1992 IPCC Supplement

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SECTION I. INTRODUCTION

At its fifth session (Geneva, March 1991), the Intergovernmental Panel on Climate Change (IPCC) decided to address the six following tasks in a short-term effort to produce an update of its First Assessment Report (August 1990):

TASK 1: Assessment of national net greenhouse gas emissions:

Sub-section 1: Sources and sinks of greenhouse gases;

Sub-section 2: Global Warming Potentials;

TASK 2: Predictions of the regional distributions of climate change and associated impact studies, including model validation studies:

Sub-section 1: Update of regional climate models;

Sub-section 2: Analysis of sensitivity to regional climate change;

TASK 3: Energy and industry related issues;

TASK 4: Agriculture and forestry related issues;

TASK 5: Vulnerability to sea-level rise;

TASK 6: Emissions scenarios.

Each Working Group presented material consisting of a supplement to the IPCC First Assessment Report (1990) together with supporting documents. The supplementary reports have been prepared by subgroups, and have been extensively scrutinized and agreed on by open-ended plenary meetings of the three Working Groups. The supporting documents are being prepared by the Working Groups, subgroups or lead authors and have been or will be extensively refereed.

The IPCC, at its seventh session (Geneva, 10-12 February 1992), recognized with appreciation the dedicated work of many scientists in preparing the reports and supporting documents, especially considering the short time available for their preparation. The IPCC considered and included the supplementary reports from the Working Groups as contributions to the 1992 IPCC Supplement. The IPCC requested that any minor inconsistencies between the Working Group reports be removed so far as possible. Other inconsistencies will be resolved in follow-up work. It was noted that the supplementary reports are overviews of the work which has been carried out and that the supporting documents provide a great deal of additional detailed information, and it was requested that these documents be made available as soon as possible. Issues common to all three working groups as well as other issues raised by members of the IPCC (in particular matters requiring further work) were discussed during the seventh session and are included in section VIII of the Supplement.

Publication of the 1992 IPCC Supplement completes the short-term work on the six Tasks agreed on at the fifth session of the IPCC (IPCC-V). Long-term work on the same Tasks was also agreed on at IPCC-V and this continues.

SECTION II. SCIENTIFIC ASSESSMENT

TASK 1: Assessment of national net greenhouse gas emissions and their implications

TASK 2: Predictions of the regional distributions of climate change and associated impact studies, including model validation studies (part on predictions of the regional distributions of climate change, including model validation studies)

TASK 6: Emissions scenarios

By Working Group I

CURRENT TASK

The fifth session of the Intergovernmental Panel on Climate Change (IPCC) (Geneva, March 1991) adopted six tasks for the ongoing work of its three working groups. While successful completion of these tasks required cooperation between all three groups, particular responsibility fell to the Scientific Assessment working group (WGI) for Tasks 1, 2 and 6:

Task 1: Assessment of net greenhouse gas emissions.

Sub-section 1: Source and sinks of greenhouse gases.

Sub-section 2: Global Warming Potentials.

Task 2: Predictions of the regional distributions of climate change and associated impact studies; including model validation studies.

Task 6: Emissions scenarios.

The tasks were divided into long- and short-term components. The purpose of the short-term workplan, whose results are reported in the present document, was to provide an update to the 1990 IPCC Scientific Assessment, addressing some of the key issues of that report. This update is by definition less comprehensive than the 1990 assessment - for example sea level rise apart from the effect of thermal expansion is not included. It is against the background of that document that the findings of this update should be read.

This assessment, in order to incorporate as much recent material as possible, necessarily includes discussion of new results which have not yet been through, or are currently undergoing, the normal process of peer review. Where such is the case the provisional nature of the results has been taken into account.

A brief progress report on the preparation of guidelines for the compilation of national inventories of greenhouse gas emissions, part of WGI's long-term work under Task 1, appears as an Annex to this Supplement.

OUR MAJOR CONCLUSIONS

Findings of scientific research since 1990 do not affect our fundamental understanding of the science of the greenhouse effect and either confirm or do not justify alteration of the major conclusions of the first IPCC Scientific Assessment, in particular the following:

- emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases: carbon dioxide, methane, chlorofluorocarbons, and nitrous oxide;

- the evidence from the modelling studies, from observations and the sensitivity analyses indicate that the sensitivity of global mean surface temperature to doubling CO_2 is unlikely to lie outside the range 1.5° to 4.5°C;

- 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;

- global mean surface air temperature has increased by 0.3° to 0.6°C over the last 100 years;

- the size of this warming is broadly consistent with predictions of climate models, but it is also of the same magnitude as natural climate variability. Thus the observed increase could be largely due to this natural variability; alternatively this variability and other human factors could have offset 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.

There are also a number of significant new findings and conclusions which we summarize as follows:

Gases and aerosols

- Depletion of ozone in the lower stratosphere in the middle and high latitudes results in a decrease in radiative forcing which is believed to be comparable in magnitude to the radiative forcing contribution of chlorofluorocarbons (CFCs) (globally-averaged) over the last decade or so.

- The cooling effect of aerosols* resulting from sulphur emissions may have offset a significant part of the greenhouse warming in the Northern Hemisphere (NH) during the past several decades. Although this phenomenon was recognized in the 1990 report, some progress has been made in quantifying its effect.

- The Global Warming Potential (GWP) remains a useful concept but its practical utility for many gases depends on adequate quantification of the indirect effects as well as the direct. We now recognize that there is increased uncertainty in the calculation of GWPs, particularly in the indirect components and, whilst indirect GWPs are likely to be significant for some gases, the numerical estimates in this Supplementary Report are limited to direct GWPs.

- Whilst the rates of increase in the atmospheric concentrations of many greenhouse gases have continued to grow or remain steady, those of methane and some halogen compounds have slowed.

- Some data indicate that global emissions of methane from rice paddies may amount to less than previously estimated.

Scenarios

- Steps have been taken towards a more comprehensive analysis of the dependence of future greenhouse gas emissions on socio-economic assumptions and projections. A set of updated scenarios have been developed for use in modelling studies which describe a wide range of possible future emissions in the absence of coordinated policy response to climate change.

Modelling

- Climate models have continued to improve in respect of both their physical realism and their ability to simulate present climate on large scales, and new techniques are being developed for the simulation of regional climate.

- Transient (time-dependent) simulations with coupled ocean-atmosphere models (CGCMs), in which neither aerosols nor ozone changes have been included, suggest a rate of global warming that is consistent, within the range of uncertainties, with the 0.3°C per decade warming rate quoted by IPCC (1990) for Scenario A of greenhouse gas emissions.

- The large-scale geographical patterns of warming produced by the transient model runs with CGCMs are generally similar to the patterns produced by the earlier equilibrium models except that the transient simulations show reduced warming over the northern North Atlantic and the southern oceans near Antarctica.

- CGCMs are capable of reproducing some features of atmospheric variability on intra-decadal time-scales.

- Our understanding of some climate feedbacks and their incorporation in the models has improved. In particular, there has been some clarification of the role of upper tropospheric water vapour. The role of other processes, in particular cloud effects, remains unresolved.

Climate observations

- The anomalously high global mean surface temperatures of the late 1980s have continued into 1990 and 1991 which are the warmest years in the record.

- Average warming over parts of the Northern Hemisphere mid-latitude continents has been found to be largely characterized by increases in minimum (night-time) rather than maximum (daytime) temperatures.

- Radiosonde data indicate that the lower troposphere has warmed over recent decades. Since meaningful trends cannot be assessed over periods as short as a decade, the widely reported disagreements between decadal trends of air temperature from satellite and surface data cannot be confirmed because the trends are statistically indistinguishable.

- The volcanic eruption of Mount Pinatubo in 1991 is expected to lead to transitory stratospheric warming. With less certainty, because of other natural influences, surface and tropospheric cooling may occur during the next few years.

- Average warming over the Northern Hemisphere during the last four decades has not been uniform, with marked seasonal and geographic variations; this warming has been especially slow, or absent, over the extratropical north west Atlantic.

- The consistency between observations of global temperature changes over the past century and model simulations of the warming due to greenhouse gases over the same period is improved if allowance is made for the increasing evidence of

* *The scientific definition of 'aerosol' is an airborne particle or collection of particles, but the word has become associated, erroneously, with the propellant used in 'aerosol sprays'. Throughout this report the term 'aerosol' means airborne particle or particles*

a cooling effect due to sulphate aerosols and stratospheric ozone depletion.

The above conclusions have implications for future projections of global warming and somewhat modify the estimated rate of warming of 0.3°C per decade for the greenhouse gas emissions Scenario A of the IPCC First Assessment Report (1990). If sulphur emissions continue to increase, this warming rate is likely to be reduced, significantly in the Northern Hemisphere, by an amount dependent on the future magnitude and regional distribution of the emissions. Because sulphate aerosols are very short-lived in the atmosphere their effect on global warming rapidly adjusts to increases or decreases in emissions. It should also be noted that while partially offsetting the greenhouse warming, the sulphur emissions are also responsible for acid rain and other environmental effects. There is a further small net reduction likely in the rate of global warming during the next few decades due to decreases in stratospheric ozone, partially offset by increases in tropospheric ozone.

Research carried out since the 1990 IPCC assessment has served to improve our appreciation of key uncertainties. There is a continuing need for increased monitoring and research into climate processes and modelling. This must involve, in particular, strengthened international collaboration through the World Climate Research Programme (WCRP), the International Geosphere Biosphere Programme (IGBP) and the Global Climate Observing System (GCOS).

How does the climate system work, and what information do we need to estimate future changes?

- **How does the climate system work?**

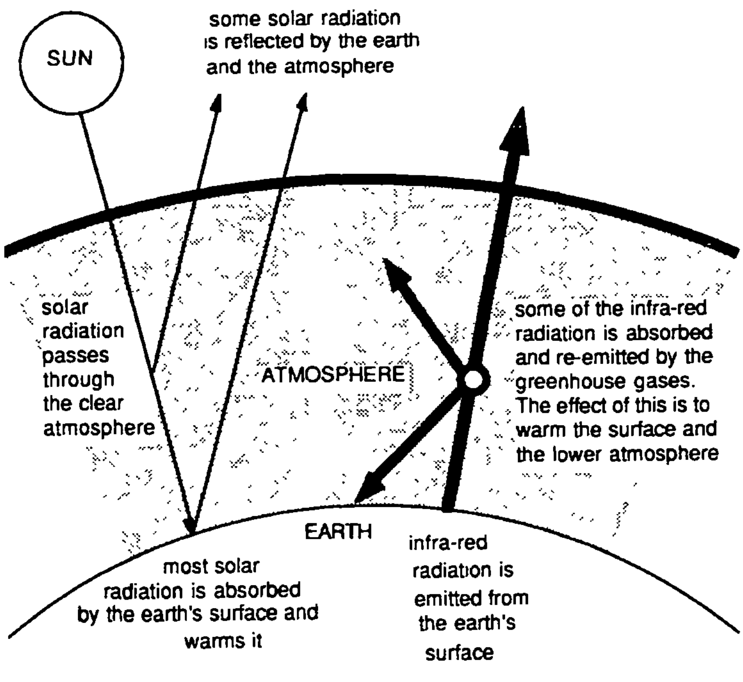
The Earth absorbs radiation from the Sun, mainly at the surface. This energy is then redistributed by the atmosphere and ocean and re-radiated to space at longer ('thermal', 'terrestrial' or 'infrared') wavelengths. Some of the thermal radiation is absorbed by radiatively-active ('greenhouse') gases in the atmosphere, principally water vapour, but also carbon dioxide, methane, the CFCs, ozone and other greenhouse gases. The absorbed energy is re-radiated in all directions, downwards as well as upwards such that the radiation that is eventually lost to space is from higher, colder levels in the atmosphere (see diagram below). The result is that the surface loses less heat to space than it would do in the absence of the greenhouse gases and consequently stays warmer than it would otherwise be. This phenomenon, which acts rather like a 'blanket' around the Earth, is known as the greenhouse effect.

- **What factors can change climate?**

Any factor which alters the radiation received from the Sun or lost to space, or which alters the redistribution of energy within the atmosphere, and between the atmosphere, land and ocean, will affect climate.

The Sun's output of energy is known to change by small amounts over an 11-year cycle, and variations over longer periods may occur. On time-scales of tens to thousands of years, slow variations in the Earth's orbit have led to changes in the seasonal and latitudinal distribution of solar radiation; these changes have played an important part in controlling the variations of past climate.

Increases in the concentration of the greenhouse gases will reduce the efficiency with which the Earth cools to



space and will tend to warm the lower atmosphere and surface. The amount of warming depends on the size of the increase in concentration of each greenhouse gas, the radiative properties of the gases involved, and the concentration of other greenhouse gases already present in the atmosphere. It also can depend on local effects such as the variation with height of the concentration of the greenhouse gas, a consideration that may be particularly germane to water vapour which is not uniformly mixed throughout the atmosphere. The effect is not a simple one and the balance which is struck between these factors depends on many aspects of the climate system.

Aerosols (small particles) from volcanoes, emissions of sulphates from industry and other sources can absorb and reflect radiation. Moreover, changes in aerosol concentrations can alter cloud reflectivity through their effect on cloud properties. In most cases aerosols tend to cool climate. In general, they have a much shorter lifetime than greenhouse gases so their concentrations respond much more quickly to changes in emissions.

Any changes in the radiative balance of the Earth, including those due to an increase in greenhouse gases or in aerosols, will tend to alter atmospheric and oceanic temperatures and the associated circulation and weather patterns. However climate varies naturally on all timescales due to both external and internal factors. To distinguish man-made climate variations from those natural changes, it is necessary to identify the man-made 'signal' against the background 'noise' of natural climate variability.

A necessary starting point for the prediction of changes in climate due to increases in greenhouse gases and aerosols is an estimate of their future concentrations. This requires a knowledge of both the strengths of their sources (natural and man-made) and also the mechanisms of their eventual removal from the atmosphere (their sinks). The projections of future concentrations can then be used in climate models to estimate the climatic response. We also need to determine whether or not the predicted changes will be noticeable above the natural variations in climate. Finally, observations are essential in order to monitor climate, to study climatic processes and to help in the development and validation of models.

RECENT IMPROVEMENTS IN SCIENTIFIC UNDERSTANDING

HOW HAS OUR UNDERSTANDING OF THE SOURCES AND SINKS OF GREENHOUSE GASES AND AEROSOLS CHANGED?

During the last eighteen months there have been a number of important advances in our understanding of greenhouse gases and aerosols. These advances include an improved quantitative understanding of the atmospheric distributions, trends, sources and sinks of greenhouse gases, their precursors and aerosols, and an improved understanding of the processes controlling their global budgets.

Atmospheric concentrations and trends of long-lived greenhouse gases: The atmospheric concentrations of the major long-lived greenhouse gases [carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), and carbon tetrachloride (CCl_4)] continue to increase because of human activities. While the growth rates of most of these gases have been steady or increasing over the past decade, that of CH_4 and some of the halocarbons has been decreasing. The rate for CH_4 has declined from about 20 ppbv/yr in the late 1970s to possibly as low as 10 ppbv/yr in 1989. While a number of hypotheses have been forwarded to explain these observations, none is completely satisfactory.

Atmospheric concentrations and trends of other gases that influence the radiative budget: Ozone (O_3) is an effective greenhouse gas both in the stratosphere and in the troposphere. Significant decreases have been observed during the last one to two decades in total column O_3 at all latitudes - except the tropics - in spring, summer and winter. The downward trends were larger during the 1980s than in the 1970s. These decreases have occurred predominantly in the lower stratosphere (below 25km), where the rate of decrease has been up to 10% per decade depending on altitude. In addition, there is evidence to indicate that O_3 levels in the troposphere up to 10km altitude above the few existing ozonesonde stations at northern middle latitudes have increased by about 10% per decade over the past two decades. Also, the abundance of carbon monoxide (CO) appears to be increasing in the NH at about 1% per year. However, there is little new information on the global trends of other tropospheric O_3 precursors, (non-methane hydrocarbons (NMHC) and oxides of nitrogen (NO_x)).

Sources and sinks of carbon dioxide: The two primary sources of the observed increase in atmospheric CO_2 are combustion of fossil fuels and land-use changes; cement production is a further important source.

The emission of CO_2 from the combustion of fossil fuels grew between 1987 and 1989. Preliminary data for 1990 indicate similar emissions to 1989. The best estimate for global fossil fuel emissions in 1989 and 1990 is 6.0±0.5 GtC*, compared to 5.7±0.5 GtC in 1987 (IPCC, 1990). The

* *1 GtC (gigatonne of carbon) equals one billion [one thousand million (10^9)] tonnes of carbon*

estimated total release of carbon in the form of CO_2 from oil well fires in Kuwait during 1991 was 0.065 GtC, about one percent of total annual anthropogenic emissions.

The direct net flux of CO_2 from land use changes (primarily deforestation), integrated over time, depends upon the area of land deforested, the rate of reforestation and afforestation, the carbon density of the original and replacement forests, and the fate of above-ground and soil carbon. These and other factors are needed to estimate annual net emissions but significant uncertainties exist in our quantitative knowledge of them. Since IPCC (1990) some progress has been made in reducing the uncertainties associated with the rate of deforestation, at least in Brazil. A comprehensive, multi-year, high spatial resolution satellite data set has been used to estimate that the average rate of deforestation in the Brazilian Amazonian forest between 1978 and 1989 was 2.1 million hectares (Mha) per year. The rate increased between 1978 and the mid-1980s, and has decreased to 1.4 Mha/yr in 1990. The Food and Agriculture Organization (FAO), using information supplied by individual countries, recently estimated that the rate of global tropical deforestation in closed and open canopy forests for the period 1981-1990 was about 17 Mha/yr, approximately 50% higher than in the period 1976-1980.

