transportation, energy, poverty and landlessness.

(iv) Strengthen, support and extend the Tropical Forestry Action Plan (TFAP) process to all countries with tropical forests, and expand support for immediate implementation of completed plans.

(v) Strengthen the role of the International Tropical Timber Organization (ITTO) in supporting the sustainable utilization of forest resources.

(vi) Strengthen the role of development banks, IMF, FAO, UNEP, and other multilateral and bilateral organizations in helping developing countries achieve conservation and sustainable development of forests by:

a) Requiring analyses of climate change implications, potential greenhouse gas emissions, and response programmes in their review of project proposals involving forests;

b) Expanding greatly aid and investment flows to the forest sector as well as for the production of energy from biomass.

c) Expanding debt relief via renegotiation of debt, and debt for conservation exchanges; and

d) Linking structural adjustment measures to alleviation of climatic impacts and reduction of gas emissions.

35. We call finally for the development of a World Forest Conservation Protocol or Convention, covering temperate, boreal and tropical forests, in the context of or in association with a Climate Convention which also addresses energy supply and use. The specific elements of such a protocol or convention are a matter for international negotiations which should begin at an early date. These elements may include: fundamental research, tropical forest planning, measures to use, protect and reforest, international trade, financial assistance and possible national and international targets for conservation, reforestation and afforestation.

(Desertification and drought)

36. We recommend that regional and/or sub-regional studies on these subjects be undertaken to cover the impacts of climate change in the following fields:

(i) Drought;

(ii) Desertification;

(iii) Water resources and their evolution;

(iv) Agriculture (positive and negative impacts);

(v) Energy;

(vi) Forests.

These studies should lead to the development of scenarios and short, medium- and long-term measures for mitigation of drought and stopping and reversing desertification for the attention of economic and political decision makers.

III. GLOBAL CONVENTION

37. We welcome the resolutions of the Executive Council of the WMO and Special Governing Council of UNEP authorising their Secretary General and Executive Director to begin negotiations for a Climate Convention, and associated Protocols. We call for such negotiations to begin without delay. We endorse the WMO and UNEP Governing Bodies Decisions in this respect. We urge all countries to join in these negotiations, with the aim of completing negotiations to ensure adoption of a Climate Convention by the time of the UN Conference on Environment and Development in 1992;

38. We recommend that such negotiations take account of the possible elements compiled by the IPCC, and that the Climate Convention be framed in such a way as to gain the support of the largest possible number of countries.

39. We welcome the offer of the Government of the United States to host the first negotiating meeting of a Working Group on the elaboration of a Climate Convention. We also welcome the possible invitation of Italy to host the first meeting of the Working Group for the elaboration of an Energy Protocol. We urge that these two meetings be convened at the beginning of 1991.

40. We recommend further that the Climate Convention and associated Protocols contain specific obligations and address in particular:

(i) the enhancement of research and systematic observation of climate.

(ii) the control of greenhouse gas emissions

(iii) the adaptation to the adverse effects of climate change in coastal areas

(iv) The needs of developing countries for financial assistance in their development efforts and transfer of technology

(v) appropriate institutional and decision-making procedures.

IV. INFORMATION AND PUBLIC AWARENESS

41. We believe that a well informed public is essential for addressing and coping with as complex an issue as climate change and urge countries to

(i) encourage wide participation of all sectors of the population in addressing climate change issues and developing appropriate responses

(ii) provide guidance for positive practices to limit/or adapt to climate change

(iii) incorporate in the curricula of their educational systems environmental education

(iv) establish national committees or clearing houses to collect, develop and disseminate accurate information on climate change issues.

V INSTITUTIONAL MATTERS

42. We congratulate the IPCC for the outstanding achievement of producing in a very short time its first report on the state of the science of climate change, the socio-economic impact and policy options. We recognize that the IPCC structure can provide an invaluable mechanism for periodic assessments, perhaps every five years, of the evolving knowledge from research and impact studies. We urge that the IPCC continue its analysis of risks of action and inaction, policy options and economic aspects of alternative measures for limiting greenhouse gas emissions, mitigating or adapting to climate change. We also urge that a further report on these issues should be produced during 1991 to support the then ongoing negotiations of a Climate Convention on Climate Change.

43. We further express our appreciation to WMO and UNEP for initiating the IPCC and providing an efficient Secretariat. We urge that this arrangement be continued and that countries continue to provide resources to support the Secretariat and participation of developing countries in the work of IPCC.

Revised, 8/7/90, 4:00 p.m.

Professor Bert Bolin
Department of Meteorology
University of Stockholm
S10691 Stockholm, Sweden

Dear Bert:

At the outset, I want to thank you for your careful consideration of the points raised in my previous letter. I realize that a wide range of comments had to be taken into account following our meeting in Geneva, and I commend your work in synthesizing these ideas into the July 1990 Draft IPCC Overview and Conclusions Paper.

I have a number of additional comments to offer on behalf of the United States.

There is concern that the careful balance which was struck in the Working Groups on a number of issues has not been maintained in this draft. We recognize that in summarizing the underlying reports of the Working Groups it is necessary to use portions of each rather than the whole. For this reason, you may wish to consider a significantly shorter Overview and Conclusions document, drawing heavily on the three Executive Summaries, to which the underlying Summaries for Policymakers would be attached.

If this goes too far, then why do we want it highlighted without changes?

a consensus version of

In addition, Section VI, "Strategies for the Future", goes significantly beyond the results of the IPCC assessment effort. We would suggest that this section be moved to the very beginning of the document and be titled IPCC Chairman's Introduction (as is done in the RSWG Summary for Policymakers).

Other comments are outlined below:

Science and Impacts Issues:

o The current draft still understates the fundamental scientific uncertainties regarding possible climate change. To put the scientific understanding of this issue in perspective, the fact that there are significant uncertainties regarding the timing, magnitude and regional distribution of climate changes should be highlighted with a separate heading.

- Scientific findings are expressed with a higher degree of confidence than is warranted (e.g. the words "will" or "would" are used throughout rather than "may" or "could") and in some cases worst-case figures are used rather than a mean figure or the full range of figures.

- A more extensive discussion of the relative impacts of <u>all</u> the greenhouse gases is needed in the science section. We suggest including the table on Global Warming Potentials (GWPs) from the WGI Policymakers Summary, with appropriate introductory language.

- In general, the discussion of possible climate change impacts places undue emphasis on the potential ~~negative~~ consequences of climate change, while minimizing the potential for neutral or positive impacts. The underlying Working Group reports give a more balanced view.

<u>Response Options</u>:

- A continuing concern is that the discussion of WGIII Task A does not reflect the uncertainties surrounding these exercises. It is important to make clear that these scenarios are not projections or predictions, but are based on varying assumptions. The explanation of how they were formulated should be taken from the WGIII Summary for Policymakers, Sections 3.1 and 3.2. and be placed in a separate section at the beginning of the document (not in an appendix).

- The ~~report~~ draft does not adequately address the uncertainties and lack of information policy makers face in dealing with climate change. To place the issue in perspective, it is important to include the language contained in the RSWG report that:

  "The information available to make sound policy analyses is inadequate because of: (a) remaining scientific uncertainties regarding the magnitude, timing, rate, and regional consequences of potential climate change; (b) uncertainty with respect to how effective specific response options or groups of options would be in actually averting potential climate change; and (c) uncertainty with respect to the cost, effects on economic growth, and other economic and social implications of specific response options or groups of options. The potentially serious consequences of climate change on the global environment, however, give sufficient reasons to begin by adopting response strategies that can be justified immediately even in the face of such significant uncertainties."

For example, the IPCC did not analyze the socioeconomic cost of potential climate change impacts or the costs and effectiveness of various response options.

o There is little discussion of the fact that the RSWG did not have time to consider the vital social and economic issues which are necessary for devising sound policies to address climate change. This point should be set forth prominently at the beginning of the Overview and Conclusions paper to place the IPCC's work in its proper perspective.

o Some of the economic concepts are not accurately stated. For example:

-- The definition of "no regrets" policies on page 31 ~~is~~ incorrect. The current wording implies that such policies include actions which have any benefits beyond ~~than~~ those related to climate change, whereas the WGIII report refers to those actions which are justified in their own right.

-- The discussion of the comprehensive approach does not describe its benefits. We suggest drawing from the WGIII Summary for Policymakers (p. 38, lines 10-13) to make clear that such an approach would advance environmental protection and minimize economic costs.

-- The description of the "tragedy of the commons" on page 30 (lines 12-16) is flawed as written. This section would be substantially improved if restated along the following lines:

> "If individual countries can continue to pollute while others pay the costs of global pollution control, this will opportunity to act as "free riders" encourage nations to avoid mutually advantageous cooperative action."

o Given the target draft audience, it is important to specify throughout the ~~report~~ the baselines being used: Are the emissions changes calculated from present levels or from projected future growth levels? Do they refer to the total flux or the anthropogenic flux?

o The draft ~~report~~ does not adequately address the important role of sinks and the possibilities either for expanding sink resources or for implementing adaptation strategies.

o The current draft overstates the ability of the industrialized countries to reduce global emissions and to stabilize atmospheric concentrations regardless of events in the rest of the world. The language from the WGIII Summary for Policymakers that "Developing countries should, within the limits feasible, take measures to suitably adapt their economies" needs to be included in the Executive Summary.

o The discussion of "narrowing the gap between the industrialized and developing world" would be more accurately characterized as follows:

"Improved economic performance and living standards in the developing world are important to developing a full global partnership to deal with the climate change issue."

These are some of the main comments I would like to bring to your attention as you continue preparations for the Sundsvall meeting. In order to assist in this process, the United States is developing more extensive comments and specific proposed wording changes.

All comments should be sent now and not deferre until meeting

I look forward to working together to develop a final IPCC paper which reflects the findings of the IPCC Working Groups. I am optimistic that the IPCC report will promote a reasoned and effective international response to this important issue.

Very best regards,

Frederick M. Bernthal

Withdrawal/Redaction Sheet
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Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
02. Memo	From D. Allan Bromley to John Sununu Re: Global Change (2 pp.)	7/5/90	P/5	

Collection:

Record Group: Bush Presidential Records
Office: Chief of Staff, White House Office of
Series: Sununu, John, Files
Subseries: Issues Files
WHORM Cat.:
File Location: Global Warming 1990 (1 of 2) [4]

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P-2/P-5 Review Case #:		**Disposition Date:**	
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(b)(7) Release would disclose information compiled for law enforcement purposes [(b)(7) of the FOIA]
(b)(8) Release would disclose information concerning the regulation of financial institutions [(b)(8) of the FOIA]
(b)(9) Release would disclose geological or geophysical information

THE WHITE HOUSE
WASHINGTON

July 5, 1990

Memo to: John Sununu
From: Allan Bromley
Re: Global Change

In case you haven't seen it, I am enclosing herewith a copy of the ICSU document on this topic. It is the best single statement that I have seen in the public domain thus far. We would have been better served if the IPCC report were more like this one.

I have met with Bob Watson and Fred Bernthal and, with their full support, have focussed Bolin's attention on a number of changes

In the draft document that you read at Kennebunkport that are essential if the final document is to have US support.

As it turns out either Bob or Fred had, at various times, had most of these points in the document only to find them removed by Balin either on his own initiative or under pressure from other countries.

I agree that it is certainly time for us to take a firm stand.

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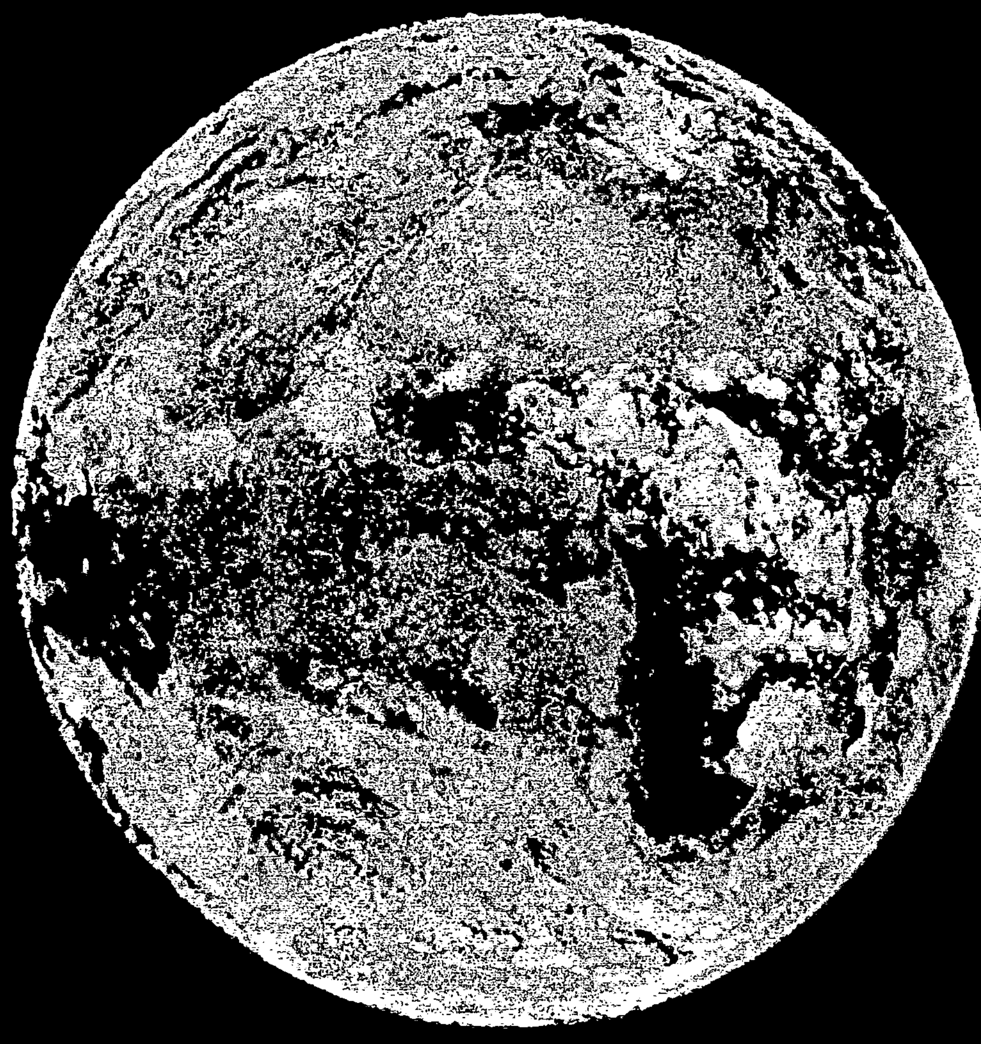
GLOBAL CLIMATE CHANGE



WORLD METEOROLOGICAL ORGANIZATION

INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

WORLD
METEOROLOGICAL
ORGANIZATION

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SCIENTIFIC UNIONS

GLOBAL CHANGE

A SCIENTIFIC REVIEW
PRESENTED BY
THE WORLD CLIMATE RESEARCH PROGRAMME
January 1990

CONTENTS

FOREWORD

The world's climate system is a sensitive combination of many interactive components: the atmosphere; oceans; biosphere; land and sea ice; and the land surface itself. Climate has large natural variability on all time and space scales. In prehistoric times, glaciers covered large portions of the land and, at other times, tropical rain forests existed at high latitudes. Now, each year, farmers around the world wait to see whether the seasonal rains will come at the right time. In Asia, society has developed around the occurrence of the monsoon. We now realize that the influence of the El Niño phenomenon or Southern Oscillation extends beyond the tropical Pacific and that it has global consequences. In some areas of the world, the social and economic structures are such that society can survive several years of abnormal climate; in other locations, droughts or excessive rainfall have immediate and catastrophic impacts. Climate is made of extreme events as well as periods of more normal conditions. Extreme events are the critical and frequently destructive part. To a large extent, human societies have become attuned to current climate; crops flourish within an expected range of climatic variations, our dams and dykes are built on assumptions based upon the climatological record of the last 30 to 50 years. Yet, the earth's climate has never been static and, for the first time in history, human activities have now reached the stage where they affect climate on regional and global scales.

