INTERGOVERNMENTAL PANEL
ON CLIMATE CHANGE

EIGHTEENTH SESSION
Wembley, UK
24-29 September 2001

IPCC-XVIII/Doc. 3a
(5.VII.2001)

Agenda item: 3.1

DRAFT SYNTHESIS REPORT

Draft Summary for Policymakers

(Submitted by the Chairman)

The draft Summary for Policymakers (SPM) is submitted to the Session for approval.

CLIMATE CHANGE 2001: SYNTHESIS REPORT
SUMMARY FOR POLICYMAKERS

SYR Reference

QUESTION 1

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 provide essential evidence needed for decisions on what constitutes "dangerous anthropogenic interference with the climate system." However, in the end, decisions are value judgments determined through socio-political processes, taking issues like development, equity, and sustainability into account.

- 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 mitigative and adaptive capacity available to cope with climate change. At the same time, the climate change problem requires a collective global determination and actions. There is no universal 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 in particular regions.

- Q1.2

The Third Assessment Report (TAR) provides new scientific information and evidence for contributing to the 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 temperatures and precipitation, sea levels, and changes in extreme climate events. It also explains that possibilities exist 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 different 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 complex causes and effects across all sectors (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 their relationship to greenhouse gas emissions, and the TAR undertook 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

[FIGURE SPM-1 CAPTION: Schematic and simplified representation of an integrated assessment framework for considering anthropogenic climate change. The arrows show a cycle of cause and effect among the four quadrants shown in the figure.]

- 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 climate impacts, 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.

- Q1.8-9

The TAR assesses certain aspects of 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.

- Q1.10

QUESTION 2

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 as of year 2000 during 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, whereas the potentially large and negative forcing from the indirect effects of aerosols on clouds is very uncertain.

- Q2.4-5

[Insert Table SPM-1 here]

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 temperatures 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 to assess such changes in the Southern Hemisphere.

- Q2.7

[**Box SPM-1: Confidence and Likelihood Statements.** The following words have been used throughout the text of the Synthesis Report to the TAR where appropriate to indicate judgmental estimates of the likelihood probability from WG1: *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); *exceptionally unlikely* (less than 1% chance). An explicit uncertainty range (±) is a *likely* range. Judgmental estimates of confidence in a result are taken from WG2: very high (95% or greater), high (67–95%), medium (33–67%), low (5–33%), and very low (5% or less).]

There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities (see Figure SPM-2). Detection and attribution studies consistently find evidence for an anthropogenic signal in the climate record of the last 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 studies find that the modeled rate and magnitude of warming due to increasing greenhouse gases are comparable to observations.

- Q2.9-11

[FIGURE SPM-2 CAPTION: Temperature anomalies (°C) from an ensemble of climate model simulations (gray band) are compared with observations (red line) for the period of instrumental record (1860–2000). Model simulations in the left panel with only natural forcings (solar output variations and volcanic activity) can explain part of the rise in the first half of the 20th century but not the rise in the last half. Adding the anthropogenic forcing from greenhouse gases and sulfate aerosols to the natural forcing in the right panel can now explain the rapid rise in temperature over the last half of the 20th century.]

- Q2 Figure 2-4

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). There are, however, no demonstrated changes in overall Antarctic sea-ice extent from 1975 to 2000, and there are insufficient data or conflicting analyses 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 are difficult to attribute to the global human influence rather than to internal climate variations, natural forcings, or regional human activities.

- Q2.12-20

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

- Q2.18-19, 2.21, & 2.27

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 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 could occur by chance alone is negligible.

- Q2.22-26

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 apparent 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.

- 2.27-29

QUESTION 3

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.

- Q3.2

For the six illustrative SRES scenarios, the projected concentration of CO_2 in 2100 ranges from 540 to 970 ppm, compared to 280 ppm in the pre-industrial era and about 368 ppm in 2000. Uncertainties, especially regarding the persistence of the present sink processes and the magnitude of the climate feedback from the terrestrial biosphere, cause a variation of about -10 to +30% in the 2100 concentration, around each scenario. Therefore, the total range is 490 to 1260 ppm (75 to 350% above the 1750 concentration). Concentrations of the primary non-CO_2 greenhouse gases by year 2100 are projected to vary considerably across the six illustrative SRES scenarios (see Figure SPM-3).

- Q3.3-6

[FIGURE SPM-3 CAPTION: The different socio-economic assumptions underlying the SRES scenarios result in different levels of emissions of greenhouse gases and aerosols. The SRES scenarios do not include additional climate initiatives and no probabilities are assigned. These emissions in turn change the concentration of these gases and aerosols in the atmosphere, leading to changed radiative forcing of the climate system.]

- Q3 Figure 3-1

Projections using the SRES emissions scenarios in a range of climate models result in an increase in globally averaged surface temperature of 1.4 to 5.8°C over the period 1990 to 2100, about two to ten times larger than the central value of observed warming over the 20th century. Temperature increases are projected to be greater than those in the SAR, which were about 1.0 to 3.5°C based on six IS92 scenarios. The higher projected temperatures and the wider range are due primarily to lower projected sulfur dioxide (SO_2) emissions in the SRES scenarios relative to the IS92 scenarios. For the periods 1990 to 2025 and 1990 to 2050, the projected increases are 0.4 to 1.1°C and 0.8 to 2.6°C, respectively. By 2100, the range in the surface temperature response across different climate models for the same emissions scenario is comparable to the range across different SRES emissions scenarios for a single climate model. Figures SPM-3 and SPM-4 show that the SRES scenarios with the highest emissions result in the largest projected temperature increases. The projected rate of warming is very likely to be without precedent during at least the last 10,000 years. Nearly all land areas will very likely warm more than these global averages, particularly those at northern high latitudes in winter.

- Q3.7-8 & 3.12

[FIGURE SPM-4 CAPTION: Radiative forcing due to the SRES scenarios results in projected increases in temperature and sea level, which in turn will cause impacts. Because the SRES

- Q3 Figure

scenarios had only been available for a very short time prior to production of the TAR, the impacts assessments here use climate model results which tend to be based on equilibrium climate change scenarios (e.g., $2xCO_2$), a relatively small number of 1% per year CO_2 increase transient scenarios, or the scenarios used in the SAR (i.e., the IS92 series). Impacts in turn can affect socio-economic development paths through, for example, adaptation and mitigation.]	3-2
Globally averaged precipitation is projected to increase, though at regional scales both increases and decreases are projected of typically 5 to 20%. It is likely that precipitation will increase in both summer and winter over high-latitude regions. In winter, increases are also projected over northern 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.	• Q3.9 & 3.13
Glaciers are projected to continue their widespread retreat during the 21st century. Northern Hemisphere snow cover, permafrost, and sea-ice extent are projected to decrease further.	• Q3.15
Global mean sea level is projected to rise by 0.09 to 0.88 m between 1990 and 2100, for the full range of SRES scenarios. This rise is due primarily to thermal expansion of the oceans and melting of glaciers and ice caps. For the periods 1990 to 2025 and 1990 to 2050, the projected rises are 0.03 to 0.14 m and 0.05 to 0.32 m, respectively.	• Q3.10 & 3.14
Projected climate change will have beneficial and adverse effects on both environmental and socio-economic systems, but the larger the changes in climate the more the adverse effects predominate.	• Q3.16
The severity of the adverse impacts will be larger for greater cumulative emissions of greenhouse gases and associated changes in climate. The risk of adverse effects relative to beneficial effects increases with increasing rate of change and absolute amount of change. Adverse effects are projected to predominate for much of the world, particularly in the tropics and sub-tropics where most developing countries are located.	• Q3.17
Overall, climate change is projected to affect human health adversely, particularly in lower income populations of tropical and subtropical countries. Climate change can affect human health directly (e.g., increased heat stress but reduced cold stress, loss of life in floods and storms) and indirectly through disease vectors (e.g., mosquitoes), water-borne pathogens, water quality, air quality, and food availability and quality. The health impacts will depend on the range of social, institutional, technological and behavioral adaptations taken to reduce the full range of threats to health.	• Q3.18
Ecological productivity will be altered and biodiversity reduced by climate change and sea-level rise, with an increased risk of extinction of some vulnerable species. Significant disruptions of ecosystems from disturbances such as fire, drought, pest infestation, invasion of exotic species, storms and coral bleaching events are expected to increase. The stresses caused by climate change, when added to other stresses on ecological systems, threaten substantial damage to or complete loss of some unique systems and extinction of some endangered species. The effect of increasing CO_2 concentrations will increase net primary productivity of plants, but climate change, and the changes in disturbance regimes associated with them, may lead to either increased or decreased net ecosystem productivity. Global models of the uptake of carbon by terrestrial ecosystems project that uptake will increase during the first half of the 21st century but level off or decline as climate change increases.	• Q3.19-21
Models of cereal crops indicate that in temperate areas yields increase with small increases in temperature but decrease with larger temperature changes. In most tropical and subtropical regions, yields are projected to decrease for almost any increase in temperature. Where there is also a large decrease in rainfall in subtropical and tropical dryland/rainfed systems, crop yields	• Q3.22

would be even more adversely affected. These estimates include some adaptive responses by farmers and the beneficial effects of CO_2 fertilization, but not the impact of projected increases in pest infestations and changes in climate extremes. The ability of livestock producers to adapt their herds to the physiological stresses associated with climate change is poorly known. Warming of more than a few degrees Celsius (2 to 3°C) is projected to increase food prices globally, and may increase the risk of hunger in vulnerable populations.

Climate change will exacerbate water shortage in many water-stressed countries. Climate change is projected to substantially reduce available water in many of the water-stressed areas of the world (e.g., in central Asia, southern Africa, and countries around the Mediterranean Sea), but to increase it in some other areas.

- Q3.23

The aggregated market sector effects, measured as changes in gross domestic product (GDP), are estimated to be negative for most developing countries for all magnitudes of warming studied, mixed for developed countries up to a few degrees Celsius warming and negative for warming beyond a few degrees. The estimates generally exclude the effects of changes in climate variability and extremes, do not account for the effects of different rates of change, only partially account for impacts on goods and services that are not traded in markets, and treat gains for some as canceling out losses for others.

- Q3.26

Populations that inhabit small islands and/or low-lying coasts are at particular risk of severe social and economic effects. Many human settlements will face increased risk of flooding, and tens of millions of people living in deltas, low-lying coastal areas, and on small islands will face risk of displacement by sea-level rise. Resources critical to island and coastal populations such as freshwater, fisheries, coral reefs and atolls, and wildlife habitat would also be at risk.

