COP-6bis presentation

Climate Change 2001

Robert T. Watson
Chair, Intergovernmental Panel on Climate Change
at the resumed
Sixth Conference of Parties
to the
United Nations Framework Convention on Climate Change

July 19, 2001

Key Findings

The key conclusions of the Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC) include:

The Earth's climate system has changed, globally and regionally, with some these changes being attributable to human activities

- The Earth has warmed 0.6±0.2 ^{o}C since 1860 with the last two decades being the warmest of the last century;
- The increase in surface temperatures over the 20th Century for the Northern hemisphere is likely to be greater than that for any other century in the last 1000 years;
- Precipitation patterns have changed with an increase in heavy precipitation events in some regions;
- Sea level has risen 10-20 cm since 1900; most non-polar glaciers are retreating; and the extent and thickness of Arctic sea ice is decreasing in summer;
- Human activities are increasing the atmospheric concentrations of greenhouse gases that warm the atmosphere and, in some regions, sulfate aerosols that cool the atmosphere; and
- Most of the observed warming of the last 50 years is attributable to human activities.

Carbon dioxide, surface temperatures, precipitation and sea level are all projected to increase globally during the 21st Century because of human activities

- All IPCC projections show that the atmospheric concentration of carbon dioxide will increase significantly during the next century in the absence of climate change policies;
- Climate models project that the Earth will warm 1.4 to 5.8^{o}C (2.5 to 10.8^{o}F) between 1990 and 2100, with most land areas warming more than the global average;
- Precipitation will increase globally, with increases and decreases locally, with an increase in heavy precipitation events over most land areas;
- Sea level is projected to increase 8-88cm between 1990 and 2100; and
- Models project an increase in extreme weather events, e.g., the number of hot days, heatwaves, heavy precipitation events, floods, droughts, fires, pest outbreaks, mid-latitude continental summer soil moisture deficits, and increased tropical cyclone peak wind and precipitation intensities, and a decrease in the number of cold days and frost events.

Biological systems have already been affected in many parts of the world by changes in climate, particularly increases in regional temperature

- Bird migration patterns are changing and birds are laying their eggs earlier; the growing season in the Northern Hemisphere has lengthened by about 1-4 days per decade during the last 40 years; and there has been a pole-ward and upward migration of plants, insects and animals.

Projected changes in climate will have both beneficial and adverse effects on water resources, agriculture, natural ecosystems and human health, but the larger the changes in climate the more the adverse effects dominate

- Socioeconomic sectors (e.g., agriculture, forestry, fisheries, water resources and human settlements), terrestrial and aquatic ecological systems, and human health, which are all vital to human development and well-being, are all sensitive to the magnitude and rate of climate change, as well as to changes in climate extremes and variability;
- While there are some positive effects of climate change, e.g., increased agricultural productivity at mid- and high latitudes for small increases in temperature and reduced winter mortality, most of the impacts are adverse, particularly in response to an increase in extreme weather events, with most natural systems and most people being adversely affected by climate change. Projections include:
    - a decrease in water availability in many water scarce regions, particularly in the sub-tropics;
    - a decrease in agricultural productivity for almost any increase in temperature in most tropical and sub-tropical regions;
    - an increase in heat stress mortality and the number of people exposed to vector-borne (e.g., malaria and dengue) and water-borne (e.g., cholera) diseases;
    - a widespread increase in the risk of flooding for tens of millions of people due to increased heavy precipitation events and sea level rise;
    - that some natural systems may undergo significant and irreversible damage, in particular glaciers, coral reefs and atolls, mangroves, and polar and alpine systems; and
    - an increased risk of extinction of some more vulnerable species and loss of biodiversity;
- Adaptation is a necessary strategy to complement climate change mitigation efforts; and
- Developing countries, and the poor within them, are the most vulnerable because they lack the financial, technical and institutional resources to adapt.

There are many technological options to reduce near-term greenhouse gas emissions and opportunities for lowering costs, but barriers to the deployment of climate friendly technologies need to be overcome

- Stabilization of the atmospheric concentrations of greenhouse gases will require emissions reductions in all regions;
- Lower greenhouse gas emissions will require different patterns of energy resource development and production (trend towards de-carbonization) and increases in end-use efficiency;
- Significant technical progress has been made in the last 5 years and at a faster rate than expected (e.g., wind turbines, elimination of industrial by-products, hybrid engine cars, fuel cell technology, and underground carbon dioxide storage);

  - half of the projected increase in global emissions between now and 2020 could be reduced with direct benefits (negative costs), while the other half at less than $100 tC; and
  - realizing these reductions involves supporting policies/overcoming barriers, increased R&D, and effective technology transfer;
- Some reductions in emissions can be obtained at no or negative costs by exploiting no regrets opportunities:
  - reducing market or institutional imperfections;
  - ancillary benefits, e.g., local and regional air quality improvements; and
  - revenues from taxes or auctioned permits can be used to reduce existing distortionary taxes through revenue recycling;
- Forests, agricultural lands and other terrestrial ecosystems offer significant carbon sequestration potential globally, i.e., up to 200GtC over the next 50 years;
- In the absence of trading, Annex B costs of complying with the Kyoto Protocol, range from 0.2 - 2%, where-as with full Annex B trading the costs are reduced to 0.1 - 1% (these models only consider energy-related emissions of carbon dioxide). These costs could be further reduced by using sinks, the Clean Development Mechanism, multiple greenhouse gases, efficient tax recycling, ancillary benefits and induced technological change; and
- Costs of stabilizing carbon dioxide increase moderately from 750 ppm to 550 ppm, but with a larger increase going from 550 ppm to 450 ppm due to the premature retirement of capital stock.

Part I: Introduction

This paper is based on the conclusions of the most recent careful, objective and comprehensive analysis of all relevant scientific, technical and economic information by thousands of experts (natural scientists, social scientists and technologists) from the appropriate fields of science from academia, governments, industry and environmental organizations from around the world under the auspices of the Intergovernmental Panel on Climate Change (IPCC), i.e., the Third Assessment Reports approved in early 2001.

Poverty alleviation and sustainable economic development are two of the major challenges facing humankind. Both are threatened by human-induced climate change. Poverty is not simply an issue of inadequate income. The poor want opportunity, capability, security and to be empowered (**figure 1**). This requires that the poor be able to earn a fair income, be healthy, educated, be less vulnerable to civil unrest, extreme weather events and ecological degradation, and to participate in decision-making. Climate change threatens the ability of many of the poor to escape poverty by: (i) adversely affecting natural resources (agriculture, forests, fisheries, coral reefs, mangroves, etc), which are a major source of income to many poor people; (ii) decreasing the availability of fresh water and degrading its quality, especially in many arid- and semi-arid areas (iii) adversely affecting human health by degrading air quality and by increasing exposure to vector- and water-borne diseases; and (iv) increasing their vulnerability to ecological degradation and to an increase in natural disasters, e.g.., floods and droughts. Hence, human-induced climate change, as well as other global environmental issues such as land degradation and loss of biological diversity, threatens our ability to meet human needs of adequate food,

clean water, a healthy environment and safe shelter. Hence climate change should not be viewed purely as an environmental issue, but should be viewed as a development issue.

The overwhelming majority of experts in both developed and developing countries recognize that scientific uncertainties exist, however, there is little doubt that the Earth's climate has warmed over the past 100 years in response to human activities and that further human-induced changes in climate are inevitable. During the last few years many parts of the world have suffered major heat waves, floods, droughts and an increase in extreme weather events leading to significant economic losses and loss of life. While individual extreme weather events cannot be directly linked to human-induced climate change, the frequency and magnitude of these types of events are expected to increase in a warmer world.

The question is not whether climate will change further in the future in response to human activities, but rather by how much (magnitude), where (regional patterns), and when (the rate of change). It is also clear that climate change will, in many parts of the world, adversely effect socio-economic sectors, including water resources, agriculture, forestry, fisheries and human settlements, ecological systems (particularly coral reefs), and human health (particularly vector-borne diseases). Indeed, the IPCC TAR concluded that most people would be adversely affected by climate change.