In recognition of the variability of climate and the immense importance of its impacts, the International Council of Scientific Unions and the World Meteorological Organization have jointly undertaken, since 1979, the World Climate Research Programme. Co-operation has been established with many international organizations and bodies to plan the activities of the Programme in various scientific disciplines, first of all the Scientific Committee on Oceanic Research of ICSU and the Intergovernmental Oceanographic Commission of Unesco.

Climate research is aimed at understanding those fundamental processes of the earth's atmosphere, ocean and ice that cause the climate to behave as its does. From observation and models will come the ability to predict the future evolution of climate. Consider the value of being able to predict whether the next growing season will be wetter and colder than normal, or hotter and dryer. Consider the usefulness to society of precise information on the long-term trends in mean sea level, changes in precipitation and river flow, or the occurrence of the next El Niño disturbance. Consider how different our policy for the use of fossil fuels might be if we knew, with confidence, how far such use will cause the climate to warm and precipitation to change, not only globally, but for each region of the world.

Confident prediction of climate will only come when we have comprehensive models of the full climate system that have been thoroughly tested against observation. Obviously, we cannot wait for climate change over the next fifty or hundred years to see whether our models are correct. We must build up the reliability of model predictions by testing forecasts against the observed evolution of climate from season to season and year to year, and also verify that our models accurately reproduce the present climate. Through this process, we can improve our prediction skill and develop confidence in model results.

Climate research is expected to provide a service to society. To deliver this service effectively, we need to determine the rate and timing of future climate warming and the impact on the global hydrological cycle; we need to predict not only global mean changes, but also regional variations and changes in the frequency and severity of extreme weather events. In consideration of the quantity of carbon dioxide and other greenhouse gases already added to the atmosphere, we can assert that some climate warming is inevitable. Climate scientists work to provide the information that society can use for adaptation to and amelioration of the consequences of this warming. **The World Climate Research Programme is the international scientific programme which has been established to provide a quantitative understanding of climate and predictions of global and regional climate changes on all time scales.**

In the following, a review of our knowledge of global climate change is presented. Although the World Climate Research Programme is concerned with all kinds of climatic variations, the emphasis of this review is climate change expected to occur during the next century due to the accumulation of greenhouse gases in the atmosphere.

G.A. McBean	A.D. McEwan
Chairman	Chairman
Joint Scientific Committee for	Committee on Climate
World Climate Research Programme	Changes and the Oceans

OVERVIEW

The climate of the world is a dynamic regime subject to natural variations on all time scales and to possible alteration by human activities. Climate is known to have varied between glacial and interglacial conditions over the past million years, due to only small changes in the amount of solar radiation absorbed by the earth. The problem of predicting future climate change, induced by man's activities, cannot be separated from that of understanding and predicting natural variations. The World Climate Research Programme (WCRP) has been established by the International Council of Scientific Unions and the World Meteorological Organization to address both problems.

Greenhouse gases reduce the amount of earth's radiation that escapes to space, with consequent warming of the lower atmosphere and the earth's surface. The concentration of the most important greenhouse gas, carbon dioxide, has already increased by 25 per cent since the beginning of industrialization. This increase results from deforestation, causing an imbalance between the absorption and release of carbon dioxide by vegetation, and from the combustion of fossil fuels extracted by man from the earth's interior. Other greenhouse gases, also found in the atmosphere in increasing amounts, are methane, nitrogen oxides and, especially, chlorofluorocarbons. Uncertainties on emissions of greenhouse gases entail corresponding uncertainty on future atmospheric concentrations and attendant greenhouse warming. Anthropogenic emissions are but small increments on the large exchanges which occur naturally between the atmosphere and the oceans or the land, and thus relatively minor adjustments in these natural fluxes could significantly affect the future concentration of greenhouse gases. The International Geosphere-Biosphere Programme, the Joint Global Ocean Flux Study and the World Climate Research Programme are working on this problem.

Currently, the accumulation of greenhouse gases in the atmosphere is proceeding at a rate such that their combined effect will reach a level equivalent to doubling the pre-industrial concentration of carbon dioxide by the middle of the next century. Nevertheless, the change in the earth's climate over the last hundred years has been substantially less than could be inferred directly from the change in the radiation budget at the surface. One reason for this is that the climate system is constituted by a "fast component" and a "slow component". The fast component is controlled by the atmospheric and upper-ocean heat engine which drives the whole earth environment and determines the ultimate amplitude and geographical patterns of climate change. The slow component is controlled by the global ocean which sets the pace for climatic change and may introduce delays of 50 years or more in the transient response of the earth's climate to greenhouse forcing.

Adjustments in the fast climate system are very complicated and involve feedback processes which amplify or reduce the primary greenhouse effect. Present climate models of the atmosphere coupled to a shallow ocean indicate a global mean warming of 3 to 5°C for the modified steady-state climate which would obtain with a doubled concentration of carbon dioxide. A major unresolved problem is that of predicting accurately the effect of clouds on the earth radiation budget. Another outstanding problem is that of predicting the global and regional changes in the precipitation and water resources. Altogether, these unsolved problems are the root of considerable uncertainty in the sensitivity of climate to a specified change of atmospheric composition. The WCRP Global Energy and Water Cycle Experiment is designed to study these processes and to incorporate them into a consistent representation of the earth's fast climate system.

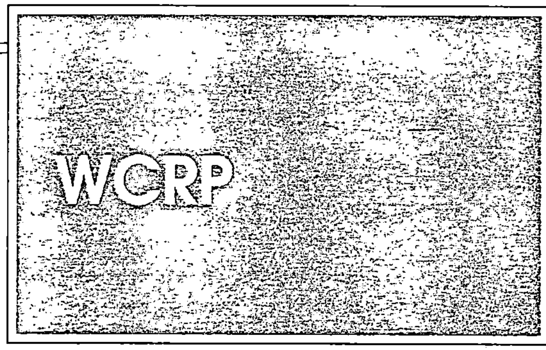
If the fast system alone was involved in climate change, the computed earth's climate change would now be a global warming of 1 to 2°C. Observational evidence shows that this is not the case. The probable reason is that the ocean, which has its own complex dynamics and feedback processes, has delayed climate change. By the same token, warming will continue toward a new quasi-steady climate long after the composition of the atmosphere is stabilized. Regardless of ongoing efforts to control emissions of greenhouse gases, the global warming to which we are already committed will be realized in the next fifty to hundred years. Global environmental change is inevitable.

The evolution of the earth climate over the next fifty years will result from ongoing natural variations combined with a warming trend forced by anthropogenic modifications of the atmospheric concentrations of greenhouse gases. At present, the trend cannot be distinguished unambiguously from natural transient climate changes. However, it must be expected that the warming trend will accelerate in the future, possibly up to 0.3 or 0.4°C per decade. This would be a faster change than any sustained temperature trend known to have occurred in the past. A central objective of climate research is to assess the delay introduced by ocean processes in the response of the earth climate, and to determine the timing of future change induced by greenhouse gases. The WCRP World Ocean Circulation Experiment is designed to acquire the basic information needed to understand quantitatively these oceanic processes and to predict the response of the whole climate system, including the global ocean.

Photo: United Nations/ A. Travis/ Ara.

A large fraction of year-to-year climate variability can be traced to the interaction between the atmosphere and oceans in the tropics. The WCRP has launched and is pursuing the Tropical Ocean and Global Atmosphere (TOGA) research programme to study and predict transient variations associated with the El Niño phenomenon and other features of tropical climate.

Ultimately, characterizing the spatial structure and time signature of natural variations will be the key to an early detection of change in the earth climate, induced by man's activities.



THE WORLD CLIMATE RESEARCH PROGRAMME

Although climatic variations and their economic impacts are seen from year to year and from region to region around the earth, the problem of both natural and man-induced climate change is global and its study is beyond the resources of any one country. It follows that scientific initiatives bearing on this problem must effectively be planned as contributions to internationally co-ordinated programmes such as the World Climate Research Programme and the International Geosphere-Biosphere Programme.

The World Climate Research Programme (WCRP) was established in 1979 as a joint undertaking of the International Council of Scientific Unions (ICSU) and the World Meteorological Organization (WMO), to determine to what extent climate can be predicted and the extent of man's influence on climate. For carrying out this task, the WCRP receives the help of many national and international organizations besides WMO and ICSU. In particular, the Unesco Intergovernmental Oceanographic Commission (IOC), ICSU's Scientific Committee on Oceanic Research (SCOR) and their joint Committee on Climatic Change and the Ocean play the major role in the organization of oceanographic projects in the WCRP.

Achieving the objectives of the WCRP requires quantitative understanding of the physical climate system, constituted by four major components:

- The **global atmosphere** which is the most rapidly varying component and also the most energetically active since it is the heat engine that drives the whole climate system and, in particular, the global water cycle.

- The **world ocean** which interacts with the overlying atmosphere on periods of months to years within its superficial layers, while the deeper ocean responds over periods of decades to centuries.

- The **cryosphere** which comprises the continental ice sheets and ice caps, mountain glaciers and sea-ice.

- The **land surface** of the continents with its surface and groundwater flow systems that control evaporation from land and water storage in the ground.

The WCRP incorporates all internationally co-ordinated research activities that are being pursued to study the physical climate system of our planet.

In particular, the WCRP has instituted three major projects to investigate climate change mechanisms which can be studied within a subset of the overall climate system. These projects are:

- The study of **Tropical Ocean and Global Atmosphere** (TOGA) interactions, which are at the root of the principal mode of climatic variation from year to year, namely the Southern Oscillation and the associated El Niño phenomenon.

- The **Global Energy and Water Cycle Experiment** (GEWEX) to study, model and predict the transport and exchanges of radiation, heat and water within the atmosphere and at the earth surface, as well as the impact of climate change on global and regional rainfall regimes.

- The **World Ocean Circulation Experiment** (WOCE) to provide, for the first time, almost simultaneous observations of all oceans, as a basis for the development of realistic mathematical models of the global ocean circulation and heat transport, similar in principle to those which exist for the atmosphere.

Further developments planned by the WCRP also include long-term monitoring of the ocean volume (sea-level) and circulation, systematic measurements of the sun energy output and the earth radiation budget, and the surveillance of polar sea-ice and ice-caps. Scientific work is constantly pursued to refine the formulation of **numerical models** of the earth climate system, which provide the most effective tool for integrating the observations from diverse sources into a consistent global picture and for exploring the range of possible future climatic variations.

The WCRP co-operates with the International Geosphere-Biosphere Programme (IGBP) of ICSU to introduce the chemical, biological and ecological dimensions into model and field studies of the earth system. The IGBP was initiated by ICSU in 1986 to describe and understand the interactive physical, chemical and biological processes that regulate the total earth system, the unique environment that it provides for life, the changes that are occurring in this system and the manner in which they are influenced by human activities. A central objective of the IGBP is to establish the scientific basis for quantitative assessments of changes in the earth's **geo-biochemical cycles**, which control the concentration of carbon dioxide and other molecules in the atmosphere. While the emphasis in the IGBP is on bio- and geo-chemical aspects and in the WCRP on physical aspects, both promote activities to further advance our knowledge of the total earth system. Together these two programmes constitute the international framework of the quest for a scientific understanding of global change.

OUR CHANGING CLIMATE

Few scientific issues in recent years have attracted greater public interest and political attention than the increase in the atmospheric burden of carbon dioxide and other gases, and possible consequences for the earth's climate. In order to consider this phenomenon in the proper perspective, one must first recognize a fact long known by climatologists, namely that climate is not a static feature of the earth environment.

Climate is a dynamic regime subject to **natural variations** on all time-scales, from years to millenia, as well as possible alteration by human activities.

Many scientific clues can be found which indicate that past climates have been quite different from the present. The best information we have about paleoclimates is that which describes the most recent glacial cycle, the last of a series of

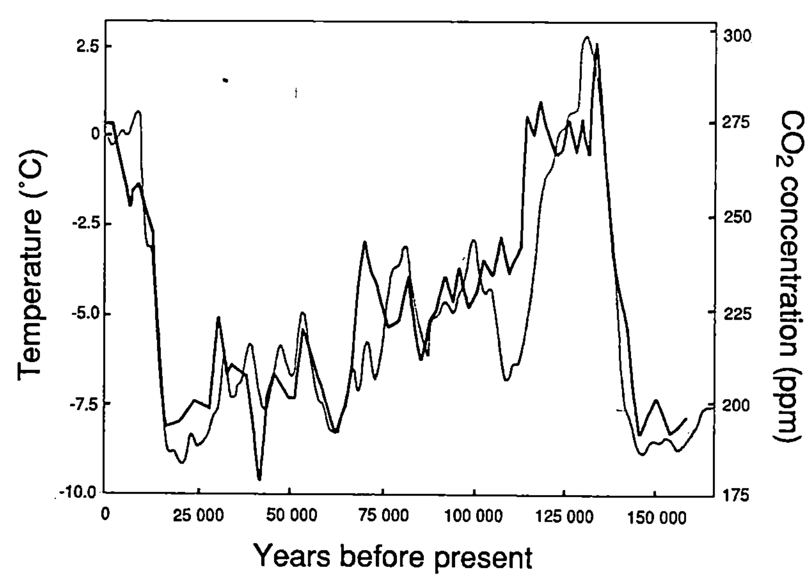


Figure 1. Paleoclimatological record of temperature change with respect to modern climate (coloured line) and atmospheric CO_2 concentration (black line) over Antarctica during the last glacial cycle (adapted from Barnola et al., 1987).