- Q3.24

Adaptation can partially offset adverse effects of climate change and can often produce immediate benefits.

- Q3.27

Numerous possible adaptation options for responding to climate change have been identified that can reduce the adverse and enhance the beneficial impacts of climate change. Quantitative evaluation of their benefits and costs and how they vary across regions and entities is incomplete, but available estimates indicate that they are highly sensitive to decision criteria for the selection and timing of specific adaptation measures.

- Q3.28

Scenarios of greater and more rapid climate change poses greater challenges for adaptation and greater risks of damages than do scenarios of lesser and slower change. Systems and communities have evolved capabilities to cope with a range of climate variability within which the risks of damage are relatively low and ability to recover is high. However, changes in climate that result in increased frequency of events that fall outside the historic range with which systems have coped, increase the risk of severe damages and incomplete recovery or collapse of the system.

- Q3.29

The impacts of climate change are likely to fall disproportionately upon the poorest countries and the poorest persons within countries, and thereby exacerbate inequities in health status and access to adequate food, clean water, and other resources. Populations in developing countries are generally exposed to relatively high risks of adverse impacts from climate change. In addition, poverty and other factors create conditions of low adaptive capacity in most developing countries.

- Q3.34

QUESTION 4

What is known about the influence of the increasing atmospheric concentrations of greenhouse gases and aerosols, and the projected human-induced change in climate regionally and globally on:

a. The frequency and magnitude of climate fluctuations, including daily, seasonal, inter-annual, and decadal variability, such as the El Niño Southern Oscillation cycles and others?
b. The duration, location, frequency, and intensity of extreme events such as heat waves, droughts, floods, heavy precipitation, avalanches, storms, tornadoes, and tropical cyclones?
c. The risk of abrupt/non-linear changes in, among others, the sources and sinks of greenhouse gases, ocean circulation, and the extent of polar ice and permafrost? If so, can the risk be quantified?
d. The risk of abrupt or non-linear changes in ecological systems?

An increase in climate variability and some extreme events is projected with the possibility of abrupt or non-linear changes in the climate system and some ecosystems. • Q4.3-4

Models project that increasing atmospheric concentrations of greenhouse gases will result in additional changes in temperature and precipitation, with more hot days, heat waves, heavy precipitation events, and fewer cold days. This would lead to the risk of more floods and droughts in many regions, and adverse impacts on ecological systems, socio-economic sectors, and human health (see Table SPM-2 for details). The majority of models project a more El Niño-like condition in the tropical Pacific. High-resolution modeling studies suggest that peak wind and precipitation intensity of tropical cyclones may increase. There is insufficient information on how small-scale extreme weather phenomena (e.g., hailstorms, tornadoes) may change. • Q4.3-7

[Insert Table SPM-2 here]

The risk of high impact abrupt or other non-linear changes in biophysical systems exist. Some of these changes have low probability of occurrence during the 21st century but may occur over a long time frame, and could be irreversible over centuries to millennia. There is a large degree of uncertainty about the mechanisms involved in the changes. Examples of changes include: • Q4.9-10

- Large climate-induced changes in vegetation may be possible and could induce further climate change through increased emissions of CO_2 from plants and soil, and changes in surface properties. • Q4.11-20
- Most models project a weakening of the thermohaline circulation of the oceans resulting in a reduction of the heat transport into high latitudes of Europe, but none show an abrupt shutdown by the end of the 21st century. However, beyond 2100, there is some evidence to suggest that the thermohaline circulation could completely, and possibly irreversibly, shut down in either hemisphere if the change in radiative forcing is large enough and applied long enough. • Q4.13
- The Antarctic ice sheet is likely to increase in mass slightly during the 21st century, but after sustained warming could lose significant mass and contribute several meters to the projected sea-level rise over the next 1000 years. Concerns have been expressed about the stability of the west Antarctic ice sheet because it is grounded below sea level. However, loss of grounded ice leading to substantial sea-level rise from this source is widely agreed to be unlikely during the 21st century. • Q4.14
- In contrast to the Antarctic ice sheet, the Greenland ice sheet is likely to lose mass during the 21st century, contributing a few centimeters to sea-level rise, but similar to the Antarctic ice sheet, with a sustained localized warming of greater than 3°C over the next 1000 years, it could contribute several meters to sea-level rise. • Q4.15

- Continued warming would increase melting of permafrost in the polar regions and would make much of this terrain vulnerable to subsidence and lead to landslides which could affect infrastructure.

- Q4.16

Abrupt changes in climate could have adverse impacts on many ecosystems, which would affect their function, biodiversity, and productivity. Examples include:

- Changes in disturbance regimes and shifts in the location of suitable climatically defined habitats may lead to abrupt breakdown of ecosystems with significant changes in composition and function, increased risk of extinctions and potential loss of biodiversity.
- Sustained increases in water temperatures of as little as 1.0°C, alone or in combination with any of several stresses (e.g., excessive pollution and siltation), can lead to corals ejecting their algae (coral bleaching) and the eventual death of some corals.
- Rice yield depends on the interactions of non-linear responses to CO_2, water, and temperature. Grain yield falls by about 10% for every degree above 26°C during the flowering and pollination process. The outcome at any location could be initially increased production but with a rapid decline as thresholds are exceeded.

- Q4.18-19

QUESTION 5

What is known about the inertia and time scales associated with the changes in the climate system, ecological systems, and socio-economic sectors and their interactions?

Inertia is widespread in the interacting climate, ecological, and human systems. Thus some impacts of anthropogenic climate change may be slow to become apparent, and some could become irreversible if climate change is not limited in good time.

- Q5.1-3 5.12, & 5.14

Climate and Ecological Systems

Stabilization of CO_2 emissions at near-current levels does not lead to stabilization of CO_2 atmospheric concentration, but to a continuous increase for at least the next millennium. Large emission reductions are eventually needed to achieve stabilization of atmospheric CO_2 concentration at any level. To avoid exceeding atmospheric concentrations of 450, 650, or 1000 ppm, global CO_2 emissions would need to fall below the year 1990 level within decades, about a century, and about two centuries, respectively. There is little inertia for short-lived greenhouse gases such as CH_4, and stabilization of their emissions leads within decades to stabilization of their atmospheric concentrations.

- Q5.2 & 5.4

Surface air temperature is projected to continue to rise by a few tenths of a degree per century for a century or more after stabilization of the atmospheric concentration of CO_2, while sea level is projected to continue to rise for many centuries (see Figure SPM-5). The slow transport of heat into the oceans and ice bodies means that long periods are required to reach a new climate system equilibrium.

- Q5.3

[FIGURE SPM-5 CAPTION: Time scales of response to reductions in CO_2 emissions by parts of the climate system. After CO_2 emissions are reduced and atmospheric concentrations stabilize, surface air temperature continues to rise slowly for a few centuries. Thermal expansion of the ocean continues long after CO_2 emissions have been reduced, and melting of ice sheets continues to contribute to sea-level rise for several millennia. Stabilization at any level between 450 and 1000 ppm shows broadly similar time courses, but the amplitude of change becomes progressively larger. The curves illustrated are based on stabilization of atmospheric CO_2 at 550 ppm, while the given

- Q5 Figure 5-2

time ranges are for stabilization from 450 to 1000 ppm. When emissions are reduced sooner, the time scales of response will be shorter and magnitudes of change are less.]

Some plausible changes in the climate system would be irreversible over many human generations. For example, major melting of the ice sheets and changes in the ocean circulation pattern would be effectively irreversible. While not likely in the 21st century, they are possible thereafter, especially if the warming is sustained over many centuries in the case of ice sheets and rapid in the case of ocean circulation. The threshold for changes in the ocean circulation may be reached at a lower degree of warming if the warming is rapid rather than gradual.

- Q5.3 & 5.12-14

Some ecosystems show the effects of climate change quickly, while others do so more slowly. For example, coral bleaching can occur in a single exceptionally warm season, while trees may be able to persist for decades under a changed climate, but not regenerate. When subjected to climate change, including changes in the frequency of extreme events, ecosystems may be disrupted as a consequence of differences in response times of species.

- Q5.6 & Q3 Table 3-2

The global terrestrial carbon sink is projected to peak during the 21st century, then level off or decline. The global net uptake of CO_2 by terrestrial ecosystems is partly a result of the delays between plant growth, death, and decay, and partly due to fertilization by CO_2 and nitrogen and changes in climate and land-use practices.

- Q5.5

<u>Socio-Economic Systems</u>

Unlike the biophysical system, inertia in human systems is not fixed; it can be reduced by policies and the choices made by individuals. Social structures and personal values interact with physical infrastructure, institutions, and technologies. The combined system generally evolves relatively slowly. It can respond quickly under pressure, although sometimes at high cost (e.g., if capital equipment is prematurely retired). There is typically a delay of years to decades between perceiving a need, researching and developing a solution, and implementing it. Anticipatory action, based on informed judgment, can improve the chance that appropriate technology is available when needed.

- Q5.8-10

The development and adoption of new technologies can be accelerated by technology transfer and supportive fiscal and research policies. Technology replacement can be delayed by “locked-in” systems that have market advantages arising from existing institutions, services, infrastructure, and available resources.

- Q5.8

Inertia in the socio-economic and biophysical systems has implications for strategies to avoid “dangerous interference in the climate system.” A safety margin is appropriate to take into account:

- The time lags between adoption of mitigation goals and their achievement
- The inertia of the climate system, which will cause climate change to continue for a period after mitigation action is implemented.

- Q5.15-18 & 5.20

Inertia in the Earth system makes a degree of adaptation already inevitable, and increases the urgency of mitigation. Hedging strategies and sequential decisionmaking may be appropriate in the presence of inertia and uncertainty. Important differences exist between optimal strategies for mitigation (a global issue) and adaptation (primarily a local issue).