The good news is, however, that the IPCC reported that significant reductions in net greenhouse gas emissions are technically feasible due to an extensive array of technologies in the energy supply, energy demand and agricultural and forestry sectors, many at little or no cost to society. However, realizing these emissions reductions would involve the development and implementation of supporting policies to overcome barriers to the diffusion of these technologies into the market place, increased funding for research and development, and effective technology transfer.

This presentation briefly describes the current state of understanding of the Earth's climate system and the influence of human activities; the vulnerability of socio-economic sectors ecological systems and human health to climate change; and approaches to mitigate climate change by reducing emissions and enhancing sinks.

Part II: The Earth's Climate System: The Influence of Human Activities

The Earth's climate is changing. The Earth's climate has been relatively stable (global temperature changes of less than 1 degree Celsius over a century) during the present interglacial (i.e., the past 10,000 years). During this time modern society has evolved, and, in many cases, successfully adapted to the prevailing local climate and its natural variability. However, the Earth's is now becoming warmer, and precipitation patterns are changing. The Earth's mean surface temperature has warmed by between $0.6\pm0.2^{o}C$ over the last century, with land areas warming more than the oceans, and with the last two decades being the hottest this century. Indeed, the twelve warmest years during the last one hundred years have all occurred since 1983 (**figure 2a**). The Earth's surface temperature warmed more during the last century than any other century during the last thousand years (**figure 2b**). In addition, there is observational evidence

that sea level is rising, non-polar glaciers are retreating world-wide, Arctic sea ice is thinning in summer, a greater fraction of precipitation is falling in heavy precipitation events, the incidence of extreme weather events is increasing in some parts of the world, and the magnitude, frequency and persistence of the El-Nino phenomena, which leads to regions of the tropics and sub-tropics with severe droughts and floods, have increased since the mid-1970s.

The atmospheric concentrations of greenhouse gases have increased due to human activities, primarily due to the combustion of fossil fuels (coal, oil and gas), deforestation and agricultural practices, since the beginning of the pre-industrial era around 1750: carbon dioxide by nearly 30% (**figure 3a**), methane by more than a factor of two (**figure 3b**), nitrous oxide by about 15% (**figure 3c**). Their concentrations are higher now than at any time during the last 420,000 years, the period for which there are reliable ice-core data and probably significantly longer. In addition, the atmospheric concentrations of sulfate aerosols have increased in some regions of the world, resulting from emissions of sulfur dioxide arising from the combustion of coal (**figure 3d**). Greenhouse gases tend to warm the atmosphere and, in some regions, primarily in the Northern Hemisphere, aerosols tend to cool the atmosphere.

Most of the observed warming in the last 50 years can be attributed to human activities. Climate models that take into account the observed increases in the atmospheric concentrations of greenhouse gases, sulfate aerosols and the observed decrease in ozone in the lower stratosphere, in conjunction with changes in natural forcing (changes in volcanic activity and solar output), simulate the observed changes in annual mean global surface temperature quite well. This, and other information, suggests that human activities are implicated in the observed changes in the Earth's climate. In fact, the observed changes in climate cannot be explained by natural phenomena alone (e.g., changes in solar output and volcanic emissions) nor anthropogenic emissions of greenhouse gases and aerosols alone.

Atmospheric concentrations of greenhouse gases, especially carbon dioxide, are projected to increase in the future due to human activities. Future emissions of greenhouse gases and the sulfate aerosol precursor, sulfur dioxide, are dependent upon the development pathway and whether governments decide to mitigate emissions in order to address the issue of climate change. They are sensitive to economic growth, the rate of development and diffusion of new technologies into the market place, demographic shifts (i.e., population growth, age structure and the rural to urban transition), and the evolution of governance structures world-wide, thus affecting, *inter-alia,* demand for energy and natural resources. All IPCC Special Report on Emissions Scenarios (SRES) projections show that the atmospheric concentration of carbon dioxide, and in most cases the other greenhouse gases, will increase significantly during the next century in the absence of policies specifically designed to address the issue of climate change. Indeed, the SRES reported, for example, carbon dioxide emissions from the combustion of fossil fuels and from land-use changes (primarily tropical deforestation) are projected to range from about 5 to 35 GtC per year in the year 2100 compared to the average emissions during the 1990s of about 7.5 GtC per year (**figure 4a**). Such a range of emissions would mean that the atmospheric concentration of carbon dioxide would increase from today's level of about 368 ppm (parts per million by volume) to between about 540 and 970 ppm by 2100 (**figure 4b**). If uncertainties in the magnitude of the climate feedback from the terrestrial biosphere and the

persistence of the current terrestrial sink are taken into account, the projected concentration range of carbon dioxide in 2100 is 490 to 1260 ppm.

While the recent projections of carbon dioxide emissions are consistent with earlier projections, projected sulfur dioxide emissions are much lower. While the SRES reported similar projected emissions for carbon dioxide to the 1992 projections, the SRES reported significantly lower projected emissions of sulfur dioxide during the latter half of the 21st century (**figure 4c**). This has important implications for future projections of temperature changes, because sulfur dioxide emissions lead to the formation of sulfate aerosols in the atmosphere, which as stated earlier can partially offset the warming effect of the greenhouse gases.

Global mean surface temperatures are projected to increase between 1990 and 2100 by about 1.4 to 5.8°C (figure 4d). This range, which takes into account the range of climate sensitivities and plausible ranges of greenhouse gas and sulfur dioxide emissions, is higher than that reported in the IPCC Second Assessment Report (SAR) of 1.0 – 3.5 °C, because of the lower projected emissions of sulfur dioxide. **Figure 5** shows the projected changes in temperature over the next 100 years compared to the historical record of the last 1000 years. Not only are the projected changes in temperature about 2-10 times larger than the central value of the observed change over the last 100 years (i.e., 0.6°C), they are unique compared to the last 1000 years and are projected to occur at a rate significantly faster than the observed changes over the last 10,000 years.

Most land areas are projected to warm more than the global average. Projected temperature changes differ by region with the high latitudes projected to warm significantly more than the global average and nearly all land areas warming more than the global average and the oceans.

More El-Nino-like conditions may exist in the future leading to an increase in the incidence of floods and droughts in many parts of the tropics and sub-tropics. Long-term, large-scale, human-induced changes in climate are likely to interact with natural climate variability on time-scales of days to decades (e.g., the El Nino-Southern Oscillation (ENSO) phenomena). Atmosphere-Ocean Coupled General Circulation Models project that as the Earth's climate warms over the next 100 years it is likely that a more El-Nino like condition may persist.

Sea level is projected to rise between 1990 and 2100 by 8-88 cm. Associated with the projected changes in temperature, sea level is projected to increase by 8 - 88 cm by 2100, caused primarily by thermal expansion of the oceans and the melting of glaciers (**figure 4e**).

Temperatures and sea level will continue to rise for a century or more and many centuries, respectively, after the atmospheric concentrations of greenhouse gases are stabilized. **Figure 6** shows the time response of the atmospheric concentration of carbon dioxide, temperature and sea level (both in responses to the thermal expansion of the ocean and to a melting of the ice caps). The figure shows that to stabilize the atmospheric concentration of carbon dioxide at 550 ppm global emissions will have to peak within a few decades and be lower than current levels a few decades later. While the atmospheric concentration of carbon dioxide would stabilize within about one century, temperature will continue to increase for several hundreds of years, and sea

level will continue to increase for several millennia due to the thermal expansion of the oceans and the melting of ice sheets.

Seasonal and latitudinal shifts in precipitation with some arid and semi-arid areas becoming drier. Model calculations show that evaporation will be enhanced as the climate warms, and that there will be an increase in global mean precipitation and an increase in the frequency of intense rainfall. However, while some areas will experience an increase in precipitation, others will experience a decrease and even those land regions with increased precipitation may experience decreases in run-off and soil moisture, because of enhanced evaporation. Seasonal shifts in precipitation are also projected. In general, it is likely that precipitation will increase at high latitudes in both summer and winter. In winter, increases are projected over mid-latitudes, tropical Africa and Antarctica, and in summer in southern and eastern Asia. Australia, Central America and southern Africa show consistent decreases in winter rainfall. Model-model consistency between projections of precipitation is relatively poor for many regions of the world.

