Climate Change 2001: Synthesis Report

Summary for Policymakers

An Assessment of the Intergovernmental Panel on Climate Change

This summary, approved in detail at IPCC Plenary XVIII (Wembley, United Kingdom, 24-29 September 2001), represents the formally agreed statement of the IPCC concerning key findings and uncertainties contained in the Working Group contributions to the Third Assessment Report.

Based on a draft prepared by:

Robert T. Watson, Daniel L. Albritton, Terry Barker, Igor A. Bashmakov, Osvaldo Canziani, Renate Christ, Ulrich Cubasch, Ogunlade Davidson, Habiba Gitay, David Griggs, Kirsten Halsnaes, John Houghton, Joanna House, Zbigniew Kundzewicz, Murari Lal, Neil Leary, Christopher Magadza, James J. McCarthy, John F.B. Mitchell, Jose Roberto Moreira, Mohan Munasinghe, Ian Noble, Rajendra Pachauri, Barrie Pittock, Michael Prather, Richard G. Richels, John B. Robinson, Jayant Sathaye, Stephen Schneider, Robert Scholes, Thomas Stocker, Narasimhan Sundararaman, Rob Swart, Tomihiro Taniguchi, D. Zhou, and many IPCC authors and reviewers

Introduction

In accordance with a decision taken at its Thirteenth Session (Maldives, 22 and 25-28 September 1997) and other subsequent decisions, the IPCC decided:

- To include a Synthesis Report as part of its Third Assessment Report
- That the Synthesis Report would provide a policy-relevant, but not policy-prescriptive, synthesis and integration of information contained within the Third Assessment Report and also drawing upon all previously approved and accepted IPCC reports that would address a broad range of key policy-relevant, but not policy-prescriptive, questions
- That the questions would be developed in consultation with the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC).

The following nine questions were based on submissions by governments and were approved by the IPCC at its Fifteenth Session (San José, Costa Rica, 15-18 April 1999).

Question 1

Q1

What can scientific, technical, and socio-economic analyses contribute to the determination of what constitutes dangerous anthropogenic interference with the climate system as referred to in Article 2 of the Framework Convention on Climate Change?

Natural, technical, and social sciences can provide essential information and evidence needed for decisions on what constitutes "dangerous anthropogenic interference with the climate system." At the same time, such decisions are value judgments determined through socio-political processes, taking into account considerations such as development, equity, and sustainability, as well as uncertainties and risk. Q1.1

The basis for determining what constitutes "dangerous anthropogenic interference" will vary among regions—depending both on the local nature and consequences of climate change impacts, and also on the adaptive capacity available to cope with climate change—and depends upon mitigative capacity, since the magnitude and the rate of change are both important. There is no universally applicable best set of policies; rather, it is important to consider both the robustness of different policy measures against a range of possible future worlds, and the degree to which such climate-specific policies can be integrated with broader sustainable development policies. Q1.2

The Third Assessment Report (TAR) provides an assessment of new scientific information and evidence as an input for policymakers in their determination of what constitutes "dangerous anthropogenic interference with the climate system." It provides, first, new projections of future concentrations of greenhouse gases in the atmosphere, global and regional patterns of changes and rates of change in temperature, precipitation, and sea level, and changes in extreme climate events. It also examines possibilities for abrupt and irreversible changes in ocean circulation and the major ice sheets. Second, it provides an assessment of the biophysical and socio-economic impacts of climate change, with regard to risks to unique and threatened systems, risks associated with extreme weather events, the distribution of impacts, aggregate impacts, and risks of large-scale, high-impact events. Third, it provides an assessment of the potential for achieving a broad range of levels of greenhouse gas concentrations in the atmosphere through mitigation, and information about how adaptation can reduce vulnerability. Q1.3-6

An integrated view of climate change considers the dynamics of the complete cycle of interlinked causes and effects across all sectors concerned (see Figure SPM-1). The TAR provides new policy-relevant information and evidence with regard to all quadrants of Figure SPM-1. A major new contribution of the *Special Report on Emissions Scenarios* (SRES) was to explore alternative development paths and related greenhouse gas emissions, and the TAR assessed preliminary work on the linkage between adaptation, mitigation, and development paths. However, the TAR does not achieve a fully integrated assessment of climate change because of the incomplete state of knowledge.

