Summary for Policymakers

(15 May 2007)

Observed changes in climate and their effects

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level (Figure SPM-1). {1.1}

Global mean surface temperature has increased with a linear trend of 0.74 [0.56 to 0.92]°C [1] over the last 100 years (1906-2005). Eleven of the past twelve years to 2006 rank among the warmest twelve years on record. Global ocean heat content increased over 1961-2003, and the ocean is taking up over 80% of the heat being added to the climate system. {1.1}

The warming is widespread over the globe, with a maximum at higher northern latitudes. On average, surface air temperatures over land have risen at about double the ocean rate after 1979. Average Arctic temperatures increased at almost twice the global average rate over the past 100 years, and Arctic sea ice extent reduced by 2.7 [2.1 to 3.3]% per decade since 1978. {1.1}

Consistent with warming, mountain glaciers and snow cover declined in both hemispheres. Global average sea level has risen since 1961 at an average rate of 1.8 [1.3 to 2.3] mm/yr [1] and since 1993 at 3.1 [2.4 to 3.8] mm/yr [1], with contributions from thermal expansion, melting glaciers and ice caps, and the Greenland and Antarctic ice sheets. {1.1}

Changes at continental, regional and ocean-basin scale include long-term trends in precipitation, a *likely* increase in heavy precipitation events and strengthening of westerly winds. Cold days, cold nights and frost have *very likely* become less frequent, while hot days, hot nights, and heat waves increased in frequency. More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics, and there is evidence of an increase of intense tropical cyclone activity in the North Atlantic since about 1970. {1.1}

It is *very likely* that the second half of the 20th century was the warmest 50-year period for the Northern Hemisphere in the past 500 years. {1.1}

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[1] Unless otherwise stated, numerical ranges given in square brackets indicate 90% uncertainty intervals around the best estimate given in front of the brackets. Uncertainty intervals are not necessarily symmetric.