Despite the new information regarding rates of deforestation, the uncertainties in estimating CO_2 emissions are so large that there is no strong reason to revise the IPCC 1990 estimate of annual average net flux to the atmosphere of 1.6 ± 1.0 GtC from land-use change during the decade of the 1980s.

Since IPCC (1990) particular attention has focussed on understanding the processes controlling the release and uptake of CO_2 from both the terrestrial biosphere and the oceans, and on the quantification of the fluxes. Based on models and the atmospheric distribution of CO_2, it appears that there is a small net addition of carbon to the atmosphere from the equatorial region, a combination of outgassing of CO_2 from warm tropical waters and a terrestrial biospheric component that is the residual between large sources (including deforestation) and sinks. There appears to be a strong Northern Hemisphere sink, containing both oceanic and terrestrial biospheric components, and a weak Southern Hemisphere (SH) sink. The previous IPCC global estimate for an ocean sink of 2.0 ± 0.8 GtC per year is still a reasonable one. The terrestrial biospheric processes which are suggested as contributing to the sinks are sequestration due to forest regeneration, and fertilization arising from the effects of both CO_2 and nitrogen (N), but none of these can be adequately quantified. This implies that the imbalance (of order 1-2 GtC/yr) between sources and sinks, i.e., "the missing sink", has not yet been resolved. This fact has significant consequences for estimates of future atmospheric CO_2 concentrations and the analysis of the concept of the Greenhouse Warming Potential.

Sources of methane: A total (anthropogenic plus natural) annual emission of CH_4 of about 500Tg can be deduced from the magnitude of its sinks combined with its rate of accumulation in the atmosphere. While the sum of the individual sources is consistent with a total of 500Tg CH_4, there are still many uncertainties in accurately quantifying the magnitude of emissions from individual sources. Significant new information includes a revised rate of removal of CH_4 by atmospheric hydroxyl (OH) radicals (because of a lower rate constant), a new evaluation of some of the sources (e.g., from rice fields) and the addition of new sources (e.g., animal and domestic waste). Recent CH_4 isotopic studies suggest that approximately 100Tg CH_4 (20% of the total CH_4 source) is of fossil origin, largely from the coal, oil, and natural gas industries. Recent studies of CH_4 emissions from rice agriculture, in particular Japan, India, Australia, Thailand and China, show that the emissions depend on growing conditions, particularly soil characteristics, and vary significantly. While the overall uncertainty in the magnitude of global emissions from rice agriculture remains large, a detailed analysis now suggests significantly lower annual emissions than reported in IPCC 1990. The latest estimate of the atmospheric lifetime of CH_4 is about 11 years.

Sources of nitrous oxide: Adipic acid (nylon) production, nitric acid production and automobiles with three-way catalysts have been identified as possibly significant anthropogenic global sources of nitrous oxide. However, the sum of all known anthropogenic and natural sources is still barely sufficient to balance the calculated atmospheric sink or to explain the observed increase in the atmospheric abundance of N_2O.

Sources of halogenated species: The worldwide consumption of CFCs 11, 12, and 113 is now 40% below 1986 levels, substantially below the amounts permitted under the Montreal Protocol. Further reductions are mandated by the 1990 London Amendments to the Montreal Protocol. As CFCs are phased out, HCFCs and HFCs will substitute, but at lower emission rates.

Stratospheric ozone depletion: Even if the control measures of the 1990 London amendments to the Montreal Protocol were to be implemented by all nations, the abundance of stratospheric chlorine and bromine will increase over the next several years. The Antarctic ozone hole, caused by industrial halocarbons, will therefore recur each spring. In addition, as the weight of evidence suggests that these gases are also responsible for the observed reductions in middle- and high-latitude stratospheric O_3, the depletion at these latitudes is predicted to continue unabated through the 1990s.

Sources of precursors of tropospheric ozone: Little new information is available regarding the tropospheric ozone precursors (CO, NMHC, and NO_x), all of which have significant natural and anthropogenic sources. Their detailed budgets therefore remain uncertain.

Sources of aerosols: Industrial activity, biomass burning, volcanic eruptions, and sub-sonic aircraft contribute substantially to the formation of tropospheric and stratospheric aerosols. Industrial activities are concentrated in the Northern Hemisphere where their impact on tropospheric sulphate aerosols is greatest. Sulphur emissions, which are due in large part to combustion effluents, have a similar emissions history to that of anthropogenic CO_2. Estimates of emissions of natural sulphur compounds have been reduced from previous figures, thereby placing more emphasis on the anthropogenic contribution.

SCENARIOS OF FUTURE EMISSIONS

Scenarios of net greenhouse gas and aerosol precursor emissions for the next 100 years or more are necessary to support study of potential anthropogenic impacts on the climate system. The scenarios provide inputs to climate models and assist in the examination of the relative importance of relevant trace gases and aerosol precursors in changing atmospheric composition and climate. Scenarios can also help in improving the understanding of key relationships among factors that drive future emissions.

Scenario outputs are not predictions of the future, and should not be used as such; they illustrate the effect of a wide range of economic, demographic and policy assumptions. They are inherently controversial because they reflect different views of the future. The results of short-term scenarios can vary considerably from actual outcomes even over short time horizons. Confidence in scenario outputs decreases as the time horizon increases, because the basis for the underlying assumptions becomes increasingly speculative. Considerable uncertainties surround the evolution of the types and levels of human activities (including economic growth and structure), technological advances, and human responses to possible environmental, economic and institutional constraints. Consequently, emission scenarios must be constructed carefully and used with great caution.

Since completion of the 1990 IPCC Scenario A (SA90) events and new information have emerged which relate to that scenario's underlying assumptions. These developments include: the London Amendments to the Montreal Protocol; revision of population forecasts by the World Bank and United Nations; publication of the IPCC Energy and Industry Sub-group scenario of greenhouse gas emissions to 2025; political events and economic changes in the former USSR, Eastern Europe and the Middle East; re-estimation of sources and sinks of greenhouse gases (reviewed in this Assessment); revision of preliminary FAO data on tropical deforestation; and new scientific studies on forest biomass. There has also been recognition of considerable uncertainty regarding other important factors that drive future emissions.

These factors have led to an update of the SA90. Six alternative IPCC Scenarios (IS92 a-f) now embody a wide array of assumptions, summarized in Table 1, affecting how future greenhouse gas emissions might evolve in the absence of climate policies beyond those already adopted. This constitutes a significant improvement over the previous methodology. However, the probability of any of the resulting emission paths has not been analyzed. IPCC WGI does not prefer any individual scenario. Other combinations of assumptions could illustrate a broader variety of emission trajectories. The different worlds which the new scenarios imply, in terms of economic, social and environmental conditions, vary widely. The current exercise provides an interim view and lays a basis for a more complete study of future emissions of greenhouse gas and aerosol precursors.

Table 1: Summary of Assumptions in the Six IPCC 1992 Alternative Scenarios. †

Scenario	Population	Economic Growth		Energy Supplies ††	Other †††	CFCs
IS92a	World Bank 1991 11.3 B by 2100	1990-2025 1990-2100	2.9% 2.3%	12,000 EJ Conventional Oil 13,000 EJ Natural Gas Solar costs fall to $0.075/kWh 191 EJ of biofuels available at $70/barrel	Legally enacted and internationally agreed controls on SO_x, NO_x and NMVOC emissions	Partial compliance with Montreal Protocol. Technological transfer results in gradual phase out of CFCs also in non-signatory countries by 2075
IS92b	World Bank 1991 11.3 B by 2100	1990-2025 1990-2100	2.9% 2.3%	Same as "a"	Same as "a" plus commitments by many OECD countries to stabilize or reduce CO_2 emissions	Global compliance with scheduled phase out of Montreal Protocol.
IS92c	UN Medium Low Case 6.4 B by 2100	1990-2025 1990-2100	2.0% 1.2%	8,000 EJ Conventional Oil 7,300 EJ Natural Gas Nuclear costs decline by 0.4% annually	Same as "a"	Same as "a"
IS92d	UN Medium Low Case 6.4 B by 2100	1990-2025 1990-2100	2.7% 2.0%	Oil and gas same as "c" Solar costs fall to $0.065/kWh 272 EJ of biofuels available at $50/barrel	Emission controls extended worldwide for CO, NO_x, NMVOC, and SO_x. Halt deforestation. Capture and use of emissions from coal mining and gas production and use	CFC production phase out by 1997 for industrialised countries. Phase out of HCFCs
IS92e	World Bank 1991 11.3 B by 2100	1990-2025 1990-2100	3.5% 3.0%	18,400 EJ conventional oil Gas same as "a" Phase out nuclear by 2075	Emission controls (30 % pollution surcharge on fossil energy).	Same as "d"
IS92f	UN Medium High Case 17.6 B by 2100	Same as "a"		Oil and gas same as "e" Solar costs fall to $0.083/kWh Nuclear costs increase to $0.09/kWh	Same as "a"	Same as "a"

† The assumptions for the 1990 Scenario A are described in IPCC (1990) Annex A, pp 331-339

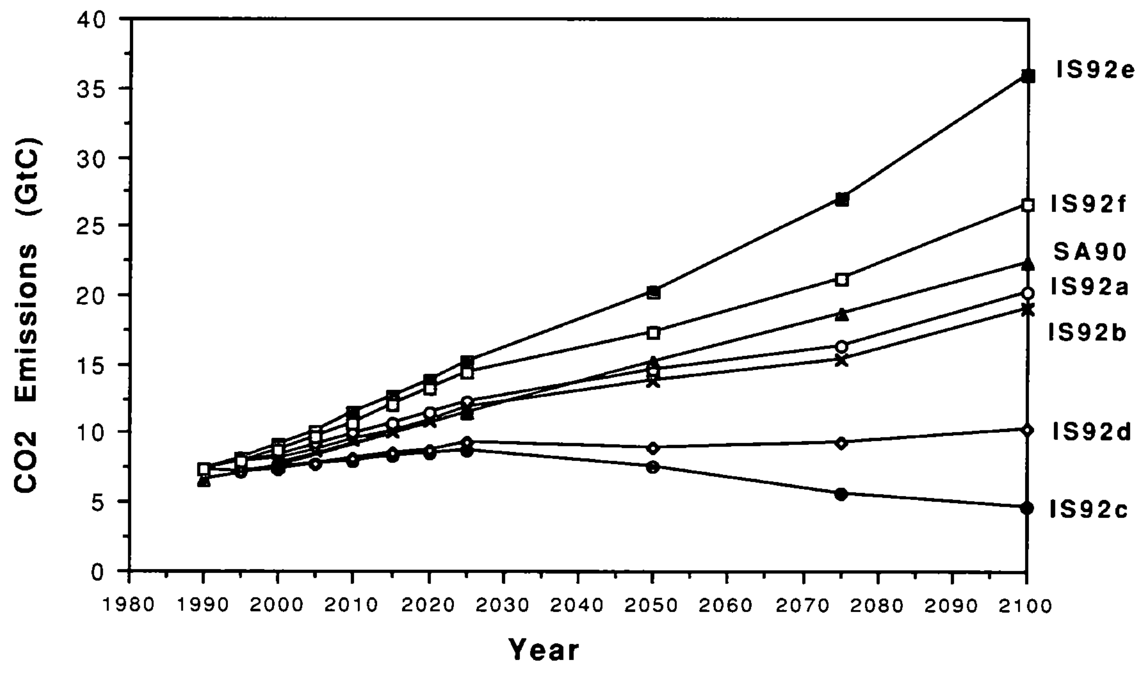
†† All scenarios assume coal resources up to 197,000 EJ. Up to 15% of this resource is assumed to be available at $1.30/gigajoule at the mine

††† Tropical deforestation rates (for closed and open forests) begin from an average rate of 17.0 million hectares/year (FAO, 1991) for 1981-1990, then increase with population until constrained by availability of land not legally protected. IS91d assumes an eventual halt of deforestation for reasons other than climate. Above-ground carbon density per hectare varies with forest type from 16 to 117 tons C/hectare, with soil C ranging from 68 to 100 T C/ha. However, only a portion of carbon is released over time with land conversion, depending on type of land conversion

Scenario results: The range of possible greenhouse gas futures is very wide, as the Figure below illustrates (showing only CO_2). All six scenarios can be compared to SA90. IS92a is slightly lower than SA90 due to modest and largely offsetting changes in the underlying assumptions. (For example, compared to SA90, higher population forecasts increase the emission estimates, while phaseout of halocarbons and more optimistic renewable energy costs reduce them.) The highest greenhouse gas levels result from the new scenario IS92e which combines, among other assumptions, moderate population growth, high economic growth, high fossil fuel availability and eventual hypothetical phase-out of nuclear power. The lowest greenhouse gas levels result from IS92c which assumes that population grows, then declines by the middle of the next century, that economic growth is low and that there are severe constraints on fossil fuel supplies. The results of all six scenarios appear in Table 2. Overall, the scenarios indicate that greenhouse gas emissions could rise substantially over the coming century in the absence of new measures explicitly intended to reduce their emission. However, IS92c has a CO_2 emission path which eventually falls below its starting 1990 level. IS92b, a modification of IS92a, suggests that current commitments by many OECD Member countries to stabilize or reduce CO_2 might have a small impact on greenhouse gas emissions over the next few decades, but would not offset substantial growth in possible emissions in the long run. IS92b does not take into account that such commitments could accelerate development and diffusion of low greenhouse gas technologies, nor possible resulting shifts in industrial mix.

Carbon dioxide: The new emissions scenarios for CO_2 from the energy sector span a broad range of futures (see Figure below).

CO_2 EMISSIONS FROM ENERGY, CEMENT PRODUCTION AND DEFORESTATION



Population and economic growth, structural changes in economies, energy prices, technological advance, fossil fuel supplies, nuclear and renewable energy availability are among the factors which could exert major influence on future levels of CO_2 emissions. Developments such as those in the republics of the former Soviet Union and in Eastern Europe, now incorporated into all the scenarios, have important implications for future fossil fuel carbon emissions, by affecting the levels of economic activities and the efficiency of energy production and use. Biotic carbon emissions in the early decades of the scenarios are higher than SA90, reflecting higher preliminary FAO estimates of current rates of deforestation in many - though not all - parts of the world, and higher estimates of forest biomass.

Table 2: Selected Results of Six 1992 IPCC Greenhouse Gas Scenarios

Scenario	Years	Decline in TPER/GNP (average annual change)	Decline in C intensity (average annual change)	Tropical Deforestation: Cumulative Net Fossil C Emissions (GtC)	Tropical Deforestation: Total Forest Cleared (million hectares)	Tropical Deforestation: Cumulative Net C Emissions (GtC)	Year	Emissions Per Year: CO_2 (GtC)	Emissions Per Year: CH_4 (tg)	Emissions Per Year: N_2O (TgN)	Emissions Per Year: CFCs (Kt)	Emissions Per Year: SO_x (Tg S)
IS92a	1990-2025	0.8%	0.4%	285	678	42	1990	7.4	506	12.9	827	98
	1990-2100	1.0%	0.2%	1386	1447	77	2025	12.2	659	15.8	217	141
							2100	20.3	917	17.0	3	169
IS92b	1990-2025	0.9%	0.4%	275	678	42	2025	11.8	659	15.7	36	140
	1990-2100	1.0%	0.2%	1316	1447	77	2100	19.0	917	16.9	0	164
IS92c	1990-2025	0.6%	0.7%	228	675	42	2025	8.8	589	15.0	217	115
	1990-2100	0.7%	0.6%	672	1343	70	2100	4.6	546	13.7	3	77
IS92d	1990-2025	0.8%	0.9%	249	420	25	2025	9.3	584	15.1	24	104
	1990-2100	0.8%	0.7%	908	651	30	2100	10.3	567	14.5	0	87
IS92e	1990-2025	1.0%	0.2%	330	678	42	2025	15.1	692	16.3	24	163
	1990-2100	1.1%	0.2%	2050	1447	77	2100	35.8	1072	19.1	0	254
IS92f	1990-2025	0.8%	0.1%	311	725	46	2025	14.4	697	16.2	217	151
	1990-2100	1.0%	0.1%	1690	1686	93	2100	26.6	1168	19.0	3	204

TPER = Total Primary Energy Requirement
Carbon intensity is defined as units of carbon per unit of TPER
CFCs include CFC-11, CFC-12, CFC-113, CFC-114 and CFC-115

Halocarbons: The revised scenarios for CFCs and other substances which deplete stratospheric ozone are much lower than in SA90. This is consistent with wide participation in the controls under the 1990 London Amendments to the Montreal Protocol. However, the future production and composition of CFC substitutes (HCFCs and HFCs) could significantly affect the levels of radiative forcing from these compounds.

Methane, nitrous oxide, ozone precursors and sulphur gases: The distribution of CH_4 and N_2O emissions from the different sources has changed from the SA90 case. Methane from rice paddies are lower, and emissions from animal waste and domestic sewage have been added. N_2O emission factors for stationary sources and biomass burning have been revised downwards. Adipic and nitric acid have been included as additional sources of N_2O. Preliminary analysis of the emissions of volatile organic compounds and sulphur dioxide suggests that the global emissions of these substances are likely to grow in the coming century if no new limitation strategies are implemented.

RELATIONSHIP BETWEEN EMISSIONS AND ATMOSPHERIC CONCENTRATIONS AND THE INFLUENCE ON RADIATIVE BUDGET

A key issue is to relate emissions of greenhouse gases, greenhouse gas precursors and aerosol precursors to future concentrations of greenhouse gases and aerosols in order to assess their impact on the radiative balance. A number of different types of model have been developed.