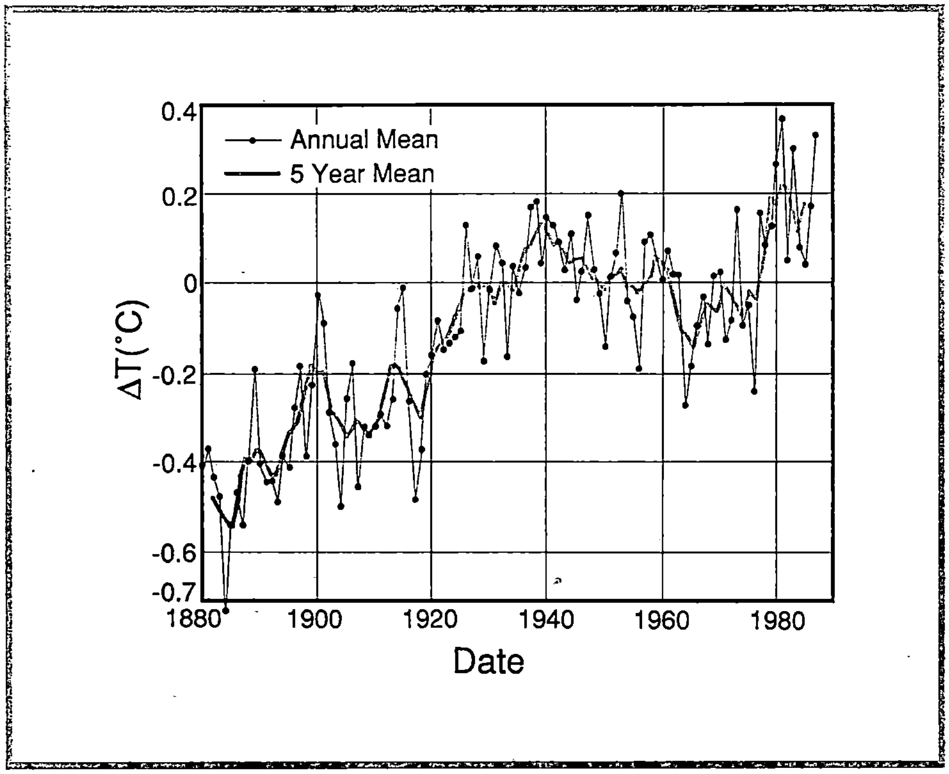


Figure 2. Record of global-mean air temperature change at the surface of the earth (adapted from Hansen and Lebedeff, 1987).

quasi-periodic variations which have occurred at about 100,000 year intervals over the past two or three million years. These variations are related to changes in the orbital parameters of the earth, according to the theory first proposed by Milankovitch (Berger, 1984).

One of these astronomical phenomena is the recurrent variation of the eccentricity of the earth's elliptical orbit around the sun, with a period of about 100,000 years. This phenomenon causes a 0.2% variation in the amount of solar radiation intercepted by the earth, equivalent to a 0.7 Watt/m^2 change in the primary solar energy input which drives the earth atmosphere and oceans, compared to a mean annual value of 342 Watt/m^2 averaged over the globe. Such a small change in the solar radiation flux must be considerably amplified by the earth climate system in order to induce such profound changes in climatic conditions as occurred in the transition to an ice age.

The ice sheets of Antarctica and Greenland preserve the climatological history of the last ice age. The isotopic composition of the ice from a 2000 metre deep ice core, drilled at the Soviet Vostok Antarctic station, allowed Barnola et al. (1987) to estimate the air temperature at this location over the past 150,000 years. This is shown as the coloured line in Figure 1. Small air bubbles

THE TROPICAL OCEAN AND GLOBAL ATMOSPHERE STUDY

The Tropical Ocean and Global Atmosphere (TOGA) study is a ten-year programme, led by the WMO/ICSU Joint Scientific Committee for WCRP in co-operation with ICSU's Scientific Committee on Oceanic Research, the Unesco Intergovernmental Oceanographic Commission and their joint Committee on Climatic Changes and the Ocean.

The objectives of TOGA are to achieve a description of large-scale transient variations of tropical ocean basins and the global atmosphere, to determine the extent to which this system is predictable on time-spans of months to several years, to understand the mechanisms underlying this predictability and to develop the means, both field observations and coupled atmospheric-oceanic models, to achieve effective predictions. The main scientific targets of the TOGA programme are the **El Niño/Southern Oscillation** phenomenon and the variations in the **monsoon** regime from month-to-month and year-to-year.

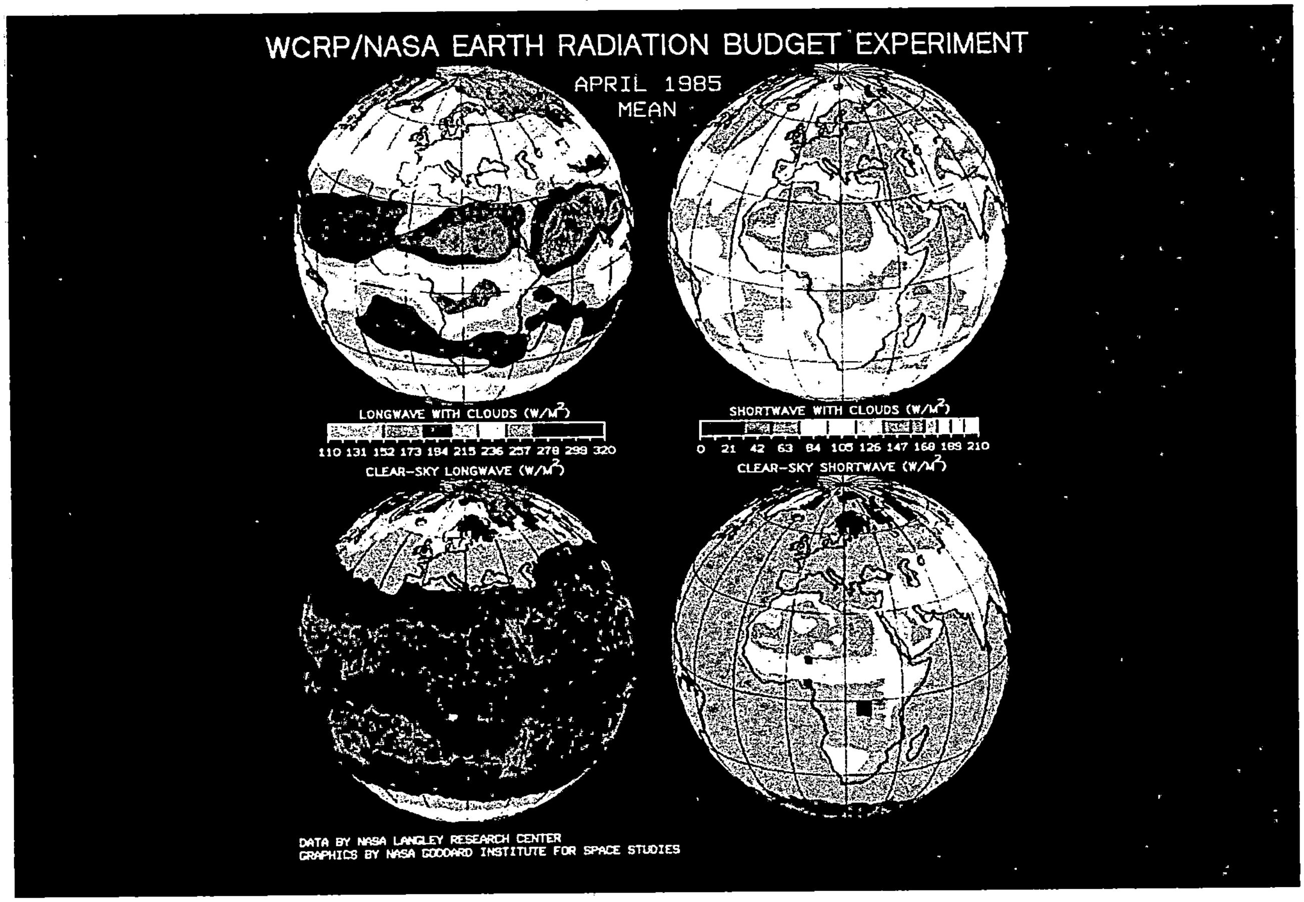
TOGA has initiated a range of specific projects to establish or complement oceanic and atmospheric observing systems in the tropical zone and the southern hemisphere. These projects include launching temperature probes from merchant vessels to provide systematic bathythermographic sections every month or every second month along selected shipping routes across the three tropical ocean basins, surface pressure and temperature measurements from automatic drifting buoys in the southern hemisphere, real-time acquisition and transmission of tide-gauge data, and upper-air wind observations at several island stations along the equator, working toward the implementation of an operational observing system in the framework of the World Weather Watch and the Integrated Global Ocean Services System. Data from TOGA systems and existing operational networks already serve as a basis for experimental predictions of El Niño or similar events in the tropical Pacific, using coupled atmosphere-ocean models. Other global modelling studies are being pursued to investigate, in particular, the sensitivity of the global atmosphere to localized anomalies in sea-surface temperature and the variability of monsoonal regimes.

Furthermore, TOGA is fostering renewed interest in the physics of meso-scale air-sea interactions in the tropics, and is planning a major field study of these complex processes in the sensitive west tropical Pacific region where the warmest ocean waters on earth can be found and where total annual rainfall currently reaches 6000 millimetres.

To learn more about TOGA, see: Scientific Plan for the Tropical Ocean and Global Atmosphere Programme (WCRP Publications Series No. 3, WMO Geneva, 1985) together with its addendum, Science Plan for the TOGA Coupled Ocean-Atmosphere Response Experiment.

are trapped in the ice sheet as it is formed from accumulated snow and the concentration of carbon dioxide (CO_2) in these bubbles can be analysed as shown by the black line in the same figure. The Antarctic air temperature and the CO_2 concentration rise and fall together.

At the end of the last ice age, the air temperature was some 10 degrees colder and the CO_2 concentration nearly 100 ppm less than modern values before the beginning of industrialization. The rises of CO_2 and temperature 15,000 and 140,000 years ago are remarkable. We do not know the processes by which the terrestrial biosphere or the ocean have caused this change in CO_2 concentration but we know that worldwide cold glacial climates could not have existed without the weakening of the greenhouse effect caused by the reduction in the amount of atmospheric CO_2.



The climate system also shows significant variations on time-scales of years to centuries. Figure 2 (on page 11) shows an estimate of global mean surface air temperatures during the past century, compiled from observations over both land and oceans by Hansen and Lebedeff (1988). This record indicates not only a noticeable warming of the earth's surface during the last hundred years but also ongoing climatic fluctuations of comparable amplitude, which do not constitute a long-term trend and must be ascribed to the natural variability of the atmosphere-ocean-ice system. The problem of predicting future climate change induced by man's activities cannot be separated from that of understanding such natural variations.

Climate research has already made significant progress towards developing the capability for actual predictions of fast (interannual) transient climate variations, from observed initial conditions. Predicting the El Niño/Southern Oscillation phenomenon, caused by dynamic and thermodynamic interactions between the atmosphere and tropical oceans, is the central objective of the Tropical Ocean and Global Atmosphere (TOGA) programme of the WCRP. Achieving even this relatively modest objective is by no means a simple task as many complex atmospheric and oceanic processes are involved, from individual clouds and storms to basin-wide oceanic waves.

THE GREENHOUSE EFFECT

Many human activities, both agricultural and industrial, are causing the emission of increasing quantities of polyatomic molecules into the atmosphere.

As a result, the concentration of these chemical substances in the air has already risen substantially and continues to rise. In particular, the atmospheric concentration of carbon dioxide has increased by 25% over the period 1740 to 1980 (Figure 3). Polyatomic molecules generally absorb infrared radiation and thus contribute to the greenhouse effect of the atmosphere by reducing the amount of far-infrared radiation emitted by the earth surface which escapes to outer space. For this reason these substances are called **greenhouse gases**. We know that the greenhouse effect causes a general warming of the lower atmosphere and earth surface, and a compensating cooling of the upper atmosphere.

The greenhouse gases, primarily water vapour and carbon dioxide, play a crucial role in **regulating the temperature of the earth** and the earth's atmosphere. In the absence of these gases, the average surface temperature would be 33 degree Celsius colder, -18°C instead of the present value of +15°C, and the earth would be a frozen lifeless planet. The natural greenhouse effect of the atmosphere is an essential component of the regulating mechanism which has maintained the earth's climate within a range suitable for the development of life in the course of four billion years However, there is now concern that tropospheric temperatures will rise further due to steadily **increasing concentrations** of the various greenhouse gases.

Well-established methods exist to compute the increase in the primary greenhouse effect, i.e., the net energy gained by the earth, for various specified contributions of greenhouse gases, in the absence of clouds and before the earth's climate can adjust to the new conditions. These computations show that the excess carbon dioxide already accumulated since the beginning of the nineteenth century has enhanced the radiative heating of the planet by 1.3 Watt/m^2, on the average over the whole earth surface. This value rises to 2.2 Watt/m^2 when the other absorbing gases are also taken into account. Doubling the concentration of carbon dioxide (from 300 to 600 ppm) would yield a net radiative heating of about 4 Watt/m^2 (Ramanathan, 1988).