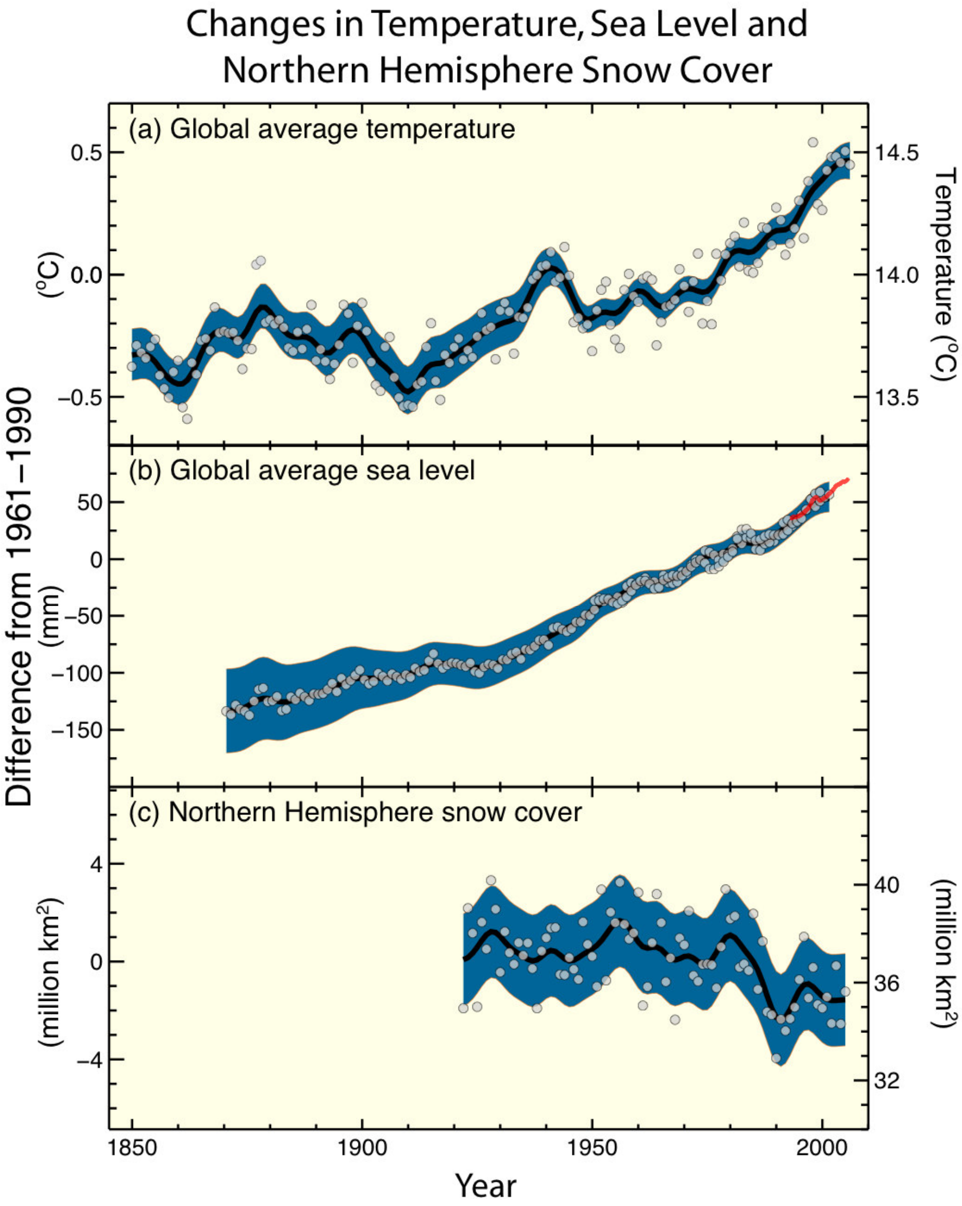


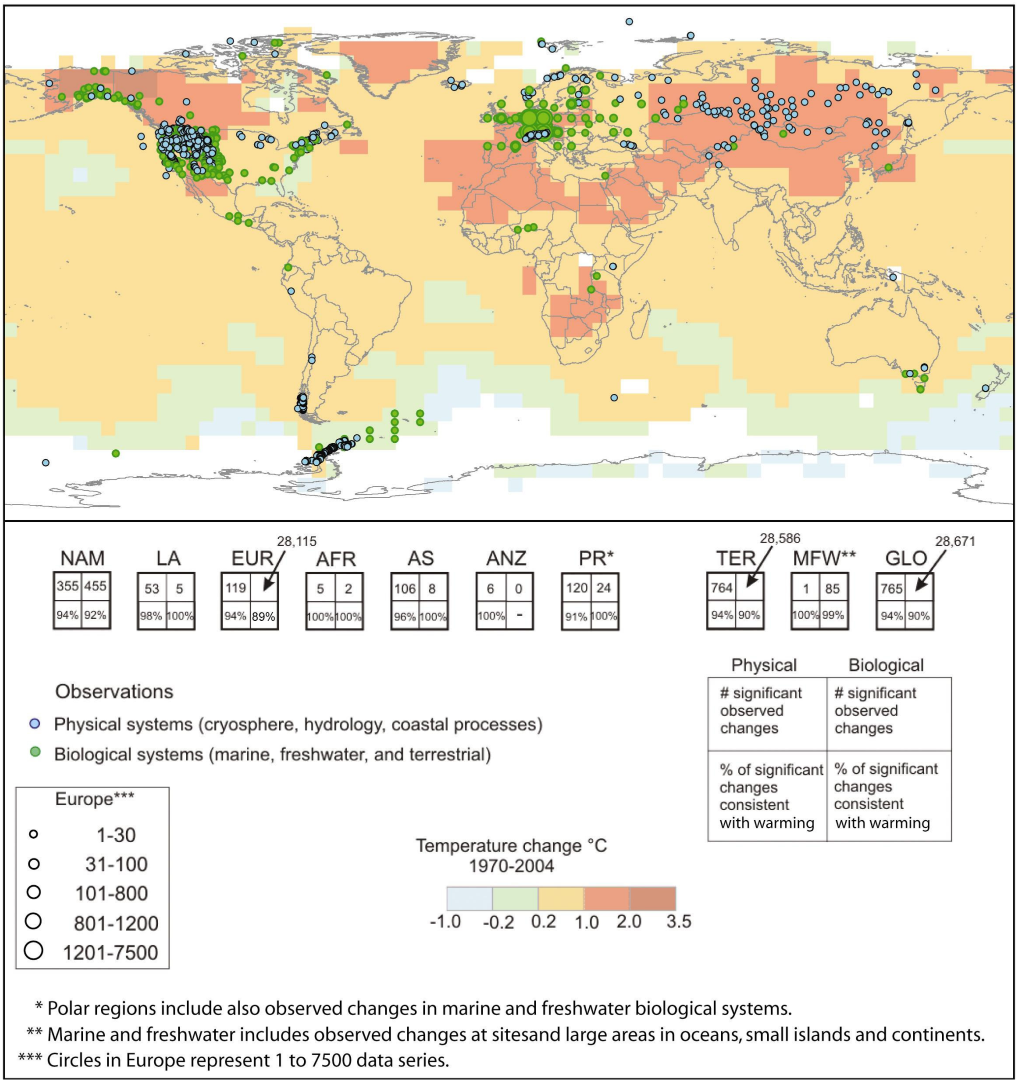
Figure SPM-1. Observed changes in (a) global average surface temperature; (b) global average sea level rise from tide gauge (blue) and satellite (red) data and (c) Northern Hemisphere snow cover for March-April. All changes are relative to corresponding averages for the period 1961-1990. Smoothed curves represent decadal averaged values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c). {Figure 1.1}

Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases. More than 89% of observed changes are consistent with a warming world (Figure SPM-2). {1.2, 1.3}

Changes in snow, ice and frozen ground have with *high confidence* increased the number and size of glacial lakes, increased ground instability in mountain and other permafrost regions, and led to changes in Arctic and Antarctic flora and fauna. {1.2}

There is *high confidence* that hydrological systems have also been affected around the world through enhanced run-off and earlier spring peak discharge in many glacier and snow-fed rivers and changing thermal structure and water quality of warming rivers and lakes. {1.2}

In terrestrial ecosystems, earlier timing of spring events and poleward and upward shifts in plant and animal ranges are with *very high confidence* linked to recent warming. In marine and freshwater systems, rising water temperatures are with *high confidence* associated with shifts in ranges and changes in algal, plankton and fish abundance. {1.2}



* Polar regions include also observed changes in marine and freshwater biological systems.

** Marine and freshwater includes observed changes at sitesand large areas in oceans, small islands and continents.

*** Circles in Europe represent 1 to 7500 data series.

Figure SPM-2. Locations of significant changes in observations of physical systems (snow, ice and frozen ground; hydrology; and coastal processes) and biological systems (terrestrial, marine, and freshwater biological systems) are shown together with surface temperature changes over the period 1970-2004. White regions do not contain sufficient observational climate data to estimate a temperature trend. The 2 x 2 boxes show the total number of data series with significant changes (top row) and the percentage of those consistent with warming (bottom row) for (i) continental regions: North America (NAM), Latin America (LA), Europe (EUR), Africa (AFR), Asia (AS), Australia and New Zealand (ANZ), and Polar Regions (PR) and (ii) global-scale: Terrestrial (TER), Marine and Freshwater (MFW), Global (GLO). For more details, see longer report. {Figure SPM-2}

There is *medium confidence* that other effects of regional climate change on natural and human environments are emerging, for example in: {1.2}

- some human activities in the Arctic (e.g., hunting and travel over snow and ice) and in lower elevation alpine areas (such as mountain sports)
- agricultural and forestry management in northern higher latitudes, such as earlier spring planting of crops and alterations of disturbance regimes in forests due to fires and pests
- aspects of human health (heat-related mortality, changes in infectious disease vectors in Europe and the allergenic pollen season in northern mid-latitudes).

Some aspects of climate and effects have not been observed to change. {1.4}

Antarctic sea ice extent shows inter-annual variability and localised changes but no statistically significant average trends. There is insufficient evidence to determine trends in the meridional overturning circulation (MOC) of the global ocean or in small-scale phenomena such as tornadoes, hail, lightning and dust-storms. There is no clear trend in the annual number of tropical cyclones. {1.4}

Responses to climate change in human and managed systems are difficult to detect due to adaptation and non-climatic drivers such as coastal population increases and infrastructure development, human interventions in water catchments, changes in health systems, and other environmental changes. {1.4}

There is a notable lack of geographic balance in data and literature on observed changes, with marked scarcity in developing countries. {1.4}

Rising carbon dioxide concentrations can also have direct (non-climate) effects. {1.5}

The oceans have become more acidic by 0.1 pH units in surface water in the last 200 years. Increasing atmospheric CO_2 can have a direct influence on terrestrial carbon uptake. However, the net effect of this cannot at present be quantified reliably at large scales due to interactions with other factors such as water and nutrient availability. {1.5}