The incidence of some extreme events is projected to increase. While the incidence of extreme high temperature events, heavy precipitation events, mid-latitude continental summer soil moisture deficits, increased tropical cyclone peak wind and precipitation intensities, floods, droughts, fires and pest outbreaks is expected to increase in many regions, it is unclear whether there will be an increase in the intensity of mid-latitude storms (**Table 1**). In addition El-Nino like conditions will become more prevalent leading to more floods and droughts in many regions of the tropics and sub-tropics.

Part III: The Vulnerability of Water Resources, Agriculture, Natural Ecosystems, and Human Health to Climate Change and Sea Level Rise

The IPCC has assessed the potential consequences of changes in climate for socio-economic sectors, ecological systems and human health for different regions of the world. Because of uncertainties associated with regional projections of climate change, the IPCC assessed the vulnerability of these natural and social systems to changes in climate, rather than attempting to provide quantitative predictions of the impacts of climate change at the regional level. Vulnerability is defined as the extent to which a natural or social system is susceptible to sustaining damage from climate change, and is a function of the magnitude of climate change, the sensitivity of the system to changes in climate and the ability to adapt the system to changes in climate. Most impact studies have assessed how systems would respond to only small changes in temperature, i.e., less than 3-4°C, which is lower than the upper end of the projections using the SRES projections. Very few have considered the dynamic responses to greater amounts of warming; fewer yet have been able to examine the consequences of multiple stress factors.

The vulnerability of socioeconomic systems (e.g., water resources, agriculture, forestry, fisheries and human settlements), terrestrial and aquatic ecological systems and human health, which are all vital to human development and well-being, are all sensitive to the magnitude and rate of climate change, as well as to changes in climate extremes and variability. Whereas many regions are likely to experience the adverse effects of climate

change—some of which are potentially irreversible—some effects of climate change are likely to be beneficial. Hence, different segments of society can expect to confront a variety of changes and the need to adapt to them. However, the IPCC concluded that most people would be adversely affected by climate change.

Developing countries are more vulnerable to climate change than developed countries. There are a number of general conclusions that can be easily drawn: (i) human-induced climate change is an important new stress, particularly on ecological and socio-economic systems that are already affected by pollution, increasing resource demands, and non-sustainable management practices; (ii) the most vulnerable systems are those with the greatest sensitivity to climate change and the least adaptability; (iii) most systems are sensitive to both the magnitude and rate of climate change, and in particular changes in climate extremes; (iv) many of the impacts are difficult to quantify because existing studies are limited in scope; and (v) successful adaptatio depends upon technological advances, institutional arrangements, availability of financing and information exchange, and that vulnerability increases as adaptive capacity decreases.

The range of adaptation options for managed systems such as agriculture and water supply is generally increasing because of technological advances, however, some regions of the world, i.e., developing countries, have limited access to these technologies and appropriate information. The efficacy and cost-effectiveness of adaptation strategies will depend upon cultural, educational, managerial, institutional, legal and regulatory practices that are both domestic and international in scope. Incorporation of climate change concerns into resource-use and development decisions and plans for regularly scheduled investments in infrastructure will facilitate adaptation.

Let me now briefly discuss the implications of climate change for a representative number of systems: water resources, food security, natural ecosystems (forests and coral reefs), human health, and human settlements.

Water Resources

Climate change could exacerbate water stress in many arid and semi-arid areas. Currently 1.3 billion people do not have access to adequate supplies of clean water, and 2 billion people do not have access to adequate sanitation. Today, some nineteen countries, primarily in the Middle East and Africa, are classified as water-scarce or water-stressed. Even in the absence of climate change, this number is expected to more than double by 2025, in large part because of increases in demand from economic and population growth. Unfortunately in many regions of the world a significant fraction of water is wasted, largely through inefficient irrigation in the agricultural sector. Run-off is projected to increase in high latitudes and south East Asia and decrease in central Asia, the area around the Mediterranean, southern Africa and Australia. For other areas in the world, changes in run-off are model dependent. Hence, climate change could further exacerbate the frequency and magnitude of droughts in some places where droughts are already a recurrent feature. Developing countries are highly vulnerable to climate change because many are located in arid and semi-arid areas.

Agricultural Productivity and Food Security

Agricultural productivity is projected to decrease in many countries in the tropics and sub-tropics for almost any increase in temperature, but increase at mid- and high-latitudes for increases in temperature of up to a few degrees Celsius. Currently, 800 million people are malnourished. As the world's population increases and incomes in some countries rise, food consumption is expected to double over the next three to four decades. Studies show that on the whole, global agricultural production could be maintained relative to baseline production for small changes in climate, i.e., global mean surface temperature changes of only a few degrees Celsius (2-3°C). However, crop yields and changes in productivity due to climate change will vary considerably across regions and among localities, thus changing the patterns of production. In general, productivity is projected to increase in middle to high latitudes, depending on crop type, growing season, changes in temperature regime, and seasonality of precipitation for small changes in temperature, but to decrease in mid-latitudes with temperature changes above 2-3°C. However, in the tropics and subtropics, where some crops are near their maximum temperature tolerance and where dryland, non-irrigated agriculture dominates, yields are likely to decrease for even small increases in temperature, especially in Africa and Latin America, where decreases in overall agricultural productivity of up to 30% are projected during the next century. Therefore, there may be increased risk of hunger in some locations in the tropics and subtropics where many of the world's poorest people live.

Natural Ecosystems

Biological systems have already been affected in many parts of the world by changes in climate, particularly increases in regional temperature, during the last several decades. There are a number of instances where changes in biological systems, e.g., earlier flowering of trees and egg-laying in birds, lengthening of the growing season in the northern hemisphere, the pole-ward and upward altitudinal shifts in insect, plant and animal ranges and the increased incidence of coral bleaching have been associated with regional changes in climate. While these biological systems are subject to numerous stresses that can alter their behavior, it should be noted that in many cases these observed changes in biological systems are consistent with well-known biological responses to climate.

Climate change is projected to alter the composition and productivity of ecological systems and decrease biological diversity. The structure, composition, productivity and geographic distribution of many ecosystems will shift as individual species respond differently to changes in climate and disturbance regimes (migration and re-establishment rates are highly variable), but many of these ecological changes are likely to lag behind the changes in climate by decades to centuries. Locally there may be increases in biological diversity due to new arrivals as the ranges of insects, birds and plants change. However, increased disturbances (pests and fires) could lead to decreased biodiversity and increases in weedy species, and habitat fragmentation will be pose barriers to climate-induced species migration, hence N-S and E-W corridors will be needed for parks and reserves. High latitude and high latitude species are most at threat. These changes will affect the goods ecosystems provide society, e.g., sources of food, fiber, medicines, recreation and tourism, and ecological services such as controlling nutrient cycling, waste quality, water run-off, soil erosion, air quality and climate control.

Some ecosystems respond rapidly to a change in climate, where-as others respond quite slowly. Coral reefs respond within a single season to unusually high temperatures, hence the observed increased incidence of coral bleaching during the recent increase in the frequency, persistence and magnitude of El-Nino events. In contrast, the conditions necessary for the re-establishment of species in some ecosystems, e.g., forests, are often more restrictive than the conditions under which individuals can persist once established. Gradual climate change may lead to the conditions unsuitable for the establishment of some important species of an ecosystem, but the inertial effects of long-lived plants hides the importance of this change until the already established individuals die or are killed in a disturbance, e.g., the regenerated composition of a mature forest stand destroyed by a disturbance (pest outbreak or fire) may be quite different from the original composition

Forests are vulnerable to projected changes in climate. The distribution of forests and forest species are projected to change in response to changes in temperature, precipitation, extreme events, pest outbreaks and fires, altering the ecosystem goods and services provided. Boreal systems are likely to be the most vulnerable, primarily due to changes in fire regime and pest outbreaks, potentially leading to forest die-back, a change in age structure and a decrease in carbon content.. The current net global terrestrial uptake of carbon (about 1GtC yr^{-1}) will likely increase during the first half of the 21st Century, and then level off or decline over time. It has even been suggested that forest systems may become a source of carbon by the end of the 21st Century.