- Q5.20

QUESTION 6

a) How does the extent and timing of the introduction of a range of emissions reduction actions determine and affect the rate, magnitude, and impacts of climate change, and affect the global and regional economy, taking into account the historical and current emissions?

b) What is known from sensitivity studies about regional and global climatic, environmental, and socio-economic consequences of stabilizing the atmospheric concentrations of greenhouse gases (in carbon dioxide equivalents), at a range of levels from today's to double that level or more, taking into account to the extent possible the effects of aerosols? For each stabilization scenario, including different pathways to stabilization, evaluate the range of costs and benefits, relative to the range of scenarios considered in Question 3, in terms of:

- **Projected changes in atmospheric concentrations, climate, and sea level, including changes beyond 100 years**
- **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**
- **The range of technologies, policies, and practices that could be used to achieve each of the stabilization levels, with an evaluation of the national and global costs and benefits, and an assessment of how these costs and benefits would compare, either qualitatively or quantitatively, to the avoided environmental harm that would be achieved by the emissions reductions**
- **Development, sustainability, and equity issues associated with impacts, adaptation, and mitigation at a regional and global level.**

The rate and magnitude of warming and sea-level rise can be lessened by reducing greenhouse gas emissions. • Q6.2

Slowing warming and sea-level rise will be larger the deeper are the reductions in greenhouse gas emissions and the earlier that reductions are introduced. Differences in projected temperature changes between scenarios that include greenhouse gas emission reductions and those that do not tend to be small for the first few decades but grow with time if the reductions are sustained. • Q6.3

To stabilize the atmospheric concentration of CO_2 at a level from 450 to 1000 ppm, global emissions can initially continue to increase from present levels, but eventually growth must be halted and emissions substantially reduced below current levels. Estimates of emissions that would stabilize CO_2 concentration at 450, 650, and 1000 ppm peak within, respectively, 1 to 2 decades, 3 to 4 decades, and roughly a century. From those time periods, stabilization would require CO_2 emissions to decline and eventually, after many centuries, reach and be sustained at the level of persistent natural sinks, which is a very small fraction of current emissions. • Q6.4

There is a wide band of uncertainty in the amount of warming that would result from any stabilized greenhouse gas concentration. Figure SPM-6 shows eventual CO_2 stabilization levels and the corresponding range of temperature change estimated to be realized in 2100 and at long-run equilibrium. Because of a factor of three uncertainty in the climate sensitivity, there is a wide range of temperature changes estimated for each stabilization level. • Q6.5

[FIGURE SPM-6 CAPTION: Stabilizing CO_2 concentrations would lessen warming but by an uncertain amount. Temperature changes in (a) 2100 and (b) at long-run equilibrium are estimated using a simple climate model for the WRE scenarios, which eventually would stabilize atmospheric CO_2 concentrations at levels ranging from 450 to 1000 ppm, and assuming that emissions of gases other than CO_2 follow the SRES A1B projection until 2100 and are constant thereafter. The low and high estimates for each stabilization level assume a climate sensitivity of 1.7 and 4.2°C, respectively. The center line is an average of the low and high estimates.]

- Q6 Figure 6-2

Emission reductions that would eventually stabilize the atmospheric concentration of CO_2 at a level below 1000 ppm are estimated to limit global mean temperature increase to 3.5°C or less through the year 2100. Global average surface temperature is estimated to increase 1.2 to 3.5°C by 2100 for scenarios that eventually stabilize the concentration of CO_2 at levels from 450 to 1000 ppm. Thus, all of the CO_2 stabilization scenarios analyzed would avoid much of the upper end of the SRES projections of warming of 1.4 to 5.8°C by 2100.

- Q6.6

Sea level and ice sheets would continue to respond to warming for many centuries after greenhouse gas concentrations have been stabilized. The projected range of sea-level rise due to thermal expansion at equilibrium is 0.5 to 2 m for a doubling (~560 pm) and 1 to 4 m for a quadrupling (~1120 ppm) of pre-industrial CO_2 concentrations. For sustained stabilization of CO_2 concentration above 560 ppm, estimates from ice sheet models indicate that the Greenland ice sheet could melt completely and add substantially to sea-level rise, potentially up to 7 m over thousands of years.

- Q6.9

Reducing emissions of greenhouse gases to stabilize their atmospheric concentrations would delay and reduce damages caused by climate change.

- Q6.10

Benefits of limiting greenhouse gas emissions are determined, in part, by the socio-economic development pathway, the stringency of the emission limits, and the sensitivity of the climate system to changes in greenhouse gas concentrations. By slowing the rate of accumulation of greenhouse gases in the atmosphere, and thereby slowing the rate of increase in global mean temperature and sea level, the pressures on natural and human systems from climate change would build more slowly and allow more time for adaptation. This is expected to yield environmental and socio-economic benefits. The more stringent the stabilization target, the greater are the avoided risks and the greater are the expected benefits.

- Q6.11

Adaptation is a necessary strategy at all scales to complement climate change mitigation efforts; together they can contribute to sustainable development objectives and reduce inequities.

- Q6.13 & 6.16

Adaptation can complement mitigation in a cost-effective strategy to reduce climate change risks. Reductions of greenhouse gas emissions, even stabilization of their concentrations in the atmosphere, will neither altogether prevent climate change, sea-level rise, nor their impacts. As a result, many reactive adaptations will occur in response to the changing climate and rising seas. In addition, the development of planned adaptation strategies to address risks and utilize opportunities can complement mitigation actions to lessen climate change impacts. However, adaptation would entail costs and cannot prevent all damages. The costs of adaptation can be lessened by mitigation of climate change that would reduce and slow the climate changes to which systems would be exposed.

- Q6.14-15

Mitigation and adaptation actions can contribute to sustainable development objectives, reduce inequities between poor and wealthier regions, and promote intergenerational equity. Mitigation and adaptation actions can, if appropriately designed, improve the prospects for sustainable development. Reducing the projected increase in climate extremes is expected to particularly benefit developing countries, which are considered to be more vulnerable to climate change than developed

- Q6.17-19

countries. Mitigating climate change would also lessen the risks to future generations from the actions of the present generation.

QUESTION 7

What is known about the potential for, and costs and benefits of, and time frame for reducing greenhouse gas emissions?

- **What would be the economic and social costs and benefits and equity implications of options for policies and measures, and the mechanisms of the Kyoto Protocol, that might be considered to address climate change regionally and globally?**
- **What portfolios of options of research and development, investments, and other policies might be considered that would be most effective to enhance the development and deployment of technologies that address climate change?**
- **What kind of economic and other policy options might be considered to remove existing and potential barriers and to stimulate private- and public-sector technology transfer and deployment among countries, and what effect might these have on projected emissions?**
- **How does the timing of the options contained in the above affect associated economic costs and benefits, and the atmospheric concentrations of greenhouse gases over the next century and beyond?**

There are many technological options to reduce near-term emissions, but barriers to their deployment exist. • Q7.3

Significant technical progress relevant to the potential for greenhouse gas emission reductions has been made since the SAR in 1995, and has been faster than anticipated. Net emissions reductions could be achieved through a portfolio of technologies (e.g., more efficient conversion of energy, shift to low- or no-greenhouse gas emitting technologies, carbon removal and storage, and improved land use, land-use change, and forestry practices). Advances are taking place in a wide range of technologies at different stages of development, ranging from the market introduction of wind turbines and the rapid elimination of industrial by-product gases, to the advancement of fuel cell technology and the demonstration of underground CO_2 storage. • Q7.4

The successful implementation of greenhouse gas mitigation options would need to overcome technical, economic, political, cultural, social, behavioral, and/or institutional barriers that prevent the full exploitation of the technological, economic, and social opportunities of these options. The potential mitigation opportunities and types of barriers vary by region and sector, and over time. In developed countries, future opportunities lie primarily in removing social and behavioral barriers; in countries with economies in transition, in price rationalization; and in developing countries, in price rationalization, increased access to data and information, availability of advanced technologies, financial resources, and training and capacity building. Opportunities for any given country, however, might be found in the removal of any combination of barriers. • Q7.7

National responses to climate change can be more effective if deployed as a portfolio of policy instruments to limit or reduce greenhouse gas emissions. The portfolio may include—according to national circumstances—emissions/carbon/energy taxes, tradable or non-tradable permits, provision and/or removal of subsidies, deposit/refund systems, technology or performance standards, product bans, voluntary agreements, government spending and investment, information campaigns, environmental labeling, and support for research and development. • Q7.8

Studies examined in the TAR suggest substantial opportunities for lowering mitigation costs.

- Q7.16-17

An increasing scale of international cooperation lowers mitigation costs. Estimates of mitigation costs assessed in the TAR are converging between bottom-up engineering-oriented analyses under the hypothetical assumption of full world-wide implementation of all mitigation opportunities cited below, and top-down macroeconomic analyses under the hypothetical assumption of full global emissions trading. The lesson to be learned from these analyses is the greater the level of international collaboration, the greater the opportunities to lower mitigation costs.

- Q7.16 & 7.19

According to bottom-up studies, global emissions reductions of 1.9–2.6 Gt C_{eq}, and 3.6–5.0 Gt C_{eq} per year[1] could be achieved by 2010 and 2020, respectively, with half of the potential emissions reductions being achieved with direct benefits exceeding direct costs, and the other half at a net direct cost of up to US$100/t C_{eq} (at 1998 prices). Depending on the emissions scenario, this could allow global emissions to be reduced below 2000 levels in 2010–2020 at these net direct costs. However, the realized potential may be different. These cost estimates are derived using discount rates in the range of 5 to 12%, consistent with public-sector discount rates. Private internal rates of return vary greatly, and are often significantly higher, affecting the rate of adoption of these technologies by private entities. In addition, these assessments do not take into account additional implementation costs, which in some cases may be substantial. (7.16)

- Q7.16

[FOOTNOTE 1: The emissions reduction estimates are most compatible with baseline emissions trends in the SRES B2 scenario.]

Forests, agricultural lands, and other terrestrial ecosystems offer significant carbon mitigation potential. Conservation and sequestration of carbon, although not necessarily permanent, may allow time for other options to be further developed and implemented. The potential of biological mitigation options is on the order of 100 Gt C (cumulative) by 2050, equivalent to about 10 to 20% of projected fossil-fuel emissions during that period, although there are substantial uncertainties associated with this estimate. Cost estimates using bottom-up analyses reported to date for biological mitigation vary significantly from US$0.1/t C to about US$20/t C in several tropical countries and from US$20/t C to US$100/t C in non-tropical countries. The cost calculations do not cover, in many instances, implementation costs.

- Q7.17 & Q7 Box 7-1

Models of the global economy show that the Kyoto mechanisms could reduce costs to Annex II countries.[2] Global modeling studies show national marginal costs to meet the Kyoto targets range from about US$20/t C up to US$600/t C without trading, and from about US$15/t C up to US$150/t C with Annex B trading.[3] In the absence of Annex B trading, losses range from 0.2 to 2% of GDP.[4] With Annex B trading, losses range from 0.1 to 1% of GDP. Reasons for the range of results both within and across regions is due in large part to varying assumptions about future GDP growth rates, carbon intensity, and energy intensity. The cost reductions from Annex B trading may depend on the details of implementation, including the compatibility of domestic and international mechanisms, constraints on emissions trading, and transaction costs.