Causes of change

Changes in the concentrations of greenhouse gases and aerosols, land-cover and solar radiation alter the Earth's energy balance. {2.2}

Greenhouse gas emissions, population, GDP and total primary energy supply have all grown during the period 1970 to 2004. {2.1}

Global greenhouse gas emissions have grown by 70% between 1970 and 2004, with CO_2 emissions growing by about 80% (28% between 1990 and 2004). CO_2 is the dominant anthropogenic greenhouse gas, accounting for 77% of total anthropogenic emissions in 2004 (for details see Figure SPM-3). {2.1}

The effect on global emissions of the decrease in global energy intensity (-33%) during 1970 to 2004 has been smaller than the combined effect of global income growth (77 %) and global population growth (69%); both drivers of increasing energy-related CO_2 emissions. {2.1}

Global anthropogenic greenhouse gas emission trends

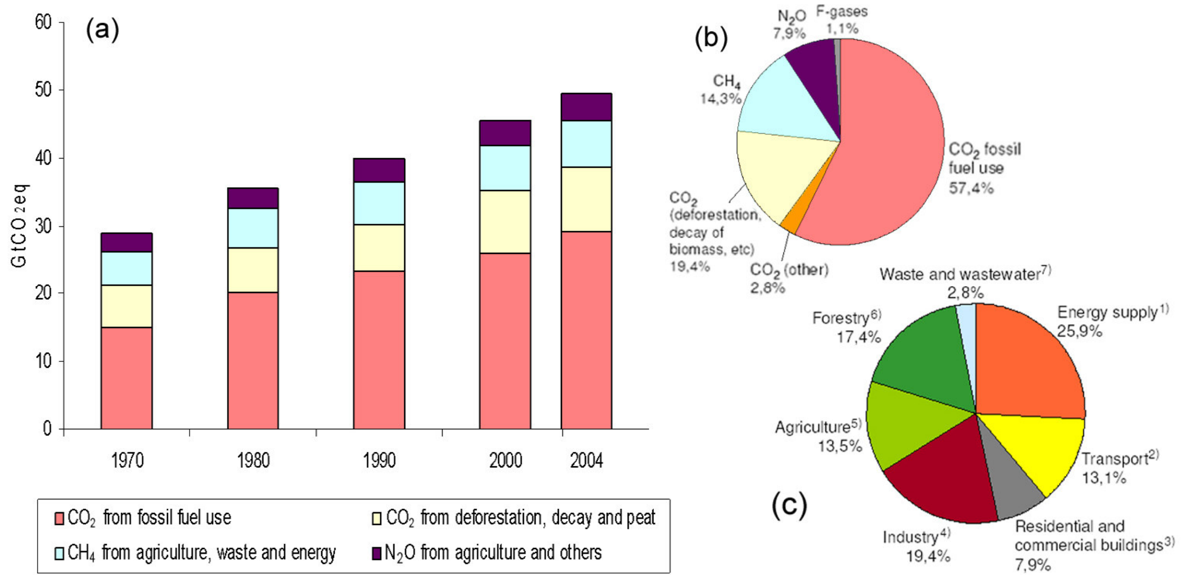


Figure SPM-3. (a) Global Anthropogenic Greenhouse gas Trends, 1970 to 2004 (F–gases accounting for around 1% excluded from this figure). (b) Share of different anthropogenic greenhouse gases in 2004. (c) Share of different sectors in total anthropogenic greenhouse gas emissions in 2004. {Figure 2.1}

Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. There is *very high confidence* that the globally averaged net effect of human activities since 1750 has been one of warming. {2.2}

The global increases in carbon dioxide concentrations are primarily due to increasing emissions from fossil fuel use and land-use change. Increases in methane and nitrous oxide are primarily due to agriculture. The rate of increase of the combined warming influences of CO_2, CH_4 and N_2O during the industrial era is *very likely* unprecedented in more than 10,000 years. Aerosols have partly offset this warming effect and also influence cloud lifetimes and precipitation. {2.2}

Most of the observed increase in globally-averaged temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations. It is *likely* that there has been significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica (Figure SPM-4). {2.4}