Coral reefs are threatened by increases in temperature. Coral reefs, which are the most biologically diverse marine ecosystems, are important for fisheries, tourism, coastal protection, and erosion control. Coral reef systems, which are already being threatened by pollution, unsustainable tourism and fishing practices, are very vulnerable to changes in climate. While these systems may be able to adapt to the projected increases in sea level, sustained increases in water temperatures of 3-4 degrees Celsius above long-term average seasonal maxima over a 6-month period can cause significant coral mortality; short-term increases on the order of only 1-2 degrees Celsius can cause "bleaching", leading to reef destruction. Branching corals will be less affected than plate and brain corals

Human Health

Human health is sensitive to changes in climate because of its impact, in particular, on changes in water supply and quality, food security and the functioning and range of ecological systems. Direct health effects would include increases in heat-related mortality and illness resulting from an anticipated increase in heatwaves, although offset to some degree in temperate regions by reductions in winter mortality. Indirect effects would include extensions of the range and season for vector organisms, thus increasing the likelihood of transmission of vector-borne infectious diseases (e.g., malaria, dengue, yellow fever and encephalitis). For example, projected changes in climate could lead to an increase in the number of people at risk of malaria of the order of tens of millions annually, primarily in tropical, subtropical, and less well protected temperate-zone populations (Table 2). Some increases in non-vector-borne infectious diseases such as salmonellosis, cholera and other food- and water-related infections could also occur,

particularly in tropical and subtropical regions, because of climatic impacts on water distribution and temperature, and on micro-organism proliferation. The impacts of climate change on food production within food-insecure regions and the consequences of economic dislocation and demographic displacement (e.g., sea level rise) would have wide-ranging health impacts.

Human Settlements

Sea-level rise is projected to have negative impacts on human settlements, tourism, freshwater supplies, fisheries, exposed infrastructure, agricultural and dry lands, and wetlands, causing loss of land, economic losses and the displacement of tens of millions of people. It is currently estimated that about half of the world's population lives in coastal zones, although there is a large variation among countries. Changes in climate will affect coastal systems through sea-level rise and an increase in storm-surge hazards and possible changes in the frequency and/or intensity of extreme events. Impacts may vary across regions, and societal costs will greatly depend upon the vulnerability of the coastal system and the economic situation of the country. Sea-level rise will increase the vulnerability of coastal populations to flooding. An average of about 46 million people per year currently experience flooding due to storm surges; a 50 cm sea-level rise would increase this number to about 92 million; a 1 meter sea-level rise would increase this number to 118 million. The estimates will be substantially higher if one incorporates population growth projections. A number of studies have shown that small islands and deltaic areas are particularly vulnerable to a one-meter sea-level rise. In the absence of mitigation actions (e.g., building sea walls), land losses are projected to range from 1.0% for Egypt, 6% for Netherlands, 17.5% for Bangladesh, to about 80% of the Marshall Islands, displacing tens of millions of people, and in the case of low-lying Small Island States, the possible loss of whole cultures. Many nations face lost capital value in excess of 10% of GDP. While annual adaptation/protection costs for most of these nations are relatively modest (about 0.1% GDP), average annual costs to many small island states are much higher, several percent of GDP, assuming adaptation is possible.

Part IV: Approaches to Mitigate Climate Change by Reducing Emissions and Enhancing Sinks

There is a near-term challenge for Annex I Parties committed to meet their emissions targets contained within the Kyoto Protocol. This can be accomplished through domestic reductions and by utilizing the flexibility mechanisms of Articles 6, 12 and 17. Although the overall emissions target for Annex I countries, an overall 5.2% reduction in 1990 emissions during the commitment period, 2008-2012, appears quite modest, emissions within many Annex I Parties have increased substantially within recent years. The longer term challenge of stabilizing the atmospheric concentrations of greenhouse gas concentrations as required by Article 2 of the UNFCCC (Article 2) will require global emissions of greenhouse gases to be significantly lower than today.

Stabilization of the atmospheric concentrations of greenhouse gases will require emissions reductions in all regions - the lower the stabilization level or the higher the baseline scenario, the earlier and the deeper the reductions. Annex I countries cannot achieve stabilization alone. If governments were to decide to stabilize the atmospheric concentration of carbon dioxide at 550ppm (about twice the pre-industrial level), global emissions would have to peak by about

2025 and fall below current levels by 2040 to 2070. This would mean that all regions would have to deviate from most "business-as-usual" scenarios within a few decades. Lower emissions will require different patterns of energy resource development and utilization (trend towards de-carbonization) and increases in end-use efficiency. A key political issue would be an equitable distribution of emissions rights, recognizing that most anthropogenic emissions of greenhouse gases to date have come from industrialized countries, and that even though total emissions from developing countries are projected to exceed those from industrialized countries within a few decades, projected per-capita emissions would still be lower in most developing countries throughout the next century. The projected contribution to global warming from developing country emissions is unlikely to equal that from developed countries until about the end of the 21st Century because the climate system responds to the cumulative emissions of greenhouse gases not the annual emissions.

Greenhouse gas emissions are highly dependent upon the development pathway, thus approaches to mitigate climate change will be both affected by, and have impacts on, broader socio-economic policies and trends, those relating to development, sustainability and equity.

Significant technical progress in climate-friendly technologies has been made in the last 5 years and at a faster rate than expected (e.g., wind turbines, elimination of industrial by-products, hybrid engine cars, fuel cell technology, and underground carbon dioxide storage). Bottom-up studies indicate that global emissions reductions of 1.9 - 2.6 GtC_{eq} and 3.6 - 5.0 GtC_{eq} could be achieved by 2010 and 2020, respectively, relative to the SRES B2 baseline, with half of the potential emissions reductions being achieved with direct benefits (negative costs), while the other half at less than $100 tC (at 1998 prices). In addition, the IPCC concluded that known technological options could achieve stabilization of carbon dioxide at levels of 450-550 ppm over the next 100 years. However, realizing either the short-term or long-term emissions reductions would involve overcoming technical, economic, political, cultural, social, behavioral and/or institutional barriers. National responses can be more effective if deployed as a portfolio of policy instruments to limit or reduce greenhouse gas emissions. Research and development and effective technology transfer could play a critical role in cost-effectively reducing global emissions.

Some reductions in greenhouse gas emissions can be obtained at no or negative costs by exploiting no regrets opportunities, i.e., (i) reducing market or institutional imperfections; (ii) using revenues from taxes or auctioned permits to reduce existing distortionary taxes through revenue recycling; and (iii) exploiting ancillary benefits, e.g., local and regional air quality improvements. For example, given the challenges of improving indoor and outdoor air pollution in many parts of the world, and the goal to reduce acid deposition, policies, practices and technologies that can simultaneously address these local and regional environmental issues, while reducing greenhouse gas emissions are particularly attractive.

While a great deal of uncertainty surrounds both bottom-up and top-down emissions reductions cost estimates it is evident that international carbon trading reduces the costs of compliance for Annex B countries. In the absence of trading, Annex B costs of complying with the Kyoto Protocol, range from US $20-$600/tC, equivalent to a GDP loss of 0.2 - 2%, where-as with full Annex B trading the costs are reduced to US $15-150/tC, equivalent to a GDP loss of

0.1 - 1%. These costs could be further reduced with efficient utilization of sink (LULUCF) activities, the Clean Development Mechanism, Joint Implementation, multiple greenhouse gases, ancillary benefits, tax recycling and induced technological change. Costs of stabilizing carbon dioxide increase moderately from 750 ppm to 550 ppm, but with a larger increase going from 550 ppm to 450 ppm because it would likely require the premature retirement of some existing capital stock.