Q1.7

Climate change decision making is essentially a sequential process under general uncertainty. Decision making has to deal with uncertainties including the risk of non-linear and/or irreversible changes, entails balancing the risks of either insufficient or excessive action, and involves careful consideration of the consequences (both environmental and economic), their likelihood, and society's attitude towards risk.

Q1.8

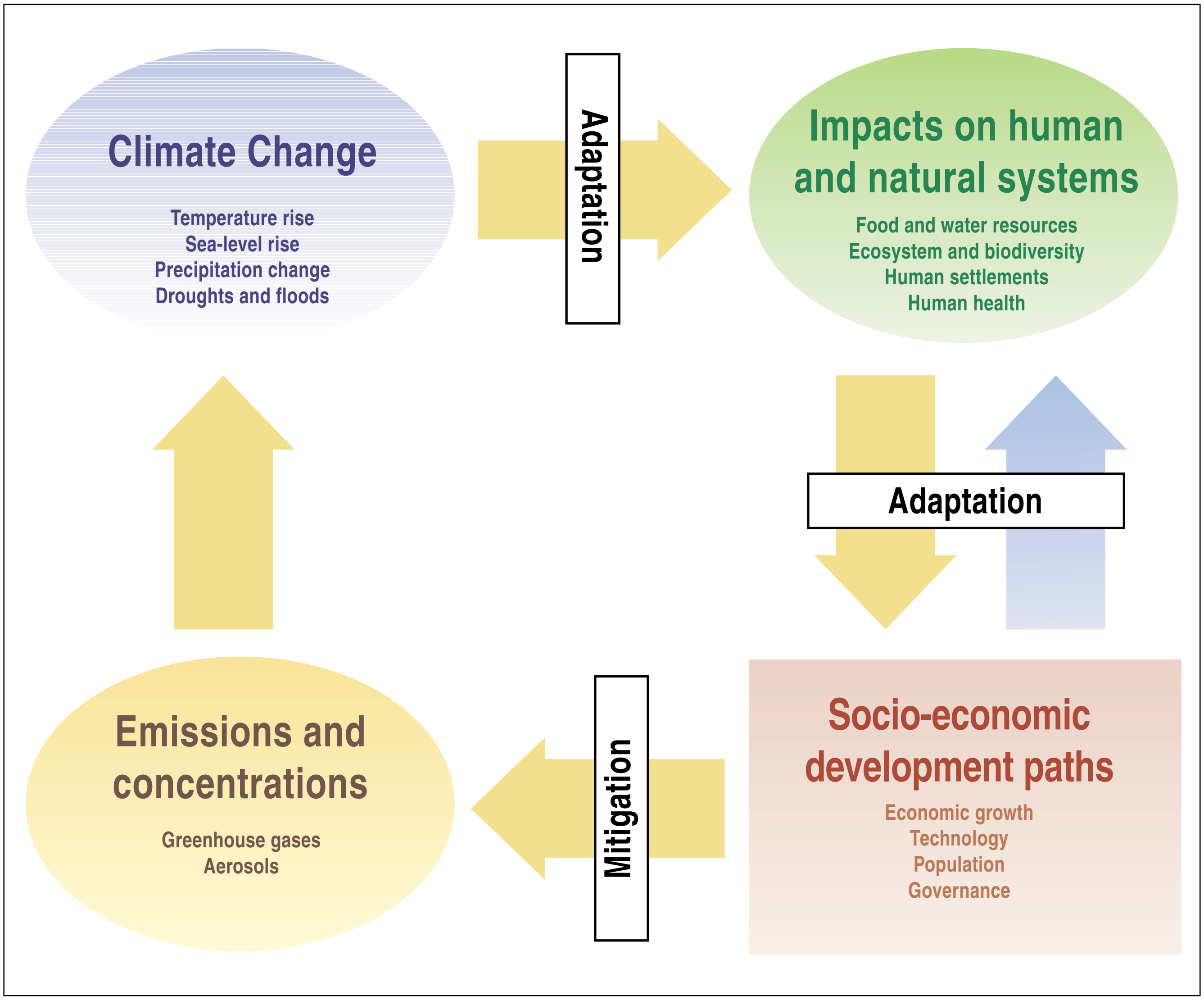

Figure SPM-1: Climate change – an integrated framework. Schematic and simplified representation of an integrated assessment framework for considering anthropogenic climate change. The yellow arrows show the cycle of cause and effect among the four quadrants shown in the figure, while the blue arrow indicates the societal response to climate change impacts. See the caption for Figure 1-1 for an expanded description of this framework.