While carbon dioxide is generally regarded as the main cause of the increased radiative heating of the planet, any gas which absorbs

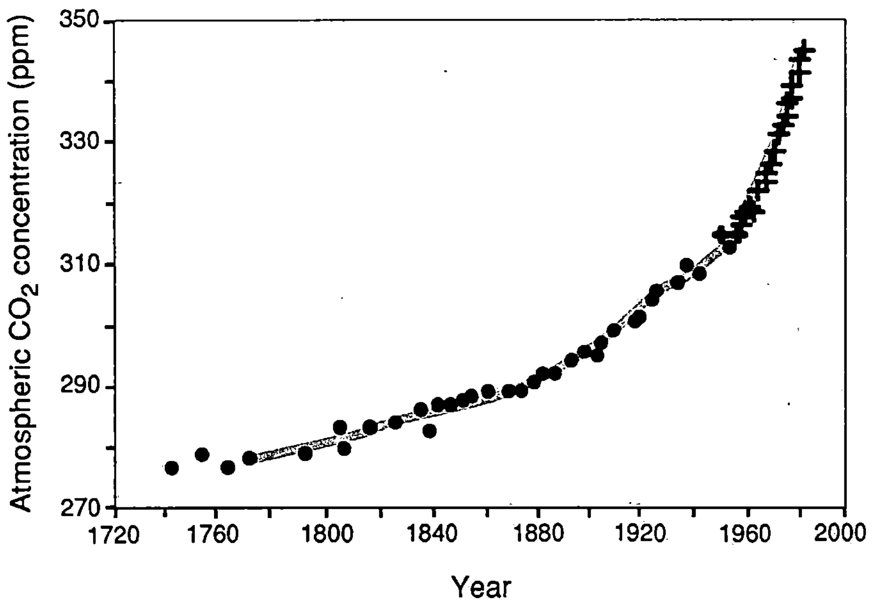
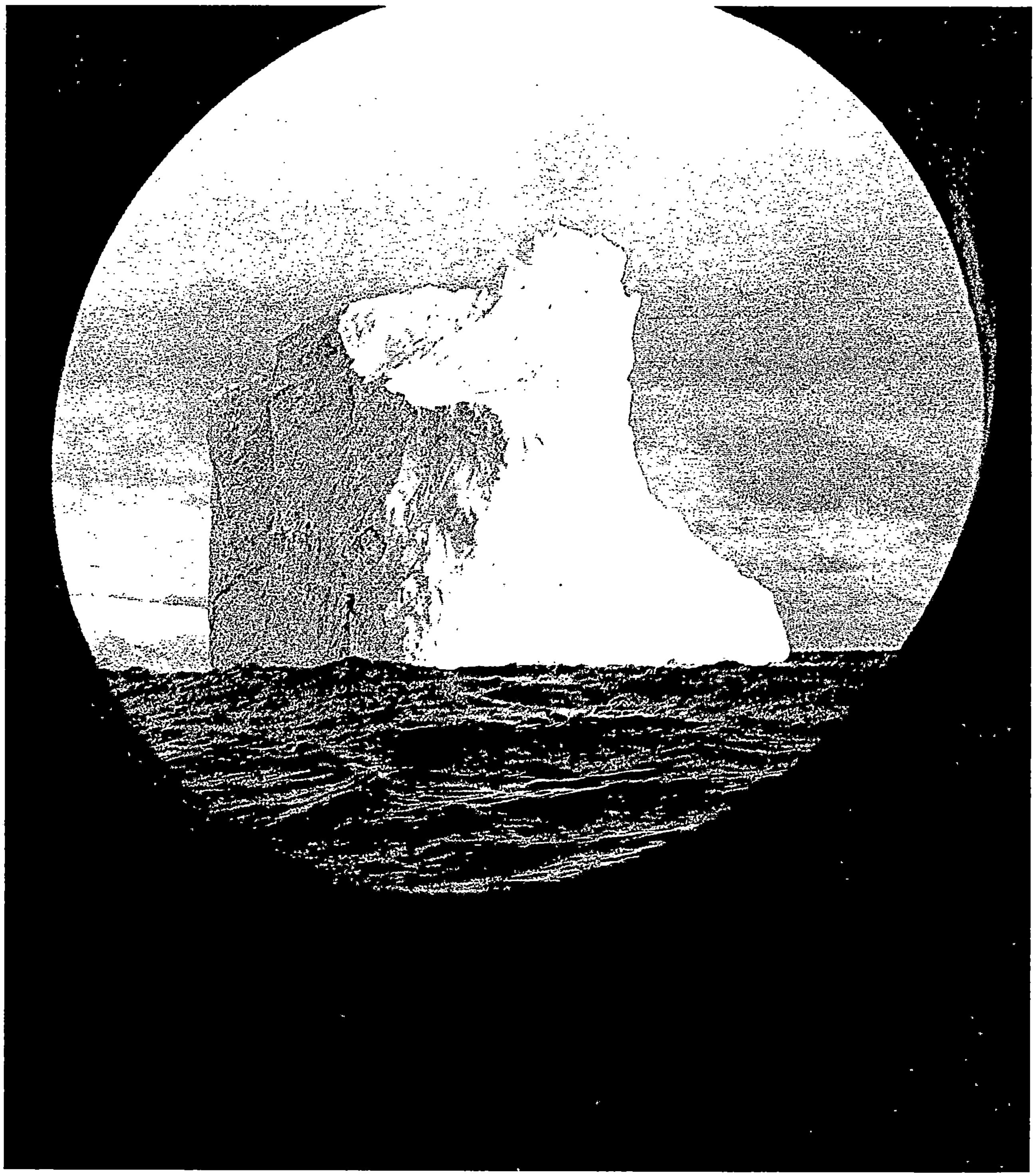


Figure 3. Record of the atmospheric concentration of carbon dioxide (adapted from Siegenthaler and Oeschger, 1987). Circles refer to the composition of air bubbles trapped in Antarctic ice. Crosses are annual values measured at the Mauna Loa Observatory.

infrared radiation contributes to the greenhouse effect. Because the existing amount of carbon dioxide in the atmosphere already absorbs most of the radiation in its particular wavelength range, absorption by other gases at different wavelengths has a disproportionate importance in the overall greenhouse effect. For this reason, an increase in the methane content has 25 times the effect of adding the same number of CO_2 molecules, and freons have an effect 10,000 times greater than CO_2 (Ramanathan et al., 1985). Figure 4 shows the contributions by various gases to the increase in radiative heating of the earth during each successive ten-year period since 1830 (adapted from Hansen et al., 1988). Altogether, it is estimated that the excess greenhouse heating due to all absorbing gases is now increasing more or less linearly with time, although the concentration of carbon dioxide may be rising exponentially (Figure 3). Unless yet unknown mechanisms can counteract this increase, humanity will eventually face a significant warming of the earth's climate.



FUTURE TRENDS

FUTURE TRENDS IN GREENHOUSE GAS CONCENTRATION

Future trends in the concentration of carbon dioxide (CO_2) and other greenhouse gases can only be surmised on the basis of assumed rates of continued release into the atmosphere. Excess carbon dioxide originates primarily from the combustion of fossil fuels for energy production. Proven reserves of fossil fuels are sufficient to allow extraction at the present rate for at least 30 years in the case of oil and more than 200 years for coal, so that consumption in the near future will not be limited by the available supply. Furthermore, the exploitation of fossil carbon deposits is an essential component of the world economy: in 1988, 88% of all commercial energy production was based on the combustion of fossil fuels, the rest being provided by hydroelectric plants (7%) and nuclear reactors (5%). No convincing technological scheme has yet been proposed to reduce the atmo-

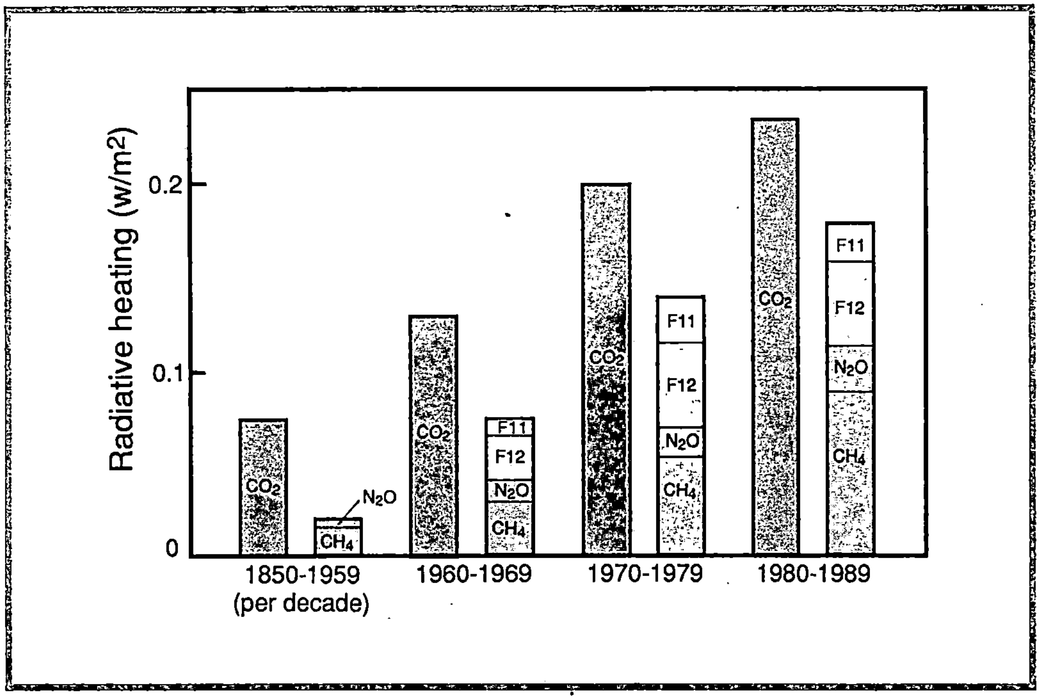


Figure 4. Computed decadal increments of the heating due to increases in the concentration of various greenhouse gases in each successive ten-year period (adapted from Hansen et a., 1988). F 11 and F 12 are the two most common chlorofluorocarbons.

spheric CO_2 burden and it may well be that any effort to scrub CO_2 from the air would consume more energy than was obtained from the combustion of fossil carbon in the first place. The most ambitious actions proposed so far are only aiming at limiting the rate of emission, thus allowing a steady increase of the concentration of carbon dioxide in the earth atmosphere.

Methane is produced by anaerobic decomposition of vegetal materials in wetlands, rice paddies and also in the stomach of cattle, so that emissions are related to the development of agriculture and animal husbandry. Accordingly, methane concentration has been rising steadily for several centuries, keeping pace with the increase in the world population and expansion of the world economy. On the other hand, chlorofluorocarbons (CFCs) do not occur naturally: they are synthetic products used in various industrial processes and also as propellant gas for sprays. The uses of CFCs, now still increasing, can be regulated and their future abundance depends on the implementation of international agreements to limit production.

The atmospheric concentration of carbon dioxide, measured with great precision at stations such as the Mauna Loa Observatory, is now increasing at the rate of 1.4 ppm per year. This annual increase corresponds to the addition of 3.3 gigatons (billion tons) to the total mass of carbon contained in the atmosphere in the form of carbon dioxide. This is to be compared to the current **annual emission of 5.5 gigatons of carbon** in carbon dioxide molecules produced by the combustion of fossil fuels, plus an amount of the order of 1 gigaton resulting from the combustion or oxidation of wood and other biomass. Thus, only about 50% of the anthropogenic carbon dioxide emission remains in the atmosphere.

This additional emission is a small percentage of the large fluxes of CO_2 between the atmosphere, the ocean and the terrestrial biosphere during a seasonal cycle, and an even smaller fraction of existing reservoirs of carbon in ocean waters and sediments. Relatively minor adjustments in the world ocean circulation and chemistry, or in the life cycle of terrestrial vegetation, could affect significantly the amount of CO_2 in the atmosphere, even when emissions are stabilized. In particular, ocean warming is likely to decrease the absorption of carbon dioxide by sea water. Conversely, positive changes in the primary biomass production of the ocean could increase the oceanic CO_2 uptake and ameliorate the greenhouse effect significantly.

Current knowledge of oceanic and terrestrial biochemical processes is not yet sufficient to account quantitatively for exchanges between the atmosphere, ocean and land

THE JOINT GLOBAL OCEAN FLUX STUDY

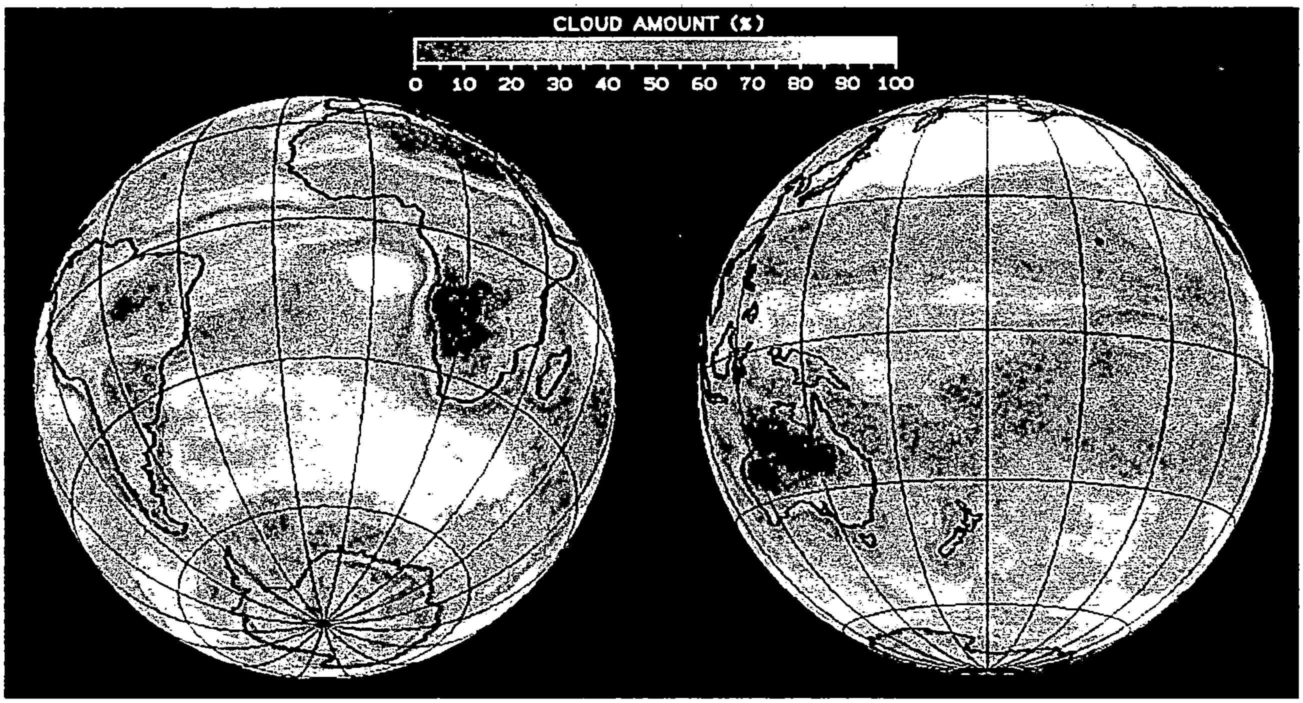
The Joint Global Ocean Flux Study (JGOFS) is an internationally co-ordinated programme, organized by ICSU's Scientific Committee on Oceanic Research, to be carried out during the period 1990-2000. The objective of JGOFS is to understand the global bio- and geo-chemical cycling of carbon and other biologically important chemical elements, which play a major role in the global environment. An essential component of JGOFS is a suite of basic physical and chemical measurements, to be carried out along representative oceanic sections, in co-operation with the WCRP World Ocean Circulation Experiment. Also essential will be satellite remote sensing of ocean colour, to characterize the marine primary biomass production and the fixation of CO_2 by the ocean.

To learn more about JGOFS, see: Report of the International Scientific Planning Meeting for Global Ocean Flux Studies, ICSU, Paris (1987).

vegetation: the discrepancy may be as large as 1 gigaton of carbon per year. Scientists have undertaken the international Joint Global Ocean Flux Study (JGOFS) to investigate the oceanic geochemical and biochemical processes that determine the cycle of carbon in the ocean and to assess the capacity of the ocean for absorbing CO_2. The new scientific knowledge sought by JGOFS may be the key to future successful intentional human interventions to control the global carbon cycle and regulate atmospheric carbon dioxide.

In summary, the global budget of atmospheric CO_2 of anthropogenic origin is not well understood quantitatively. Until this problem is resolved, predictions of the proportion of future CO_2 emissions which will remain in the atmosphere will be subject to considerable uncertainty. An even larger uncertainty lies in the future worldwide use of fossil fuels, for which estimates range from an annual increase of 1.5% to at least double this figure.