Reductions in greenhouse gases can be achieved by utilizing an extensive array of technologies and policy measures that accelerate technology diffusion in:

- energy supply (more efficient conversion of fossil fuels; switching from high to low carbon fossil fuels; increased use of modern renewable sources of energy (e.g., plantation biomass, micro-hydro, wind, and solar); decarbonization of flue gases and fuels, coupled with carbon dioxide storage; and increasing the use of nuclear energy;
- energy demand (industry, transportation, and residential/commercial buildings), and
- agriculture, rangelands and forestry sectors (afforestation, reforestation, slowing deforestation, improved forest, cropland and rangeland management, including restoration of degraded agricultural lands and rangelands, promoting agroforestry, and improving the quality of the diet of ruminants).

Policy instruments will be needed to facilitate the penetration of lower carbon intensive technologies into the market place. The optimum mix of the following policies will vary from country to country as policies need to be tailored for local situations and developed through consultation with stakeholders:

- energy pricing strategies (e.g., carbon taxes and reduced energy subsidies);
- reducing or removing subsidies that increase greenhouse gas emissions (e.g., agricultural and transport subsidies);
- incentives such as provisions for accelerated depreciation and reduced costs for the consumer;
- domestic and international tradable emissions permits and joint implementation;
- voluntary programs and negotiated agreements with industry;
- utility demand-side management programs;
- regulatory programs including minimum energy efficiency standards;
- market pull and demonstration programs that stimulate the development and application of advanced technologies; and
- product labeling.

Part V: Summary

Policymakers are faced with responding to the risks posed by anthropogenic emissions of greenhouse gases in the face of scientific uncertainties. Policymakers should recognize that scientific uncertainties can go in either direction, i.e., we may be either over-estimating or under-estimating the impact of human activities on the Earth's climate system. They should also recognize that climate-induced environmental changes cannot be reversed quickly, if at all, due to the long time scales (decades to millennia) associated with the climate system (figure 6). Decisions taken during the next few years may limit the range of possible policy options in the future because high near-term emissions would require deeper reductions in the future to meet

any given target concentration. Delaying action might reduce the overall costs of mitigation because of potential technological advances but could increase both the rate and the eventual magnitude of climate change, and hence the adaptation and damage costs.

Policymakers will have to decide to what degree they want to take precautionary measures to limit anthropogenic climate change by mitigating greenhouse gas emissions and enhancing the resilience of vulnerable systems by means of adaptation. Uncertainty does not mean that a nation or the world community cannot position itself better to cope with the broad range of possible climate changes or protect against potentially costly future outcomes. Delaying such measures may leave a nation or the world poorly prepared to deal with adverse changes and may increase the possibility of irreversible or very costly consequences. Options for mitigating change or adapting to change that can be justified for other reasons today and make society more flexible or resilient to anticipated adverse effects of climate change appear particularly desirable.

Without action to limit greenhouse gas emissions the Earth's climate will warm at an unprecedented rate. If, actions are not taken to reduce the projected increase in greenhouse gas emissions, the Earth's climate is projected to change at an unprecedented rate (**figure 5**) with adverse consequences for society, undermining the very foundation of sustainable development. Proactive adaptive strategies to deal with this issue need to be developed, recognizing issues of equity and cost-effectiveness.

This paper and all power-point slides used in my presentation will be available on the IPCC web page by the end of this week.

Table 1: Projected Changes in Extreme Climate Events and Resulting Impacts

Projected Changes during the 21st Century in Extreme Climate Phenomena and their Likelihood[a]	Representative Examples of Projected Impacts[b] (all *high confidence* of occurrence in some areas[c])
Simple Extremes	
Higher maximum temperatures, more hot days and heat waves[d] over nearly all land areas (*Very likely*[a])	• Increased incidence of death and serious illness in older age groups and urban poor [4.7] • Increased heat stress in livestock and wildlife [4.2 and 4.3] • Shift in tourist destinations [Table TS-2 and 5.7] • Increased risk of damage to a number of crops [4.2] • Increased electric cooling demand and reduced energy supply reliability [Table TS-4 and 4.5]
Higher [Increasing] minimum temperatures, fewer cold days, frost days and cold waves[d] over nearly all land areas (*Very likely*[a])	• Decreased cold-related human morbidity and mortality [4.7] • Decreased risk of damage to a number of crops, and increased risk to others [4.2] • Extended range and activity of some pest and disease vectors [4.2 and 4.3] • Reduced heating energy demand [4.5]
More intense precipitation events (*Very likely*[a], over many areas)	• Increased flood, landslide, avalanche, and mudslide damage [4.5] • Increased soil erosion [5.2.4] • Increased flood runoff could increase recharge of some floodplain aquifers [4.1] • Increased pressure on government and private flood insurance systems and disaster relief [Table TS-4 and 4.6]

Table 1 continued: Projected Changes in Extreme Climate Events and Resulting Impacts

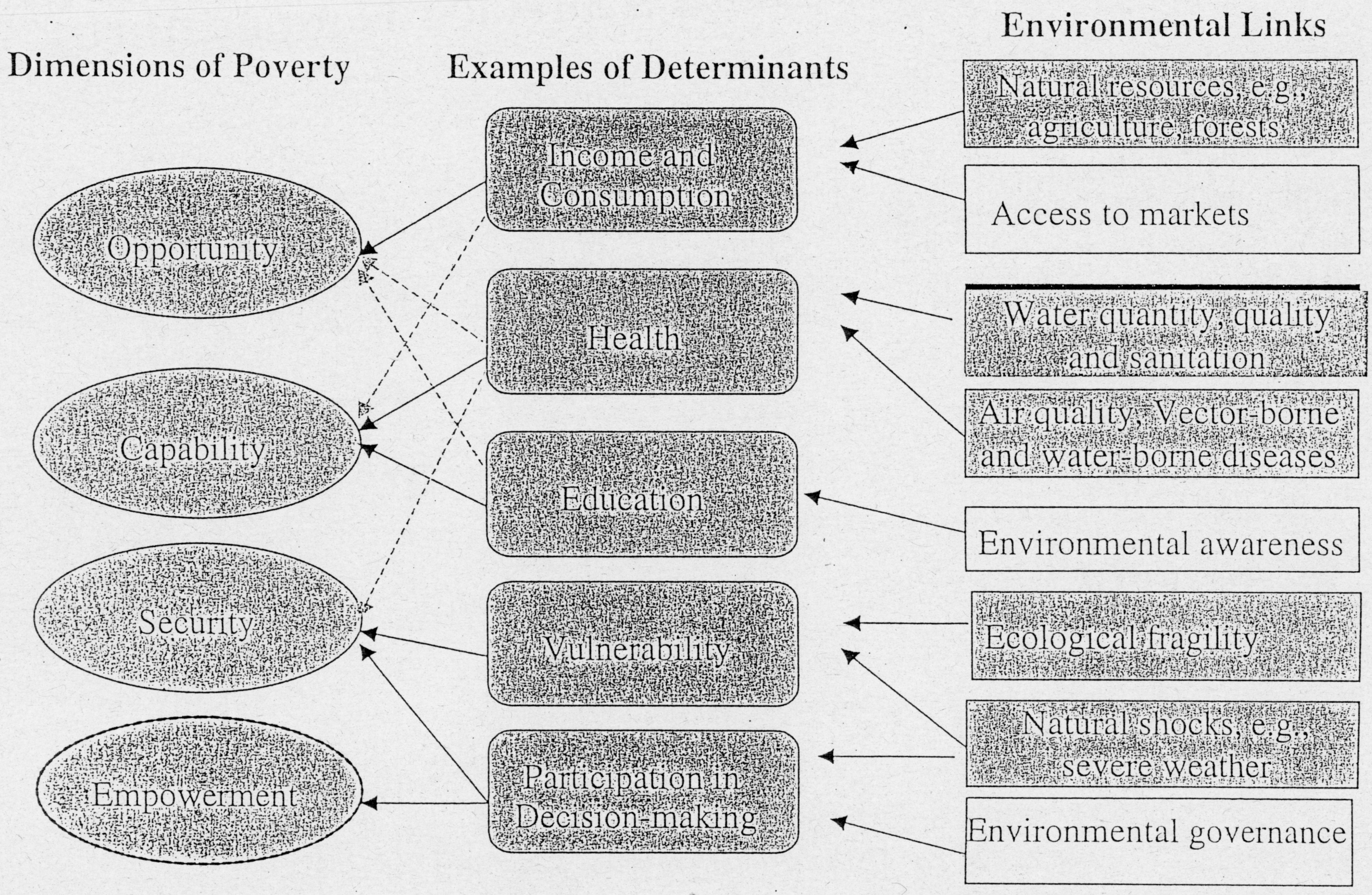
Complex Extremes	
Increased summer drying over most mid-latitude continental interiors and associated risk of drought (*Likely*[a])	• Decreased crop yields [4.2] • Increased damage to building foundations caused by ground shrinkage [Table TS-4] • Decreased water resource quantity and quality [4.1 and 4.5] • Increased risk of forest fire [5.4.2]
Increase in tropical cyclone peak wind intensities, mean and peak precipitation intensities (*Likely*[a], over some areas)[e]	• Increased risks to human life, risk of infectious disease epidemics and many other risks[4.7] • Increased coastal erosion and damage to coastal buildings and infrastructure [4.5 and 7.2.4] • Increased damage to coastal ecosystems such as coral reefs and mangroves [4.4]
Intensified droughts and floods associated with El Niño events in many different regions (*Likely*[a]) [See also under droughts and intense precipitation events]	• Decreased agricultural and rangeland productivity in drought- and flood-prone regions [4.3] • Decreased hydro power potential in drought-prone regions [5.1.1 and Figure TS-7]
Increased Asian summer monsoon precipitation variability (*Likely*[a])	• Increase in flood and drought magnitude and damages in temperate and tropical Asia [5.2.4]
[illegible]	