Carbon cycle models: While there is a variety of carbon cycle models (including 3-D ocean-atmosphere models, 1-D ocean-atmosphere box-diffusion models, and box models that incorporate a terrestrial biospheric sink) all such models are subject to considerable uncertainty because of an inadequate understanding of the processes controlling the uptake and release of CO_2 from the oceans and terrestrial ecosystems. Some models assume a net neutral terrestrial biosphere, balancing fossil fuel emissions of CO_2 by oceanic uptake and atmospheric accumulation, others achieve balance by invoking additional assumptions regarding the effect of CO_2 fertilization on the different parts of the biosphere. However even models that balance the past and contemporary carbon cycle may not predict future atmospheric concentrations accurately because they do not necessarily represent the proper mix of processes on land and in the oceans. The differences in predicted changes in CO_2 concentrations are up to 30%. This does not represent the major uncertainty in the prediction of future climate change compared with uncertainties in estimating future patterns of trace gas emissions, and in quantifying climate feedback processes. A simple empirical estimate can be based on the assumption that the fraction of emissions which remains in the atmosphere is the same as that observed over the last decade; i.e., 46±7%.

Atmospheric gas phase chemistry models: Current tropospheric models exhibit substantial differences in their predictions of changes in O_3, in the hydroxyl radical (OH) and in other chemically active gases due to emissions of CH_4, non-methane hydrocarbons, CO and, in particular, NO_x. These arise from uncertainties in the knowledge of background chemical composition and our inability to represent small-scale processes occurring within the atmosphere. These deficiencies limit the accuracy of predicted changes in the abundance and distribution of tropospheric O_3, and in the lifetimes of a number of other greenhouse gases, including the HCFCs and HFCs, all of which depend upon the abundance of the OH radical. Increases in CH_4, NMHCs, and CO all lead to increases in O_3, and decreases in OH, thus leading to an increase in radiative forcing. On the other hand because increases in NOx lead to an increase in both O_3 and OH, the net effect on radiative forcing is uncertain.

Atmospheric sulphate aerosol models: The atmospheric chemistry of sulphate aerosols and their precursors has been extensively studied in relation to the acid rain issue. While our understanding of processes related to chemical transformations has increased significantly in recent years, substantial uncertainties remain, especially regarding the microphysics of aerosol formation, interaction of aerosols with clouds, and the removal of aerosol particles by precipitation.

HOW HAS OUR UNDERSTANDING OF CHANGES IN RADIATIVE FORCING CHANGED?

Since IPCC (1990), there have been significant advances in our understanding of the impact of ozone depletion and sulphate aerosols on radiative forcing and of the limitations of the concept of the Global Warming Potential.

Radiative forcing due to changes in stratospheric ozone: For the first time observed global depletions of O_3 in the lower stratosphere have been used to calculate changes in the radiative balance of the atmosphere. Although the results are sensitive to atmospheric adjustments, and no GCM studies of the implications of the O_3 changes on surface temperature have been performed, the radiative balance calculations indicate that the O_3 reductions observed during the 1980s have caused reductions in the radiative forcing of the surface-troposphere system at mid- and high- latitudes. This reduction in radiative forcing resulting from O_3 depletion could, averaged on a global scale and over the last decade, be approximately equal in magnitude and opposite in sign to the enhanced radiative forcing due to increased CFCs during the same time period. The effect at high latitudes is particularly pronounced and, because of these large variations with latitude and region, studies using GCMs are urgently required to further test these findings

Radiative forcing due to changes in tropospheric ozone: While there are consistent observations of an increase in tropospheric ozone (up to 10% per decade) at a limited number of locations in Europe, there is not an adequate global set of observations to quantify the magnitude of the increase in radiative forcing. However, it has been calculated that a 10% uniform global increase in tropospheric ozone would increase radiative forcing by about a tenth of a watt per square metre.

Radiative effects of sulphur emissions: Emissions of sulphur compounds from anthropogenic sources lead to the presence of sulphate aerosols which reflect solar radiation. This is likely to have a cooling influence on the Northern Hemisphere (there is negligible effect in the Southern Hemisphere). For clear-sky conditions alone, the cooling caused by current rates of emissions has been estimated to be about $1Wm^{-2}$ averaged over the Northern Hemisphere, a value which should be compared with the estimate of $2.5Wm^{-2}$ for the heating due to anthropogenic greenhouse gas emissions up to the present. The non-uniform distribution of anthropogenic sulphate aerosols coupled with their relatively short atmospheric residence time produce large regional variations in their effects. In addition, sulphate aerosols may affect the radiation budget through changes in cloud optical properties.

Global Warming Potentials: Gases can exert a radiative forcing both directly and indirectly: direct forcing occurs when the gas itself is a greenhouse gas; indirect forcing occurs when chemical transformation of the original gas produces a gas or gases which themselves are greenhouse gases. The concept of the Global Warming Potential (GWP) has been developed for policymakers as a measure of the possible warming effect on the surface-troposphere system arising from the emission of each gas relative to CO_2. The indices are calculated for the contemporary atmosphere and do not take into account possible changes in chemical composition of the atmosphere. Changes in radiative forcing due to CO_2, on a kg basis, are non-linear with changes in the atmospheric CO_2 concentrations. Hence, as CO_2 levels increase from present values, the GWPs of the non-CO_2 gases would be higher than those evaluated here. For the concept to be most useful, both the direct and indirect components of the GWP need to be quantified.

Direct Global Warming Potentials: The direct components of the Global Warming Potentials (GWPs) have been recalculated, taking into account revised estimated lifetimes, for a set of time horizons ranging from 20 to 500 years, with CO_2 as the reference gas. The same ocean-atmosphere carbon cycle model as in IPCC (1990) has been used to relate CO_2 emission to concentrations. Table 3 shows values for a selected set of key gases for the 100 year time horizon. While in most cases the values are similar to the previous IPCC (1990) values, the GWPs for some of the HCFCs and HFCs have increased by 20 to 50% because of revised estimates of their lifetimes. The direct GWP of CH_4 has been adjusted upward, correcting an error in the previous IPCC report. The carbon cycle model used in these calculations probably underestimates both the direct and indirect GWP values for all non-CO_2 gases. The magnitude of the bias depends on the atmospheric lifetime of the gas, and the GWP time horizon.

Table 3: Direct GWPs for 100 year Time Horizon

Gas	Global Warming Potential (GWP)	Sign of the Indirect Component of the GWP
Carbon dioxide	1	none
Methane	11	positive
Nitrous oxide	270	uncertain
CFC-11	3400	negative
CFC-12	7100	negative
HCFC-22	1600	negative
HFC-134a	1200	none

Indirect Global Warming Potentials: Because of our incomplete understanding of chemical processes, most of the indirect GWPs reported in IPCC (1990) are likely to be in substantial error, and none of them can be recommended. Although we are not yet in a position to recommend revised numerical values, we know, however, that the indirect GWP for methane is positive and could be comparable in magnitude to its direct value. In contrast, based on the sub-section above, the indirect GWPs for chlorine and bromine halocarbons are likely to be negative. The concept of a GWP for short-lived, in homogeneously distributed constituents, such as CO, NMHC, and NO_x may prove inapplicable, although, as noted above, we know that these constituents will affect the radiative balance of the atmosphere through changes in tropospheric ozone and OH. Similarly, a GWP for SO_2 is viewed to be inapplicable because of the non-uniform distribution of sulphate aerosols.

Influence of changes in solar output: The existence of strong correlations between characteristics of the solar activity cycle and global mean temperature has been reported. The only immediately plausible physical explanation of these correlations involves variability of the sun's total irradiance on time-scales longer than that of the 11-year activity cycle. Since precise measurements of the irradiance are only available for the last decade, no firm conclusions regarding the influence of solar variability on climate change can be drawn.

WHAT TOOLS DO WE USE AND WHAT INFORMATION DO WE NEED TO PREDICT FUTURE CLIMATE?

Models

The most highly developed tool which we have to model climate and climate change is known as a general circulation model or GCM. These models are based on the laws of physics and use descriptions in simplified physical terms (called parametrizations) of the smaller-scale processes such as those due to clouds and deep mixing in the ocean. 'Coupled' general circulation models

(CGCMs) have the atmospheric component linked to an oceanic component of comparable complexity.

Climate forecasts are derived in a different way from weather forecasts. A weather prediction model gives a description of the atmosphere's state up to 10 days or so ahead, starting from a detailed description of an initial state of the atmosphere at a given time. Such forecasts describe the movement and development of large weather systems, though they cannot represent very small-scale phenomena; for example, individual shower clouds.

To estimate the influence of greenhouse gases or aerosols in changing climate, the model is first run for a few (simulated) decades. The statistics of the model's output are a description of the model's simulated climate which, if the model is a good one and includes all the important forcing factors, will bear a close resemblance to the climate of the real atmosphere and ocean. The above exercise is then repeated with increasing concentrations of the greenhouse gases or aerosols in the model. The differences between the statistics of the two simulations (for example in mean temperature and interannual variability) provide an estimate of the accompanying climate change.

We also need to determine whether or not the predicted changes will be noticeable above the natural variations in climate. Finally, observations are required in order to monitor climate, to improve the understanding of climate processes and to help in the validation of models.

The long-term change in surface air temperature following a doubling of carbon dioxide (referred to as the climate sensitivity) is generally used as a benchmark to compare models. The range of values for climate sensitivity reported in the 1990 Assessment, and re-affirmed in this Supplement, was 1.5° to 4.5°C, with a best estimate, based on model results and taking into account the observed climate record, of 2.5°C.

Simpler models, which simulate the behaviour of GCMs, are also used to make predictions of the evolution with time of global temperature from a number of emission scenarios. These so-called box-diffusion models contain highly simplified physics but give similar results to GCMs when globally averaged. Only comprehensive GCMs, however, can provide three-dimensional distributions of the changes in other climate variables, including the changes due to non-linear processes that are not given by simplified models. The extraction of this information from the results of coupled GCMs has only just begun.

Future concentrations of greenhouse gases and aerosols

A necessary starting point for the prediction of changes in climate due to changes in atmospheric constituents is an estimate of their future concentrations. This requires a knowledge of their sources and sinks (natural and man-made) and an estimate of how the strengths of these sources and sinks might change in the future (an emissions scenario). The projections of future concentrations can then be used in climate models to estimate the climatic response.

Do GCMs predict future climate?

To make a prediction of future climate it is necessary to fulfil two conditions: (a) include all of the major human and natural factors known to affect climate, and (b) predict the future magnitudes of atmospheric concentrations of greenhouse gases. So far, GCMs (and CGCMs) have included only radiative forcing induced by greenhouse gases, and therefore their results relate only to the greenhouse gas component of climate change.

At the time of IPCC (1990), it was recognized that sulphate aerosols exert a significant negative radiative forcing on climate but this forcing was not well quantified. Since then progress has been made in understanding radiative forcing by sulphate aerosols, and an additional source of negative forcing has been identified in the depletion of stratospheric ozone due to halocarbons. The lack of these negative forcing factors in GCMs does not negate the results obtained from them so far. For example the estimates of climate sensitivity, which is defined purely in terms of CO_2 concentrations, are unchanged, and it is still believed that anthropogenic greenhouse gases, now and even more so in the future, represent the largest perturbation to the natural radiative balance of the atmosphere. However it does mean that the rates of change of, say, surface temperature do need to be adjusted for additional forcing factors before they can fulfil condition (a). The second condition is fulfilled when we use a specific prediction (as opposed to a scenario) of future atmospheric concentrations of greenhouse gases.

CONFIDENCE IN MODEL PREDICTIONS

There continues to be slow improvement in the ability of models to simulate present climate, although further improvements in the model resolution and the parametrization of physical processes are needed. Since the last report, further evidence has accumulated that atmospheric models are capable of reproducing a range of aspects of atmospheric variability. Coupled ocean-atmosphere models produce variability on decadal time-scales similar in some respects to that observed, and ocean models show longer term fluctuations associated with changes in the thermohaline circulation.

There has been some clarification of the nature of water vapour feedback, although the radiative effects of clouds and related processes continue to be the major source of uncertainty and there remain uncertainties in the predicted changes in upper tropospheric water vapour in the tropics. Biological feedbacks have not yet been taken into account in simulations of climate change.

Increased confidence in the geographical patterns of climate change will require new simulations with improved coupled models and with radiative forcing scenarios that include aerosols.

Confidence in regional climate patterns based directly on GCM output remains low and there is no consistent evidence regarding changes in variability or storminess. GCM results can be interpolated to smaller scales using statistical methods (correlating regional climate with the large-scale flow) or a nested approach (high-resolution, regional climate models driven by large-scale GCM results). Both methods show promise but an insufficient number of studies have yet been completed to give an improved global picture of regional climate change due to increases in greenhouse gases; in any event both interpolation methods depend critically on the quality of the large-scale flow in the GCM. Given our incomplete knowledge of climate, we cannot rule out the possibility of surprises.

SIMULATED RATES OF CHANGE IN CLIMATE AND THEIR GEOGRAPHICAL DISTRIBUTION

Results of General Circulation Models (GCMs) available to IPCC (1990) mainly concerned *equilibrium* simulations. Only one *transient* model run (i.e., where the time-varying response of the climate to steadily increasing greenhouse gas concentrations is simulated) had been completed.

Since then many papers have appeared in the refereed literature concerned with climate models and their results. Significant progress has been made in the area of transient models, with four modelling groups having carried out climate simulations for up to 100 years using coupled atmosphere-ocean global climate models (CGCMs) which incorporate a detailed description of the deep ocean and therefore can simulate the climate lag induced by the deep ocean circulation. These models require substantial adjustments to fluxes of heat and fresh water in order to achieve a realistic simulation of present climate and this may distort the models' response to small perturbations such as those associated with increasing greenhouse gases. For simulations of future climate with these models, carbon dioxide concentrations have been increased at rates close to 1% per year (approximately the equivalent radiatively to the current rate of increase of greenhouse gases).

Internal variability obscures the geographical patterns of change during the first few decades of the experiments. However, once these patterns become established, they vary relatively little as the integrations progress and are similar to those produced by equilibrium models in a number of ways for instance:

- (i) surface air temperatures increase more over land than over oceans;
- (ii) precipitation increases on average at high latitudes, in the monsoon region of Asia and in the winter at mid-latitudes;
- (iii) over some mid-latitude continental areas values of soil moisture are lower on average in summer.

The transient CO_2 simulations, however, show that over the northern North Atlantic and the southern oceans near Antarctica the warming is reduced by 60% or more relative to equilibrium simulations at the time of doubling CO_2.

Much further development and validation of coupled models is required.

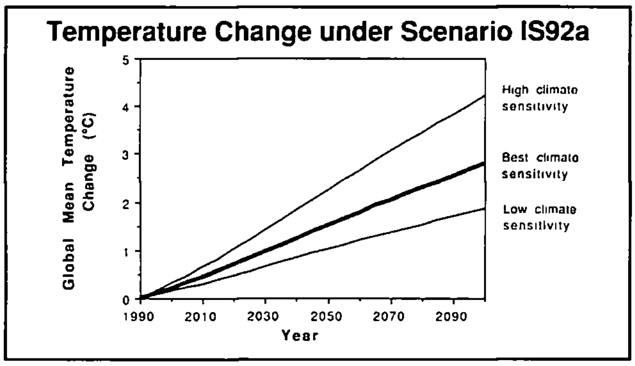
WHAT WOULD WE NOW ESTIMATE FOR CLIMATE CHANGE?

The new simulations using coupled ocean-atmosphere GCMs, which do not include the effects of sulphates and ozone depletion, generally confirm the IPCC 1990 estimates of future warming at rates of about 0.3°C/decade (range 0.2 to 0.5°C/decade) over the next century for IPCC 1990 scenario A. Because GCMs do not yet include possible opposing anthropogenic influences, including the forcing from sulphate aerosols and stratospheric ozone depletion, the net rate of increase in surface temperature is expected to be less, at least during the period for which sulphur emissions continue to increase, than would be expected from greenhouse gas forcing alone. However, the globally averaged magnitude of the effect of sulphate aerosols has not yet been calculated accurately and further work is needed.

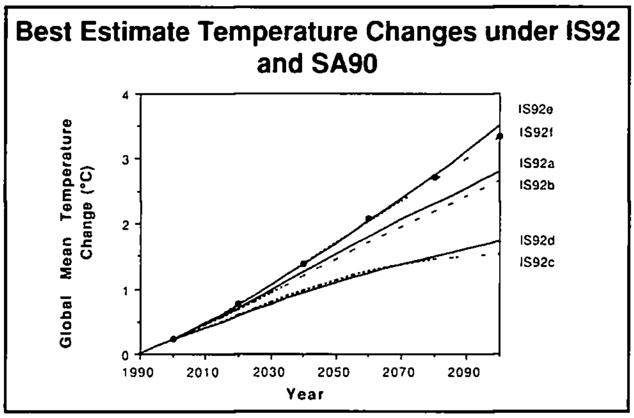
The simulated rate of change of sea level *due to oceanic thermal expansion only* ranges from 2 to 4cm per decade, again consistent with the previous report.

New IPCC 1992 emissions scenarios (IS92a-f; see para. on "SCENARIOS OF FUTURE EMISSIONS") have been derived in the light of new information and international agreements. In order to provide an initial assessment of the effect of the new scenarios, the change in surface temperature has been estimated with the simple climate model used in IPCC (1990) which has been calibrated against the more comprehensive coupled ocean-atmosphere models (see box on models). These calculations include, in the same way as did the 1990 calculations, the direct radiative forcing effects of all the greenhouse gases included in the scenarios.