- Q7.19

[FOOTNOTE 2: The global economic modeling studies cited here are from an Energy Modeling Forum model comparison of the costs of complying with the Kyoto Protocol. They evaluated only reductions in CO_2. In contrast, the estimates cited from the bottom-up analyses above included all greenhouse gases.]

[FOOTNOTE 3: In the hypothetical case of full global emissions trading, marginal cost estimates drop to US$5–90/t C, similar to the positive marginal cost estimates for potential emissions reductions from the bottom-up studies quoted above.]

[FOOTNOTE 4: GDP is an oft used but incomplete measure of welfare.]

Emission constraints on Annex I countries have well-established, albeit varied, "spillover" effects[5] on non-Annex I countries. Analyses report reductions in both projected GDP and in projected oil revenues for oil-exporting, non-Annex I countries. Other non-Annex I countries may be adversely affected by reductions in demand for their exports to OECD nations and by the price increase of those carbon-intensive and other products they continue to import. These countries may benefit from the reduction in fuel prices, increased exports of carbon-intensive products, and the transfer of environmentally sound technologies and know-how. The possible relocation of some carbon-intensive industries to non-Annex I countries and wider impacts on trade flows in response to changing prices may lead to carbon leakage on the order of 5-20%.

- Q7.20

[FOOTNOTE 5: Spillover effects incorporate only economic effects, not environmental effects.]

A great deal of uncertainty surrounds both the bottom-up and top-down cost estimates reported. No analysis incorporates all relevant factors. The inclusion of multiple greenhouse gases, sinks, ancillary benefits, efficient tax revenue recycling, induced technical change, international emissions trading, Clean Development Mechanism (CDM) and Joint Implementation (JI) can lower costs. On the other hand, limitations on the use of domestic and international market mechanisms, inclusion of ancillary costs, and ineffective tax recycling measures can have a counter effect.

- Q7 Box 7-1

Technology development and diffusion are important components of cost-effective stabilization.

- Q7.10

Development and transfer of environmentally sound technologies could play a critical role in reducing the cost of stabilizing greenhouse gas concentrations. Transfer of technologies between countries and regions could widen the choice of options at the regional level. Economies of scale and learning will lower the costs of their adoption. Governments through sound economic policy and regulatory frameworks, transparency, and political stability could create an enabling environment for private- and public-sector technology transfers. Adequate human and organizational capacity is essential at every stage to increase the flow, and improve the quality, of technologies. In addition, networking among private and public stakeholders, and focusing on products and techniques with multiple ancillary benefits, that meet or adapt to local needs and priorities, is essential for most effective technology transfers.

- Q7.10-13 & 7.25

Lower emissions scenarios require different patterns of energy resource development and an increase in energy research and development to assist accelerating the development and deployment of advanced environmentally sound energy technologies. Changes will occur in the global energy mix during the 21st century irrespective of climate change, among other reasons because the carbon in proven conventional oil and gas reserves, or in conventional oil resources, is limited. The choice of energy mix and associated technologies and investments—either more in the direction of exploitation of unconventional oil and gas resources, or in the direction of non-fossil energy sources or fossil energy technology with carbon capture and storage—will determine whether, and if so, at what level and cost, greenhouse concentrations can be stabilized.

- Q7.29

Both the pathway to stabilization and the stabilization target itself are key determinants of mitigation costs.

- Q7.26-27

Stabilization levels depend more on cumulative emissions than on the emissions pathway. A gradual transition away from the world's present energy system towards a less carbon-emitting economy minimizes costs associated with premature retirement of existing capital stock and provides time for technology development, and avoids premature lock-in to early versions of rapidly developing low-emission technology. On the other hand, more rapid near-term action would decrease environmental and human risks and the associated costs with projected changes in climate,

- Q7.26

and may stimulate more rapid deployment of existing low-emission technologies and provide strong near-term incentives to future technological changes.

Studies show that the costs of stabilizing CO_2 concentrations in the atmosphere increase as the concentration stabilization level declines (see Figure SPM-7). Different baselines can have a strong influence on absolute costs. While there is a moderate increase in the costs when passing from a 750 to a 550 ppm concentration stabilization level, there is a larger increase in costs passing from 550 to 450 ppm unless the emissions in the baseline scenario are very low. In no case did the stabilization scenarios lead to significant declines in global GDP growth rates over this century. The losses, however, did vary across regions and time. These studies did not incorporate carbon sequestration or non-CO_2 gases and did not examine the possible effect of more ambitious targets on induced technological change.

- Q7.27

[FIGURE SPM-7 CAPTION: The mitigation costs (1990 US$, present value discounted at 5% per year for 1990–2100) of stabilizing CO_2 concentrations at 450–750 ppm are calculated using three global models. Ancillary benefits are not included. In each instance, costs were calculated based on two emission pathways for achieving the prescribed target: WGI/S and WRE. The bar chart shows cumulative carbon emissions between 1990 and 2100. Cumulative future emissions until carbon budget ceiling is reached. These cumulative emissions are reported above the bars in Gt C.]

- Q7 Figure 7-3

QUESTION 8

What is known about the interactions between projected human-induced changes in climate and other environmental issues (e.g., urban air pollution, regional acid deposition, loss of biological diversity, stratospheric ozone depletion, and desertification and land degradation)? What is known about environmental, social, and economic costs and benefits and implications of these interactions for integrating climate change response strategies in an equitable manner into broad sustainable development strategies at the local, regional, and global scales?

Local, regional, and global environmental issues are inextricably linked and affect sustainable development. Therefore, there are synergistic opportunities to develop more effective response options to these environmental issues that enhance benefits, reduce costs, and more sustainably meet human needs.

- Q8.1-2

Meeting human needs in many instances is causing environmental degradation, which in turn threatens the ability to meet present and future needs. For example, increased agricultural production can be achieved through increased use of nitrogenous fertilizers, irrigation, or the conversion of natural grasslands and forests to croplands. However, these changes can affect the Earth's climate through the release of greenhouse gases, lead to land degradation through erosion and salinization of soils, and contribute to the loss of biodiversity and reduction of carbon sequestration through the conversion and fragmentation of natural ecological systems. Agricultural productivity can in turn be adversely affected by changes in climate, especially in the tropics and sub-tropics, loss of biodiversity at the genetic and species level, and land degradation through loss of soil fertility. Many of these changes adversely affect food security and disproportionally impact the poor.

- Q8.3 & 8.15

The primary factors underlying anthropogenic climate change are similar to those for most environmental and socio-economic issues—that is, economic growth, broad technological changes, demographic shifts (population size, age structure, and migration), and governance structures. These give rise to:

- Increased demand for natural resources and energy

- Q8.4

- Market imperfections, including subsidies that lead to the inefficient use of resources and act as a barrier to the market penetration of environmentally friendly technologies; the lack of recognition of the true value of natural resources; failure to appropriate the global values of natural resources at the local level; and failure to internalize the costs of environmental degradation into the market price of a resource
- Inefficient use of technologies and inadequate investment in research and development for the technologies of the future
- Institutional failures to manage adequately the use of natural resources and energy.

Climate change affects environmental issues such as loss of biodiversity, desertification, stratospheric ozone depletion, freshwater availability, and local air quality, and in turn climate change is affected by many of these issues. For example, climate change is projected to exacerbate local and regional air pollution and delay the recovery of the stratospheric ozone layer. In addition, climate change could also affect the productivity and composition of terrestrial and aquatic ecological systems, with a potential loss in both genetic and species diversity; could accelerate the rate of land degradation; and could exacerbate problems related to freshwater quantity and quality in many areas. Indeed, natural climate variations have demonstrated the impacts of changes in climate on both natural and managed ecosystems. Conversely, local and regional air pollution, stratospheric ozone depletion, changes in ecological systems, and land degradation would affect the Earth’s climate by changing the sources and sinks of greenhouse gases, radiative balance of the atmosphere, and surface albedo.

- Q8.5-20

The linkages among local, regional, and global environmental issues, and their relationship to meeting human needs, offer opportunities to capture synergies in developing response options and reducing vulnerabilities to climate change. Multiple environmental and development goals can be achieved by adopting a broad range of technologies, policies, and measures that explicitly recognize the inextricable linkages among environmental problems and human needs. Addressing the need for energy, while reducing local and regional air pollution and global climate change cost-effectively, calls for an integrated assessment of the synergies and trade-offs of meeting energy requirements in the most environmentally and socially sustainable manner. Greenhouse gas emissions, as well as local and regional pollutants, could be reduced through more efficient use of energy and by substituting the combustion of fossil fuels by renewable energy technologies (e.g., increased use of environmentally and socially sound biofuels, hydropower, solar, wind- and wavepower). Further, such emissions can be mitigated also by enhanced sequestration of carbon through afforestation, reforestation, slowing deforestation, and improved forest, rangeland, and cropland management, which can have favorable effects on biodiversity, food production, land, and water resources. Reducing vulnerability to climate change can often reduce vulnerability to other environmental stresses and vice versa. Climate mitigation and adaptation options can yield ancillary benefits that meet human needs, improve well-being, and bring other environmental benefits, but in some cases there will be trade-offs. Countries with limited economic resources and low level of technology are often highly vulnerable to climate change and other environmental problems. The capacity of these countries to adapt and mitigate can be enhanced when climate policies are integrated with non-climate objectives of national policy development.

- Q8.21-27

A great deal of interaction exists among the environmental issues that Multilateral Environmental Agreements address, and synergies can be exploited in their implementation.

- Q8.28-29

QUESTION 9

What are the most robust findings and key uncertainties regarding attribution of climate change and regarding model projections of:

- **Future emissions of greenhouse gases and aerosols?**
- **Future concentrations of greenhouse gases and aerosols?**
- **Future changes in regional and global climate?**
- **Regional and global impacts of climate change?**
- **Costs and benefits of mitigation and adaptation options?**

A ***robust finding*** for climate change is defined as one that holds under a variety of approaches, methods, models, and assumptions and one that is expected to be relatively insensitive to uncertainties. ***Key uncertainties*** in this context are those that, if reduced, may lead to new and policy-relevant robust findings. In the examples in Table SPM-3, many of the robust findings relate to the *existence* of a climate response to human activities and the sign of the response. Many of the key uncertainties are concerned with the *quantification* of the magnitude and/or timing of the response. After addressing the attribution of climate change, the table deals in order with the issues illustrated in Figure SPM-1. Figure SPM-8 illustrates some of the main robust findings regarding the science of climate change.