Table 2: Vector (insect)-borne Diseases

Disease	*Vector*	*Population at risk (millions)*	*Present distribution*	*Likelihood of altered distribution with warming*
Malaria	mosquito	2,100	(sub)tropics	✓✓
Schistosomiasis	water snail	600	(sub)tropics	✓✓
Filariasis	mosquito	900	(sub)tropics	✓
Onchocerciasis (river blindness)	black fly	90	Africa/Latin America	✓
African trypanosomiasis (sleeping sickness)	tsetse fly	50	tropical Africa	✓
Dengue	mosquito	unavailable	tropics	✓✓
Yellow fever	mosquito	unavailable	tropical South America & Africa	✓

Likely ✓
Very likely ✓✓

Figure 1: Poverty is Multi-Dimensional

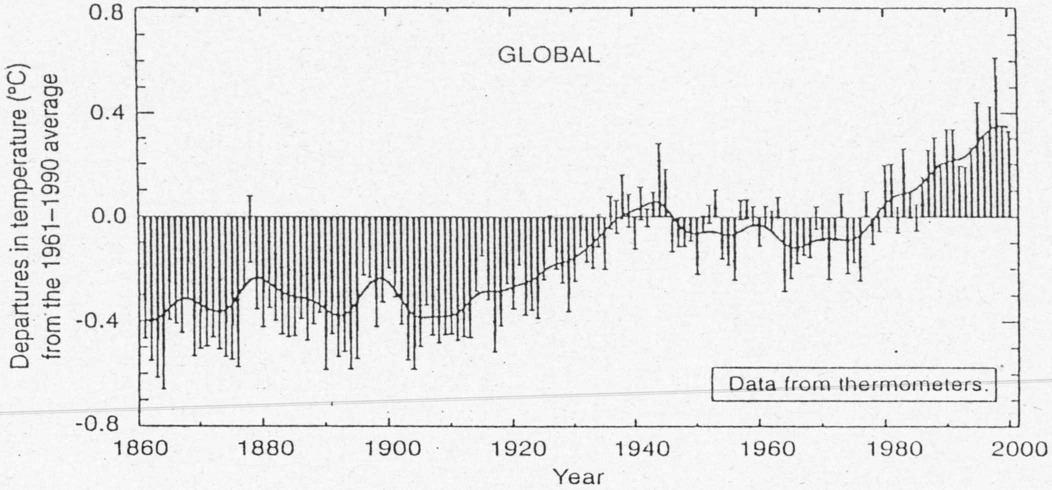


Shaded boxes represent links affected by climate change

Figure 2: Variations of the Earth's Surface Temperature

This figure shows that the Earth's mean surface temperature has increased by 0.6 ±0.2°C and that the last two decades are the warmest of the last 140 years.

(a) the past 140 years



This figure shows that the temperature increase in the last 100 years is larger than for any other century in the last 1000 years