The effect of stratospheric ozone depletion and of sulphate aerosols have not been included, which again parallels the 1990 calculations. The accompanying diagrams show (i) the temporal evolution of surface temperature for IS92a, assuming the high, "best estimate" and low climate sensitivities (4.5, 2.5 and 1.5°C), and (ii) the temperature changes for the six 1992 IPCC scenarios and the 1990 Scenario A, assuming the "best estimate" of climate sensitivity (see earlier box on "What tools do we use ....?" for the definition of climate sensitivity).



Estimates of global mean temperature change for IS92a using high (4.5°C) "best estimate" (2.5°C) and low (1.5°C) values of climate sensitivity. The effects of sulphate aerosol and ozone depletion have not been taken into account.



Estimates of global mean temperature change for the IPCC 1992 scenarios (IS92a-f) assuming the IPCC "best estimate" climate sensitivity. The effects of sulphate aerosol and ozone depletion have not been taken into account. SA90 is represented by solid circles.

THE UPDATED RECORD OF GLOBAL MEAN TEMPERATURES

Continuing research into the 19th century ocean temperature record has not significantly altered our calculation of surface temperature warming over the past 100-130 years of 0.45±0.15°C. Furthermore, global surface temperatures for 1990 and 1991 have been similar to those of the warmest years of the 1980s and continue to be warmer than the rest of the record. The research has, however, led to a small adjustment in hemispheric temperatures. The long-term warming trends assessed in each hemisphere are now more nearly equal, with the Southern Hemisphere marginally warmer in the late nineteenth century and the Northern Hemisphere trend unchanged from previous estimates.

A notable feature over considerable areas of the continental land masses of the Northern Hemisphere is that warming over the last few decades is primarily due to an increase of night-time rather than daytime temperatures. These changes appear to be partly related to increases in cloudiness but other factors cannot be excluded such as a direct cooling effect of aerosols on maximum temperatures in sunny weather, an influence of increasing concentrations of greenhouse gases and some residual influence of urbanisation on minimum temperatures. A more complete study is needed as only 25% of the global land area has been analysed. In this regard, regional changes in maximum, minimum and mean temperature related to changes in land use (e.g., desertification, deforestation or widespread irrigation) may need to be identified separately.

A new source of information that supports higher sea surface temperatures in many tropical regions over the last decade concerns evidence that the bleaching of tropical corals has apparently increased. Bleaching has been shown to be related (in part) to episodes of sea surface temperature warmer than the normal range of tolerance of these animals, though increasing pollution may be having an influence.

There has been considerable interest in mid-tropospheric temperature observations made since 1979 from the Microwave Sounding Unit (MSU) aboard the TIROS-N satellites. The MSU data have a truly global coverage but there is only a short record (13 years) of measurements; the surface and the radiosonde data are less spatially complete but have much longer records (over 130 and near 30 years respectively). Globally-averaged trends in MSU, radiosonde and surface data sets between 1979 and 1991 differ somewhat (0.06, 0.17, and 0.18°C per decade, respectively), although the differences are not statistically significant. Satellite sounders, radiosonde and surface instruments all have different measurement characteristics, and, in addition, geographical and temporal variations in mid-tropospheric and surface temperatures are not expected to be identical. Despite this, correlations between global annual values of the three data sets are quite high.

Note that it is not possible to rank recent warm years in an absolute way; it depends on which record is used, what level is referred to and how much uncertainty is attached to each value.

MSU data have been able to detect the impact on lower stratospheric temperature of volcanic eruptions in a striking way. Variability in these data between 1979 and 1991 is dominated by short-term temperature fluctuations (greatest in the tropics) following the injection of large amounts of aerosol into the stratosphere by the eruptions of El Chichon (1982) and Mt. Pinatubo (1991). Globally, temperature rises in the lower stratosphere were about 1°C and 1.3°C respectively; stratospheric warming due to El Chichon lasted nearly two years while that due to Mt. Pinatubo is still underway. The longer radiosonde record, however, shows a significant global cooling trend of about 0.4°C per decade since the middle 1960s in the lower stratosphere.

ARE THERE ANY TRENDS IN OTHER CLIMATICALLY IMPORTANT QUANTITIES?

Precipitation variations of practical significance have been documented on many time and space scales, but due to data coverage and inhomogeneity problems nothing can be said about global-scale changes. An apparent increase of water vapour in the tropics parallels the increase in lower tropospheric temperature but it is not yet possible to say to what extent the changes are real and whether they are larger than natural variability.

A small, irregular, decrease of about 8% has been observed in annually averaged snow cover extent over the Northern Hemisphere since 1973 in a new, improved, compilation of these data. The reduction is thought to be real because annual values of snow cover extent and surface air temperatures over the extratropical Northern Hemisphere land have a high correlation of -0.76.

There is evidence that, regionally, relatively fast (sometimes called abrupt) climate changes can occur. These changes may persist for up to several decades but are often a function of season. These fast changes are poorly understood, but can be of considerable practical importance.

ARE THE OBSERVED TEMPERATURE CHANGES CONSISTENT WITH PREDICTED TEMPERATURE CHANGES?

CGCMs, which do not yet take into account changes in aerosols, predict a greater degree of warming in the Northern Hemisphere (NH) than in the Southern Hemisphere (SH), a result of the greater extent of land in the NH which responds more rapidly to forcing. The observed larger warming of the SH in recent decades (0.3°C between 1955 and 1985) than in the NH (which hardly warmed at all over the same period) is at first sight in conflict with this prediction. Recently, however, the NH has started to warm quite rapidly. The reasons for the differences in observed warming rates in the two hemispheres are not known though man-made aerosols (see para. on "HOW HAS OUR UNDERSTANDING .....?) and changes in ocean circulation may have played a part.

Furthermore, increases in CFCs may have reduced ozone levels sufficiently to offset in a globally-averaged sense the direct greenhouse effect of CFCs. Consequently, the estimates of warming over the last 100 years due to increases in greenhouse gases made in the original report may be somewhat too rapid because they did not take account of these cooling influences. Taking this into account could bring the results of model simulations closer to the observed changes.

Individual volcanic eruptions, such as that of El Chichon, may have led to surface cooling over several years but should have negligible effect on the long-term trend. Some influence of solar variations on time-scales associated with several sunspot cycles remains unproven but is a possibility.

The conclusion of IPCC (1990) remains unchanged:
"the size of this warming is broadly consistent with predictions of climate models, but it is also of the same magnitude as natural climate variability. Thus the observed increase could be largely due to this natural variability; alternatively this variability and other human factors could have offset a still larger human-induced greenhouse warming".

KEY UNCERTAINTIES AND FURTHER WORK REQUIRED

The prediction of future climate change is critically dependent on scenarios of future anthropogenic emissions of greenhouse gases and other climate forcing agents such as aerosols. These depend not only on factors which can be addressed by the natural sciences but also on factors such as population and economic growth and energy policy where there is much uncertainty and which are the concern of the social sciences. Natural and social scientists need to cooperate closely in the development of scenarios of future emissions.

Since IPCC (1990) there has been a greater appreciation of many of the uncertainties which affect our predictions of the timing, magnitude and regional patterns of climate change. These continue to be rooted in our inadequate understanding of:

- sources and sinks of greenhouse gases and aerosols and their atmospheric concentrations (including their indirect effects on global warming)
- clouds (particularly their feedback effect on greenhouse gas-induced global warming, also the effect of aerosols on clouds and their radiative properties) and other elements of the atmospheric water budget, including the processes controlling upper level water vapour
- oceans, which through their thermal inertia and possible changes in circulation, influence the timing and pattern of climate change
- polar ice sheets (whose response to climate change also affects predictions of sea level rise)
- land surface processes and feedbacks, including hydrological and ecological processes which couple regional and global climates

Reduction of these uncertainties requires:

- improvements in the systematic observation and understanding of climate-forcing variables on a global basis, including solar irradiance and aerosols
- development of comprehensive observations of the relevant variables describing all components of the climate system, involving as required new technologies and the establishment of data sets
- better understanding of climate-related processes, particularly those associated with clouds, oceans and the carbon-cycle
- an improved understanding of social, technological and economic processes, especially in developing countries, that are necessary to develop more realistic scenarios of future emissions

- the development of national inventories of current emissions

- more detailed knowledge of climate changes which have taken place in the past

- sustained and increased support for climate research activities which cross national and disciplinary boundaries; particular action is still needed to facilitate the full involvement of developing countries

- improved international exchange of climate data.

Many of these requirements are being addressed by major international programmes in particular by the World Climate Research Programme (WCRP), the International Geosphere Biosphere Programme (IGBP) and the Global Climate Observing System (GCOS). Adequate resources need to be provided both to the international organisation of these programmes and to the national efforts supporting them if the new information necessary to reduce the uncertainties is to be forthcoming. Resources also need to be provided to support on a national or regional basis, and especially in developing countries, the analysis of data relating to a wide range of climate variables and the continued observation of important variables with adequate coverage and accuracy.

Reference:

IPCC, 1990: Climate Change, The IPCC Scientific Assessment, Press Syndicate of the University of Cambridge, Cambridge CB2 1RP, UK.

ANNEX

Progress in the development of an IPCC methodology for national inventories of net emissions of greenhouse gases

Scientific assessment is primarily concerned with sources and sinks at the global, and large region level but, in order to support national and international responses to climate change, it is necessary to estimate emissions and sinks at the national level in an agreed and consistent way.

IPCC (1991) has established a work programme to:

i) develop an approved detailed methodology for calculating national inventories of greenhouse gas emissions and sinks

ii) assist all participating countries to implement this methodology and provide results by the end of 1993.

This programme is based on preliminary work sponsored by the Organization for Economic Cooperation and Development (OECD, 1991). OECD and the International Energy Agency (IEA) are continuing to provide technical support to the IPCC work programme. The programme will manage the development and approval of inventory methods and procedures, and the collection and evaluation of data. It will collaborate with other sponsors including the Global Environment Facility (GEF), the Asian Development Bank, the European Community, UNECE and individual donor countries, to encourage funding of technical cooperation projects in greenhouse gas (GHG) inventories.

The IPCC requested that participating countries provide any available GHG emissions inventory data to the IPCC by the end of September 1991. As of January 1992, 18 countries have submitted complete or partial GHG inventories (see Table below); most relate to average emissions over one, two or three years in the period 1988 to 1990. This process has been particularly useful in identifying problems in coverage and consistency of currently available inventories.

An IPCC Workshop on National GHG Inventories, held in Geneva from 5-6 December 1991, provided guidance on needed improvements in the draft methodology and priorities for the work programme. Numerous improvements to the methodology were agreed upon, and priorities were proposed for the work programme and for technical cooperation activities. As a result of the preliminary data collection, the workshop, and other comments received, the following major priorities for the IPCC work programme have been established:

Methodology

- Develop a simpler methodology and streamlined "workbook" document to assist users in its implementation
- Work with experts to develop a new and simpler method for calculating CO_2 emissions from forestry and land-use change
- Establish technical expert groups to improve the methodology for CH4 from rice and fossil fuel production, and other key gases and source types
- Work with experts to include halocarbons in the GHG inventory starting with data available from the Montreal Protocol process
- Develop and disseminate regionally-applicable emissions factors and assumptions.

Work programme

- Priorities for national inventories are: (a) CO_2 from energy for all countries, (b) CO_2 from forestry and land use if important for the country, and (c) CH_4 for important source categories by country
- Initiate intercomparison studies of existing detailed inventories
- Include a scientific review of national inventory data and aggregated totals by region and globally in the work programme.

Technical cooperation

- IPCC will improve communications among technical focal points in all participating countries and with other interested international organizations
- High priority should be placed on country case studies, training, regional cooperation and other activities to assist non-OECD countries in testing and implementing the GHG inventory methodology
- Provide methods in the form of a streamlined workbook in several languages. A user-friendly computer spreadsheet version will also be developed as a high priority.

Annex Table: Countries which have submitted complete or partial inventories of national greenhouse gas emissions (by January 1992).

Australia	Germany	Sweden
Belgium	Italy	Switzerland
Canada	Netherlands	Thailand
Denmark	New Zealand	Vietnam
Finland	Norway	United Kingdom
France	Poland	United States

References

IPCC, 1991: Report of the Fifth Session of the WMO/UNEP Intergovernmental Panel on Climate Change (IPCC) 13-15 March 1991, Geneva.

OECD, 1991: Estimation of Greenhouse Gas Emissions and Sinks: Final Report from the OECD Experts Meeting, 18-21 February 1991, Paris. Revised August 1991.

SECTION III. ASSESSMENT OF POTENTIAL IMPACTS OF CLIMATE CHANGE

TASK 2: **Prediction of the regional distributions of climate change and associated impacts studies, including model validation studies**

TASK 3: **Energy and industry related issues (part on impacts of climate change)**

TASK 4: **Agriculture and forestry related issues (part on impacts of climate change)**

TASK 5: **Vulnerability to sea level rise (part on impacts of climate change)**

BY WORKING GROUP II

Introduction

Working Group II examined aspects of four of the tasks approved at the fifth session of IPCC (March 1991). These tasks include:

- prediction of the regional distributions of climate change and associated impacts studies, including model validation studies;
- energy and Industry related issues;
- agriculture and Forestry related issues;
- vulnerability to sea level rise.

The first of these includes the development of guidelines for assessment of impacts, and the identification of regional/national components of monitoring systems which could be used for impact studies.

Also included here is additional work on water resources and hydrology, a subject mentioned most frequently as the area of maximum concern by nations in response to a questionnaire circulated by the Working Group (and on other topics related to the structure of the Working Group itself). The work reported focuses only on the portions of these tasks that directly relate to the impacts of climate change.

Since the IPCC First Impacts Assessment Report (1990), studies have been included which have served to extend our knowledge of the potential impacts of climate change. These, however, do not radically alter the conclusions despite uncertainties of that report.

From the stimulus provided by the publication of the IPCC First Impacts Assessment Report, a large number of regional studies have been carried out on assessment of impacts of climate change. A questionnaire circulated by Working Group II was valuable in revealing new information, and in defining areas of common concern to many countries. Thus, roughly 50% of the responses highlighted the impacts of climate change on hydrology and water resources, emphasizing the importance of water in most countries. Other topics of priority interest, particularly for developing countries, were agriculture and forestry, and world's oceans and coastal zones. Both reflect the concerns of countries over availability of food supplies from land and sea sources.

Additional areas of concern identified in the questionnaire were desertification (particularly in Africa and Asia), cyclones and other extreme events (particularly for island nations and deltaic areas), recreation and tourism (particularly their economic impacts), and climate variability associated with the El-Niño - Southern Oscillation (ENSO) phenomenon, prolonged droughts and extreme events. The national responses included concern that changes in climate variability as a consequence of climate change may create increased risks, especially in those parts of the world where climate variability is known to have significant social and economic impacts. It is important to note that many countries, particularly in the Southern Hemisphere, also identified increases in UV-B radiation as a significant area of concern.

THE ENERGY, HUMAN SETTLEMENT, TRANSPORT AND INDUSTRIAL SECTORS, HUMAN HEALTH AND AIR QUALITY

Recent studies for the Maldives and for the Pacific island states including Tuvalu, Kiribati, Tokelau and the Marshall Islands have reconfirmed that small low-lying island states and large populations living in low-lying coastal areas will be increasingly vulnerable, particularly if adaptive measures are inadequate, to the combination of sea level rise, storm surges and coastal flooding.

The high dependency on biomass and hydropower in many developing countries indicates that these countries are quite sensitive to the impacts of climate change. Biomass production, on which developing countries such as Bangladesh depend for 90 to 100% of their energy needs, could be damaged by a combination of climate-change-induced drought or inundation.

On the other hand, there has been little work that has shed new light on the question of socio-economic impacts in the areas of energy, human settlement, transport and industrial sectors, human health and air quality.

A UK study shows soil shrinkage and swelling as a result of climate change in clay-rich areas has major implications for the construction and insurance industries and for human settlement. Water-dependent industries such as food processing, paper making, and power generation could be affected by hydrological changes under changed climate conditions.

Knowledge of climate change on human health has extended and confirmed the previously reported results with greater understanding of potential shifts in disease vector habitats with global warming particularly in New Zealand and Australia. Diseases such as malaria, lymphatic filariases, schistosomiasis, leishmaniasis, onchocerciasis (river blindness), dengue fever, and Australian and Japanese encephalitis could increase or be reintroduced in many countries as a consequence of global warming. Regarding the impact of UV-B radiation on health, recent studies show that it affects human immunosuppression system and vision.

AGRICULTURE AND FORESTRY

New studies, such as those in the European Community, North America, and Southeast Asia highlight the IPCC First Impacts Assessment Report (1990) conclusions that impacts will vary greatly depending on the extent of climate change and on the type of agriculture. These findings largely amplify, but do not radically alter, the conclusions made in the 1990 report. They do, however, confirm that the impact of global warming on agriculture may be serious if warming is at the upper end of the range projected by the IPCC Working Group I.

Recent studies have reinforced concern that drought is the area in which climate change poses the greatest risk for agriculture and consequently arid and semi-arid regions are likely to be most vulnerable to climate change.

Other recent studies confirm the IPCC earlier conclusions that climate change may benefit ecological conditions for insect growth and abundance which is likely to have a negative effect on crop, livestock and forest production in some regions.