Under any circumstance, it is expected that considerable increase in the atmospheric concentration of most, if not all, greenhouse gases will occur in the next century. The working assumption adopted by the WMO/UNEP Intergovernmental Panel on Climate Change consists of three possible scenarios concerning the rate of increase of the total atmospheric burden. The high rate scenario is **equivalent to doubling the early 20th century concentration of carbon dioxide** (from 300 to 600 ppm) by the year 2030, the medium scenario by the year 2060 and the low rate scenario by the year 2090.



THE INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT

The International Satellite Cloud Climatology Project (ISCCP), is one of several systematic data collection and analysis efforts organized by the WCRP to derive essential climatological information. The objectives of the ISCCP, initiated on 1 July 1983, is to produce a continuous record of monthly mean cloud amounts and optical properties over the whole earth.

The properties of the cloud fields are described by more than eighty different parameters computed every month for each 2.5° latitude by 2.5° longitude box. To produce this information with appropriate time and space sampling, the project collects visible and infrared image data, produced **every three hours** by a multiple satellite array including one or two polar orbiting satellites and four geostationary meteorological satellites distributed around the equator. The vast task of assembling and processing these data from four different satellite systems, and extracting meaningful cloud parameters, is carried out by the NASA Goddard Institute for Space Studies in the USA.

To learn more about ISCCP, see Schiffer and Rossow, 1985.

THE CLIMATE RESPONSE

The earth climate has changed only minimally during the last fifty years, certainly much less than could be inferred directly from the imbalance of the radiative energy budget. The reason is that **the climate regime is determined by a fast system and a slow system**. The fast system is controlled by the atmospheric "heat engine" which drives the whole earth environment and determines the ultimate amplitude and geographical patterns of climate change. The slow system is regulated by the global ocean which sets the pace for climatic change and may introduce a delay of 50 years or more in the transient response of the earth's climate to greenhouse forcing.

It would be a serious mistake to imagine that the response of climate to the increasing greenhouse effect will be anything but complex. One may consider that the atmosphere and the upper-ocean layer (subject to an annual cycle of vertical stirring and mixing under the action of wind) constitute the fast component of the climate system. The fast component encompasses also transient processes at the air-land and air-sea interfaces, like the formation of snow and sea-ice. It is the active mechanism, the thermodynamic engine, which drives the whole climate system by transforming heat derived from the sun into kinetic energy. The slow component, on the other hand, is constituted by the deep ocean and perennial sea- and land-ice: its response sets the pace of long-term climate trends and climate change.

Interactions between the fast and the slow components are relatively weak over most of the globe because mixing between the warm upper ocean and the colder and denser deep water is limited by the stable stratification of the ocean. The slow response is associated with the transfer of heat by upwelling and downwelling motion of ocean water and, at high latitudes, by the sinking of cold, dense water from the surface. The slow pace of downwelling and subsequent upwelling sets a timetable, decades to centuries, for the adjustment of the deeper ocean to changes of the fast system.

The Response of the Fast Climate System

By the simple device of including only a shallow layer of upper ocean water, numerical models of the fast component can be made to adjust quickly to any specified change of externally imposed conditions and nevertheless simulate realistic meteorological processes on all time scales from a few hours to several weeks, and seasonal variations. Numerical experiments have been carried out recently on this basis,

Modelling Experiment	Computed Annual Mean Surface Warming
Manabe and Wetherald (1987)	4.0°C
Hansen et al. (1984)	4.2°C
Washington and Meehl (1984)	3.5°C
Wilson and Mitchell (1987)	5.2°C

Table 1: Computed global mean warming of the earth's surface for a doubled concentration of CO_2, when the atmosphere has reached equilibrium with the ocean.

with a 50 or 60 metres thick upper-ocean layer (Washington and Mehl, 1984; Wilson and Mitchell, 1987; Manabe and Wetherald, 1987; Hansen et al., 1984). These experiments show that the fast component comes to a state of **climatic equilibrium** after some 5 years of simulated time, with stable mean properties and no systematic climate drift. Such experiments are therefore suitable for describing the complex re-adjustments which would occur in the atmosphere and at the surface of the earth as a result of artificially switching-on new environmental conditions such as doubling the concentration of carbon dioxide.

Adjustments in the fast climate system are very complicated and involve **feedback processes** which amplify or reduce the primary greenhouse effect. The combined result of these feedback processes is a considerable augmentation of the computed climatic response. The most significant re-adjustment is the increase in the amount of atmospheric water vapour, which is itself a greenhouse gas. The next most significant feedback process is the change in the amount and distribution of clouds.

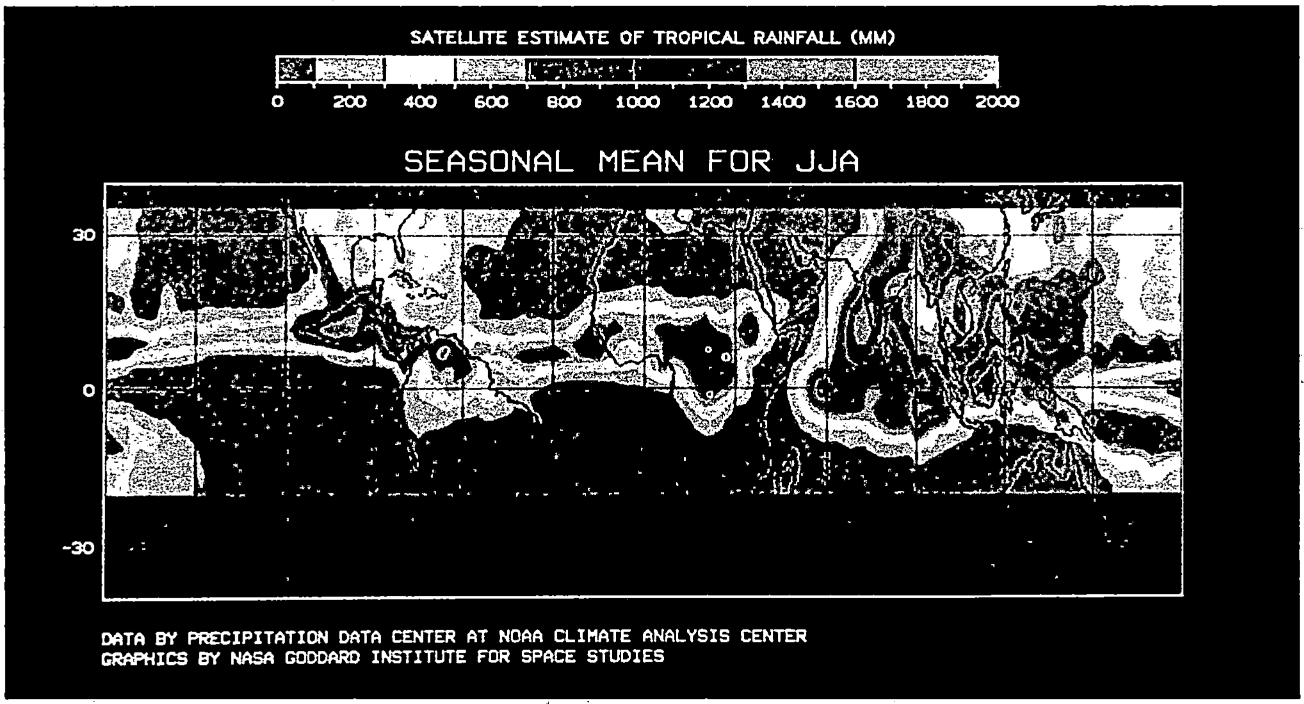
The response of the fast climate system affects all aspects of climate, in particular, the temperature of the lower atmosphere and earth surface. The **surface warming** varies with geographical location and season, but can be summarized by the global and annual average over the whole earth (Table 1).

The geographical patterns of temperature change appear broadly similar in all four simulations, with larger warming at high latitudes (up to twice the global average in the winter hemisphere) and lesser warming of the ocean compared to land. However, the predicted regional changes in temperature, and even more so precipitation, are very unevenly distributed and differ widely from one model to another. It is generally accepted that current models cannot provide reliable estimates of climate change on the regional scale.

The basic physical relationship between temperature and the saturation pressure of water vapour is such that a warmer climate entails a wetter atmosphere and thus a general **increase in precipitation**. On the other hand, a warmer climate results in **increased evaporation** and dryness, especially in the already arid sub-tropical belts. Some model simulations suggest that the increasing greenhouse effect will exacerbate soil aridity and the depletion of ground water in dry mid-continental temperate regions. One should recall, however, that ground water storage is a small difference between rainfall and evaporation, the latter being much dependent upon soil and vegetation properties, in models as well as in nature. A small and altogether plausible modification of assumed soil characteristics can make the difference between wet or dry soil predictions with a doubled CO_2 concentration (Mitchell and Warrilow, 1987).

The sensitivity of land hydrological processes to many poorly determined factors is, at present, an impediment to reliable computation of climate warming impacts on water resources. On the other hand, this very sensitivity is an indication that undesirable climatic impacts may be amenable to amelioration, at least in some regions, by appropriate treatment of soil and adaptation of vegetation. A central component of WCRP, the Global Energy and Water Cycle Experiment, is aimed at elucidating these problems.

Finally, it should be emphasized that even the general agreement obtained for global mean warming in recent model studies may be more an indication of the evolving state-of-the-art than a real proof of accuracy. A major unsolved problem is that of predicting reliably **the effect of clouds on the earth climate**. Low-level clouds reduce the absorption of sunlight and tend to cool the earth, while high clouds are essentialy transparent to sunlight but trap infrared radiation from the earth, thus contributing positively to the greenhouse warming of the surface. Not only is the cloud amount important to climate, but also cloud altitude and cloud optical properties. To illustrate this point, we note that a recent change made at the UK Meteorological Office, to introduce a more detailed formulation of physical and optical properties of ice and water clouds in their climate model, has yielded a drastically reduced estimate of global warming associated with a doubled CO_2 concentration, i.e. 1.9°C instead of 5.2°C as shown in Table 1 (Mitchell et al., 1989). The matter is made more difficult by the lack of reliable global statistics of observed cloudiness, cloud properties or precipitation, which could serve to calibrate existing climate models. The WCRP has undertaken the International Satellite Cloud Climatology Project to produce the required global cloud statistics.



The Response of the Slow Climate System

The model studies tell us that, if the fast system alone was involved in climate change, the earth climate would almost immediately follow the computed increase in greenhouse heating. Computations made with such simplified climate models indicate that the rise in greenhouse gases concentration already caused by human activities since the eighteenth century corresponds to a global surface warming in excess of 1.5°C. Such a highly visible climatological change has not occurred yet, as demonstrated by Figure 5, showing a 125-year time series of global mean sea-surface temperature compiled by Folland et al., (1984). As a matter of fact, it can be seen from this work that the mean ocean surface temperature during the period 1860-1880 was essentially the same as now, although a noticeable cooling and subsequent warming occurred in the intervening period. The record of the global mean near-surface air temperature, combining measurements over ocean and land (Figure 2), indicates a definite warming trend, about + 0.6°C over the last hundred years. However, most of the temperature rise was observed during the first fifty years from 1880 to 1930, although less than one third of the total greenhouse gas increase occurred during that period. Global warming for the period 1940-1990 has only been about 0.2°C. In short, it is clear that the real climate is behaving quite differently from the fast response of a planet with only a very shallow ocean, and **does not follow directly the trend in radiative heating** induced by the increasing greenhouse effect.

In simple terms, the response of the slow climatic system is

THE GLOBAL ENERGY AND WATER CYCLE EXPERIMENT

The Global Energy and Water Cycle Experiment (GEWEX) is a programmme launched by the WCRP to observe, understand and model the hydrological cycle and energy fluxes in the fast component of the climate system. The goal of the programme is to reproduce and predict, by means of suitable models, the variations of the global hydrological regime and its impact on atmospheric and oceanic dynamics, as well as variations in regional hydrological processes and water resources, and their response to change in the environment such as the increase of greenhouse gases. The GEWEX programme incorporates a major atmospheric modelling and analysis component requiring a substantial increase in computer capabilities, especially because high spatial resolution is needed in climate models to achieve realistic simulations of regional effects.

The GEWEX programme has begun with an ensemble of modelling studies focused on both atmospheric and hydrological processes, such as reproducing the hydrology of a continent-size river basin driven by daily precipitation and evaporation estimates and field studies on the scale of a small region (10 to 100 km). The GEWEX programme has also undertaken assembling available raingauge measurements and meteorological data with satellite observations of rainclouds, using either infrared images or microwave radiation, to produce the first climatological record of monthly-mean rainfall totals over the whole earth including, of course, the oceans.

It is clear that achieving the objective of GEWEX will require a major step forward in the development of global observing techniques using new, more massive and power-demanding satellite sensors, such as lidars and radars, which will be placed on the next generation of heavy earth observation spacecraft in polar orbit and/or the International Manned Space Station in the late 1990s. For this reason, the support of the major space agencies, particularly in the USA, Europe and Japan, is essential to the success of GEWEX. In addition, GEWEX also requires strong support from meteorological and hydrological agencies and institutions to upgrade the collection and interpretation of essential ground-based measurements of radiation, rain, riverflow, etc.

GEWEX has been formally endorsed by WMO and ICSU as a major component of the international climate research strategy, including the participation of the International Association of Hydrological Sciences. GEWEX and the IGBP programme on the biospheric aspects of the hydrological cycle are jointly planning interdisciplinary field studies.

To learn more about GEWEX, see: Concept of the Global Energy and Water Cycle Experiment, WCRP-5 (WMO Technical Document TD-215, Geneva, Switzerland.