(b) the past 1000 years

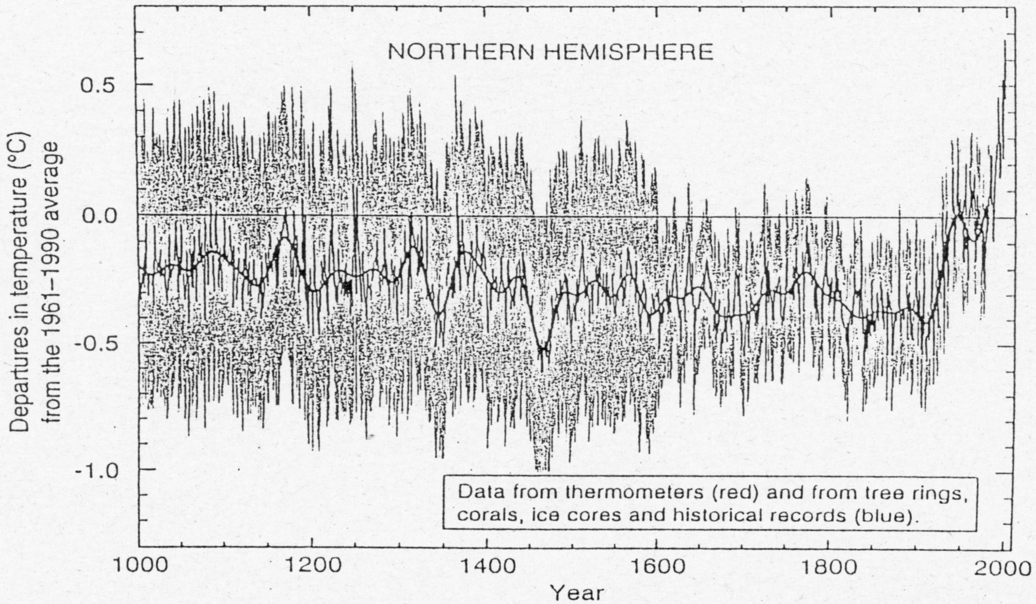
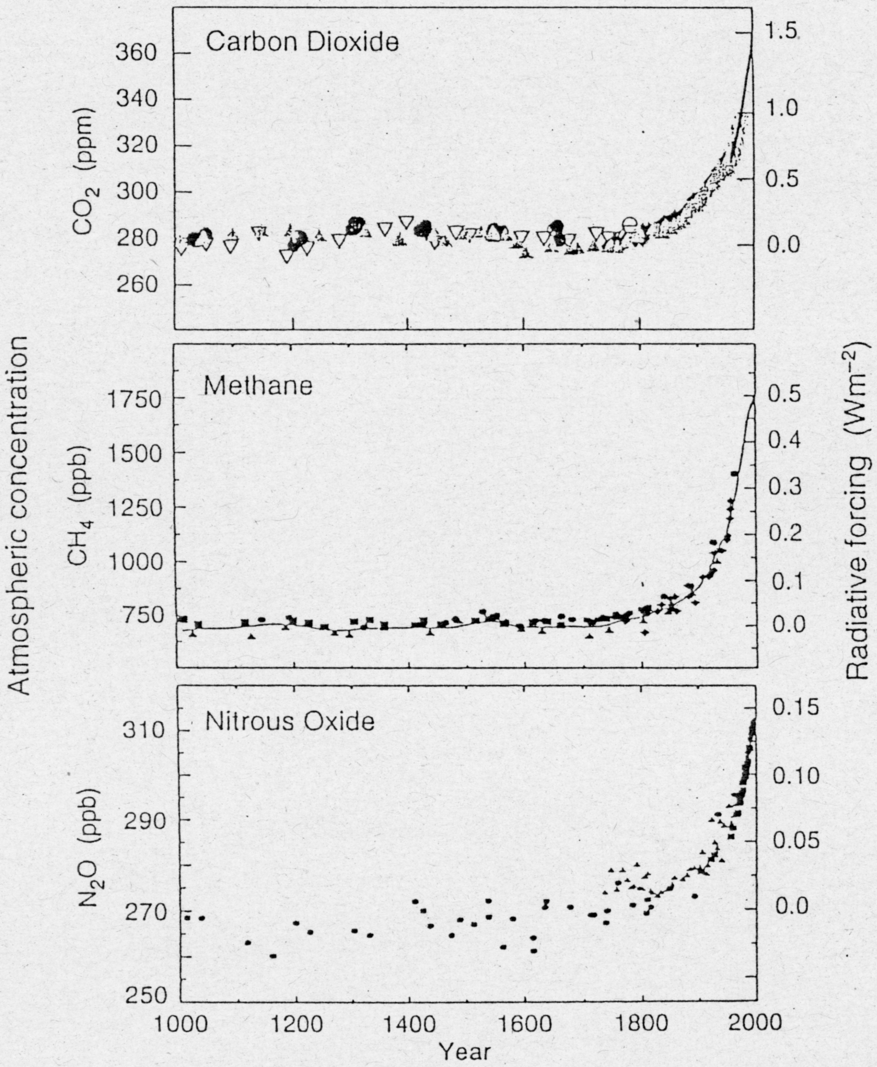
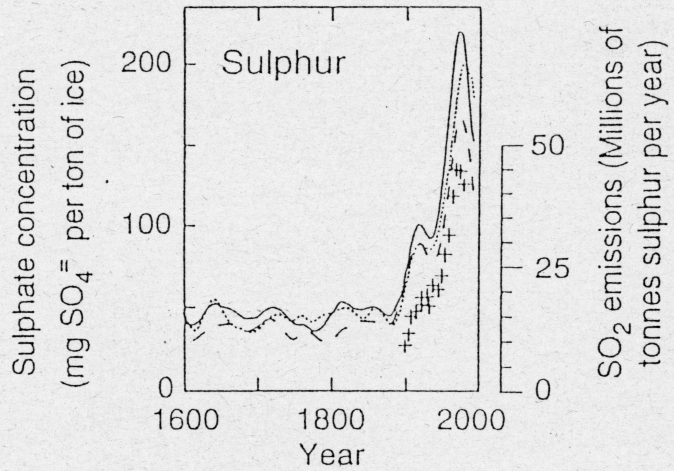


Figure 3: Indicators of the Human Influence on the Atmosphere during the Industrial Era