It is *extremely unlikely* that the global temperature change of the past fifty years can be explained without external forcing. During this time, the sum of solar and volcanic forcings would be *likely* to have produced cooling, not warming. The observed patterns of warming and their changes over time are simulated only by models that include both natural and anthropogenic forcings. However, difficulties remain in reliably simulating and attributing observed temperature changes to external forcings at smaller than continental scales. {2.4}

Global and continental temperature change

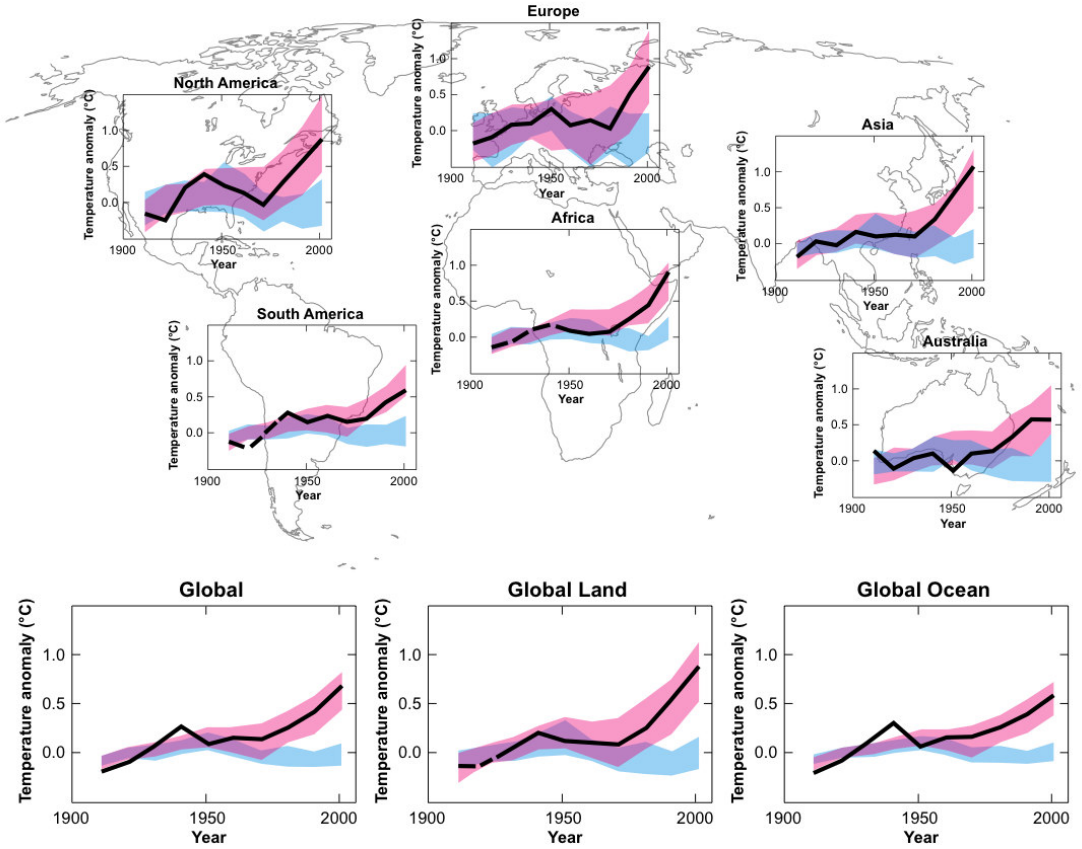


Figure SPM-4. Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906-2005 (black line) plotted against the centre of the decade and relative to the corresponding average for the 1901–1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5–95% range for 19 simulations from 5 climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5–95% range for 58 model simulations from 14 climate models using both natural and anthropogenic forcings. {Figure 2.5}

Discernible human influences also extend to other aspects of climate. {2.4}

Human influences on the climate system have: {2.4}

- *very likely* contributed to sea level rise during the latter half of the 20th century
- *likely* contributed to changes in wind patterns, affecting extra-tropical storm tracks and temperature patterns
- *likely* increased temperatures of the most extreme hot nights, cold nights and cold days
- *more likely than not* increased the risk of heat waves and the area affected by drought since the 1970s
- exerted some influence on changes in land precipitation over the 20th century.

At the global scale, anthropogenic warming over the last three decades has *likely* had a discernible influence on observed changes in many physical and biological systems. {2.4}

This assessment is based on: {2.4}

- a small number of studies that have linked responses in physical and biological systems directly to anthropogenic climate change

- a global-scale assessment of the consistency of the observed changes in physical and biological systems and observed warming, which shows that it is *very likely* that the observed changes in many systems cannot be explained entirely due to natural variability or other non-climate factors.