Research continues to address the relative importance of direct and indirect effects of CO_2, in combination with a rise in temperatures, on future crop production. While some scientists emphasize enhanced photosynthesis and more efficient water use seen in controlled settings, others are sceptical that these benefits will be seen in farmer's fields under changing climate conditions.
The effects on plant growth may result in the maintenance of present-day soil conditions in some regions, as greater soil organic matter and denser ground cover may counter the effects of soil erosion caused by increased rainfall intensities and oxidation rates of organic matter in soils caused by higher temperatures.

Adaptation to climate change by the existing agricultural production system should be possible, and the worldwide systems of agricultural research should be able to provide new crop cultivars that maintain high yields and nutritional quality. However, efforts will be needed to make such developments available to small farmers in developing countries in time to respond to changes in local climatic conditions.

New analyses support the 1990 report conclusion that the impacts of climate change on forests could have significant socio-economic consequences. This is especially important for those countries and regions where economic and social welfare and economic development are highly dependent on the forest sector.

Key uncertainties require continued data collection and research for policy development and decision-making. These include: (1) the extent of managed and natural forests, their spatial and temporal variation and their roles in the global carbon cycle; (2) genetics and physiology of tree species and the relationships among subordinate and competitive species; (3) regional impacts; and, (4) the linkages among the regional impacts, socio-economic structures, and the thresholds and critical limits where changes take place.

NATURAL TERRESTRIAL ECOSYSTEMS

Analyses subsequent to those included in the IPCC First Assessment Report (1990) reinforce the major conclusion of that report that natural terrestrial ecosystems could face significant environmental impacts as a result of the global increases in the atmospheric concentration of greenhouse gases and associated climatic changes. In particular, these studies continue to suggest that the rate of these changes will be the major factor in determining the type and degree of impacts with a variety of responses expected for different regions and for different communities within ecosystems. Current climatic projections continue to suggest that the rates of change are likely to be faster than the ability of some component species to respond and that species and ecosystem responses may be sudden, potentially leading to ecosystem destabilization or degradation.

The promotion of heightened public awareness of the general values of natural terrestrial ecosystems is essential to gaining public support for sustaining these ecosystems in a changing climate. Particular emphasis should be placed on involving ecosystem managers and local people in the assessment of the impacts, consequences and response strategies.

One of the major issues regarding the impacts of climate change on terrestrial ecosystems is water availability with recent studies suggesting that while water use efficiency of vegetation could increase in an enriched CO_2 atmosphere, the same amount of water per unit soil area may be necessary because of increased leaf area ratios due to greater biomass produced in that enriched atmosphere.

Projected climate changes are expected to result in an accelerated reduction of tropical forest on the African continent and an encroachment of the Sahel syndrome into the savannas. These changes could worsen the already precarious production systems in the affected regions of Africa, further stressing the associated natural ecosystems and component species. Degradation of wetlands and shallow lakes (e.g., within savanna ecosystems in Africa and within the Great Plains of North America) as a result of projected decreases in rainfall or soil moisture could adversely impact on resident animals and migratory species.

With projected climate change, profound impacts, both beneficial and destructive, can be expected for the distribution and productivity of valuable fisheries and the industries associated with them. The added stresses to freshwater ecosystems as a result of climate change can be expected to reduce species numbers and genetic diversity within freshwater populations in the short term. With warming, a longer growing season could lead to greater fish productivity where temperature is currently limiting factor.

Uncertainties and gaps in the knowledge base continue to exist in terms of our understanding of the environmental impacts and associated socio-economic consequences of climate changes. National, regional and global efforts need to cooperatively focus on reducing these deficiencies which primarily exist as a result of the lack of sufficient information and data on: a) fundamental ecological processes; b) the links between climate and atmospheric chemistry on the one hand and the response of natural terrestrial ecosystems and their component species on the other; and c) the links between natural terrestrial ecosystem changes and social and economic welfare under a changing climate. In particular, there is a lack of information on the sensitivity of these ecosystems and their component species to climate change, the vulnerability of social and economic systems to ecosystem changes, and thresholds/critical levels for these ecosystems and associated social and economic systems. Existing international programmes such as GEMS and MAB can provide one means of examining these deficiencies.

WORLD OCEANS AND COASTAL ZONES: ECOLOGICAL EFFECTS

Since the IPCC First Impacts Assessment Report (1990), new studies reconfirm that rising sea level is of more concern in low-lying coastal ecosystems than rising water temperatures. However, the combination of sea level and temperature rise, along with changes in precipitation and UV-B radiation, are expected to have strong impacts on marine ecosystems, including redistributions and changes in biotic production.

The impact of sea level rise depends on the total net rise resulting from the relative vertical movements of the land and of the sea. In areas undergoing natural eustatic uplifting of the land due to tectonic plate movement, glacial rebound, and vulcanism, there will be little relative rise of sea level. In land areas that are naturally falling as in the southeastern USA, due to tectonic and compaction forces, impacts of sea level rise will be more important. A new study of the Bering Sea indicates that in areas without natural land uplift, there could be important impacts where there is a high density of marine organisms dependent on certain types of on-shore and near-shore marine environments that may be affected by sea level change. Nevertheless, sea level rise is of far less consequence in northern areas than are other impacts of climate change to northern ecosystems and to global carbon cycling. These regions are very important in the global carbon cycle and a small temperature rise may cause significant increases in bioproductivity and in carbon flux to the oceans.

Coral organisms grow 1-20 cm/year and reef growth rates as a whole are known to be up to 1.5 cm/year. Not all reefs accumulate at these rates, but most should keep pace with the expected rise in sea level if other factors do not alter growth conditions. Stress on the reefs from other variables (storms, sedimentation, disease, rainfall, radiation, turbidity, overfishing, mass mortality in algal grazers, etc.) may prevent some reefs from keeping pace with rising sea level, resulting in changes to nearshore hydrodynamics.

With respect to temperature rise, marine organisms in the tropics live closer to their maximum thermal tolerance than those in more temperate climates. Although a 1-2°C temperature rise would raise the summertime mean temperature to over 30°C over much of the tropical/subtropical region, most migratory organisms are expected to be able to tolerate such a change. Temperature rise may trigger bleaching events in some corals, but it is expected that the other stresses mentioned above will be more important.

Intertidal plants, such as mangroves, can withstand high temperature, and unless temperature rise affects reproduction, it is unlikely to have any effect. Because mangroves grow best in moderately saline environments, mangroves can probably keep pace with sea level rise in rainfed humid areas, but may be overstepped and abandoned in more arid areas, particularly if inland retreat is not possible. Thus, future changes in patterns of rain and runoff and of overcutting may be more important than sea level rise. With respect to marshes, new studies indicate that mid-latitude plants seem to tolerate salinity better and are more productive under elevated CO_2.

New findings of WMO/UNEP indicate that UV-B radiation reaching oceanic and coastal zone environments will increase faster than expected when the first Report was written. Since so many marine resources spend all or vulnerable parts of their lives near the water surface, there is a significant threat to some fisheries. The first Report expressed concern about leaching of contaminants during sea level rise, from coastal waste disposal sites. There are also bacteria and viral agents in such sites and in coastal septic sewerage systems which could be increasingly released into coastal waters. There are potential impacts on coastal resources, but the primary concern is for the humans who consume them and the loss of commerce due to the closure of fish and shellfish areas by health authorities. Lastly, potential changes in storm frequency or intensity could have important ecological consequences to coastal resources.

HYDROLOGY AND WATER RESOURCES

Since the publication of the IPCC First Impacts Assessment Report (1990), a number of studies on impacts of climate change on hydrology and water resources have been conducted. Unfortunately, there is not yet adequate information on regions affected by aridity and desertification, and an effort should be undertaken to fill that gap. The new studies expanded on the geographic scope of the original surveys, but few new insights were offered on hydrologic sensitivities and vulnerability of existing water resources management systems, while confirming many previous conclusions.

The principal conclusions suggested by the new studies are:

- Significant progress has been made in hydrologic sensitivity analyses in developed countries, yet large gaps exist in the information base regarding the implications of climate change for less developed nations;

- Comparative sensitivity analyses that rely on existing GCMs offer generic insights regarding the physical hydrologic effects and water resources management impacts, but the differences in the outputs of the GCMs coupled with large differences in hydrologic sensitivity analyses makes it difficult to offer region-specific impact assessments.

- Temporal streamflow characteristics in virtually all regions exhibited greater variability and amplification of extremes, with larger flood volumes and peak flows as well as increased low flow episodes and a shift in the turning of the seasonal runoff;

- The higher the degree of water control, regulation and management of sectoral water demands, the smaller the anticipated adverse effects of global warming. Conversely, unregulated hydrologic systems are more vulnerable to potential hydrologic alterations;

The principal recommendations are:

- Increased variability of floods and droughts will require a re-examination of engineering design assumptions, operating rules, system optimization, and contingency planning for existing and planned water management systems;

- More studies on hydrologic sensitivity and water resource management vulnerability need to be focused in arid and semi-arid regions and small island states.

- A uniform approach to the climate change hydrologic sensitivity analyses needs to be developed for comparability of results.

CRYOSPHERE

Analyses continue to support the conclusion that projected changes in climate associated with enhanced atmospheric concentrations of greenhouse gases are expected to substantially reduce the areal extent and volume of seasonal snow cover, mountain glaciers, terrestrial ice sheets and frozen ground including permafrost and seasonally frozen ground.

Recent analyses have shed some further light on the potential impacts for these elements of the terrestrial cryosphere.

- Analysis of satellite-derived snow cover data has shown that the extent of northern hemispheric snow to be at record low levels since the middle of 1987 with the largest negative anomalies occurring in the Spring.

- Above normal temperatures throughout much of the Northern Hemisphere in 1989 led to the initiation of extensive active layer detachment slides within permafrost in some regions of the Canadian and Russian Arctic with damming and degradation of water quality in affected streams and further failures initiated.

- Emissions in Arctic regions of methane from hydrates as a result of permafrost degradation may have been underestimated.

- There is some evidence to suggest that glaciers in the Northern Hemisphere polar and subpolar regions are receding at a slower rate than previously suggested with some having advanced in the past 30 years. Although the Southern Hemisphere record is not as detailed, records for several New Zealand glaciers show that these have retreated since the mid-1800s with the suggestion that this has been the result of an increase in temperature and an accompanying decrease in precipitation.

Key uncertainties are associated with understanding fundamental cryological processes, the relationship among these elements (e.g., impacts of changes in snow cover on permafrost and glacier dynamics), the impacts of climate change on these elements of the cryosphere, the interdependency of associated ecosystems (e.g., soil erosion and stability changes associated with permafrost degradation) and human systems (e.g., structures, transportation, transmission lines), and the role of the cryosphere in local, regional and global climate and climate change.

REGIONAL CLIMATE CHANGE PREDICTION

The prediction of climate change at regional level precision is subject to great uncertainty. Precipitation changes are particularly uncertain, although these changes are of great practical significance. Progress in the development of GCM models is urgently needed, particularly in terms of improving their capability for regional predictions, especially to understand changes in the arid and semi-arid regions. Work on improving regional predictions using the paleo-analogue method continues in Russia and other countries. In the further work of IPCC, all methods of regional climate prediction should be reviewed and assessed together.

GUIDELINES FOR ASSESSING IMPACTS OF CLIMATE CHANGE

Working Group II is preparing guidelines to assess the socio-economic and environmental impacts of potential climate change. These guidelines will outline a framework for the study of climate-environment-society interactions and the estimation of the impacts of climate change that will allow comparisons and integration of impacts across various geographical areas and economic sectors. Preliminary guidelines will be available, after peer review, in 1992. Further work will continue as a long-term task.

Impact assessments involve several steps: (i) definition of the problem; (ii) selection of analytical method(s): (iii) testing the method; (iv) development of climatic and socio-economic scenarios; (v) assessment of potential impacts; (vi) evaluation of technical adjustments; and (vii) consideration of policy options.

Definition of the problem includes identifying the specific goals of the assessment, the sector(s) and geographical area(s) of interest, the time horizon of the study, the data needs and the wider context of the work.

Selection of analytical method(s) depends upon the availability of resources, models and data. Impact assessment analyses could range from the qualitative and descriptive to the quantitative and prognostic. Thoroughly testing the method(s), including model validation and sensitivity studies, prior to undertaking the full assessment is necessary to ensure credibility.

Development of the climatic and socio-economic scenarios involves several steps. The current and projected climatic, socio-economic and environmental conditions expected to exist over the study period in the absence of climate change should be established. Scenarios of regional climate change over the study time frame must also be developed. Third, biophysical and environmental effects should be projected under the altered climate. Then these projections should be used, preferably in integrated environment-economic models, to calculate the socio-economic effects under the altered climate. Assessment of potential impacts for the sector(s) or area(s) of interest involves estimating the differences in environmental and socio-economic conditions projected to occur with and without climate change.

Projections of effects with and without climate change should incorporate "automatic" adjustments. However, the impact assessment should seek to evaluate the additional technical adjustments resulting from application of existing and new technologies or practices that may be available over the study period, assuming no changes in the current legal and institutional framework.

The costs and benefits of climate change should be assessed, to the extent possible, using a common measure and discounted to net present value. Alternatively, costs and benefits should be described qualitatively. The above general framework would also allow consideration of policy options and their socio-economic and environmental impacts.

MONITORING TO IDENTIFY CLIMATE CHANGE CONSEQUENCES

There is a need to increase the available information and data to support impact studies, particularly in developing countries. This need can be met through enhancing and, where appropriate, establishing integrated monitoring programmes including biological, chemical, physical and climatological parameters, as well as constructing concurrent social and economic assessments, at the national, regional and global levels to identify climate change consequences. Data quality needs to be assured and data analyses and their interpretation need to be carried out carefully. The use of common protocols for collection and analysis processes (including Geographical Information Systems or GIS) and for equipment will aid in assuring intercomparability and further encourage international cooperation. The development of the preliminary IPCC guidelines for assessing the impacts of climate change is an important contribution to this end.

Monitoring of sensitive terrestrial and marine ecosystems, including the cryosphere, and component species should be given priority as they could provide early detection/warning of climate change and its impacts. Also to be given priority are those species and ecosystems which have significant (locally/regionally defined) social and/or economic values. The classic ground station approach (including points, plots and transects) should provide the basic building blocks of monitoring programmes, however, these should also be supplemented with remotely sensed observations (e.g., satellite, radar, and photogrammetry). Advantage should be taken of automatic data transmission and processing systems.

At present, international organizations such as UNEP, WMO and IOC are implementing monitoring programmes to help identify ecological and socio-economic consequences of climate change. UNEP has an initial programme for observing terrestrial ecosystems with observations extending on either side of the present boundaries of plant zones for early detection of possible shifts of these boundaries. WMO and IOC, among their many monitoring activities, have designed a satellite observation system for climatic and ocean parameters. Current planning of the Global Climate Observing System (GCOS) and the Global Ocean Observing System (GOOS) should consider the value of including the monitoring of terrestrial and marine ecological impacts of climate change. These can provide an early indication of the integrated effect of climate change.

SECTION IV.

TASK 3: ENERGY AND INDUSTRY RELATED ISSUES

BY WORKING GROUP III

INTRODUCTION

In March 1991, the Panel identified key areas for further study by the Energy and Industry Subgroup. Their purposes were:

(a) to fill significant gaps in the analysis achieved to date on energy and industry sector responses to limit climate change: and

(b) to begin new areas of analysis and suggest areas of research which were too difficult to address in the first phase of the IPCC.

These studies, which have not yet been peer-reviewed, or progress reports thereon are presented below in a summary manner. Peer review will take place later this year. Nevertheless, in the interim, these studies may provide useful information for policy analysis and decision making. Although attempts have been made to reflect all available material, some studies were confined to a limited number of sources or data bases. Some studies had to rely upon works which were not conducted with consistent methodologies or data bases.

SUMMARY OF SUBTASKS

1) Comprehensive assessment of technological options for mitigating global warming

The objective of this study is to assess various technological options for reducing greenhouse gases, particularly CO_2, in a comprehensive way. Building upon the IPCC Response Strategies Report (1990) (see table 3.2), this paper reports some tentative findings in the survey of technologies as the first part of the work. The results of the second part of the work, building future scenarios on the use of these technologies, will be available with an updated first part in late 1992.

The tentative findings are:

(a) Energy conservation and improved efficiency in the production, conversion distribution and end use of energy is one of the most effective options available now and in the future. System restructuring, such as energy cascading and infrastructure improvement, has promising potential.

(b) The technologies to capture and sequester CO2 from fossil fuel combustion deserve investigation, considering the expected continuing dependence on fossil fuels as primary energy sources.

(c) Nuclear power has the technological potential to be one of the major energy sources in the next century, but faces various socio-economic, security and safety constraints.

(d) There are various existing and promising non-fossil fuel technologies such as photovoltaics (PV), wind, hydropower, geothermal, biomass and solar thermal systems. PV may be first applied in a small scale on roofs, and then in larger scale on deserts and ocean surface if energy distribution technology can be advanced substantially.

(e) The physical potential of biomass for energy use is apparently high but in some regions, competition in land use for food may limit its production. Environmentally sound intensification of agriculture for more efficient production of food may be considered. (see also para. on biomass below).

2) The IPCC Technology Characterization Inventory (TCI)

The IPCC Technology Characterization Inventory (TCI) provides an information source of consistent, well-documented technology data for analysis and planning activities to limit greenhouse gas emissions. Special emphasis is given to technologies having potential interest to developing countries and economies in transition. Information from many sources is used to describe technologies in five catgories: (1) Primary Energy Production (2) Secondary Energy Conservation and Processing (3) Energy Transfer (4) End-Use Technologies and (5) Greenhouse Gases Control Technologies.