Q1 Figure 1-1

The climate change issue is part of the larger challenge of sustainable development. As a result, climate policies can be more effective when consistently embedded within broader strategies designed to make national and regional development paths more sustainable. This occurs because the impact of climate variability and change, climate policy responses, and associated socio-economic development will affect the ability of countries to achieve sustainable development goals. Conversely, the pursuit of those goals will in turn affect the opportunities for, and success of, climate policies. In particular, the socio-economic and technological characteristics of different development paths will strongly affect emissions, the rate and magnitude of climate change, climate change impacts, the capability to adapt, and the capacity to mitigate.

Q1.9-10

The TAR assesses available information on the timing, opportunities, costs, benefits, and impacts of various mitigation and adaptation options. It indicates that there are opportunities for countries acting individually, and in cooperation with others, to reduce costs of mitigation and adaptation and to realize benefits associated with achieving sustainable development.

Q1.11

Question 2

Q2

What is the evidence for, causes of, and consequences of changes in the Earth's climate since the pre-industrial era?

(a) Has the Earth's climate changed since the pre-industrial era at the regional and/or global scale? If so, what part, if any, of the observed changes can be attributed to human influence and what part, if any, can be attributed to natural phenomena? What is the basis for that attribution?

(b) What is known about the environmental, social, and economic consequences of climate changes since the pre-industrial era with an emphasis on the last 50 years?

The Earth's climate system has demonstrably changed on both global and regional scales since the pre-industrial era, with some of these changes attributable to human activities.

Q2.2

Human activities have increased the atmospheric concentrations of greenhouse gases and aerosols since the pre-industrial era. The atmospheric concentrations of key anthropogenic greenhouse gases (i.e., carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and tropospheric ozone (O_3)) reached their highest recorded levels in the 1990s, primarily due to the combustion of fossil fuels, agriculture, and land-use changes (see Table SPM-1). The radiative forcing from anthropogenic greenhouse gases is positive with a small uncertainty range; that from the direct aerosol effects is negative and smaller; whereas the negative forcing from the indirect effects of aerosols on clouds might be large but is not well quantified.

Q2.4-5

An increasing body of observations gives a collective picture of a warming world and other changes in the climate system (see Table SPM-1).

Q2.6

Globally it is very likely that the 1990s was the warmest decade, and 1998 the warmest year, in the instrumental record (1861–2000) (see Box SPM-1). The increase in surface temperature over the 20th century for the Northern Hemisphere is likely to have been greater than that for any other century in the last thousand years (see Table SPM-1). Insufficient data are available prior to the year 1860 in the Southern Hemisphere to compare the recent warming with changes over the last 1,000 years. Temperature changes have not been uniform globally but have varied over regions and different parts of the lower atmosphere.

Q2.7

Table SPM-1 20th century changes in the Earth's atmosphere, climate, and biophysical system.[a]	
Indicator	***Observed Changes***
Concentration indicators	
Atmospheric concentration of CO_2	280 ppm for the period 1000–1750 to 368 ppm in year 2000 (31±4% increase).
Terrestrial biospheric CO_2 exchange	Cumulative source of about 30 Gt C between the years 1800 and 2000; but during the 1990s, a net sink of about 14±7 Gt C.
Atmospheric concentration of CH_4	700 ppb for the period 1000–1750 to 1,750 ppb in year 2000 (151±25% increase).
Atmospheric concentration of N_2O	270 ppb for the period 1000–1750 to 316 ppb in year 2000 (17±5% increase).
Tropospheric concentration of O_3	Increased by 35±15% from the years 1750 to 2000, varies with region.
Stratospheric concentration of O_3	Decreased over the years 1970 to 2000, varies with altitude and latitude.
Atmospheric concentrations of HFCs, PFCs, and SF_6	Increased globally over the last 50 years.
Weather indicators	
Global mean surface temperature	Increased by 0.6±0.2°C over the 20th century; land areas warmed more than the oceans (*very likely*).
Northern Hemisphere surface temperature	Increase over the 20th century greater than during any other century in the last 1,000 years; 1990s warmest decade of the millennium (*likely*).
Diurnal surface temperature range	Decreased over the years 1950 to 2000 over land: nighttime minimum temperatures increased at twice the rate of daytime maximum temperatures (*likely*).
Hot days / heat index	Increased (*likely*).
Cold / frost days	Decreased for nearly all land areas during the 20th century (*very likely*).
Continental precipitation	Increased by 5–10% over the 20th century in the Northern Hemisphere (*very likely*), although decreased in some regions (e.g., north and west Africa and parts of the Mediterranean).
Heavy precipitation events	Increased at mid- and high northern latitudes (*likely*).
Frequency and severity of drought	Increased summer drying and associated incidence of drought in a few areas (*likely*). In some regions, such as parts of Asia and Africa, the frequency and intensity of droughts have been observed to increase in recent decades.