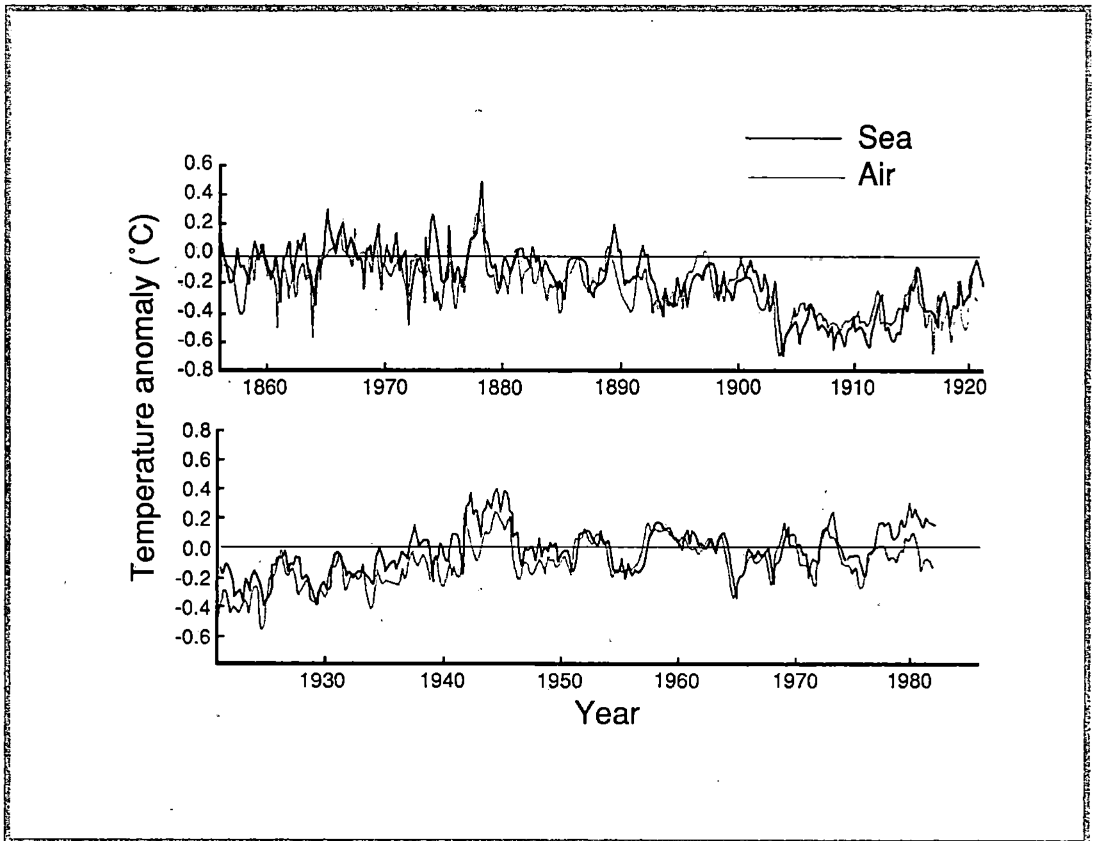


Figure 5. Record of the sea-surface and night-time air temperature anomalies (relative to the period 1951-1960) averaged over all oceans (adapted from Folland and Parker, 1984). The global mean sea-surface temperature during the last fifty years has not been markedly different from that prevailing around 1860.

controlled by two basic parameters: first, the change in the net energy flux at the surface of the ocean produced by the increase in the concentration of greenhouse gases and subsequent readjustments of the atmosphere and land surface, and second, the heat capacity of that part of the ocean which will be effectively subject to warming over a period of several decades. The first quantity can be estimated from suitably designed numerical experiments with models of the atmosphere and upper-ocean layer only. The effective heat capacity of the ocean is determined by the **penetration of heat in deep water.** This penetration into the upper kilometre of the ocean cannot be represented by a simple diffusion process because it results, for the main part, from the sinking of water at mid-latitudes and subsequent equatorward and downward circulation in the ocean, itself controlled by surface winds and surface cooling. The rate of renewal of water below the near-surface mixed layer can be inferred from the penetration of ^{14}C isotopes released into the atmosphere by the mid-1950s series of thermonuclear explosions (Figure 6). Such observations, combined with knowledge of the subsurface temperature/salinity structure and ocean circulation, allow the estimation of the residence time of water at different density levels.

Information about net surface heat fluxes and the world ocean circulation can be combined to estimate the characteristic response-time for realizing a given fraction (e.g. 70%) of the computed equilibrium surface warming after a constant double CO_2 concentration is introduced.

This "e-folding time" indicates the **delay of the response** of the whole climatic system, compared to that of the fast component alone. A wide range of values has been proposed

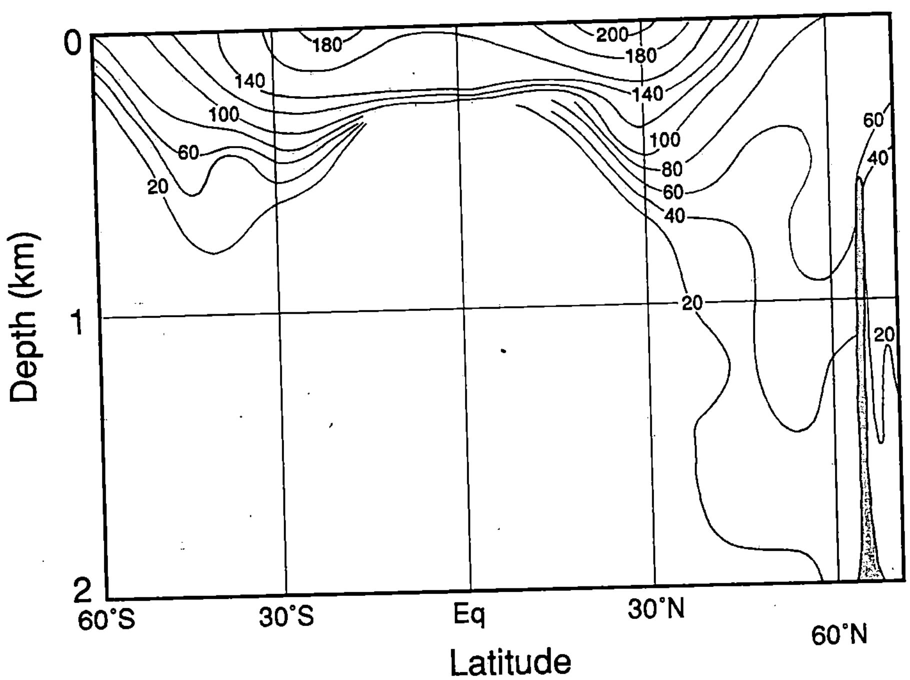


Figure 6. Penetration of the radioactive isotope ^{14}C from the time of the first thermo-nuclear bomb tests in the mid-1950s until the 1973 GEOSECS survey in the Atlantic ocean (arbitrary radioactivity units). Mixing has occurred down to a depth of about 300 m in the course of twenty years, except at high northern latitudes where deep sinking occurs.

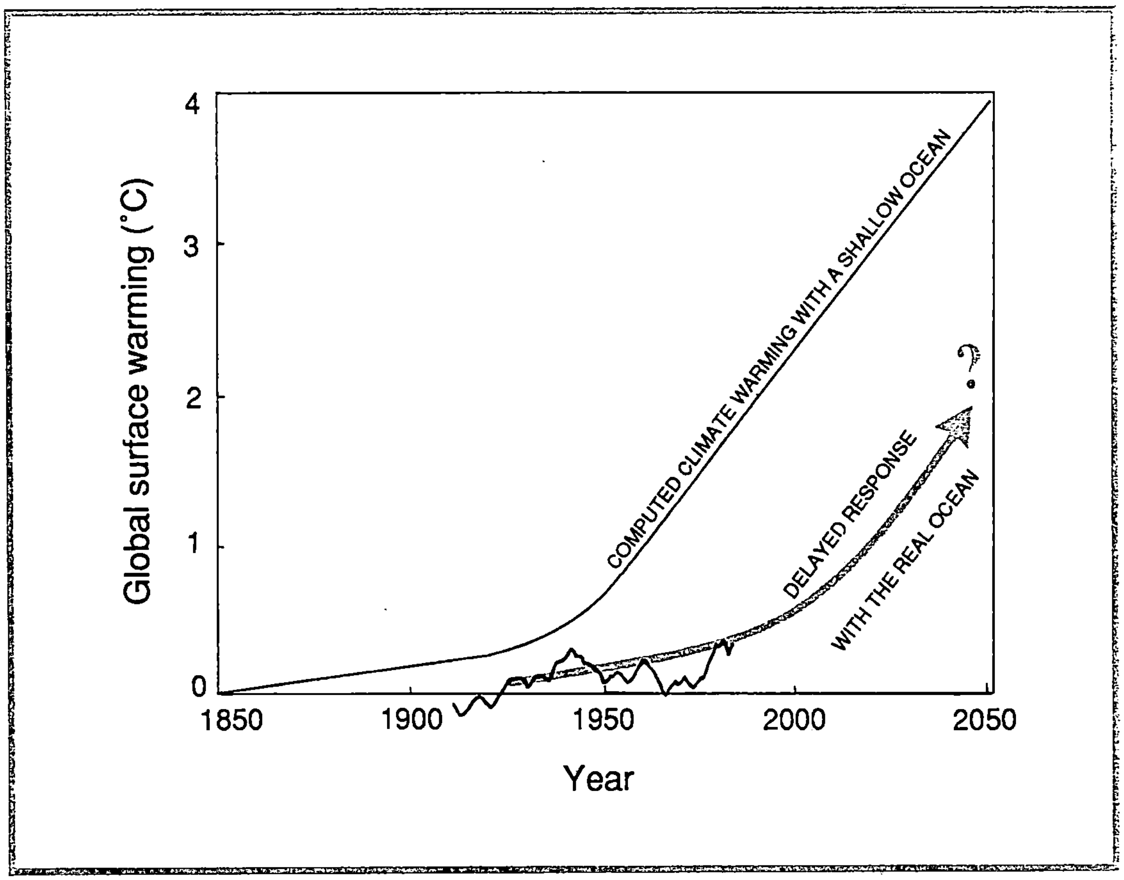


Figure 7. A possible climate warming scenario for the global atmosphere only (black line) and the complete earth climate system (coloured line). The observed global temperature record is shown on the same scale (Morel, personal communication).

for this e-folding time, from 10 to 100 years. Values derived from global ocean circulation models developed so far are in the upper part of this range: 75 - 100 years for the Oregon State University model (Schlesinger et al., 1985) and about 50 years for the Geophysical Fluid Dynamics Laboratory model (Bryan et al., 1988).

Figure 7 compares the plausible response of the coupled atmosphere and ocean, with the computed change in earth surface temperature for the atmosphere alone, given a linear increase of greenhouse heating equivalent to doubling the pre-industrial concentration of CO_2 by year 2050 (Morel, personal communication).

Deep water formation, renewing the water in the lower two kilometres of the ocean, occurs at high latitudes through surface cooling, formation of sea-ice and subsequent deep convective mixing. However, it is possible that surface warming (and permanent melting of sea-ice) would

THE WORLD OCEAN CIRCULATION EXPERIMENT

The World Ocean Circulation Experiment (WOCE) is a worldwide oceanographic programme, led by ICSU's Scientific Committee on Oceanic Sciences (SCOR) and the Unesco Intergovernmental Oceanographic Commission, and organized as a component of the WCRP, to determine the oceanic circulation at all depths and on the global domain, within a five-year period (1990-1995).

The primary goal of WOCE is to develop global ocean models that are useful in the prediction of climate change and to develop the data sets necessary to test those models. Over the five years of the programme, there will be an intensification of the effort to determine air-sea fluxes globally by combining marine meteorological and satellite data, an upper-ocean measurement programme to determine the annual and interannual oceanic response to atmospheric forcing, and a programme of high quality hydrographic and chemical tracer observations, surface and under-water drifters, current meter arrays, tide gauges and satellite altimetry to determine the zero order deep-ocean circulation. WOCE will also make intensive use of historical oceanographic data to assess the longer-term variability of ocean circulation.

All major oceanographic agencies and institutions are joining forces to deploy the research vessel fleet needed to implement the WOCE hydrographic and geochemical surveys at sea, which call for 25 years of ship operation time. In addition, three new satellite missions are in the final stages of preparation or are being planned to support WOCE:

- The US-French TOPEX/POSEIDON precision altimetry mission, to measure the ocean surface topography with unprecedented accuracy (1991);
- The European Space Agency ERS-1 mission to measure wave-height and ocean surface topography, wind stress and temperature (1991);
- The US-Japanese ADEOS mission to provide, in particular, more complete observations of the wind stress over the global ocean (1995).

In addition to observing activities at sea and in space, WOCE is planning a major oceanic modelling and data analysis activity, requiring a substantial increase in computer capabilities. Larger and faster computers are necessary to develop and run global eddy-resolving ocean models with sufficient vertical resolution, to adequately simulate the process of convection in the upper layers, the flow of deep water over sills and through passages and the eddy exchanges of momentum, heat and salt in the strong boundary currents of the principal ocean gyres.

To learn more about WOCE, see: J.D. Woods, 1985; also: World Ocean Circulation Experiment, Implementation Plan, Vols. I and II, WCRP-11 and 12 (WMO Technical Documents TD-242 and 243, Geneva, 1988).

suppress this sinking and essentially insulate the deep ocean water from the upper-ocean and atmosphere. The consequences of such an event would be catastrophic for marine life and would drastically reduce the buffering of further change by the ocean.

The World Ocean Circulation Experiment is a major worldwide oceanographic programme, undertaken under the WCRP, to achieve a global description of the ocean circulation and to establish on a firm scientific basis, the estimation of the transient response of the ocean to atmospheric influences.

PREDICTING SEA-LEVEL RISE

In past historical times, variations of the mean sea-level at a particular shore have been caused mainly by tectonic effects which force the **land to sink or rise** locally with respect to the global reference geoid, without much change in the mean ocean surface. The rapid increase in greenhouse gases and consequent climate warming is expected to cause, in the 21st century and thereafter, a global rise in mean sea-level resulting from an actual increase in the **volume of the world ocean** due both to the addition of meltwater from glaciers and polar ice caps and to the thermal expansion of sea water. An upper limit of 60 centimetres can be estimated for the rise in global sea-level expected by the end of the next century, but this estimate is fraught with large uncertainties.

Few coastal stations exist where long time-series of consistent sea-level measurements are available and these stations are not distributed evenly around the globe. For this reason, estimates of variation in the global mean sea-level can only be obtained for the last century. The latest and most rigorous analysis of tide-gauge data (Barnett, 1984) indicates a global rising trend of 14 cm per century with a tendency to accelerate in the last fifty years. There is no way to relate this observed rise to possible causes with any degree of certainty.

If all mountain glaciers and small inland ice caps were to disappear entirely and add their meltwater to the ocean, they would cause the global sea-level to rise by only 33 cm. It is clear that the continuing retreat of mountain glaciers, begun two centuries ago, could not add much to the volume of the ocean, possibly a further 20 cm rise by the end of the 21st century. On the other hand, the interplay between snow accumulation on large ice caps and melting or iceberg calving, when ice discharge takes place into the sea, could in principle cause much more substantial excursions in global sea-level.

Ice budget estimates for the Greenland and Antarctic ice caps under the warmer climate conditions expected in the 21st century have been given in the review published by ICSU's Scientific Committee on Problems of the Environment (SCOPE, 1986).

Increased ablation is expected to dominate the ice budget of the Greenland ice cap, yielding a general decrease of the inland ice mass and a 13 to 26 cm rise in mean sea-level due to the release of meltwater during the next century. On the other hand, temperatures are and will remain well below freezing in

Antarctica, so that melting can be altogether neglected there.