- Q9.2-3

[Insert Table SPM-3 here]

[FIGURE SPM-8 CAPTION: (a) Atmospheric CO_2 concentration from 1000 to 2000 from ice core and firn data supplemented with data from direct atmospheric samples over the past few decades. From 2000 to 2100 are shown projections of CO_2 concentrations based on the six illustrative SRES scenarios and IS92a (for comparison with the SAR). (b) From 1000–1860 are shown variations in average surface temperature of the Northern Hemisphere (adequate data from the Southern Hemisphere not available) constructed from proxy data (tree rings, corals, ice cores, and historical records). The line shows the 50-yr average, the grey region the 95% confidence limit in the annual data. From 1860–2000 are shown variations in observations of globally and annually averaged surface temperature from the instrumental record; the line shows the decadal average. From 2000–2100 are shown projections of globally averaged surface temperature for the six illustrative SRES scenarios and IS92a as estimated by a model with average climate sensitivity. The grey region marked “several models all SRES envelope” shows the range of results from the full range of 35 SRES scenarios in addition to those from a range of models with different climate sensitivities.]

- Q9 Figures 9-2 & 9-3

Significant progress has been made in the TAR in many aspects of the knowledge required to understand climate change and the human response to it. However, there remain major gaps where further work is required, in particular in:

- The understanding and prediction of climate extremes
- The quantification of the damage from climate change impacts at the global, regional, and local levels
- The development of effective, efficient, and equitable adaptation and mitigation policies
- The integration of all aspects of the climate change issue into strategies for sustainable development.

- Q9.41

Table SPM-1: *20th century changes in the Earth's atmosphere, climate, and biophysical system.**

Indicator	**Observed Changes**
Atmospheric concentration of CO_2	280 ppm for 1000-1750 to 368 ppm in 2000 (31±4% increase)
Terrestrial biospheric CO_2 uptake	Cumulative source of about 30 GtC between 1800 and 2000; but during the 1990s, a net sink of about 14 GtC (consisting of large global uptake less emissions from deforestation)
Atmospheric concentration of CH_4	700 ppb for 1000-1750 to 1750 ppb in 2000 (150±25% increase)
Atmospheric concentration of N_2O	270 ppb for 1000-1750 to 316 ppb in 2000 (17±5% increase)
Tropospheric concentration of O_3	Increased by 35±15% from 1750 to 2000, varies with region
Stratospheric concentration of O_3	Decreased from 1970 to 2000, varies with altitude and latitude
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	Increased over the 20th century greater than during any other century in the last 1000 years; 1990s warmest decade of the millennium (likely)
Diurnal surface temperature range	Decreased from 1950 to 2000 over land: night-time minimum temperatures increased at twice the rate of day-time 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)
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 two 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	Wide-spread retreat during the 20th century
Snow cover	Decreased in area by 10% since 1960s (very likely)
Permafrost	Thawed, warmed and degraded in parts of the polar regions
El-Nino events	Became more frequent, persistent and intense during the last 20-30 years compared to the previous 100 years
Growing season	Lengthened by about 1-4 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, earlier emergence of insects in the Northern Hemisphere
Coral reef bleaching	Increased frequency, especially during El-Nino events
Weather-related economic losses	Global inflation-adjusted losses rose 14 fold over the last 40 years

* 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.

Table SPM-2: *Examples of climate variability and extreme climate events and examples of their impacts.*

Projected Changes during the 21st Century in Extreme Climate Phenomena and their Likelihood	**Representative Examples of Projected Impacts**[a] **(all high confidence of occurrence in some areas)**
Higher maximum temperatures, more hot days and heat waves[b] over nearly all land areas (*very likely*)	• Increased incidence of death and serious illness in older age groups and urban poor • Increased heat stress in livestock and wildlife • Shift in tourist destinations • Increased risk of damage to a number of crops • Increased electric cooling demand and reduced energy supply reliability
Higher (Increasing) minimum temperatures, fewer cold days, frost days and cold waves[b] over nearly all land areas (*very likely*)	• Decreased cold-related human morbidity and mortality • Decreased risk of damage to a number of crops, and increased risk to others • Extended range and activity of some pest and disease vectors • Reduced heating energy demand
More intense precipitation events (*very likely*, over many areas)	• Increased flood, landslide, avalanche, and mudslide damage • Increased soil erosion • Increased flood runoff could increase recharge of some floodplain aquifers • Increased pressure on government and private flood insurance systems and disaster relief
Increased summer drying over most mid-latitude continental interiors and associated risk of drought (*likely*)	• Decreased crop yields • Increased damage to building foundations caused by ground shrinkage • Decreased water resource quantity and quality • Increased risk of forest fire
Increase in tropical cyclone peak wind intensities, mean and peak precipitation intensities (*likely*, over some areas)[c]	• Increased risks to human life, risk of infectious disease epidemics and many other risks • Increased coastal erosion and damage to coastal buildings and infrastructure • Increased damage to coastal ecosystems such as coral reefs and mangroves
Intensified droughts and floods associated with El Niño events in many different regions (*likely*) (see also under droughts and intense precipitation events)	• Decreased agricultural and rangeland productivity in drought- and flood-prone regions • Decreased hydro-power potential in drought-prone regions
Increased Asian summer monsoon precipitation variability (likely)	• Increase in flood and drought magnitude and damages in temperate and tropical Asia
Increased intensity of mid-latitude storms (Little agreement between current models)[b]	• Increased risks to human life and health • Increased property and infrastructure losses • Increased damage to coastal ecosystems

[a] These impacts can be lessened by appropriate response measures.
[b] Information from WGI TAR Technical Summary (Section F.5).
[c] Changes in regional distribution of tropical cyclones are possible but have not been established.

Table SPM-3: *Robust findings and key uncertainties.*

ROBUST FINDINGS		KEY UNCERTAINTIES
Observations show Earth's surface is warming. Globally, 1990s very likely warmest decade in instrumental record (Figure SPM-8b). [Q9.8] Atmospheric concentrations of main anthropogenic greenhouse gases [CO_2 (Figure SPM-8a), CH_4, N_2O, and tropospheric O_3] increased substantially since 1750. [Q9.10] Most of observed warming over last 50 years likely due to increases in greenhouse gas concentrations due to human activities. [Q9.8]	**Climate change and attribution**	Magnitude and character of climate variability. [Q9.8] Climate forcings due to anthropogenic aerosols (particularly indirect effects). [Q9.8] Climate sensitivity, cloud and water vapor feedbacks. [Q9.8] Relating regional trends to anthropogenic climate change. [Q9.8 & 9.22]
CO_2 concentrations increasing over 21st century mainly due to fossil fuel emissions (Figure SPM-8a). [Q9.10] To stabilize atmospheric CO_2 concentrations at 450, 650, or 1000 ppm, emissions would have to peak within, respectively, 1 to 2 decades, 3 to 4 decades, and roughly a century. [Q9.30] Reduction in global SO_2 emissions (precursor for sulfate aerosols) by 2100 compared with 2000. [Q9.10]	**Future emissions and concentrations of greenhouse gases and aerosols based on projections with SRES scenarios**	Assumptions underlying wide range[a] of SRES emissions scenarios relating to economic growth, technological progress, population growth, and governance structures (lead to largest uncertainties in projections). Inadequate emission scenarios for ozone and aerosol precursors. [Q9.10] Factors in modeling of carbon cycle including effects of climate feedbacks.[a] [Q9.10]
Global average surface temperature during 21st century rising at rates very likely without precedent during last 10,000 years (Figure SPM-8b). [Q9.13] Land areas very likely to warm more than global average. [Q9.13] Significant rise in sea level during 21st century that will continue for further centuries. [Q9.15] Hydrological cycle more intense. Increase in globally averaged precipitation and more intense precipitation events very likely over many areas. [Q9.14] Increased summer drying and associated risk of drought likely over most mid-latitude continental interiors. [Q9.14]	**Future changes in global and regional climate based on model projections with SRES scenarios**	Assumptions associated with a wide range[b] of SRES scenarios, as above. [Q9.10] Factors associated with model projections[b], in particular feedback processes especially those involving water vapor, clouds, and aerosols (including aerosol indirect effects). [Q9.16] Limited capabilities of models on regional scales (especially regarding precipitation) leading to inconsistencies in model projections on local and regional scales. [Q9.16]

[a] Accounting for these above uncertainties leads to range of CO_2 concentrations in 2100 between about 490 and 1260 ppm.

[b] Accounting for these above uncertainties leads to range for surface temperature increase, 1990–2100, of 1.4 to 5.8 C (Figure SPM-8b) and of sea-level rise of 0.09 to 0.88 m.