Because information and data are not sufficiently detailed for design of specific technology installations, addresses for specialists around the world are provided. The data base includes information for energy sources and major regions of the world. Country-specific information can be included as it becomes available from specific applications and analyses.

Phase I consists of a preliminary design of the data base and descriptions of eighteen technologies. These eighteen technologies shown in Table 1 were submitted to the IPCC for review in February 1992. The Phase II effort began in December 1991. By June 1992, the TCI will include about 90 technologies. Future versions of the data base are expected, including both updated and added technologies.

Table 1: TCI Phase I Technologies

SUPPLY TECHNOLOGY

- Pulverized Coal Steam Generation
- Gas Turbine-Steam injected, inter-cooled (ISTIG)
- Atmospheric Fluidized Bed Combustion
- Diesel Cogeneration
- Solar Thermal Electric-Parabolic trough
- Mass Burning of Municipal Solid Waste
- Efficient Electrical Transformers

ENERGY END-USE TECHNOLOGY

- Electric Motors
- Lighting-Compact fluorescent lighting
- Lighting-Electronic Fluorescent Ballasts
- Alternative Fuelled Vehicles-methanol
- Alternative Fuelled Vehicles-CNG
- Advanced Road Traffic Signalization

MANUFACTURING TECHNOLOGY

- Motors-Industrial electric motors
- High Efficiency Welding Power Supply
- Chemicals-Efficient fertilizer production
- Pulp & Paper-Mechanical dewatering
- Petroleum Refining-Process (Distillation) control systems

3) Technological options for reducing methane emissions

Reducing global anthropogenic methane emissions by about 15-20 percent can halt rising atmospheric concentration of methane. A technological assessment of options for reducing methane emissions from anthropogenic sources (about 60 percent of global methane emissions) has been developed through the United States/Japan Working Group on Methane, which compiled information submitted by IPCC participating countries. Technological options are available for limiting emissions from the major sources, other than flooded rice cultivation and biomass burning. These options may be economically viable at suitable locations in many regions of the world, and represent different levels of technical and capital needs (summarized in Table 2). In many cases, these options provide a range of benefits, including better air quality, better protection of surface and groundwater, enhanced productivity, reduced risk of explosion, and improved availability and use of energy resources. Some of these technologies are already established and proven beneficial in certain markets. Barriers which hinder the further implementation of these options in many countries, especially developing countries include availability of capital, lack of technical information, and conflicting incentive systems. These barriers need to be addressed on a country and site-specific basis.

Table 2: Summary of Characteristics of Methane Emissions Reduction Options

			Availability					Benefits			
Source	Emissions (Tg)[1]	Methane Reductions from Individual Options	by 1995	by 2005	post 2005	Includes Profitable Options	Includes Low-Tech Options	Air/Water Quality	Safety	Productivity	Energy Recovery
EIS Sources											
Coal Mining		up to 90%	X	X		X	X	X	X	X	X
Oil & Gas	70-120	up to 80%	X	X		X	X	X	X	X	X
Combustion		NQ	X	X		X		X			
AFOS Sources											
Ruminants	65-100	up to 75%[2]	X	X	X ·	X	X			X	
Animal Wastes	20-35	up to 80%	X			X	X	X		X	X
Landfills	20-70	up to 90%	X			X	X	X	X		X
Wastewater		up to 80%	X			X	X	X			X
Biomass Burning[3]	20-80	NQ		X			X	X	X	X	
Rice Growing	20-150	up to 30%			X					X	

[1] Estimates prepared by IPCC Working Group I

[2] Methane reductions per unit product

[3] In situ burning and cook stove use

NQ = Not Quantified

4) Increasing electricity end-use efficiency

The study addresses the topic of increasing electricity end-use efficiency by providing an in-depth review of the following: (a) the status of available technologies for increasing electric end-use efficiency; (b) factors that limit the application and widespread deployment of these technologies: and (c) policies that have been implemented to increase the efficiency of electricity end-use.

The conclusions of the report are summarized as follows. A substantial fraction of increased anthropogenic carbon emission over the next several decades is likely to come from electricity generation. Increases in end-use efficiency improvements beyond those expected to occur under current technologies and policies could cut significantly the growth of electricity use and associated growth in projected carbon emissions. Based on experience among industrialized and developing countries concerning the technologies and programmes and policies, significant increases in electricity end-use efficiency are possible. It appears that many of these increases can be achieved in a cost-effective manner. Enhancing adoption of these efficient technologies by developing countries is an essential part of a successful strategy to curtail growth in emissions of greenhouse gases.

5) Natural gas prospects and policies

One option for reducing CO2 emissions is the substitution of natural gas for more carbon-intensive fuels. The demand for gas is growing worldwide and is expected to nearly double by the year 2005. As the starting point for its analysis, the IPCC has reviewed the International Energy Agency's (IEA) natural gas study, Natural Gas Prospects and Policies (October 1991). This study provides a comprehensive analysis of demand and supply for natural gas including the institutional framework surrounding the production, transmission and use of natural gas. The study's primary focus is on demand for natural gas in OECD countries, but sources from outside the OECD are extensively treated. The IEA forecasts that demand for natural gas outside OECD will be approximately twice that of OECD by 2005. The study indicates that ample gas resources exist worldwide even with the expected doubling of demand in some of the regions through the year 2005 at prices ranging from $3 to $6 per MBtu (in 1990 US$). However, the study did not address the ability to meet demand after 2005. Intergovernmental agreements to facilitate and maintain competitive markets, access to resources and transmission systems, and commercial contracts on a non-discriminatory international basis are likely to be required before private capital can be mobilized to back very large, long term gas development in remote parts of the world.

Further IPCC analysis should be devoted particularly to non-OECD countries, greatly increased global and regional demand, and supply and demand issues beyond 2005.

6) Thematic assessment of the road transport sector

Because of the importance of the road transport sector, to present and future emissions of greenhouse gases, the Panel decided to carry out a thematic analysis of the sector. The work will concentrate on such measures as fuel efficiency, alternative transport fuels, emission reduction devices and structural, institutional, and organizational changes. The work is just beginning so no conclusions are available at this time.

7) Biomass, bioenergy and limitation of greenhouse gas emissions

A review of the use of biomass as a source of energy concludes that bioenergy offers important opportunities to reduce greenhouse gases through displacement of fossil fuels. It is noted that CO_2 emissions from renewed or waste biomass do not add to the overall atmospheric burden of carbon on a life cycle basis. Some biomass combustion technologies are available that, additionally, reduce other greenhouse gases (e.g., CH_4 and N_2O).

Greenhouse gas emissions can be reduced both by sequestration of carbon and production of bioenergy. The following measures should be considered: use of waste biomass as a fuel and production of biomass by intensive but environmentally sound forestry and agriculture practices, consistent with conservation of carbon in forests and soils.

Combustion of biomass can already be competitive with fossil fuels for (1) production of heat or steam and (2) cogeneration of steam and electricity. Environmentally sound production of liquid biofuels should also be considered.

The first part of the report is available for review. The second part of the report dealing with technologies will be available late in 1992 for review.

8) World economic impacts of response measures by industrialized countries

Carbon dioxide and carbon taxes in the energy sector have been the focus of several available studies. The economic impacts of such measures to control greenhouse gas emissions would vary among industrialized countries, because of the difference existing among them in their resource endowments, the relative structure of energy prices, the ability for fuel substitution and the achieved levels of energy efficiency. The studies reviewed to date in this effort indicate that the costs of applying carbon tax measures could reduce GDP growth in industrialized countries. The costs could be reduced if flexible, phased, comprehensive and concerted response strategies were adopted to control greenhouse gases. Further systematic and comprehensive analysis of available studies is needed on this important and complex subject.

The impacts of these measures will not be limited to industrialized economies, but will also affect the economies of developing countries. One general economic study by the World Bank indicates that a change in OECD growth could affect the growth rate of developing countries rather significantly without off-setting programmes. Factors of this economic interdependency include energy prices, balance of trade, developing country revenue, external debt, investment and aid flows.

9) Analysis of factors affecting energy consumption and CO_2 emissions and their regional and sectoral differences

This assessment deals with factors affecting regional and sectoral differences in energy consumption and related CO_2 emissions. The supporting material contains: (a) analysis of factors affecting total and sectoral CO_2 emissions; (b) regional comparison of changing rates of factors; (c) long run changes in carbon intensity and technology improvements; and (d) non-commercial energy consumption in developing countries. The assessment indicates that such factors as economic development, population growth, energy conservation, changes in industrial structure, fuel switching, and technological advance influence the regional and sectoral patterns of historical energy consumption and CO_2 emissions. Other factors such as climatic conditions could be also considered. These factors function differently in different countries and regions.

Analysis of energy consumption and CO_2 emissions would be important to select and plan a suitable set of options for mitigating global warming. The analytical methods reviewed in the assessment underway can be useful tools. Some methods discussed can provide a common analytical framework for countries, even with present limitations on data availability. The analysis will also deepen common understanding of historical and current situations of individual countries.

Future subjects of this interim assessment include: (a) separation of industrial structure changes and energy efficiency improvements in the energy conservation factors; and (b) sectoral analysis of factors affecting energy consumption and CO_2 emissions in developing countries. The analyses discussed in this study could serve as starting points. Further detailed research would be useful on more factors affecting energy consumption, economic cycles and CO_2 emissions in each sector, on the basis of results obtained in the work now underway.

10) Country studies

A survey of country studies has been developed in cooperation with UNEP and through a review of other sources. The term "country studies" is defined to include any official national study on greenhouse gas emission inventories, impact assessments, and emission mitigation analyses. It includes energy and industry, agriculture, forests and other sectors. Numerous other studies have been undertaken by institutions in various countries which are not reflected in this survey, since they have not been endorsed as official national studies. As of February 1992, more than fifty countries have or plan to initiate some form of country study through internal, bilateral or multilateral support *. In addition, several countries have indicated a wish to participate in country studies, but lack the financial and/or technical resources to carry out such studies.

As yet, a comprehensive methodology for country studies has not been developed, although work is underway in several IPCC working groups and elsewhere to partially address this need. Current efforts include a project supported by UNEP to establish a consistent methodological framework for undertaking cost assessments of greenhouse gas abatement options. The project is being implemented by Riso National Laboratory in Denmark. In addition, draft guidelines have been prepared by Finland and the US. All these activities may assist countries in preparing future studies, but there is an urgent need to give a higher priority to these activities.

FUTURE WORK

Draft final reports from subtasks (2), (3), and (4) and draft preliminary reports from subtasks (1), (7), (8), (9), and (10) were distributed to IPCC participants in February 1992. After the review comments are incorporated, these reports will be produced as final or interim reports in June 1992. Subtask (5) was met by use of a complete IEA report. Subtask (6) is just beginning under Austrian leadership with a contribution from IEA.

As can be seen from the foregoing summaries, several ongoing projects require continuing work. Several of the studies need to be expanded to include other regions.

An element of Task 3 which has not yet been undertaken is the "identification of the full economic, environmental and other types of costs and benefits." It may be useful to initiate a review and assessment of alternative methodologies or concepts which could be of value in such analyses.

* *Argentina, Australia, Austria, Bangladesh, Belgium, Brazil, Canada China, Congo, Costa Rica, Czechoslovakia, Denmark, Finland, France, Gambia, Germany, India, Italy, Indonesia, Ireland, Japan, Kenya, Korea DPR, Korea, Rep , Malaysia, Mauritius, Mexico, Mongolia, Morocco, Myanmar, Netherlands, New Zealand, Nigeria, Norway, Pakistan, Philippines, Poland, Romania, Senegal, Seychelles, Sri Lanka, Sweden, Switzerland, Tanzania, Thailand, Turkey, Tuvalu Uganda, United Kingdom, United States, Venezuela, Vietnam, Zimbabwe*

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SECTION V.

TASK 4: AGRICULTURE AND FORESTRY RELATED ISSUES

BY WORKING GROUP III.

INTRODUCTION

During the session of WG III on 1 November 1991 and in accordance with decisions of the Fifth Session of IPCC (Geneva, March, 1991), the Subgroup (AFOS) was charged to contribute to the ongoing update of the IPCC Response Strategies Report (1990) by:

(a) an assessment of the greenhouse gas (GHG) emissions, taking into consideration sources and sinks in agriculture, forestry and other related human activities, and

(b) an assessment of technologies and management systems in these areas for mitigation and adaptation to climate change.

AGRICULTURE

Present and future agricultural GHG emissions

Recent improvements in scientific understanding support the previous findings of the 1990 report, in particular the following.

As far as the net carbon dioxide release from agricultural activities is concerned, forest clearing in the tropical and subtropical areas of the world continue to be the major source. Additionally, the cultivation of virgin land, whether in tropical or temperate agricultural areas, results in gradual carbon losses. Its relative contribution, however, to CO_2 concentrations is still to be determined. At the other extreme, long-standing arable soils do not constitute a major net source of CO_2, because their carbon contents reach equilibria which do not change very much unless cropping and management practices are altered.

Projections of the future GHG emissions related to land use depend on the initial use, the rate of land conversion, and productivity including cultivation density. If production did not increase, expected population growth and rising food demand would require the area of tropical agriculture to expand by over 60% by the year 2025. It is unlikely this additional land would be available. If all the additional land were to come from forest or grassland, it would cause a gradual breakdown of soil organic matter, releasing CO_2.

There may be another effect in that global warming will speed up the decomposition of soil organic matter, thereby releasing additional CO_2 to the atmosphere. Model calculations, assuming no increase in organic residue returns, predict this soil carbon loss to be up to 60 Gtons within about 60 years. This corresponds to a current global CO_2 release from fossil fuel of about 10 years. On the other hand, there are indications that this could be offset by an enhanced plant residue formation both above and below ground, due to the CO_2 fertilization effect.

As for the release of methane, total global and individual source emission estimates remain essentially as presented in the IPCC First Assessment Report (1990), but with some individual source changes. There has been a reevaluation of some sources, particularly rice, and the additional sources such as animal and domestic wastes. A large portion of these emissions comes from liquid waste handling systems. Uncertainties in global and regional emissions remain significant. A detailed analysis of new information on rice suggests annual emissions in the lower end of the 20-150 Tg/year range.

In the absence of mitigation measures, methane emissions are likely to continue to increase from each source as increases in animal products and rice are required in order to feed the world population. Current emissions for animals, rice, and animal wastes could grow by about 40-60%, 50-60% and 30-40% respectively by 2025.

Unfortunately, the data concerning the release of nitrous oxide from agriculture still cannot be reliably derived. Keeping in mind that the annual increase of N_2O in the atmosphere is 3 - 4.5 Tg of nitrogen as N_2O, and knowing that the release from combustion processes has thus far been overestimated, most of this net increase may be due to anthropogenic nitrogen inputs. About 80 Tg of industrially-fixed nitrogen is presently applied to world agriculture. Taking the upper value of estimates for the conversion of fertilizer nitrogen into N_2O, which is 3.2 %, the fertilizer-induced release for 1990 could be calculated as 2.5 Tg of nitrogen as N_2O. Since another 90 Tg of nitrogen or so are fixed by managed leguminous plants, this combination could account for most of the increase of N_2O in the atmosphere.

Large nitrogen surpluses are frequent, especially in intensive agricultural systems. This excess nitrogen is prone to both nitrate leaching and denitrification, although the ratio of N_2 to N_2O formation varies considerably from case to case. However, it should also be borne in mind that not only the unused but virtually the whole nitrogen introduced by mankind into the world ecosystem will sooner or later become denitrified, thus adding to the overall N_2O increase in the atmosphere. The significant unknown is the time scale over which this will occur.

Background assumptions about future food and land demand being the same as above, nitrogen fertilizer consumption may increase by the year 2025 from 80 to more than 120 Tg of nitrogen per year. Without changes in technology, the fertilizer-derived release of nitrous oxide is likely to increase by some 50%.

Agricultural potentials for mitigation and adaptation

In order to reduce the net carbon dioxide release from agriculture, improving the productivity of existing arable land should be given priority over the cultivation of virgin soils. Furthermore, in the less populated areas of the world, marginal farmland could be set aside for either rangeland or forest use.

Reduced soil tillage, improved utilization of organic wastes as amendments of carbon into the soil and crop rotations including forages are agricultural practices which reduce carbon losses and/or sequester additional carbon in soils. Although these practices may sequester several gigatonnes (Gt) of carbon over a few decades, this represents only a fraction of the release of carbon from fossil fuels over the same period. This is because soils have a finite capacity for accumulating organic matter. Nevertheless, these management practices are essential if soil fertility is to be maintained or enhanced.

As for the control of methane, while investigations are continuing on emission reducing options, the principal approaches remain as reported in 1990 report. Opportunities exist to reduce methane from enteric fermentation and animal waste storage, for example, by modifying feeding practices, using productivity enhancing practices and agents, and modifying waste management practices. Emissions reductions of 25 to 75% per unit product in some animal management systems appear feasible. Due to the diversity of animal management systems, including economic and socio-cultural factors, the importance of categorizing management systems and matching emission-reducing options to the systems is now being emphasized. Additionally, the implications of reduction options for the emissions from animal waste of other greenhouse gases, including nitrous oxide, are now being addressed.

Methane emissions from rice cultivation may potentially be reduced while maintaining or enhancing productivity. Mitigative practices may include modifying water depth and timing of irrigation, the type, rate, and application method of fertilizer, alternative cultivation technologies, and cultivar selection. Much research is still required in order to realize these opportunities, and therefore a short-term reduction of methane emissions from rice growing cannot be expected. However, over a number of decades, while doubling rice production, an integrated management approach may succeed in reducing methane releases by 20 - 40%.