The ice budget of the Antarctic ice sheet will therefore be balanced by snow accumulation and iceberg discharge into the ocean. Because the horizontal extent of the ice sheet is limited by the size of the Antarctic continent, barring a "fast" surge of the west Antarctic ice sheet, now solidly anchored offshore by submarine obstructions, the budget of the Antarctic ice cap under warmer climate conditions will be dominated by more abundant snowfall and increased accumulation, yielding a thicker ice cover and a consequent **lowering of mean sea level**, between -20 and -90 cm by the year 2100. For lack of more precise knowledge, glaciologists tend to the view that melting of the Greenland ice sheet and snow accumulation on the Antarctic ice sheet will counter-balance over the next century. This would leave a net contribution to sea-level rise of about 20 cm, coming mainly from the melting of mountain glaciers.

The global ocean, on the other hand, has been storing energy for several decades and may continue to do so at an even faster rate during the next century as the greenhouse effect increases. Since the variations of the thermal expansion coefficient are relatively moderate in the upper layer of the ocean, where most of the warming will take place, the linear expansion of a water column is, to first order, independent of its depth and directly proportional to the total amount of heat stored in the column.

The problem of ocean thermal expansion is thus reduced to that of estimating the integrated heat intake of the world ocean over a particular period in the future, given a specific scenario for the increase of the greenhouse heating. Based on a full three-dimensional computation of the initial response of a coupled ocean-atmosphere model to doubling the concentration of CO_2, Bryan and co-workers estimated a net heating rate of 2.5 Watts/m^2 (Bryan et al., 1988). This value has been obtained after adjustment of model properties in the troposphere and on the land surface (fast component of the climate system) but before significant adjustment of the ocean temperature (slow component). Since the ocean surface must warm up eventually, it is plausible that the imbalance, measured by the net energy flux at the ocean-atmosphere interface, should not exceed 2.5 Watts/m^2 during the next century. This line of reasoning places an upper limit of about 40 cm on the global sea-level rise which can be expected from thermal expansion of the oceans by the year 2100.

Critical elements in these estimations are the changes in the rate of snowfall over Antarctica and net energy flux at the ocean-atmosphere interface under changing climate conditions. Both quantities are strongly dependent upon climate model assumptions and the accuracy of computed energy and water fluxes in the atmosphere. A major scientific objective being pursued by the WCRP is to determine these fluxes correctly. The planned Global Energy and Water Cycle Experiment is the centrepiece of the scientific strategy to achieve this goal. In addition, detailed investigations will be required in the future to understand heat and water exchanges around the Antarctic continent and the mass budgets of the Greenland and Antarctic ice sheets and shelves.

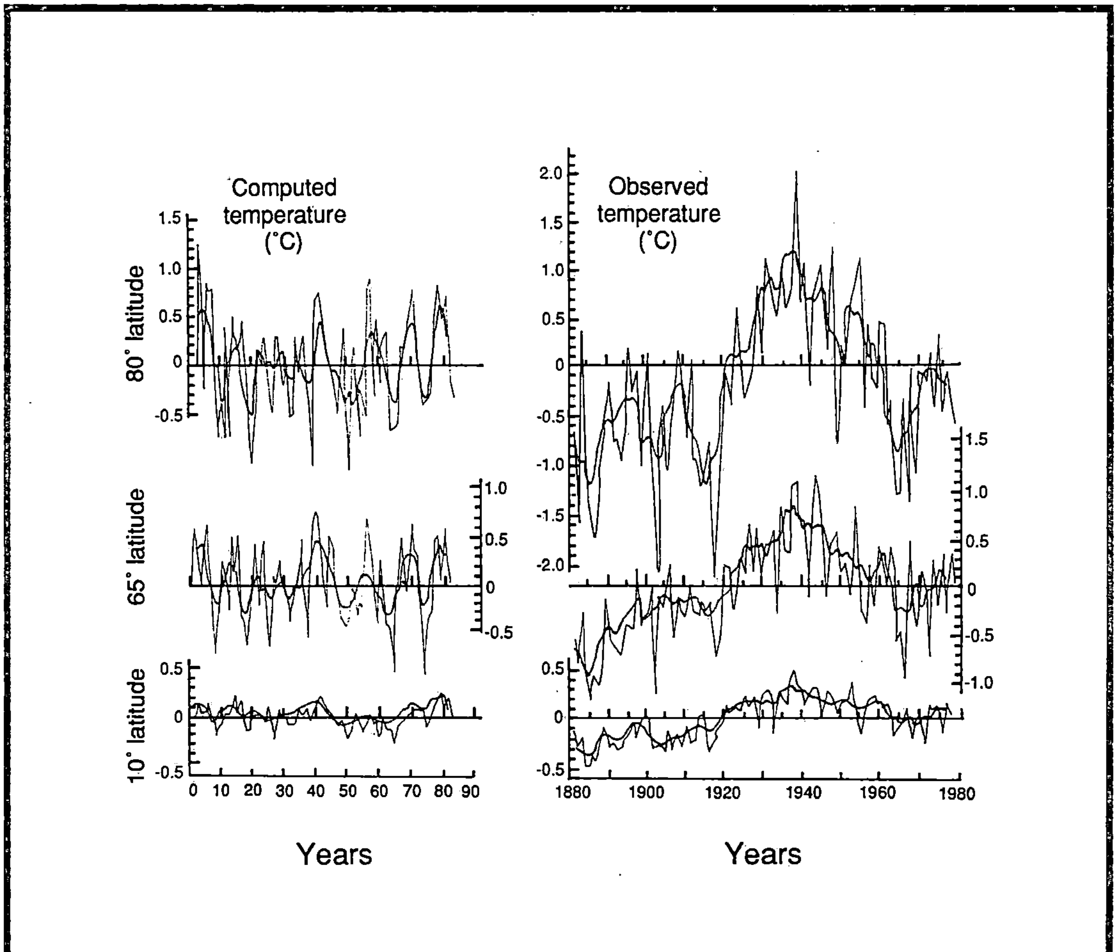


Figure 8. Zonal-mean temperature in the northern hemisphere, as computed by a global atmosphere-ocean model on the left hand panel and as observed on the right-hand panel, according to Mahlman (personal communication) and Vinnikov et al. (1980). The model simulation gives a reasonable facsimile of shorter-term climate variations but does not predict climate change resulting from (still unknown) processes of the deep-ocean circulation.

PREDICTING FUTURE CLIMATE CHANGE

The evolution of the earth climate in the next fifty years will result from ongoing natural variations combined with a warming trend forced by man-made modifications of the atmospheric concentration of greenhouse gases. Natural variations on relatively short time-periods of decades to a century will be caused by the internal dynamics of the earth's climate system. The warming trend, on the other hand, will be induced by the steady increase of the greenhouse effect in the atmosphere. Actual warming is being delayed by the thermal inertia of the world ocean, but it will also continue long after the composition of the atmosphere is stabilized. No matter how drastic the actions taken to control the emission of greenhouse gases into the atmosphere, the global warming to which we are already committed will be realized in the next fifty to hundred years: global environmental change is inevitable.

The warming realized so far is still well within the range of transient natural variations and cannot be separated from these with our present knowledge. It is possible, however, that the limits of natural variability could be exceeded in the next ten to twenty years.

The left-hand panel of Figure 8 represents the mean zonal surface temperature of the earth in various latitude bands for the last period of a 200-year simulation of the earth's climate carried out at the Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey (USA) with coupled models of the global oceanic and atmospheric circulations.

The computation reproduces fairly the observed climate variability on short time-periods (i.e. year-to-year or decade-to-decade) and also the latitude dependence of this variability which increases from the equator to the Arctic, as can be seen by comparing with climatological statistics compiled by Vinnikov et al. (1980), on the right-hand panel. The simulation, however, does not reproduce the substantial longer-term climate variations which have occurred during the last hundred years. This discrepancy was expected because, unlike the real climate, the simulated system was, by the very nature of the experiment, forced into an artificial state of climate equilibrium.

The experiment illustrates the fact that the real climatological history of the earth includes transient variations which involve, in an essential way, the behaviour of the deep ocean and substantial departures from equilibrium between the fast and the slow components of the earth climate system. Any attempt to predict the future evolution of climate must include a forecast of the evolution of this slow component, starting from **observed initial conditions**. We are unable at present to carry out such a forecast for lack of suitably accurate ocean circulation models (not yet perfected) and even more so, for lack of an adequate synoptic (instantaneous) description of the global ocean circulation. The WCRP World Ocean Circulation Experiment (1990-1995) will be the first attempt to collect the observations needed to produce this kind of global description, which will be essential to discriminate the warming trend caused by the increase in the man-made greenhouse effect from transient natural variations.

For the purpose of estimating long-range climatic trends such as mean global warming, however, the climate system may be approximated by a simple conceptual model, consisting of a heat reservoir receiving cumulative annual net energy inputs. A property of this simple model is its long latency period during which the climate response to greenhouse forcing remains small, as observed now. However, after a delay of the order of the e-folding time, the pace of global warming accelerates markedly and approaches that of the response to greenhouse heating of the atmosphere alone.

The **global warming rate**, consistent with an assumed equivalent doubling of the concentration of carbon dioxide by the year 2050 and an estimated 4°C equilibrium warming for this doubled concentration, is about 0.3°C per decade (Figure 7). A transient climate warming simulation experiment, reported by the Goddard Institute for Space Studies (Hansen et al., 1988), actually indicates a warming rate of 0.35°C per decade for a similar greenhouse gases scenario. This rate of global warming exceeds the fastest global temperature trend observed during any ten-year period since 1880 (Figure 2) and would soon cause a major departure from the prevailing climatic regime.

Detailed investigation into the dynamics and thermodynamics of natural transient climate variations, and quantitative computations of the response to the steady increase in greenhouse heating, is the approach WCRP is pursuing for detection of incipient warming and prediction of the future course of global and regional climates.

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EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

June 13, 1990

MEMORANDUM FOR JOHN H. SUNUNU AND RICHARD G. DARMAN

THROUGH: ROBERT E. GRADY

FROM: JACK D. FELLOWS

SUBJECT: Thermal Expansion of the Oceans

This memo is in response to the question on the validity of the IPCC Working Group I (WGI) assumptions concerning the relationship between sea level rise and thermal expansion of the oceans. If I understand the question correctly, the concern is that the WGI estimate was too high because the cold water from melting polar ice would offset much of the thermal expansion. Not right

It is unlikely that this would be the case. Of the 18 centimeter (with a 8 cm to 29 cm range) sea level rise by the year 2030 that was predicted by the WGI in response to the IPCC High Emission Scenario (also referred to as "Business-as-Usual" case), 10 cm is due to thermal expansion, 7 cm from the melting of mountain glaciers, 2 cm due to the melting of the Greenland Ice sheet, and -1 cm due to the freezing in the Antarctic Ice sheet. Thus, polar melting is a relatively minor contribution to sea level rise and unlikely to affect thermal expansion in any significant way.

However, there are plenty of other weak assumptions that undermine the validity of these predictions, including:

- The use of extremely primitive "box" climate models to estimate the oceanic mixing processes and heat transfers. This box model represents the world's land and oceans by a few boxes.

- There are large uncertainties in the estimates of glacier and ice cap volumes. Although the surface area is known fairly well, there is little data on the depths of glaciers and ice caps. The WGI assumed a global average depth of 200 meters.

- Depending on the location of ice, it will either contribute to a sea rise (Greenland Ice sheet) or sea lowering (Antarctic Ice sheet). As you know regional surface temperatures are one of the weakest products from climate models.

- The models do not correct for changes in local and regional vertical land movements from erosion, earthquakes, subsidence, and other solid earth changes.

All of these uncertainties are discussed in detail in the WGI full report but not in the Executive Summary and Policymakers Summary. I do not believe this is intentional, but part of the difficult job of summarizing a complex and lengthy technical report into a policy-level summary. I did have an opportunity to discuss these sea level uncertainties with Dr. Bromley last Friday.

Global warming

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Cover: Video color image of an INSAT-1B VHRR visible image from 0630 UTL 4 June 1984 produced on the Micro-based Image Display and Graphics Enhancement Tool (MIDGET). Both the East Asian (Burma) and Southwest (Indian) monsoons are active as indicated by the organized convective systems in the Arabian Sea and the northern portion of the Bay of Bengal. The date of Indian Monsoon onset for 1984 was 31 May, which is within one day of normal (1 June). The image is a full earth sector made up of 22 km pixels; an on-line MIDGET navigation package provides the earth location gridding.

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Greenhouse Policy and Climate Uncertainty[1]

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1. Introduction

The global climate warming issue has now become an international scientific and political happening. It is difficult today to pick up a newspaper or view television without encountering a story or an interview on the subject of global climate warming, now familiarly embraced in the vernacular under the rubric of the "greenhouse effect."

No ideological or political boundary separates the calls to action. From General Secretary Gorbachev of the USSR and Prime Minister Thatcher of the United Kingdom, to prime ministers Mulroney of Canada and Brundtland of Norway, calls for international action resound.

In March 1989, representatives of 23 nations, including many heads of state, gathered in the Hague at the urging of President Mitterand of France and other European leaders and recommended that the United Nations be given supranational authority to regulate global activities regarded as the causes of the greenhouse problem.

Not to be outdone, in the bidding for international leadership on the issue, the United States through the pronouncements and actions of President Bush and Secretary of State Baker, is urging action on many international environmental fronts. The Congress is no less active. A half-dozen new pieces of climate legislation are being considered.

Nor have the academies of sciences and engineering been silent. Quite the contrary, we have been vocal and forward on the issue. For over a decade these academies have conducted studies on global climate change, making assessments that have buttressed the legitimacy of the concerns expressed by our political representatives. Most recently, as a result of legislation in the last Congress, the academies have embarked on new studies of climate and the underlying energy issues. In a move to place its views before the new Bush administration, the academies have issued a "white paper" on global change with broad policy recommendations.

The scientific community has identified an issue that lends itself to support by leaders everywhere—the mission of saving the inhabitability of the planet. It is a mission that now ranks in importance and political panache with saving the planet from nuclear destruction. Like the mission to save the planet from nuclear destruction, it raises politically divisive concerns such as those between the technologically advanced and developing nations.

How robust is the scientific basis for this grand outpouring of world concern? What are the policy directions that make sense in the light of the certainties and uncertainties in our knowledge? What are the policy problems that need resolution given the likely social and economic costs of action or the consequences of inaction?

My colleagues Bert Bolin and Steve Schneider have ably described the state of our knowledge of the forcing functions (those activities that cause the changes in the composition of the atmosphere) and the atmosphere's response to these changes, or the ways in which the earth's climate is projected to be altered as a result of such compositional changes.

As scientists and engineers we often eschew responsibility for policy decisions because they are laden with judgments balancing known facts, uncertain interpretation, and social and economic costs more properly made in the political arena. Unfortunately, we cannot totally escape that responsibility because those political judgments are shaped by the way we present our conclusions to those who have to formulate policy. We have it in our power to trigger political action unwarranted by data or scientific findings. Conversely, we can so allay real concerns that inaction results when action is desirable.

Whether we in the scientific community like it or not, we have awakened the political beast and those communities of scholars who revel in the challenge of public policy formulation and debate. The ability of the scientific community to influence actions recedes as groups are increasingly locked into policy positions.