Box SPM-1 Confidence and likelihood statements.

Where appropriate, the authors of the Third Assessment Report assigned confidence levels that represent their collective judgment in the validity of a conclusion based on observational evidence, modeling results, and theory that they have examined. The following words have been used throughout the text of the Synthesis Report to the TAR relating to WGI findings: *virtually certain* (greater than 99% chance that a result is true); *very likely* (90–99% chance); *likely* (66–90% chance); *medium likelihood* (33–66% chance); *unlikely* (10–33% chance); *very unlikely* (1–10% chance); and *exceptionally unlikely* (less than 1% chance). An explicit uncertainty range (±) is a *likely* range. Estimates of confidence relating to WGII findings are: *very high* (95% or greater), *high* (67–95%), *medium* (33–67%), *low* (5–33%), and *very low* (5% or less). No confidence levels were assigned in WGIII.

Q2 Box 2-1

Q2.9-11

There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities. Detection and attribution studies consistently find evidence for an anthropogenic signal in the climate record of the last 35 to 50 years. These studies include uncertainties in forcing due to anthropogenic sulfate aerosols and natural factors (volcanoes and solar irradiance), but do not account for the effects of other types of anthropogenic aerosols and land-use changes. The sulfate and natural forcings are negative over this period and cannot explain the warming; whereas most of these studies find that, over the last 50 years, the estimated rate and magnitude of warming due to increasing greenhouse gases alone

Table SPM-1	20th century changes in the Earth's atmosphere, climate, and biophysical system.[a] (continued)
Indicator	***Observed Changes***
Biological and physical indicators	
Global mean sea level	Increased at an average annual rate of 1 to 2 mm during the 20th century.
Duration of ice cover of rivers and lakes	Decreased by about 2 weeks over the 20th century in mid- and high latitudes of the Northern Hemisphere (*very likely*).
Arctic sea-ice extent and thickness	Thinned by 40% in recent decades in late summer to early autumn (*likely*) and decreased in extent by 10–15% since the 1950s in spring and summer.
Non-polar glaciers	Widespread retreat during the 20th century.
Snow cover	Decreased in area by 10% since global observations became available from satellites in the 1960s (*very likely*).
Permafrost	Thawed, warmed, and degraded in parts of the polar, sub-polar, and mountainous regions.
El Niño events	Became more frequent, persistent, and intense during the last 20 to 30 years compared to the previous 100 years.
Growing season	Lengthened by about 1 to 4 days per decade during the last 40 years in the Northern Hemisphere, especially at higher latitudes.
Plant and animal ranges	Shifted poleward and up in elevation for plants, insects, birds, and fish.
Breeding, flowering, and migration	Earlier plant flowering, earlier bird arrival, earlier dates of breeding season, and earlier emergence of insects in the Northern Hemisphere.
Coral reef bleaching	Increased frequency, especially during El Niño events.
Economic indicators	
Weather-related economic losses	Global inflation-adjusted losses rose an order of magnitude over the last 40 years (see Q2 Figure 2-7). Part of the observed upward trend is linked to socio-economic factors and part is linked to climatic factors.

[a] This table provides examples of key observed changes and is not an exhaustive list. It includes both changes attributable to anthropogenic climate change and those that may be caused by natural variations or anthropogenic climate change. Confidence levels are reported where they are explicitly assessed by the relevant Working Group. An identical table in the Synthesis Report contains cross-references to the WGI and WGII reports.

are comparable with, or larger than, the observed warming. The best agreement between model simulations and observations over the last 140 years has been found when all the above anthropogenic and natural forcing factors are combined, as shown in Figure SPM-2.