Table SPM-3 (contimued)

ROBUST FINDINGS		KEY UNCERTAINTIES
Ecosystems and species are vulnerable to climate change (as illustrated by observed effects of recent regional climate changes) and some will be irreversibly damaged. For warming beyond a few °C, and because of changes in climate extremes, effects on food production, access to freshwater, and on human health expected to be adverse in most regions. Impacts of sea-level rise will be exacerbated by coastal storms especially for low-lying coastal areas and small islands. Developing countries are the most vulnerable.	**Regional and global impacts of climate change**	Reliability of local or regional detail in projections of climate, especially climate extremes. [Q9.22] Assessing and predicting response of ecological and socio-economic systems to the combined effect of climate change and other stresses such as land-use change, local pollution, etc. [Q9.22]
Adaptations to future climate conditions are inevitable. Those with the least resources have the least capacity to adapt and are the most vulnerable. Planned adaptation can diminish vulnerability to climate change impacts. [Q9.24] Mitigation costs can be substantially reduced and sometimes turned into net benefits through a portfolio of policy instruments (including those that help to overcome barriers). [Q9.34] Emissions trading reduces costs of mitigation. [Q9.35] Stabilization could be achieved with hardly noticeable effects on global GDP growth averaged over the 21st century. However, mitigation costs may be significant for particular sectors and countries over some periods. [Q9.36] Costs of stabilization tend to rise as stabilization levels are reduced. [Q9.36] Unplanned and unexpected policies (“quick fixes”) with sudden short-term effects may cost much more than planned and expected policies with gradual effects. [Q9.37] Near-term action in mitigation and adaptation would reduce risks. [Q9.38] Effectiveness of adaptation and mitigation increased and costs reduced if integrated with policies for sustainable development. [Q9.39] Development paths that meet sustainable development objectives may result in lower levels of greenhouse gas emissions. [Q9.40]	**Costs and benefits of adaptation and mitigation options.**	Lack of appropriate knowledge on the interactions between climate change and other environmental issues and the related socio-economic implications. [Q9.40] The price of energy, and the cost and availability of low-emissions technology. [Q9.32] How to overcome any barriers that impede adoption of cost-effective low-emission technologies, and the costs of overcoming such barriers. [Q9.34]

FIGURE SPM-1

SEE PAGE 1 LINES 50–52 FOR FIGURE CAPTION

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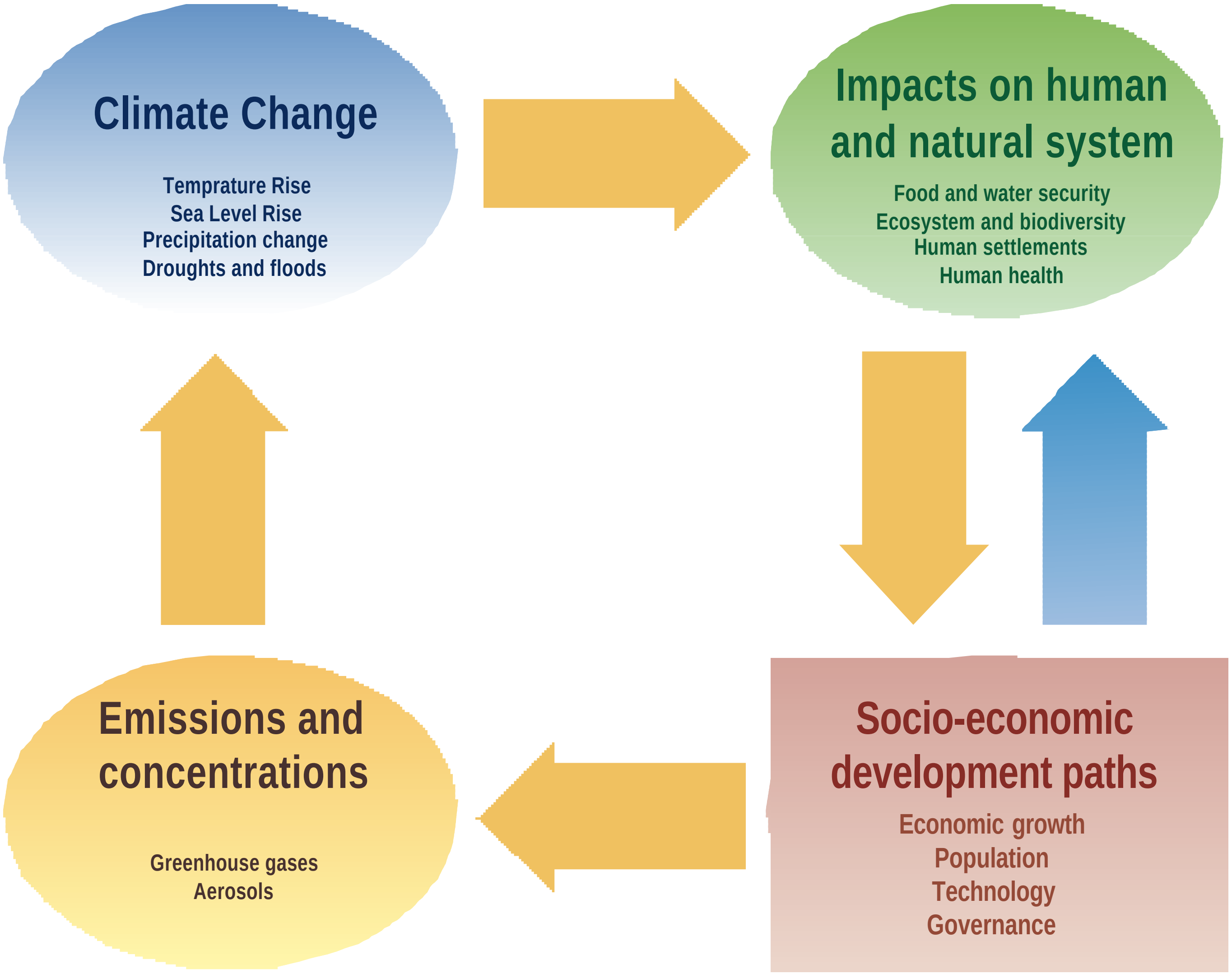

FIGURE SPM-2

SEE PAGE 3 LINES 13–19 FOR FIGURE CAPTION

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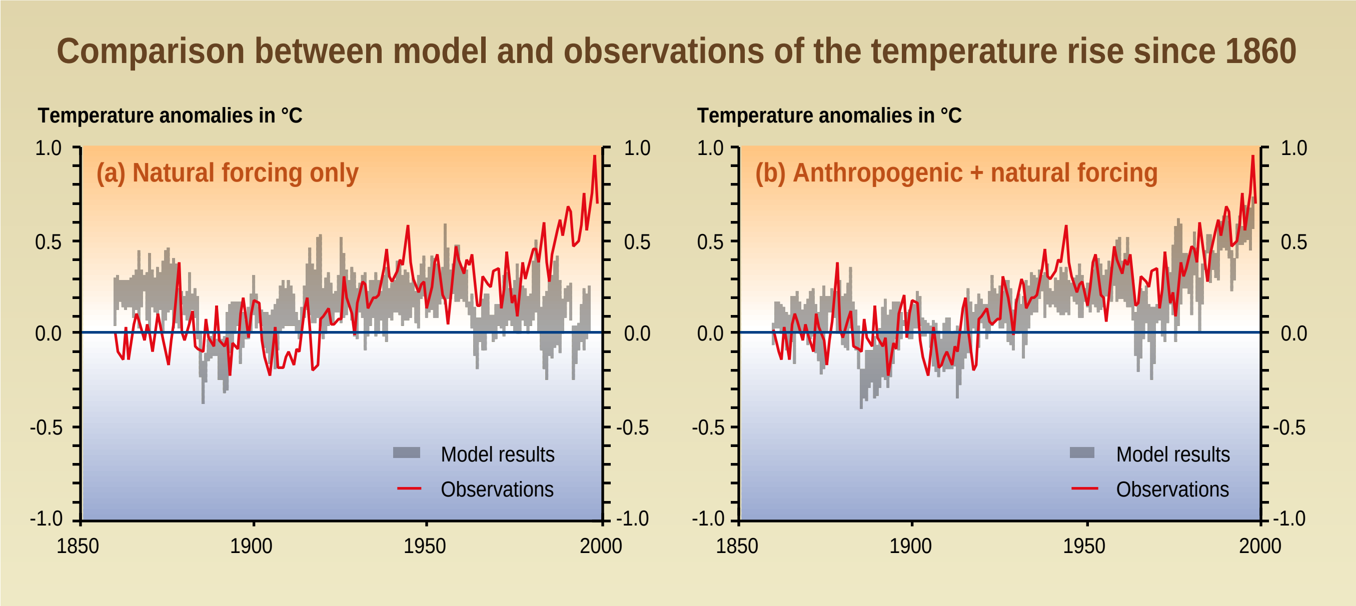

FIGURE SPM-3 (LEFT PANEL OF 2-PAGE SPREAD)

SEE PAGE 4 LINES 32–36 FOR FIGURE CAPTION

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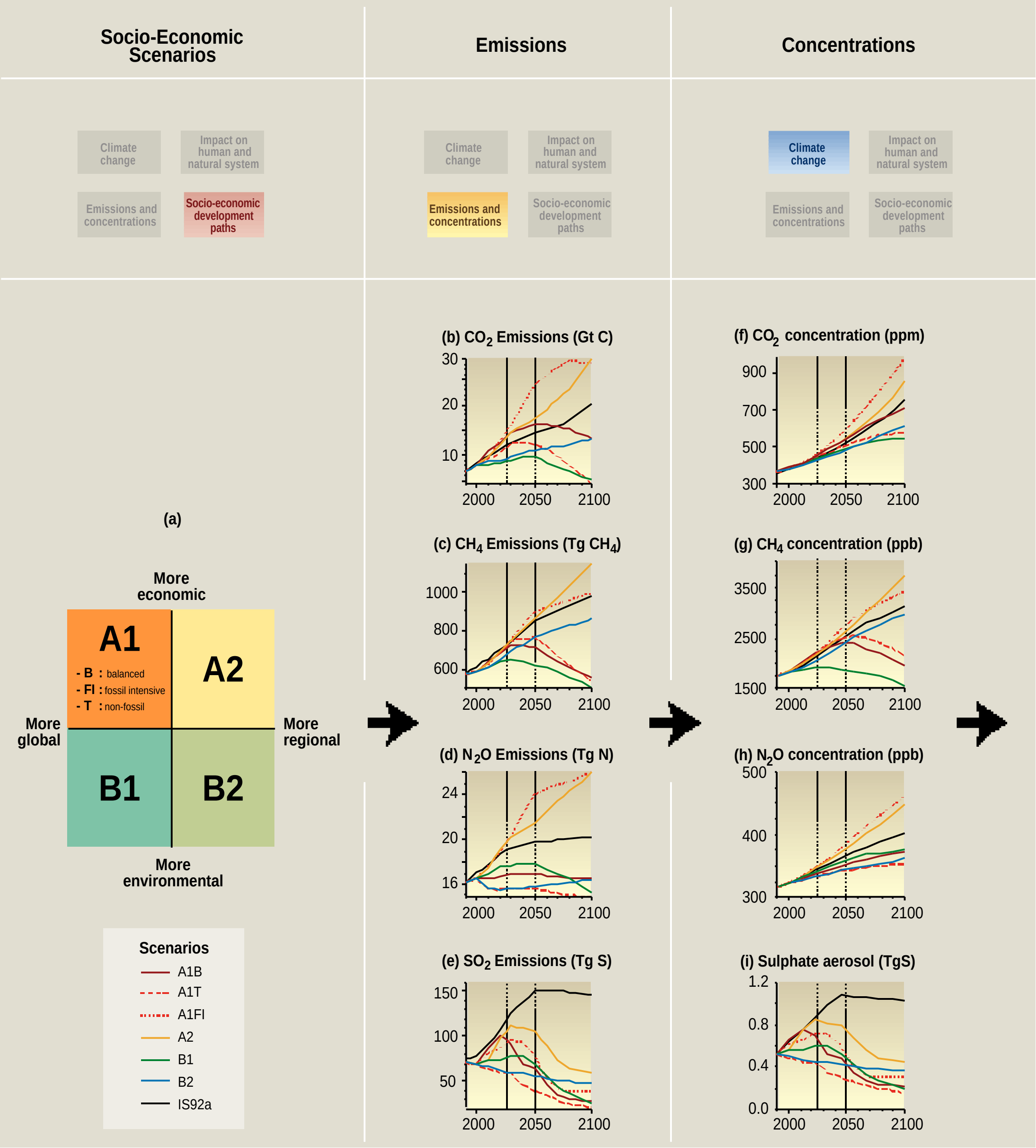

SCENARIOS

A1 FI, A1 T and A1 B

The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1 FI), non-fossil energy sources (A1 T), or a balance across all sources (A1 B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvment rates apply to all energy supply and end use technologies).