(a) Global atmospheric concentrations of three well mixed greenhouse gases

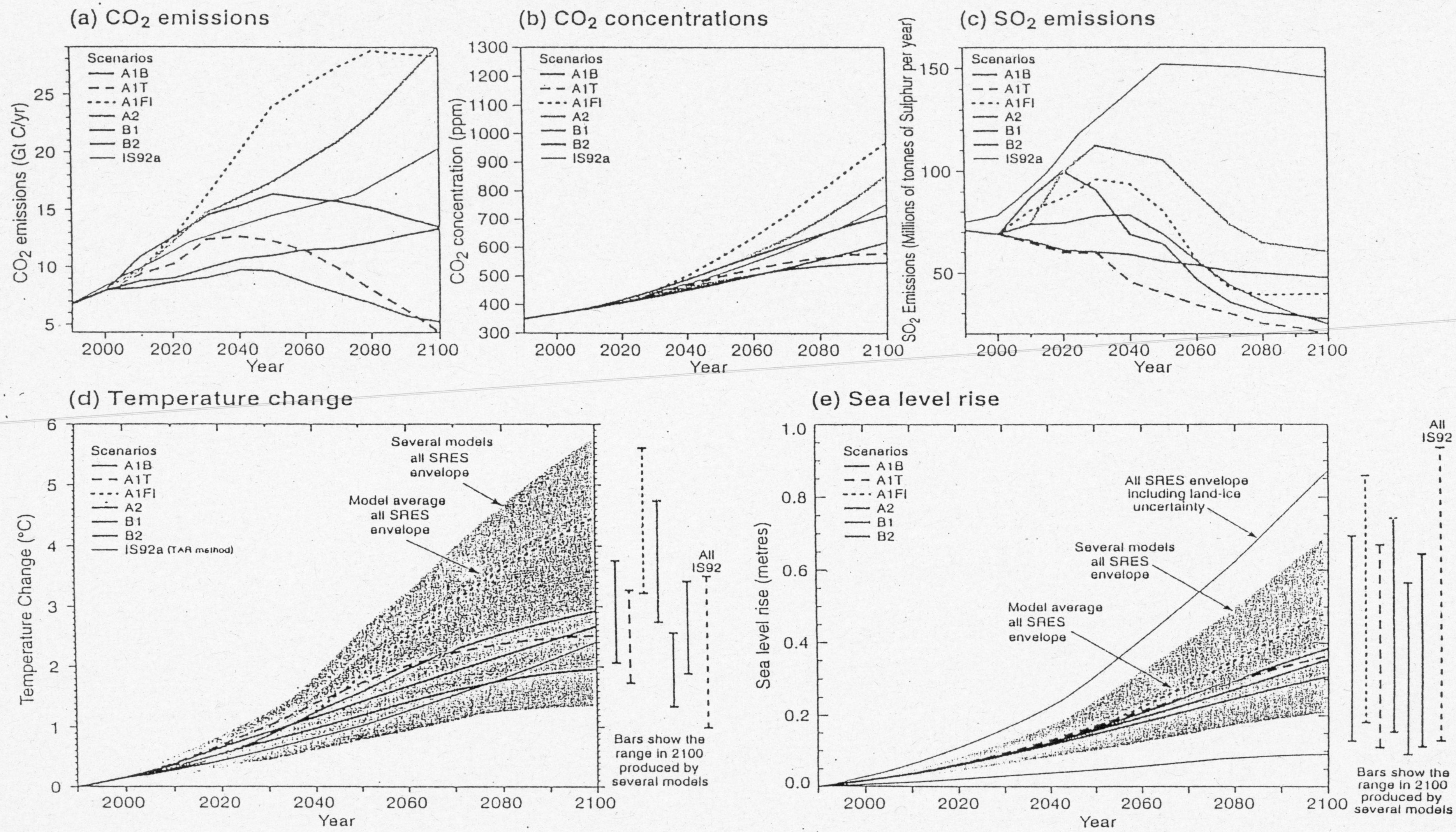


(b) Sulphate aerosols deposited in Greenland ice



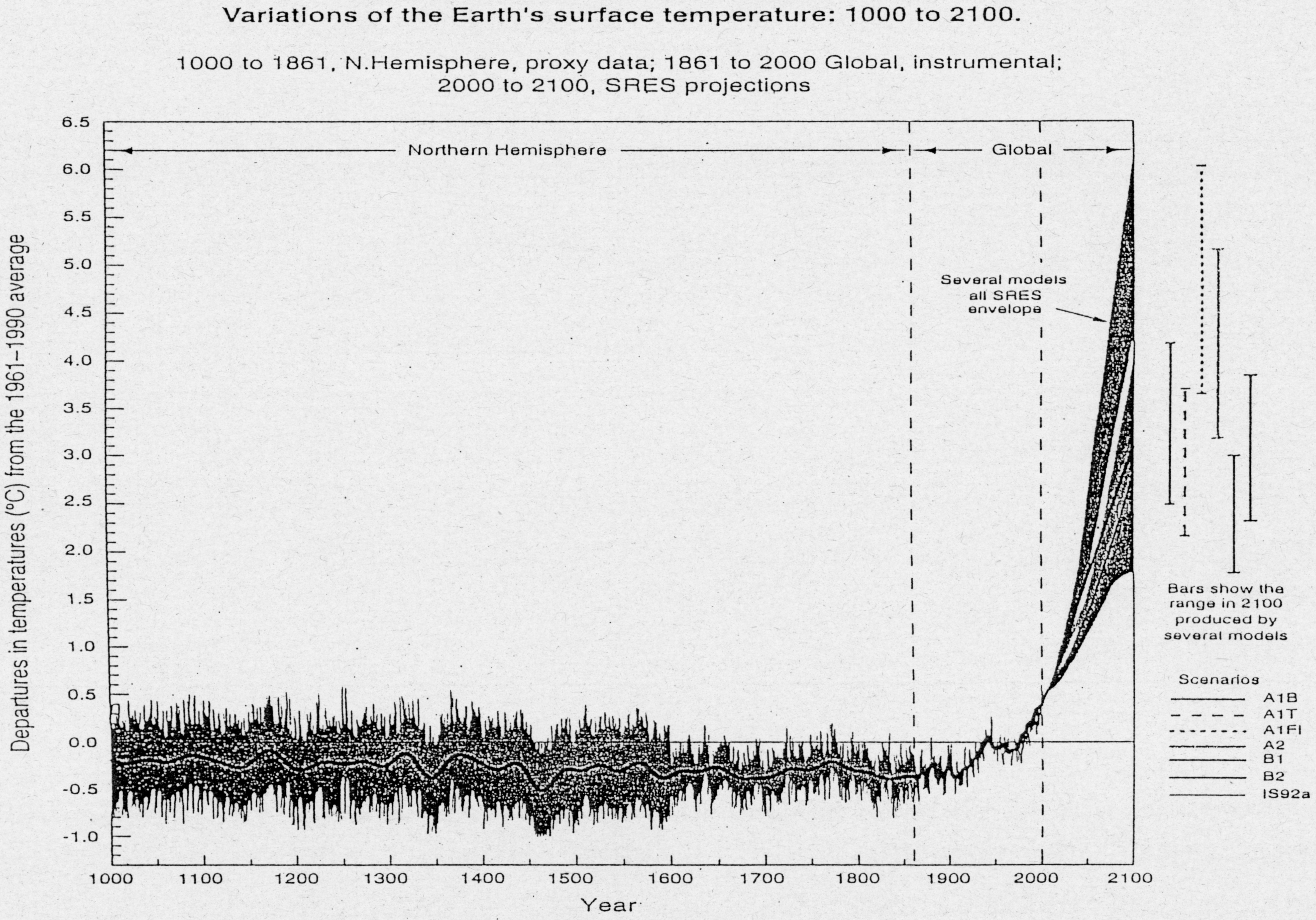
This figure shows that the atmospheric concentrations of greenhouse gases and sulfate aerosols was constant until the industrial era began, and then rose rapidly in response to human activities, primarily due to the combustion of fossil fuels and land-use practices

Figure 4: The Global Climate of the 21st Century



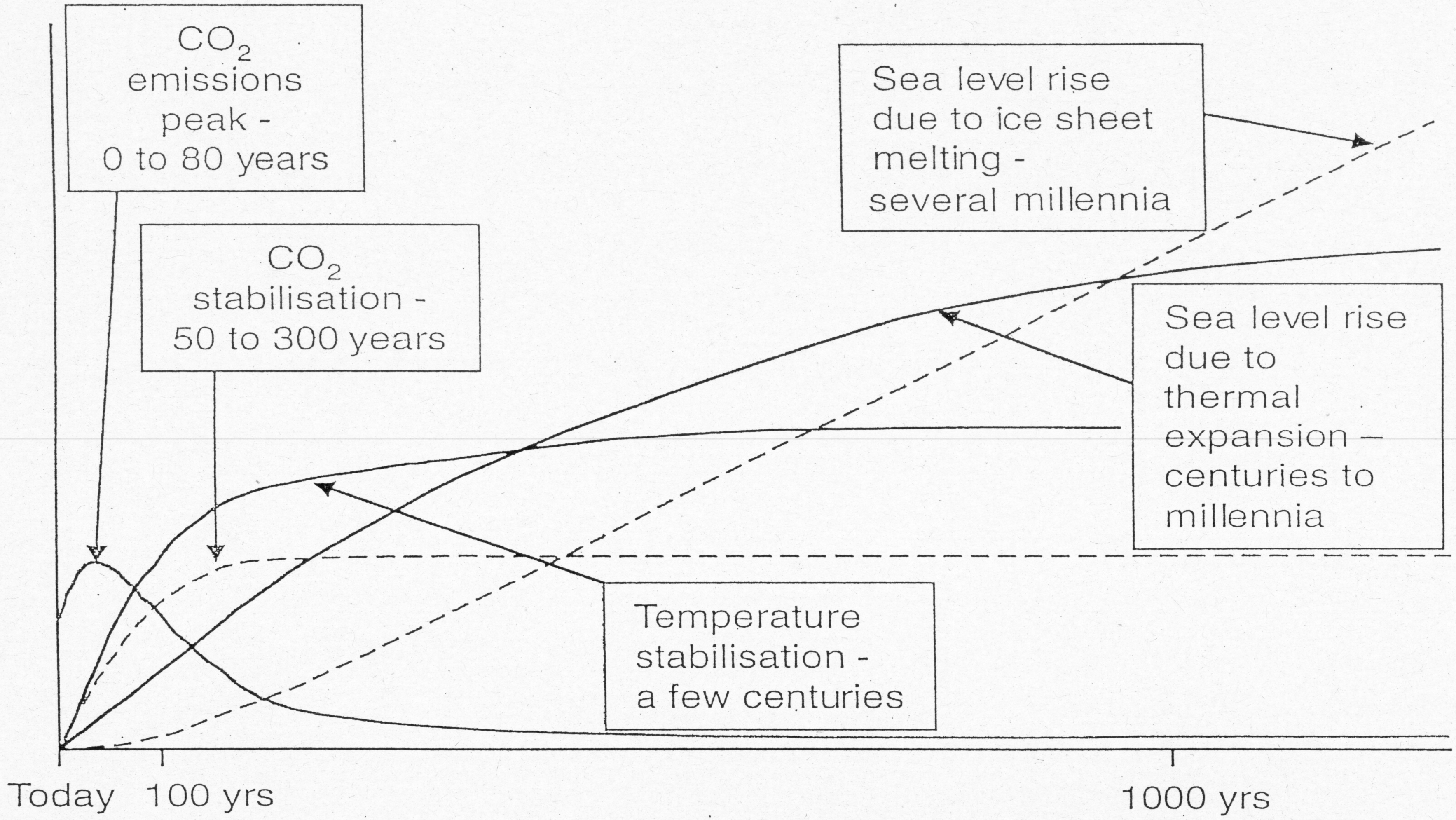
This figure shows the wide range of projected changes in emissions (carbon dioxide and sulfur dioxide), concentrations (carbon dioxide), temperature and sea level between 1990 and 2100 caused by plausible changes in economic growth, demography, technologies and governance.

Figure 5: Variations of the Earth's Surface Temperature: 1000 to 2100



This figure shows how the Earth's mean surface temperature is projected to be significantly greater by 2100 than at any time in the last 1000 years .

Figure 6: The Inertia of the Climate System



This figure shows that stabilization of the atmospheric concentration of carbon dioxide requires emissions to be well below 1990 levels within a hundred years of so. It also shows the long time lags between stabilizing the atmospheric concentrations of carbon dioxide and stabilization of temperature (a few hundred years) and sea level (centuries to millennia)