Changes in sea level, snow cover, ice extent, and precipitation are consistent with a warming climate near the Earth's surface. Examples of these include a more active hydrological cycle with more heavy precipitation events and shifts in precipitation, widespread retreat of non-polar glaciers, increases in sea level and ocean-heat content, and decreases in snow cover and sea-ice extent and thickness (see Table SPM-1). For instance, it is very likely that the 20th century warming has contributed significantly to the observed sea-level rise, through thermal expansion of seawater and widespread loss of land ice. Within present uncertainties, observations and models are both consistent with a lack of significant acceleration of sea-level rise during the 20th century. There are no demonstrated changes in overall Antarctic sea-ice extent from the years 1978 to 2000. In addition, there are conflicting analyses and insufficient data to assess changes in intensities of tropical and extra-tropical cyclones and severe local storm activity in the mid-latitudes. Some of the observed changes are regional and some may be due to internal climate variations, natural forcings, or regional human activities rather than attributed solely to global human influence.

Q2.12-19

Observed changes in regional climate have affected many physical and biological systems, and there are preliminary indications that social and economic systems have been affected.

Q2.20 & Q2.25

Comparison between modeled and observations of temperature rise since the year 1860

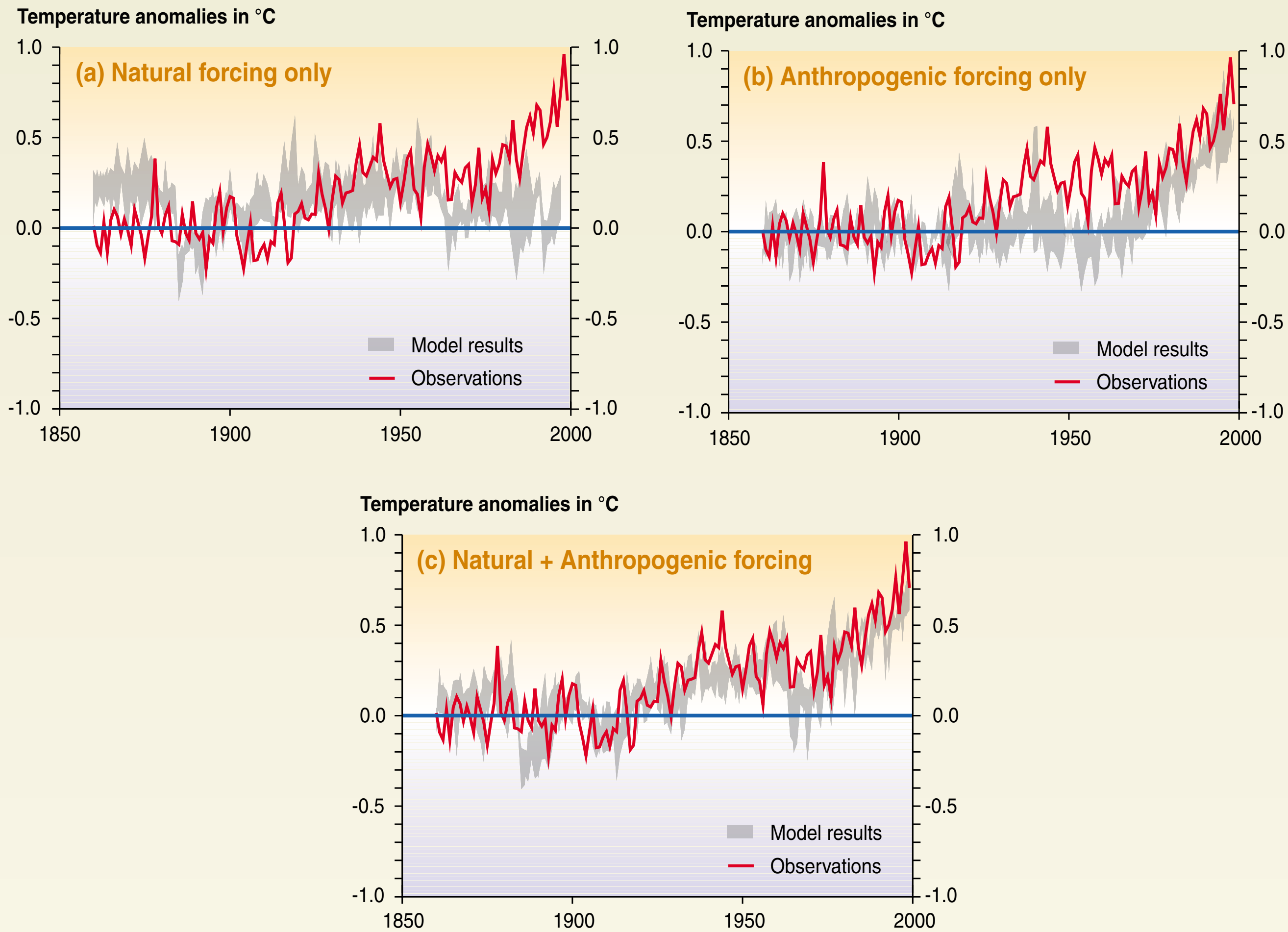

Figure SPM-2: Simulating the Earth's temperature variations (°C) and comparing the results to the measured changes can provide insight to the underlying causes of the major changes. A climate model can be used to simulate the temperature changes that occur from both natural and anthropogenic causes. The simulations represented by the band in (a) were done with only natural forcings: solar variation and volcanic activity. Those encompassed by the band in (b) were done with anthropogenic forcings: greenhouse gases and an estimate of sulfate aerosols. And those encompassed by the band in (c) were done with both natural and anthropogenic forcings included. From (b), it can be seen that the inclusion of anthropogenic forcings provides a plausible explanation for a substantial part of the observed temperature changes over the past century, but the best match with observations is obtained in (c) when both natural and anthropogenic factors are included. These results show that the forcings included are sufficient to explain the observed changes, but do not exclude the possibility that other forcings may also have contributed.

Q2 Figure 2-4