Better balanced nitrogen budgets, especially in intensive agriculture, are a key measure for reducing overall nitrous oxide emissions. This should also include a better accounting for the nitrogen from livestock wastes within fertilizer application regimes. Other options include nitrification inhibitors or improved fertilizer formulations and application. However, the most promising way to reduce N_2O losses is an integrated nitrogen-management system which maximises nitrogen recycling while minimising fertilizer inputs. This is all the more important since N_2O, due to its long lifetime, will accumulate in the atmosphere, constituting an increasing threat to the ozone layer.

In addition to these mitigation strategies, future efforts of AFOS should assess the ability of agricultural systems to adapt to climate change.

FORESTRY

Forests provide mankind with a wide range of economic, social and environmental benefits, but they are increasingly being threatened by unsustainable forest management practices, air pollution, and climate change. Concerted action needs to be taken at national and international levels to protect the world's forests. Action will be successful only if it takes into account the interdependence of the economic, social and cultural factors that bear on the management of forests.

Status of forests

It is difficult to determine the present extent of tropical forest cover. Recent estimates on a country basis indicate that there are approximately 1.9 billion hectares of tropical forests.

One concern has been given particular attention since the 1990 report is the rate of deforestation globally and in individual countries. The FAO estimated rates of global deforestation for the 1980's in closed forests (about 14 million hectares/year) and in closed and open forests (about 17 million hectares/year) are much higher than for the late 1970's), by 90% and 50%, respectively. Calculations by other authoritative sources show significantly lower figures in the order of about 10 million hectares.

Approximately 770 million hectares of forests belong to the temperate zones with an estimated carbon storage of 25 Gt in biomass excluding soils. Forest area in boreal zones amounts to about 920 million hectares, storing 150-190 Gt of carbon in biomass including soils. In addition a considerable amount of carbon is stored in forest soils and peatlands, especially in boreal zones.

Forestry options

The following four options were identified:

<u>Slowing currently ongoing deforestation and forest degradation</u>

For an accurate assessment of cost effectiveness, it would be necessary to quantify the reduction of the amount of carbon released to the atmosphere. So far, only preliminary estimates can be given. Nevertheless, it seems evident that first priority should be given to this option, thus maintaining already existing biomass in natural as well as in managed forests. In tropical regions, it is necessary to involve local people in sustainable silvicultural practices. In temperate and boreal zones, this refers especially to the new type of forest decline attributed to man-made air pollution, logging, and to the potential effects of climate change itself. Slowing deforestation and forest degradation bears a significant potential to keep carbon stored in biomass, retards desertification and is the requirement for further action.

Increasing forest biomass

There is generally a significant potential for increasing biomass in forests, especially in young, understocked, overlogged and/or misused forests. However, the costs and time-frame are uncertain.

Improved use of wood

The use of wood for long-lived products provides benefits in terms of carbon storage as well as sustainable forest management. Industrialised countries have possibilities for improved use of wood, such as the recycling of paper and paperboard, and the replacement of more fossil energy intensive raw-materials by wood. The use of wood as a source of energy offers important opportunities for reducing GHG emissions by substituting fossil fuels (as described in the EIS report).

Afforestation

The potential for afforestation in boreal, temperate and tropical biomes is uncertain. However, the current estimates for afforestation are 50-150 million hectares in boreal, 50-125 million hectares in temperate and 400-750 million hectares in tropical zones (200-300 million hectares in dry tropical areas). For tropical zones, the land potentially available will be less than the amount physically capable of afforestation because the ultimate decisions on land use are based on many other factors. For the boreal zones, the potential to increase the forest area is limited because not all non-forested land is environmentally capable of supporting forest ecosystems.

At present, plantations account for most of the afforestation in temperate zones. Preliminary assessments of gross costs of afforestation have recently become available and range from US$ 30 - US$ 60 per ton of carbon in boreal and temperate zones and US$ 10 - US$ 30 per ton of carbon in the tropical zone. However, it is uncertain how much carbon could be sequestered at such costs.

Noordwijk request

The Noordwijk Conference on 'Atmospheric Pollution and Climate Change' in November 1989 established the target of a net global increase in forest area of 12 million hectare a year by the beginning of the next century. The Bangkok Workshop (1991) concluded that the prospect of attaining the target was very limited, and that the net rate of forest loss would be slowed or reversed over a longer period of time. However, the option of afforestation would still be important and better data need to be developed to assess the potential.

OTHER HUMAN ACTIVITIES

Present and future emissions

Efforts to better understand the emissions of methane from domestic wastes managed in landfills have produced results which are consistent with the previously estimated 20-70 Tg/year from this source and better describe the regional differences in waste generated per capita and quantities of waste landfilled. Currently, about 60% of these emissions are from the OECD countries. No additional information is available to describe the 20-25 Tg/year of estimated methane emissions from wastewater lagoons primarily in developing countries.

Forecasting efforts continue to estimate 50-90 Tg/year from landfills globally by 2025. Developing countries will represent an increasing share of these emissions, over 50% by 2025. This is due to the expected increases in urban populations over the next 30 years and the increasing prevalence in these countries of landfilling, which generates more methane than waste piles. No additional work appears to have been performed for wastewater lagoons.

Potentials for mitigation

Recent work better characterizes the technological options for reducing methane emissions identified in the 1990 report. This work continues to show a range of options are available that can reduce methane emissions at modern landfill sites by 60 to 90% and up to 80% from wastewater lagoons. These options require varying degrees of initial capital and are of varying levels of technical complexity. They generally provide other benefits such as increased safety, better air quality, better waste management and fuel recovery, and therefore can have positive economic returns. Continued efforts need to address barriers which limit the further implementation of these options such as availability of capital and technical information.

Competing land use

Currently, most developed countries have virtually static populations and have achieved high productivity growth rates. In developing countries, the situation is the reverse, with low productivity, high population growth, unfavourable climatic conditions, lack of appropriate technology and inadequate infrastructure. Consequently, food security in these countries remains uncertain and economic growth may continue to be slow or even stagnant. It is clear that the historic growth pattern for land use cannot be sustained over the next century. For example, between 1882 and 1991, arable land use expanded by 74%. Similar rates of expansion in the future would exceed the area of land potentially suitable for ecologically sound and sustainable agriculture. It is also clear that the pressure for additional land use for agriculture is largely an issue for the developing countries, with competing demands for agriculture and forestry.

CONCLUDING REMARKS

This updated report supports and confirms that some individual options in the different sectors of agriculture and forestry to mitigate GHG emissions or even to sequester existing CO_2 are relatively small on a global basis, but together they may contribute significantly to national or global abatement strategies.

SECTION VI.

TASK 5: VULNERABILITY TO SEA LEVEL RISE BY WORKING GROUP III

INTRODUCTION

In 1991, the Coastal Zone Management Subgroup (CZMS) of Working Group III, began to implement the recommendations in its report entitled: STRATEGIES FOR ADAPTATION TO SEA LEVEL RISE (CZMS REPORT, 1990). Among the recommendations was the need to provide to coastal countries, including small island nations, in the context of their socio-economic development, technical assistance to:

(i) identify coastal areas at risk;

(ii) assess their vulnerability to potential impacts of an accelerated sea level rise (ASLR) as described in the IPCC First Assessment Report 1990); and,

(iii) idevelop and, where possible, implement comprehensive coastal zone management plans to reduce vulnerability to ASLR before the year 2000, especially for countries with vulnerable coastal areas.

The benefits of these steps should be seen in the context of accelerating socio-economic development worldwide in coastal areas and the related increasing environmental stress on coastal resources. In this regard, integrated coastal planning would facilitate sustainable development of coastal areas and conservation of natural ecosystems.

Capacity building and institutional strengthening to develop and implement coastal zone management is identified as a priority for low-lying coastal areas. Related to this, the present international framework for cooperation should be strengthened.

In order to better assess and respond to the needs of coastal countries, the CZMS has:

(1) developed a common methodology to be used in country studies to assess vulnerability and consider possible response strategies;

(2) assisted in coordinating a number of case studies which incorporate the assessment steps identified in the common methodology; and have initiated work on global vulnerability assessment in close cooperation with IPCC Working Groups I and II;

(3) identified the need for strengthening the capabilities of vulnerable developing countries in implementing adaptive CZM programmes, aiming at sustainable and ecologically sound development, and identified the need for structural facilities for bilateral and multilateral financing of:

- sharing information, data and methodologies; and
- assisting in implementation of CZM programmes; and
- strengthening institutional capabilities.

While all of the assessment work has not been completed, what has been learned to date is in line with the conclusions and findings of the CZMS as presented in the IPCC First Assessment Report (FAR).

IPCC TASK 5 OBJECTIVES

Following the conclusions of the FAR, the CZMS was tasked at the March 1991 IPCC Plenary to address the following:

- commence an assessment of the vulnerability of developing and developed countries to ASLR;
- develop a common methodology for assessing vulnerability through country case studies;
- undertake developing country case studies on a bilateral basis and in cooperation with the UNEP Regional Seas Programme;
- support the development of CZM plans that incorporate response measures to reduce vulnerability to ASLR and address pressing coastal management concerns, where appropriate, by the year 2000;

- develop links with the coastal zone impacts studies being undertaken by WGII while undertaking the country case study assessments;
- convene workshops to assess the results of the case studies undertaken;
- identify the appropriate response strategies and mechanisms for implementing them;
- estimate the level and kind of assistance needed from international organizations and donor nations for further assessments and implementation of coastal management plans; and,
- consider recommendations for proposed future work.

Completion of the task is a long-term objective. In the short-term, the task requires the development of a methodology to assess vulnerability to ASLR, the application of the methodology to assessment work underway, and the consideration of the needs of coastal developing countries for assistance.

ASSESSMENT WORK COMPLETED

IPCC First Assessment Report. The CZMS contributed to the IPCC FAR by producing a CZMS Report on the STRATEGIES FOR ADAPTATION TO SEA LEVEL RISE. As a result of the significant participation from developing countries at two major international workshops held in Miami (November 1989) and Perth (February 1990), the CZMS report identified the response strategies for coastal areas: to retreat, to accommodate, or to protect from the potential adverse impacts associated with ASLR (including the conservation and protection of natural coastal defense, e.g., tidal flats, mangroves, sea grass beds and coral reefs). Each response strategy has implications for trade-offs and can be implemented within a framework of integrated coastal zone management planning.

The CZMS Report. The CZMS made 10 recommendations divided among three major categories: National Coastal Planning; International Cooperation; and Research, Data and Information. A suggested ten-year timeline for the implementation of comprehensive CZM planning was included, along with an estimated cost for providing five years of technical assistance to support this effort. Lastly, the Report provided a "World-wide Cost Estimate of Basic Coastal Protection Measures."

Common Methodology. The CZMS developed "The Seven Steps to the Assessment of the Vulnerability of Coastal Areas to Sea Level Rise - A Common Methodology" in early 1991. After a detailed process of review, comments and revisions made by IPCC participants, the CZMS feels that the Common Methodology provides a useful methodological framework for coastal countries to assess their vulnerability to ASLR and consider response strategies. The use of this common methodology could for many countries, be a first step in the establishment of a systematic approach in the management of coastal areas. Such CZM planning would facilitate the decision making process for socio-economic development and the mitigation of vulnerability of coastal areas and resources. As more countries conduct vulnerability analysis assessments, the Common Methodology would provide a framework for global assessments based on a global database. In addition, this information could facilitate priority setting by institutional bodies. The Common Methodology has been translated into French, Spanish and Arabic.

Case studies. In many instances, the CZMS has been successful in serving as a coordination body bringing together countries to conduct case studies assessing vulnerability. For example, Australia, France, Japan, The Netherlands, the United Kingdom and the United States are sponsoring, on a bilateral basis, more than two dozen case studies in developing countries, as well as conducting studies within their own borders. The UNEP is also conducting a number of case studies. Coordination between the two efforts has provided mutual benefits. The results of the case studies will be presented at a CZMS workshop hosted by Venezuela in March 1992, after which a report will be produced. A full list of countries participating in the vulnerability programmes and list of countries still desiring assistance is presented in the supporting IPCC CZMS report.

The interest expressed by developing countries for conducting vulnerability analysis and identifying response strategies has been tremendous, with a number of countries asking for country study assistance. A number of developing countries have also conducted their own country studies, which indicates the seriousness of the matter to them. However, because much of the work is being done on an ad hoc basis, the CZMS is not able to satisfy the demand. To better respond to the many requests that arise from vulnerable developing coastal countries, both the institutional and the financial aspects need further attention.

Status of country activities. The CZMS prepared a one-page questionnaire regarding the current status of country activities concerning ASLR and CZM planning. This questionnaire was answered by 37 countries. The preliminary results indicate that nearly 90 percent of those who responded expect that all or portions of their coastlines will be vulnerable to sea level rise, that only 30 percent have conducted an impact study of sea level rise on their coastal zone resources with even fewer (20 percent) studying response options, and that only 20 percent have some form of coastal zone management which includes policies that incorporate sea level rise. On the positive side is the fact that more than 50 percent of those responding have some form of coastal management policy "in-place". On the potential demand side, more than 80 percent expressed a willingness to cooperate with assisting countries in conducting vulnerability assessment studies.

COMMON METHODOLOGY

The Common Methodology is a guideline for assessing vulnerability to ASLR. In assessing vulnerability, three levels of boundary conditions and scenarios are incorporated in the methodology: (1) the impacts on socio-economic developments; (2) the impacts on the natural coastal systems; and (3) the implications of possible response strategies for adaptation.

The Common Methodology now includes consideration of the present situation and a rise of 0.3 meters and 1.0 meters by the year 2100. These scenarios represent the low and the high estimates of the 1990 IPCC FAR. Appropriate modifications are made for subsidence, uplift and storm surges and any other circumstances peculiar to a study area. At the present stage, the focus of the Common Methodology is on the effects of ASLR (and existing storm patterns). In the future, more attention will have to be given to the vulnerability of coastal areas with regard to other aspects of climate change, such as changing storm intensities, storm patterns, and soil moisture.

The objectives of the present Common Methodology are:

(a) to provide a basis for coastal countries to assess the vulnerability of their coastal areas to ASLR;

(b) to provide a basis for a world-wide comparative assessment of vulnerability of coastal areas;

(c) to provide a mechanism for identifying priority needs of developing coastal countries; and

(d) to provide a basis for decisions on responsive measure.

The process, therefore, helps each country to identify the actions needed to plan for and cope with the impacts associated with potential ASLR. These steps will help each country: to define its vulnerability; to examine the feasibility of response options, including their institutional, economical, technical and social implications; and to identify needs for assistance in order to apply the response options.

CASE STUDIES AND WORKSHOPS

The evaluation of vulnerability to ASLR is being undertaken in a number of countries. As of 1 January 1992, studies were either completed, in progress or in planning in 27 countries by members of the CZMS with an additional 14 cases being sponsored through the UNEP Regional Seas Programme. These case studies represent different types of coasts and a wide range of techniques and methodologies. Some studies are a portion of a larger country study on climate change impacts, while others are focused on ASLR. Some have evaluated response options, including the need for CZMS planning to reduce vulnerability to ASLR.

As each coastal country undertakes vulnerability assessment studies, that information will assist in providing a better global picture of the potential problems of ASLR on coastal resources and level of effort that may be required in response. The CZMS is now working on a world-wide estimate of socio-economic and ecological implications of sea level rise (e.g., the number of people at risk and an estimate of ecological impacts). This analysis will be based on information made available through case studies, questionnaires, and additional fact finding.

The Common Methodology is being used and tested in more than a dozen case studies. From these efforts, advantages and disadvantages are being revealed which are proving very valuable to the development of the methodology. The Common Methodology will be updated based on the case studies discussed at the Venezuela workshop in March 1992 and as appropriate in the future.

The consensus is that the Common Methodology provides a broad basis for coastal countries to assess their vulnerability to ASLR and to identify, evaluate and select response

The Common Methodology utilizes a seven-step approach as shown in Table A:

Table A
Common Methodological Steps to Determine and Reduce Vulnerability from Future Sea Level Rise

1. Delineate case study area and specify ASLR and Climate Change conditionds.
2. Inventory study area characteristics.
3. Identify relevant development factors.
4. Assess physical changes and natural system responses.
5. Formulate response strategies identifying potential costs and benefits.
6. Assess the vulnerability profile and interpret results.
7. Identify future needs and develop plan of action.

options to reduce their vulnerability to ASLR. This broad basis allows for flexibility such that local and national conditions can be fully taken into account. The studies indicate that coastal planning can reduce vulnerability to ASLR. Vulnerability to ASLR is the cumulative effect of natural processes, coastal development and climate change. CZM can reduce the effects of development on natural processes and the effects of natural processes on development. As a result, coastal planning can reduce vulnerability to ASLR while promoting sustainable development.

International workshops. International workshops have played a significant role in the gathering of information from a wide variety of sources. Two international workshops will be convened to discuss the results of the case studies. At the Venezuela workshop, representatives of 25 countries will present reports on their case studies. Much will be learned, including information on the potential costs and benefits of various response options or strategies, and on each country's capability to respond to ASLR within the framework of comprehensive CZM planning. Another workshop will be held in New Caledonia in April 1992 that will focus on climate change, sea level rise and coastal zone management in the South Pacific.

INTERNATIONAL COOPERATION

The CZMS was asked to estimate the level and kind of assistance needed from international organizations and donor nations for further assessments and implementation of national management plans. So far, there is only a rough estimate of resources required to meet the target: "by the year 2000 all relevant coastal countries should have comprehensive coastal management programs to reduce their vulnerability to ASLR and other impacts of climate change". Considerable resources would be required and many countries would need financial support.