FIGURE SPM-4

SEE PAGE 4 LINE 53 – PAGE 5 LINE 5 FOR FIGURE CAPTION

Color version can be downloaded at <http://www.metoffice.com/sec5/CR_div/ipcc/wg1/drafts/>

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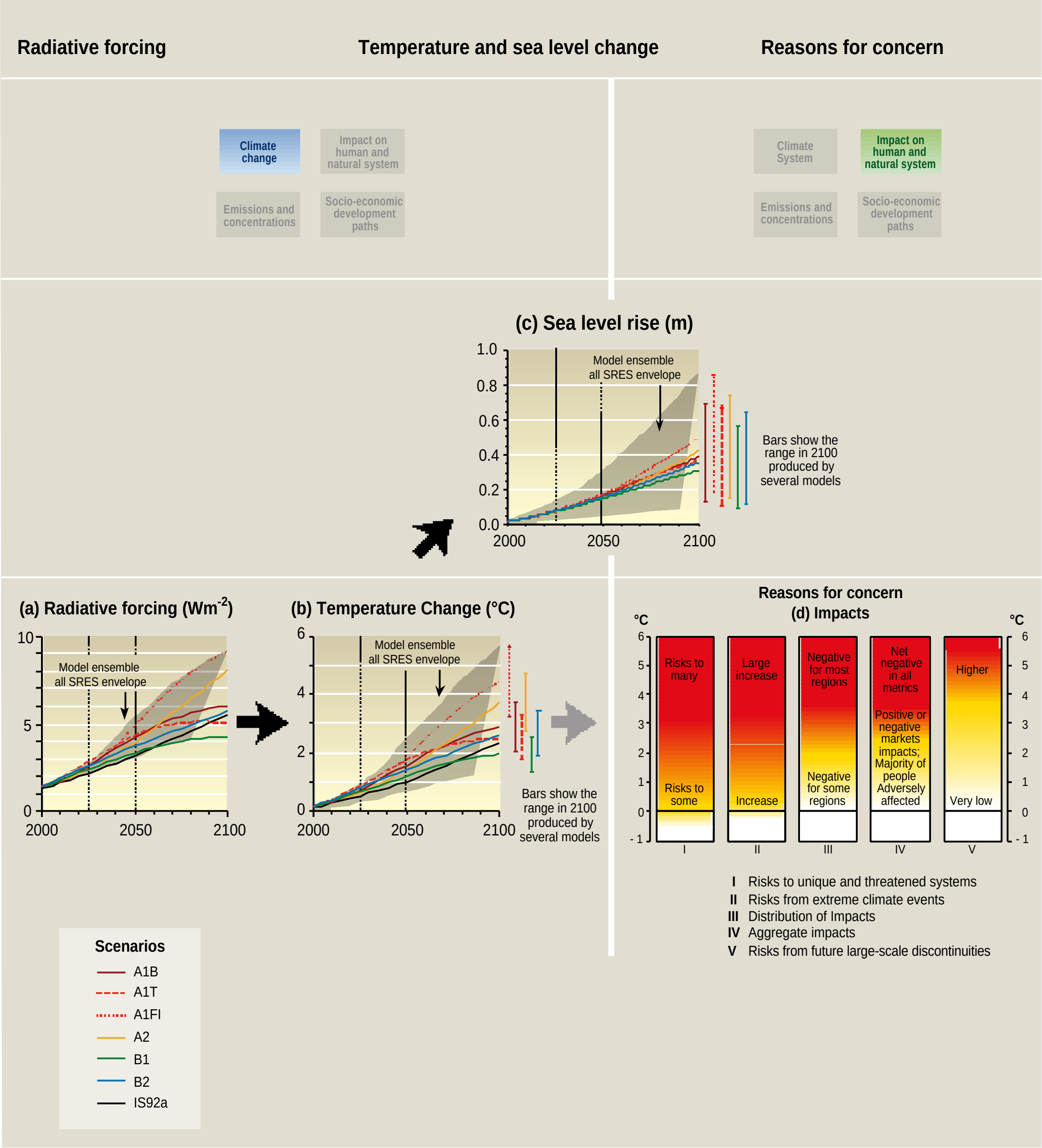

DECRIPTIONS

A2

The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1

The B1 storyline and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environment sustainability, including improved equity, but without additional climate initiatives.

B2

The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

FIGURE SPM-5

SEE PAGE 8 LINE 47 – PAGE 9 LINE 2 FOR FIGURE CAPTION

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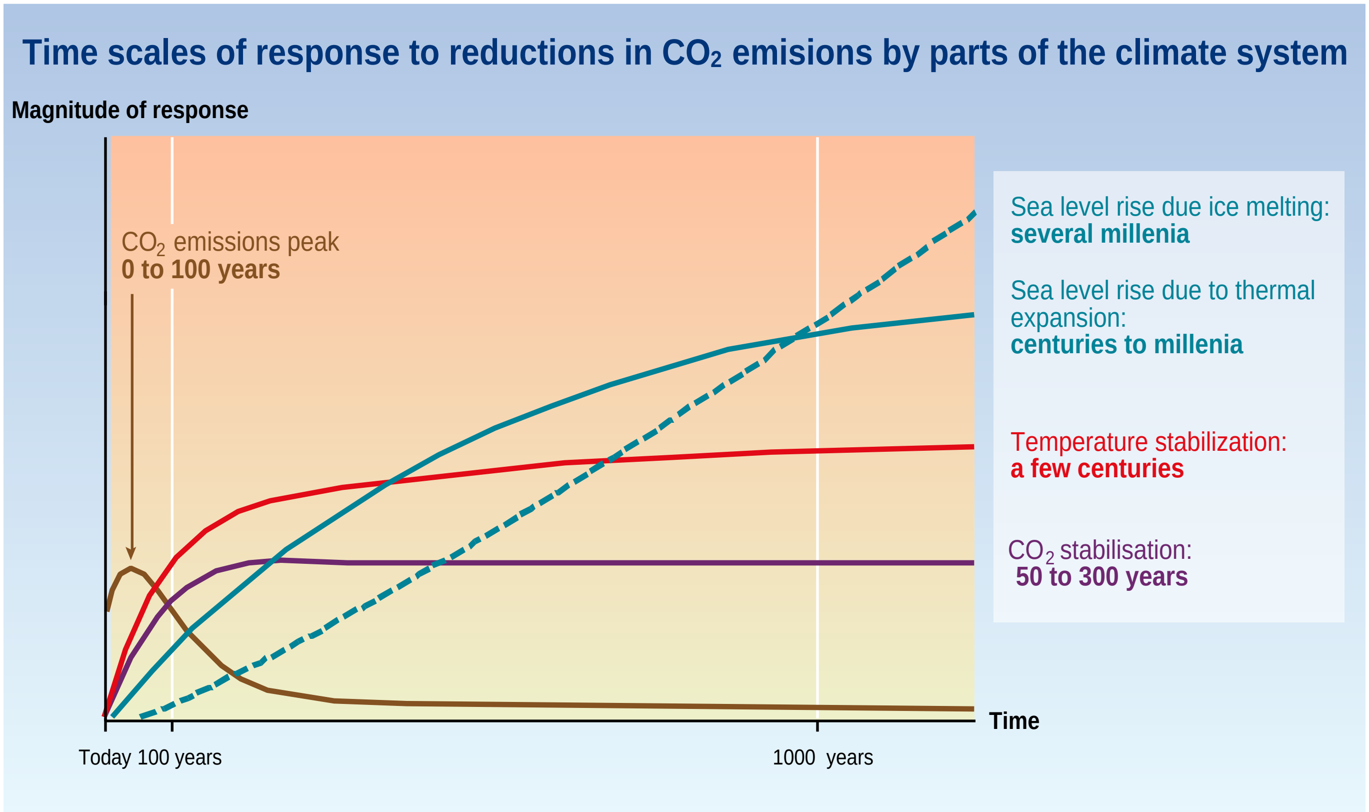

FIGURE SPM-6

SEE PAGE 11 LINES 2–8 FOR FIGURE CAPTION

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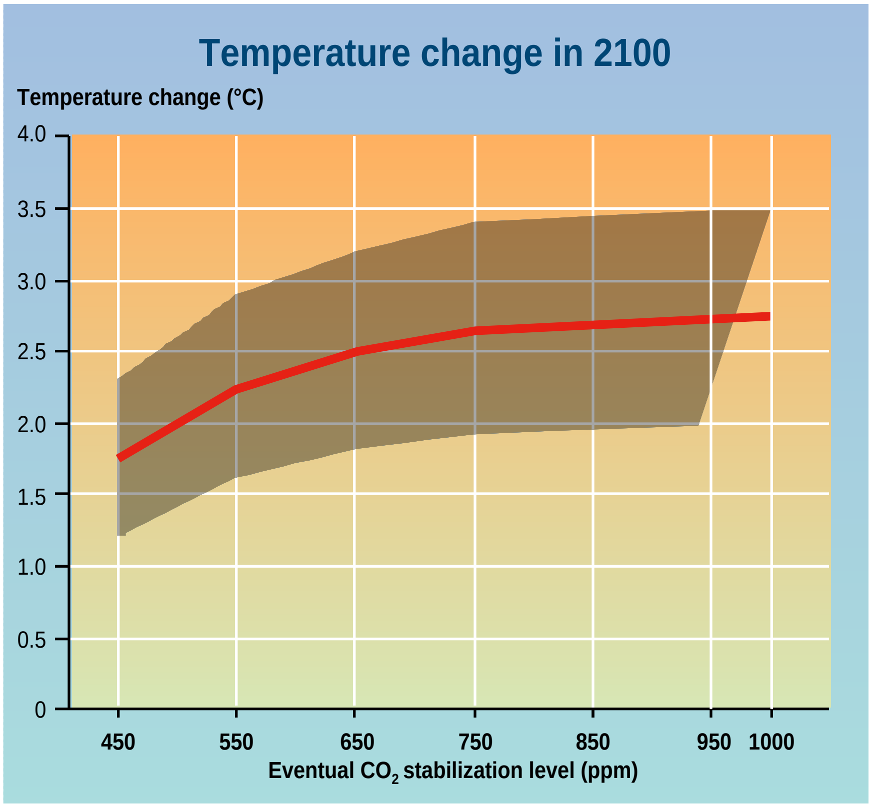