Recent regional changes in climate, particularly increases in temperature, have already affected hydrological systems and terrestrial and marine ecosystems in many parts of the world (see Table SPM-1). The observed changes in these systems[1] are coherent across diverse localities and/or regions and are consistent in direction with the expected effects of regional changes in temperature. The probability that the observed changes in the expected direction (with no reference to magnitude) could occur by chance alone is negligible.

Q2.21-24

[1] There are 44 regional studies of over 400 plants and animals, which varied in length from about 20 to 50 years, mainly from North America, Europe, and the southern polar region. There are 16 regional studies covering about 100 physical processes over most regions of the world, which varied in length from about 20 to 150 years.

The rising socio-economic costs related to weather damage and to regional variations in climate suggest increasing vulnerability to climate change. Preliminary indications suggest that some social and economic systems have been affected by recent increases in floods and droughts, with increases in economic losses for catastrophic weather events. However, because these systems are also affected by changes in socio-economic factors such as demographic shifts and land-use changes, quantifying the relative impact of climate change (either anthropogenic or natural) and socio-economic factors is difficult.

Q2.25-26

Question 3

Q3

What is known about the regional and global climatic, environmental, and socio-economic consequences in the next 25, 50, and 100 years associated with a range of greenhouse gas emissions arising from scenarios used in the TAR (projections which involve no climate policy intervention)?

To the extent possible evaluate the:

- Projected changes in atmospheric concentrations, climate, and sea level
- Impacts and economic costs and benefits of changes in climate and atmospheric composition on human health, diversity and productivity of ecological systems, and socio-economic sectors (particularly agriculture and water)
- The range of options for adaptation, including the costs, benefits, and challenges
- Development, sustainability, and equity issues associated with impacts and adaptation at a regional and global level.

Carbon dioxide concentrations, globally averaged surface temperature, and sea level are projected to increase under all IPCC emissions scenarios during the 21st century.[2]

Q3.2

For the six illustrative SRES emissions scenarios, the projected concentration of CO_2 in the year 2100 ranges from 540 to 970 ppm, compared to about 280 ppm in the pre-industrial era and about 368 ppm in the year 2000. The different socio-economic assumptions (demographic, social, economic, and technological) result in the different levels of future greenhouse gases and aerosols. Further uncertainties, especially regarding the persistence of the present removal processes (carbon sinks) and the magnitude of the climate feedback on the terrestrial biosphere, cause a variation of about –10 to +30% in the year 2100 concentration, around each scenario. Therefore, the total range is 490 to 1,250 ppm (75 to 350% above the year 1750 (pre-

Q3.3-5