To support an efficient and effective development of such plans, international cooperation is important, especially to ensure:

- the continuation of vulnerability assessments;
- the development of guidelines for CZM planning programs; and
- an efficient coordination through bilateral and multilateral cooperation.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions. Since its creation in 1989, the CZMS has:

- held international workshops that were widely attended by developing and developed nations and initiated global assessments of vulnerability to ASLR;
- developed a common methodology for conducting assessments of the vulnerability of coastal areas to ASLR; and
- served as a coordinator of 30 case studies conducted on a bilateral basis between CZMS member countries.

Throughout this period, it has become increasingly clear of the need for coastal countries:

- to assess the multiple components of their vulnerabilities to future sea level rise and related extreme events in relation to development and the protection of coastal ecosystems;
- to understand its implications to their natural, social, legal and economic systems; and
- to begin to plan appropriate response strategies in areas of awareness and institution building.

Part of this response would be to develop integrated coastal management planning capable of addressing, in a comprehensive way, the impacts of ASLR, along with the other pressing problems impacting coastal resources. This integrated planning in coastal areas must focus on sustainable development. Strengthening the institutional and legal capability of vulnerable developing countries is a base line condition and can be stimulated by information exchange and technology cooperation within the framework of a network as established by the IPCC CZMS in association with UNEP.

The CZMS has identified a growing awareness in coastal countries of the potential impacts on the coastal resources due to ASLR and other impacts of climate change. This awareness has manifested itself in their interest in integrated management planning. This interest must be encouraged and assisted. Most coastal developing countries have not developed CZM planning capabilities, or made assessments of their vulnerability to ASLR. Even though, in many cases, long lead times are required to begin the process of adaptation to sea level rise, very few have begun any planning or taken any measures as might be necessary.

The CZMS still has much to accomplish. Preliminary findings indicate there is a need to:

- Complete current and requested country case studies and conduct additional studies in the framework of CZMS, in cooperation with the UNEP, WMO, IOC and other international organizations.
- Promote further research on the effects of climate change on coastal areas, in particular with regard to extreme events.

- Include, as regional climate models improve, their results (e.g., the potential changing intensity and patterns of cyclones, hurricanes and typhoons), in the assessment of vulnerability of coastal areas to ASLR and other impacts of global climate change.

Recommendations. The following recommendations are made based on the progress to date:

- Coastal countries, that have not already done so, should:

  (1) assess their vulnerability to ASLR and other potential impacts of global climate change and assess the assets at risk;

  (2) start the planning process for appropriate response strategies; and

  (3) adevelop, by the year 2000, comprehensive coastal management programmes to reduce their vulnerability to ASLR and other impacts of global climate change.

- Countries should continue to support relevant intergovernmental and international organizations and programmes and their members should continue to:

  (1) support research and observations on ASLR and related severe storms, (e.g., under the Global Ocean Observing System and the Global Climate Observing System) and on other coastal impacts of global climate change (e.g., coastal inundation and habitat destruction resulting from changes in the frequency and intensity of severe storms);

  (2) assist developing countries in building their own national capacity to participate in international activities on research and observations in these areas;

  (3) support research on cost-effective response measures to assist coastal nations to adapt to the adverse impacts of global climate change;

  (4) promote public education and initiatives which increase awareness of the implications of ASLR and other potential impacts of global climate change on coastal resources and of the feasibility of response options to mitigate or adapt to those impacts;

  (5) strengthen national, regional and international programmes and institutions, with a view to coordinating the assessment of the vulnerability of coastal areas to ASLR and the needs, in this regard, of developing countries for assistance; and

  (6) recognize the effectiveness of a world-wide cooperation between coastal nations and international organizations as has been developed under the IPCC framework, and to give further support to the CZMS and its network as a catalyst for strengthening world-wide cooperation by data and information exchange, technology cooperation, integrated coastal zone management, training programmes and communications.

FUTURE ACTIVITIES

The following CZMS future activities are proposed:

- The CZMS envisages producing additional global vulnerability assessment reports working jointly with Working Group I and Working Group II, and in cooperation with other relevant United Nations organizations. Because of the close links between impacts and response strategies, the CZMS has coordinated with WGII, which has a major focus on the concern impacts of climate change, including ASLR, on coral and mangrove ecosystems and on commercial and subsistence fisheries. The focus of CZMS is to identify response options to manage these resources to reduce their vulnerability to ASL;

- The development of CZM guidelines,as being discussed in the United Nations Conference on Environment and Development process, in cooperation with UNEP by the year 1994;

- IPCC Second Assessment Report (1994 or 1995) In cooperation with WGI and WGII, complete a global assessment of the vulnerability of coastal areas to ASLR, as a first step to CZM planing and programs, using the Common Methodology; and

- Support Coastal Zone Management Planning, in cooperation with the UNEP and other organizations, and provide technical cooperation, as requested, to assist coastal countries to develop integrated coastal management plans by the year 2000.

In order to execute the above-mentioned activities, it would be necessary to seek funding for the work of IPCC CZMS as mentioned in the recommendations. Further analysis should be made to assess the availability of funds from UNEP, other international organizations and donor countries and the pace and scope of work which could thereby be supported. International cooperation is essential for the success of these activities.

SECTION VII.

RESUME OF THE POLICYMAKER SUMMARY (1990) OF THE IPCC SPECIAL COMMITTEE ON THE PARTICIPATION OF DEVELOPING COUNTRIES

INTRODUCTION

The IPCC, in its sixth session (Geneva, 29-31 October 1991), decided that a resume of the recommendations of its Special Committee on the Participation of Developing Countries would be included in the 1992 IPCC Supplement. Further, it "agreed with the Chairman's proposal that the IPCC Secretariat be tasked to draft the resume from the Policymaker Summary of the Special Committee (see the IPCC First Assessment Report, 1990) for review by all countries". This contribution is the result of that decision.

Resume of the Executive Summary of the Special Committee

Full participation includes 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.

Actions to promote the full participation of the developing countries in climate change issues should not await the outcome of negotiations on the Framework Convention on Climate Change. They need to be taken now, through existing arrangements and should be planned and carried out for several years.

The factors identified by the Special Committee as inhibiting the full participation of the developing countries in the IPCC process, inter alia, are:

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

(i) Insufficient information: Many developing countries do not have sufficient information on the issue of potential climate change to appreciate the concern it evokes elsewhere in the world. Information is often insufficient with respect to the scientific basis for concern, on the potential physical and socio-economic impacts of climate change as well as on response options. This applies not only to scientific milieux but also to policymakers and public opinion.

(ii) Insufficient communication: Even if the situation with respect to information were to improve, there is the problem of insufficient internal and external communication mechanisms for the proper dissemination of the information on matters related to climate change.

(iii) Limited human resources: Lack of adequate number of trained personnel in almost all areas ranging from academic, scientific efforts to applications of knowledge to food and energy production, to water management, to human settlements problems, to trade and economic growth, and to a host of other related endeavours is common to many developing nations. Most of them, if not all, can command only limited pool of experts and responsible and knowledgeable officials, and even that only in a few of these areas.

(vi) Institutional difficulties: The multi-disciplinary and cross-cutting nature of the issues involved demands relatively high degree of co-ordination among the various departments/ ministries of governments.

(v) Limited financial resources: Survival needs come first. After that, the limited financial, and consequent general lack of technological, resources dictate the priorities. Means of meeting the incremental costs of ensuring a viable environment frequently cannot be found. Also, local immediate, environmental concerns generally receive political priority over impersonal, global concerns.

The legitimate concerns on the part of the developing countries that, although their impact on global climate change is minimal, its impact on them can be grave, need to be taken into account.

RECOMMENDED ACTIONS

Uninterrupted travel assistance to the developing countries for attendance at the meetings of IPCC and follow-up activities should be ensured. The Special Committee called the attention of the Panel to the importance of continuing this effort and of the donor nations continuing and increasing their financial support to the effort.

Serious consideration should be given to supporting more than one expert from each participating developing country to those climate-change-related meetings that deal with several aspects of the problem.

Governments and organizations from the industrialized nations are encouraged to continue and increase their efforts in organizing seminars. Developing countries could organize, under the sponsorship of international organizations or otherwise, regional seminars and workshops in order to exchange scientific and technical information. For this purpose, necessary programmes and lists of experts should be developed. As part of the continuing process of information exchange, the Special Committee recommended that IPCC circulate the Policymaker Summary (of the Special Committee) to all concerned. The developing countries on their part could where appropriate designate focal points, as soon as possible, for transmittal of reports, documentation, data and information on seminars. Such focal points should be briefed on forwarding the material to appropriate recipients within the nation for response, review etc.

The establishment of mechanisms for national co-ordination of all (national) activities related to climate change could be considered by the developing countries. The mechanisms could aid such areas as information dissemination, development and implementation of plans for research and monitoring, and formulation of policy options. The industrialized countries could consider assisting the developing countries in setting up the mechanisms.

The Special Committee recommended that acquisition, analyses and interpretation of information on climatic and related data would enable developing countries to take more effective account of climate change considerations in formulating national policies. Such actions are necessary also at regional levels to undertake and refine impact studies. The current unevenness in the acquisition and use of such data which is evident between the hemispheres should be eliminated. The Special Committee further recommended that the developing countries take immediate action to identify their specific financial needs in this regard. It would also be necessary to mobilize appropriate funding in order to mount a sustained programme and create regional centres to organize information networks on climate change.

In many developing countries the meteorological/ hydrological service is the main and often the only institution collecting and recording data with relevance to climate. If associated weather patterns are modified, as some predict they would as a result of climate change, then the capabilities of such services need to be reinforced to enhance their contributions to sustainable development.

The Special Committee further recommended that its findings be duly taken into account in all relevant areas of the work of IPCC. Programmes of action should be developed and implemented (and the concepts which would lead to such programmes of action developed where needed) without delay, with a view to ensure, provided the necessary means are made available, the full participation of developing countries in the future work and activities on climate change. UNEP and WMO should take the lead in this regard and initiate the necessary consultations. Other multilateral or bilateral organizations should also be contacted for elaborating and implementing these programmes of action.

SECTION VIII.

SUMMARY OF COMMENTS AND ISSUES FOR FURTHER CONSIDERATION BROUGHT OUT AT THE SEVENTH SESSION OF IPCC

Discussion of the results described in the reports of the three Working Groups identified a number of areas for priority emphasis in the future work of IPCC. In the plenary meetings, references were made to issues and recent work not fully taken into account or peer-reviewed during the preparation of the Working Groups' supplementary reports. All available studies should be thoroughly peer-reviewed as part of the IPCC follow-up process.

Desertification

Climate change and drought and desertification are issues of great importance in many parts of the world. Extensive study of the links between climatic variations, climate change and desertification is urgent and has been requested by numerous affected countries in Sahelian and other parts of Africa, in Latin America, and in Australia, India, China and other parts of Asia. Desertification is a complex phenomenon largely associated with human causes such as land degradation exacerbated by climatic variability; the affected arid and semi-arid regions are therefore most likely to be vulnerable to climate change. The declaration following the International Congress on Impacts of Climate Variations and Sustainable Development in Semi-Arid Regions (Fortaleza, Brazil, 1992)) emphasizes the urgency of addressing the issue of desertification in respect of its causes of observed impacts on affected human societies.

Fluorinated greenhouse gas species, not included in the Montreal Protocol

There are two species concerned: firstly, the hydrofluorocarbons (HFCs), now replacing the chlorofluorocarbons (CFCs); secondly, some fully fluorinated species with high GWPs and very long lifetimes such as tetrafluoromethane (CF_4), hexafluoroethane (C_2F_6) and sulphur hexafluoride (SF_6). Consideration should be given to achieving a better understanding of sources and sinks and to including these gases in the IPCC methodology for national inventories of greenhouse gas emissions and sinks, as well as to assessing response options.

Regional climate predictions

The Panel continued to stress that research leading to information on likely regional climate change (and its association with global change) was of the highest priority, and noted that there are certain aspects of regional climate change which are particularly important in some areas. Among these are tropical cyclones and the tidal surges associated with such storms. Guidance on likely changes in frequency, intensity and distribution of such events, as a result of climate change, is urgently needed in states in and bordering the Pacific, Indian and Atlantic Oceans. Special attention should be given to the needs of small island states which are particularly vulnerable to climate change. Prediction of regional precipitation is another area of particular concern. Moreover, the connections between local, regional and global pollution requires further study.

The question of the validity of the technique of palaeo-analogue for the prediction of regional climate change was raised. Although, palaeo-data concerning past climate are of great value, clear analogues from the past which can be applied to future climate change have not yet been identified. In the further work of IPCC, all methods of regional climate prediction should be reviewed and assessed on a continuing basis.

Country studies and methodologies

The Panel recognized the valuable work on methodologies for country studies - such as those for national inventories of greenhouse gas emissions and sinks, vulnerability to sea level rise and other impacts assessments - which were being carried out by the three Working Groups and elsewhere. It acknowledged that this is a cross-cutting issue. It recognized the utility of further work on methodologies for both limitation and adaptation and, in particular, their integration into a broader framework. There was a consensus that priority should be given to further assessing the work in progress and to development of coherent guidelines for country studies, keeping in mind the circumstances of different countries and the evolving nature and pattern of their natural resource use. The next step in this process should be the convening of a workshop possibly prior to the eighth Session of the Panel, with a report to be reviewed at that time.

Nuclear energy technologies

Nuclear power, along with safety and waste disposal issues, should be fully evaluated by the IPCC as an alternative energy source to mitigate climate change.

Inventory of possible response options

Future work should include the preparation of a broad inventory of possible response options to identify an evolving list of measures that countries may wish to consider in their national context. With regard to each option, the inventory should include feasibility factors that will enable countries to assess the applicability of an individual option to national situations. These factors include

- technical factors
- economic factors
- other factors

that may inhibit the introduction of these technologies or practices in a specific national situation.

The options considered should include management practices, techniques and technologies, and should cover all sectors, including energy, industry, transportation, agriculture and forestry as well as adaptation measures for natural and developed areas.

The Technology Characterization Inventory is the first step towards this goal. The report on task 4 also identifies specific response options, and the report on task 5 notes coastal zone management practices that can facilitate adaptation to sea-level rise.

Natural gas prospects

The concern over the future availability of natural gas to meet expected higher demand, including its relation to reducing greenhouse gas emissions, was raised. Assessment of natural gas availability, deliverability and demand beyond the year 2005 is needed, particularly in non-OECD countries.

Economic impacts of response measures

Some studies very recently became available and could not be considered by the IPCC in the review described in this report. These studies indicate mixed results and show the need for a continuing examination of the question of the effects of carbon taxes and other measures on national GDP growth.

Other areas to be considered for future work

- Specification of a minimum set of parameters for monitoring for impact analyses, and how to measure them.
- Impacts on mountain ecosystems (forests, water resources, socio-economic impacts, etc.).
- Impacts of climate change on urban areas and other human settlements.
- Indirect GWPs.
- Monitoring and databases.
- Further follow-up on the Noordwijk afforestation targets.

- Emissions from road transportation and other transportation sectors which could be used as alternative options.

- Development of an action plan to fulfil the recommendations of the IPCC Special Committee on the Participation of Developing Countries, especially the long-term objectives (see section VII).

Dissemination of IPCC information

With financial support provided by some countries, the IPCC has conducted a series of information exchange seminars in several developing countries, and the IPCC First Assessment Report (1990) and some other IPCC reports have been translated into several languages. Non-governmental organizations are also contributing significantly to the dissemination of information on climate change. The seminars have attracted participation from all levels of society, including heads of state and government ministers, experts, non-governmental organisations and the public. They have contributed significantly to the understanding of the various aspects of the climate change issue. Further seminars in other developing countries could be undertaken in response to requests, but this depends on the availability of financial and human resources.

Resource issues

The IPCC assessments are fundamentally dependent on research and development carried out under international programmes and by research teams within countries of the world. The need to increase these research efforts has become obvious in the course of the IPCC work. Insufficient knowledge and understanding of both the climate change issue itself as well as all socio-economic impacts and further societal implications exist at all levels of society. The IPCC strongly urges that increasing resources be made available for these activities and that the major international global programmes be adequately resourced. It is particularly important that means are made available to permit developing countries to become genuine partners in this global research effort. The progress of our understanding is indeed dependent upon addressing the global environment in its entirety.

LIST OF ACRONYMS AND CHEMICAL SYMBOLS

ASLR	Accelerated Sea Level Rise
CF_4	Tetrafluoromethane
CFCs	Chlorofluorocarbons
C_2F_6	Hexafluoroethane
CGCM	Coupled General Circulation Model
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CNG	Compressed Natural Gas
ENSO	El-Niño Southern Oscillation
GCOS	Global Climate Observing System
GEF	Global Environment Facility
GHG	Greenhouse Gas
GtC	Gigatonnes (10^9 tonnes) carbon
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Programme
IPCC	Intergovernmental Panel on Climate Change
ISTIG	Intercooled, Steam Injected Gas Turbine
IS92a-f	1992 IPCC Emissions Scenarios
Mha	Million hectares
MSU	Microwave Sounding Unit
Mt	Megatonne (10^6 tonnes)
N_2O	Nitrous oxide
NOx	Nitrogen oxides
NH	Northern Hemisphere
NMHC	Non-methane hydrocarbons
O_3	Ozone
OECD	Organization for Economic Cooperation and Development
pa	Per annum
ppm	Part per million
SF_6	Sulphur hexafluoride
tC	Tonnes Carbon
Tg	Teragram (10^{12} grams)
UN	United Nations
UNEP	United Nations Environment Programme
WMO	World Meteorological Organization