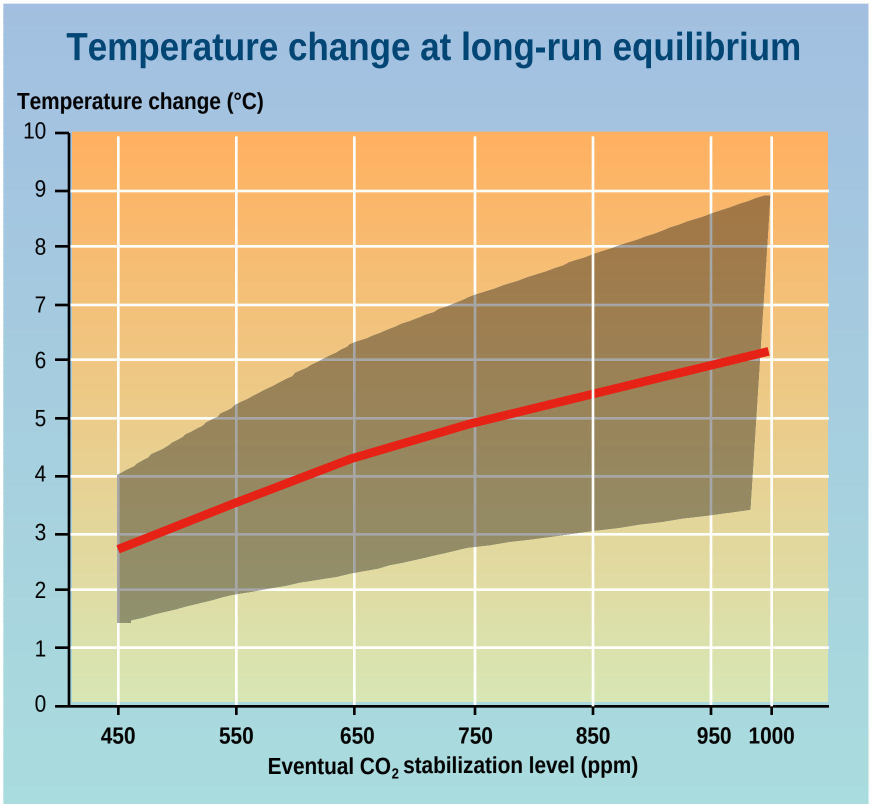

FIGURE SPM-7

SEE PAGE 15 LINES 14–19 FOR FIGURE CAPTION

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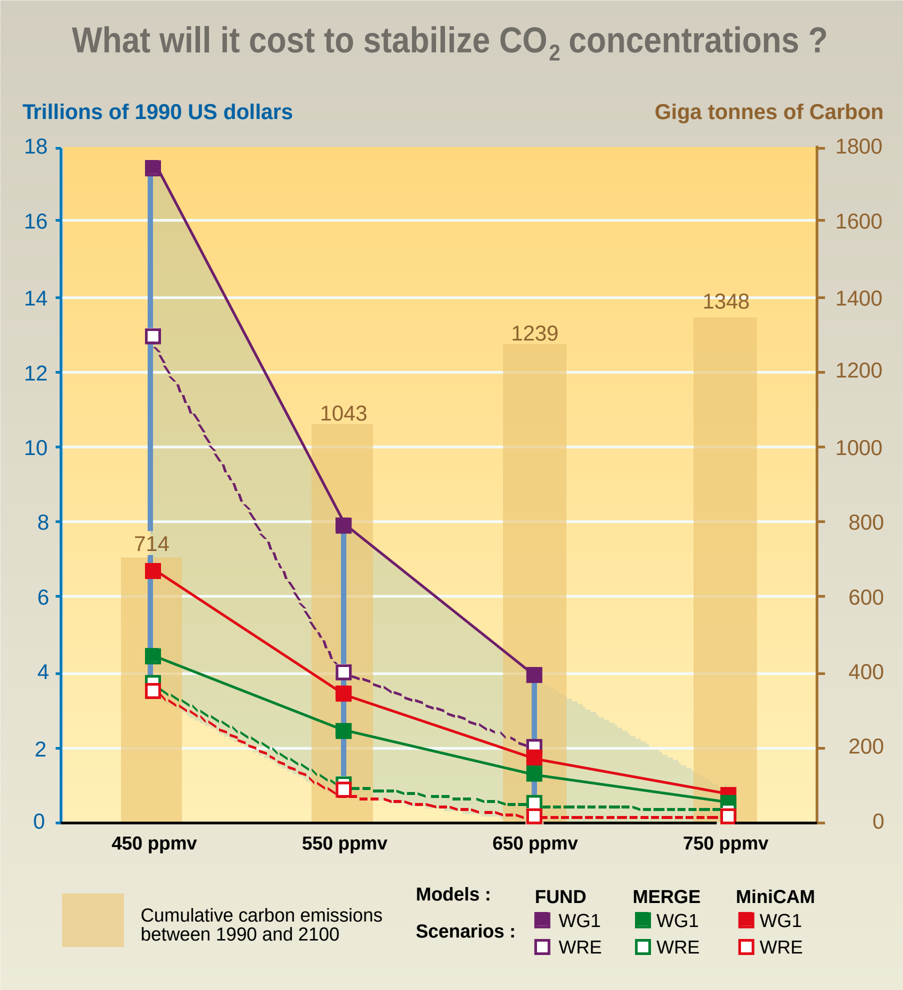

FIGURE SPM-8a

SEE PAGE 17 LINES 24–36 FOR FIGURE CAPTION

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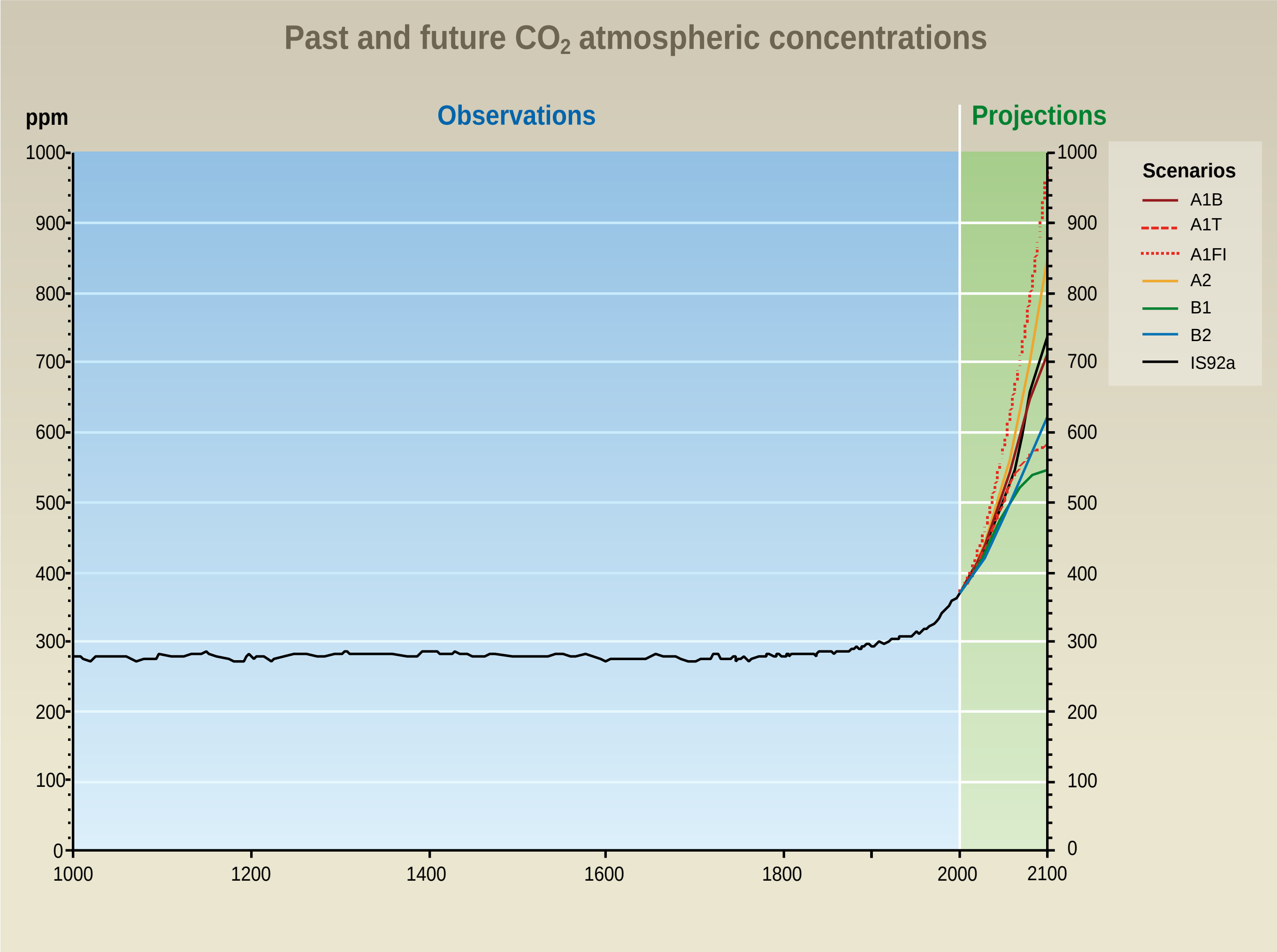

FIGURE SPM-8b

SEE PAGE 17 LINES 24–36 FOR FIGURE CAPTION

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