The fact is that we grapple with an issue that is noisy in many dimensions. The climate record is noisy, as are the results of mathematical computations. Knowledge of likely effects is speculative and the policy debate is informed with contradictory data and interpretations. Can we isolate the signals from

[1] Speech given at the Annual Meeting of the National Academy of Science, April 1989, Washington, D.C.

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the noise in all significant dimensions? That is our task. That is our obligation.

2. The knowledge base

Any soundly based policy actions must emerge from our knowledge of causes and effects and the uncertainties in that knowledge weighed against the risks, consequences, and costs of action. We know much about the former and little about the latter. Our knowledge of the likely causes is well documented. Our knowledge of the climate system response to these causes is extensive but fraught with uncertainty. Our knowledge of the social and economic consequences is weak and speculative.

The concentrations of greenhouse gases have been accurately measured for over a quarter of a century in many parts of the world and they reveal inexorable increases. The CO_2 record of observations taken at the National Oceanic and Atmospheric Administration (NOAA) Mauna Loa Observatory in Hawaii is arguably the most important geophysical record of this century. We know much about causes of changing atmosphere composition—the burning of fossil fuels, the industrial production of CFCs, and the agricultural production of nitrous oxides. We know less about others, the sources of the increases in methane, for example.

We can assess the climate system response in two ways. We can simulate the system with mathematical models and examine the range of responses to the known and projected forcing functions. We can also examine the actual climatic record. Mathematical models developed by many groups in the United States and abroad yield the basic projections on which our concerns are principally based. As Steve Schneider has described, they yield projections of global average surface temperature increases ranging from 2°–5°C since the turn of the century with greater increases in polar regions for a doubling of greenhouse gas concentrations sometime after the middle of the next century. The models do not portray regional and local effects well.

The models are approximations to the real world and their simulation of natural physical processes is well known to generate considerable uncertainties in the results, especially as they reproduce critical feedback processes.

Our confidence in the mathematical models is based on their ability to reproduce the seasonal variations of climate, the general reasonableness of the manner in which climatic factors are portrayed, and the consistency of results. Some question whether our confidence in the output of these models is well placed given the uncertainties. Yet there is a preponderance of views among those who have worked the problem, that a large measure of confidence is warranted but that the uncertainties are troubling and need much attention.

What about the system response as deduced from the observational record? Does the observational system response support the theoretical response calculations and does the response evidence any systematic changes in climate.

It is well documented that climate is observed to fluctuate on all time and space scales. Drought and wet climates have been the perennial scourge of mankind. For the past century, during which humanity's introduction of greenhouse gases into the atmosphere has increased greatly, the instrumental record is equivocal. It is a noisy record affected by the sampling of the global atmosphere through a network of observations established for other reasons—principally weather forecasting. It is affected by the accuracy and representativeness of the observations. It is also affected by external factors such as urban growth, which produces real, but climatically artificial, local and regional temperature readings. Such data reveal that global average surface temperatures have had a roller coaster history. During the period 1900–40, temperatures increased, cooled during the 1940–65 period, and have increased again from 1965–88.

In over-land areas of the United States where we have the richest and probably most reliable data, there has been no detectable increase in temperature since the turn of the century. This could be a sampling problem. The United States may be unrepresentative of the global average temperature. The data pool also presents sampling difficulties for the globe. Over many parts of the less-developed world, the tropics, and the oceans, data are of poor quality, sparse, and may be unrepresentative. The best analyses of such data reveal a net increase of about 0.5°C over the past century. This net temperature change is consistent with the lower end of the projections from the mathematical models but could also be a natural phenomenon. Recent findings of the effects of urban growth suggest that this increase may be an overestimate.

But, there are puzzling features of the observed global climate record. For example, temperature increases, largely attributable to the records from tropical and ocean areas, are not consistent with model projections that the largest temperature increases should occur in polar regions.

Is it too early to extract the signal from the noise of the record? Many would argue yes. Others would argue that a century during which the CO_2 content of the atmosphere has increased some 25% should have revealed a clear signal by now. Those who argue that the global temperatures of the past five years, the warmest in the instrumental record, signal the onset of the greenhouse climate could have come to an analogous conclusion during the drought of the thirties. However, they would have encountered the systematic cooling during the midcentury years, which incidentally gave rise at that time to predictions by some of a new ice age. In my view, the jury is out.

We are confronted with an inverted pyramid of knowledge; a huge and growing mass of proposals for policy action is balanced upon a handful of real facts. Data on likely causes are robust, though future emission projections vary widely. Projections based upon mathematical approximations of atmospheric and oceanic conditions are credible but uncertain. Evidence from the climatic data is equivocal.

Policy actions must reflect the risk of serious social and economic consequences of climatic change. They could be severe but are in the realm of informed speculation. Most of our information is analogue or scenario based. We know a great deal about the effect of weather and climate on agriculture, water resources, forestry, and other economic functions from extensive study of the effects of droughts or heat waves or severe winters. We know the devastating ramifications for economic and social conditions—witness the effects of the droughts of the Sahel in Africa in recent years, and the drought of last summer on the Midwest. Such analogue information is sound and can be extrapolated. It is the scenario based information that is speculative. By "scenario" I refer to the "what if" studies. These studies are useful if they are considered for what they do: provide a range of possibilities. But frequently they are interpreted as forecasts. It is here that the apocalyptic nature of outcomes emerges and penetrates the political consciousness through news stories about imminent global catastrophe.

If our model projections are correct we can say some interesting things. For example, we can expect an increase in sea level. Recent observations seem consistent with this projection. If sea level rises we can be reasonably certain that coastal areas will be affected with saline intrusions and increased coastal erosion. On the other hand, we cannot say much about local and regional effects of temperature and precipitation changes and their specific local effects on agriculture, water resource, and ecological and economic systems. There would be effects on agriculture, but we are not quite sure what they would be and whether they might be acceptable or even beneficial. Increased carbon dioxide content of the atmosphere favors increased photosynthesis and crop growth. There would be effects on storm tracks, probably moving them toward the poles, a result of the reduced pole-to-equator temperature gradients. Precipitation belts would likely migrate to more polar latitudes with consequences for agriculture and water resources in the Southwest. There would be effects on natural ecosystems and their resiliency would depend upon the rate of change of climatic temperatures and precipitation. But it is impossible to be specific beyond such generalization.

3. Policy principles

And so we find ourselves in a classic dilemma of policy formulation—possibly severe but unknown levels of risk of undesirable consequences of climatic change in the face of great uncertainty about causes, costs and consequences. The dilemma is compounded because the consequences will be visited on future generations unevenly through the redistribution of global climatic resources. Policy principles in such a situation would suggest (1) investment in improving the information base to reduce uncertainties so that policy actions could be based on improved understanding; and (2) adoption of policies—insurance policies, if you wish—that address causes and predicted consequences in such a way that future options are not foreclosed if projections turn out to be incorrect, and which may be desirable for other environmental and economic reasons.

The policy framework would have to recognize the inherent international nature of the issue, its potential divisiveness as between developed and developing nations, the considerable social and economic costs attendant on significant actions, and the absence of institutions on the international scene in a position to formulate and implement necessary policies. Let us examine the policy issues and see to what conclusions they lead.

Improving the information base to reduce uncertainties in our data, in our projections, and in the understanding of consequences would seem to be a sine qua non. These actions are not costly, do not preclude future policy options, and can sharpen policy decisions. This means investment in improved understanding of physical processes so that they can be modeled more accurately, intensified examination of climate data bases, improved assessments of projected emission rates of greenhouse gases, and improved space and ground based monitoring systems. Programs to achieve some of these objectives have been formulated in President Bush's proposed Global Change Initiative and it is expected that strong support will be forthcoming from Congress. The World Climate Research Program of the World Meteorological Organization and the International Geosphere-Biosphere Program of the International Council of Scientific Unions are underway and receiving widespread international support. The first international intergovernmental forum has been established to examine the full range of climate problems, including the possibilities for national and international responses under the aegis of the World Meteorological Organization and the United Nations Environmental Program.

The really controversial policy issues surround the possibilities for intervention in the climate change process. Can we arrest or slow the processes that increase the concentrations of greenhouse gases? The answer is yes. But we have no grasp on the social and economic ramifications of intervention. We have a reasonable grip on the sources and amounts of emissions and we have a reasonable grasp on the reductions in emissions that would be necessary to constrain the global temperature increase.

The possible courses of policy action are in a sense obvious, and they relate largely to the production, distribution, and end use of energy. If fossil fuels use is the principal culprit in the CO_2 buildup, policies should be directed to the use of the least polluting fossil fuels, the reduction in use of all fossil fuels, and development and use of nonfossil energy sources. In practical terms, we must shift from coal to oil to natural gas, undertake major efforts to increase energy efficiency, and develop and deploy passively safe and publicly acceptable nuclear power as well as other nonfossil energy sources.

Energy policy actions have great leverage because they also address a broad set of environmental issues. Most environmental problems are interrelated through their physics, chemistry, and biology and have common causes. Thus certain policies will have multiple environmental leverage. For example, the problems of acid rain, global warming, and local air pollution are largely energy-based environmental problems generated by the use of fossil fuels.

Energy policies that move the national energy system toward energy efficiency also serve many other national objectives: the lessening of dependence on foreign sources of oil, thus achieving a greater measure of energy independence; reduction of the energy component of the trade deficit; and increasing industrial competitiveness to the extent that energy efficiency can lower costs of production.

It is in the implementation of policies that the issues are joined. It is here that we finally address the economic and social consequences and the hard questions of who pays, who is affected, at what costs, and with what societal disruptions. In the case of the greenhouse problem, we are forced to address the fundamental activities of society that relate to economic growth, the production of food, and the sources of energy. We are talking about changing the global energy and agricultural systems, to say nothing of the implications for global population growth.

Recently the Environmental Protection Agency (EPA) issued a most useful report in response to a congressional request for options for stabilizing the greenhouse gas concentrations in the atmosphere. A sampling of some of their proposals indicates the pervasiveness of the measures that need to be considered (the social and economic costs were not assessed): raise average gasoline mileage of new cars to 50 mpg—a doubling of present fleet mileage; impose fuel emission fees to reflect full social costs of about \$30/ton of coal and \$3.00/barrel of oil; launch major reforestation programs; and phase out CFCs.

Ultimately if the climate warming is to be prevented other forms of intervention in the world energy structure will be required. The logical direction for policy is to encourage the development and use of nonfossil energy sources. Science, engineering, and technology offer the promise of alternative energy sources, such as nuclear energy. Today the problems of public acceptability of nuclear power are severe. Concerns about nuclear power plant safety and the disposal of radioactive wastes dominate any concerns about the greenhouse problem. But research on passively safe reactors has been underway for years and it appears that commercially useful passively safe reactors are on the horizon.

The world must face up to the fact that within the bounds of current technological knowledge there may be no way out of the greenhouse problem without some recourse to the nuclear option. Other forms of nonfossil energy have become more promising as the years have passed. There is new promise in photovoltaics, with efficiency increases up to 30% in recent experiments. Biomass as a source of energy can be further emphasized. Policy options aimed at other causes of increasing greenhouse gas concentrations, such as the release of CFCs and deforestation, present their own politically divisive features. The tropical deforestation issue confronts us with the conflict between economic development and environmental protection in a direct way. Mankind has traditionally used the environment for economic growth and mankind's track record is poor. We in the United States have polluted our rivers, destroyed our wildlife, and replaced our forests with farms. We continue to overuse the last of our natural rain forests in the northwest for economic gain.

Now, recognizing the global consequences of the destruction of forests, we call upon other nations emerging from economic penury to arrest their development to protect the global environment. Is it any wonder that countries like Brazil or India or China perceive our proposals as hypocritical? Nobody has yet advanced a workable proposal, but many have been suggested. The swap of foreign debt for the preservation of tropical forests is an interesting proposal, but who will pay?

The issue of economic development and environmental protection arose in March 1989 in London at a conference called by Prime Minister Thatcher to phase out the production of CFCs. China, India, and other nations refused to submerge their need for CFCs and associated economic development in the global interest in environmental protection. If we are to be serious about international action, a global bargain will be necessary. But what kind of global bargain makes sense?

The divisive nature of the issue is also evident in the suggestion that we shift from fossil fuels such as coal to other kinds of fossil fuels such as oil and gas. But what of countries like China whose energy future is dependent on their large supplies of coal? The recent United Nations report, *Our Common Future* (1987), on economic development and the environment carried the message on the necessary global bargain clearly. Global environmental protection will only be resolved in the context of the economic development of less prosperous nations.

If we cannot arrest the processes of climate change then we will need to adapt to them. Adaptation policies need to be those that will foreclose least on future options. It seems wise that we introduce into our long range planning for our coastal areas the possibility of a sea level rise of the order of one-half meter over the next fifty years. Water resource planning must take into account the possibility that the climatic regimes of the future will be different and water resource infrastructures and management techniques will have to incorporate a flexibility not inherent in present planning. Planning for agricultural adjustment will need to take advantage of genetic engineering of plants and animals so that they can be more tolerant of environmental extremes.

Perhaps, however, the policy approaches to the climate warming issue which we seem to be taking are inappropriate to the problem. We are dealing with intergenerational matters where the consequences of action taken by one generation are visited on another. Nor do we have guidelines for developing policies in the face of uncertainties of the scope involved in the climate problem. We address a problem in which knowledge and information are being continually refreshed by new findings and interpretations, and our assessment of risk and uncertainties are continually changing.

Robert Lind of Cornell University has suggested that we should not think in terms of choosing a static "best policy," but think in terms of strategies and sets of options. We should think in terms of a continuous policy process where we periodically reassess our responses in light of new findings and information. In such a policy approach, the design of research and information gathering projections must become an integral part of the policy process.

This view suggests that what we might do is establish continuing mechanisms and processes that periodically, say every three or five years, would be charged with performing an evaluation of the state of our knowledge about the science and implications of various policy options. Through this process, recommendations for changes in policies and in areas of scientific investigation would emerge. In this way, by a series of incremental policy steps, policy would be kept in lockstep with knowledge.

In the end, scientists and engineers must accept the responsibility for having triggered a worldwide movement that may result in policies of a pervasive nature affecting all humanity. Each of us is responsible for representing the extent of our knowledge and accompanying uncertainties so that there is a balance between optimism and catastrophism. Each of us can make headlines any day by projecting or intimating that mankind faces a global catastrophe.

We have sufficient experience to know that controversy makes headlines and those not as familiar with the scientific uncertainties take us at our word. Our pronouncements will be excerpted to suit the needs of an exciting story. We need to make sure that the uncertainties in our knowledge are well understood and that there are risks in action as well as in inaction. We need to be true to ourselves and our work as well as to the humanity we serve.

Let us not confuse selected observations with representative samples. Let us not confuse scenarios with predictions. Let us not confuse short-term fluctuations with long-term implications. Above all, let us not confuse our friends and colleagues who must make the political decisions that will ensure the inhabitability of this planet.