More complete attribution of observed natural system responses to anthropogenic warming is prevented by short time scales of many impact studies, greater natural climate variability at regional scales, and possible contributions of non-climate factors in some regions. Studies that directly link observed effects with global climate model simulations are few. {2.4}

Climate change and its impacts in the near and long term under different scenarios

There is *high agreement* and *much evidence* that with current climate change mitigation policies and related sustainable development practices, global greenhouse gas emissions will continue to grow over the next few decades. {3.1}

Baseline (non-mitigation) emissions scenarios published since the IPCC Special Report on Emission Scenarios (SRES) are comparable in range to those presented in SRES. {3.1}

SRES scenarios project an increase of baseline global greenhouse gas emissions by 25-90% between 2000 and 2030, with fossil fuels maintaining their dominant position in the global energy mix to 2030 and beyond. {3.1}

Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* be larger than those observed during the 20th century (Figure SPM-5). {3.2.1}

For the next two decades a warming of about 0.2°C per decade is projected for a range of plausible baseline emissions scenarios, while beyond the next few decades, projections depend increasingly on socio-economic scenarios and resulting emissions pathways.{3.2}

Table SPM-1 lists the best estimates and assessed *likely* uncertainty ranges of projected warming for the end of the 21st century for each of the six SRES marker scenarios, as well as model-based projections of sea-level rise. {3.2.1}

Table SPM-1. Projected globally averaged surface warming and sea level rise at the end of the 21st century. {Table 3.1}

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999) [a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations [b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

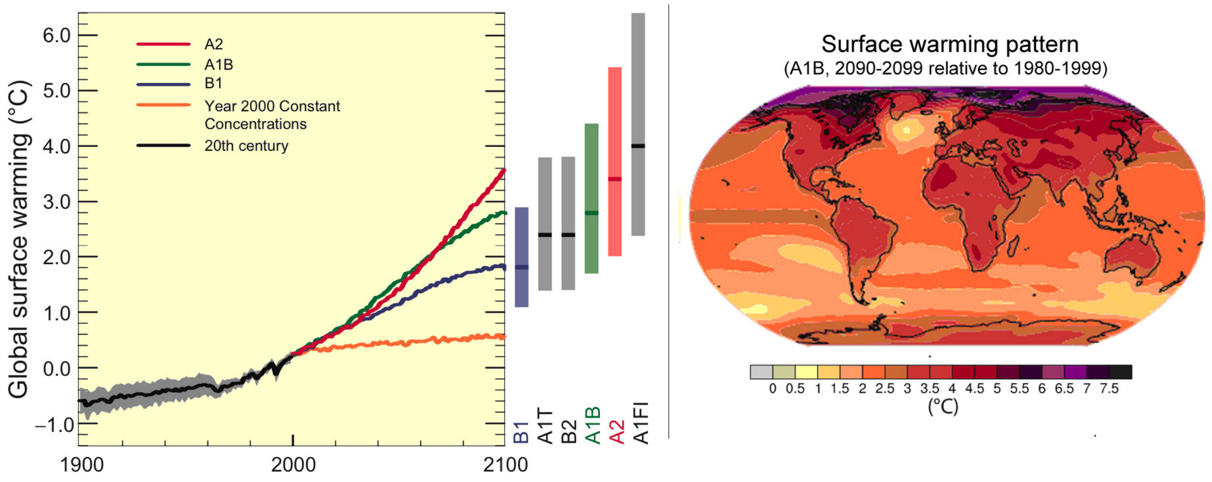
Notes:

[a] *These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth Models of Intermediate Complexity (EMICs), and a large number of Atmosphere-Ocean General Circulation Models (AOGCMs).*

[b] *Year 2000 constant composition is derived from AOGCMs only.*

The range of projections is broadly consistent with the previous assessment, but assessed uncertainties and upper ranges for temperature projections are larger because a broader range of models and carbon cycle feedbacks have been considered. Warming tends to reduce land and ocean uptake of atmospheric CO_2, increasing the fraction of anthropogenic emissions that remains in the atmosphere. The strength of this feedback effect varies markedly among models. {2.3, 3.2.1}

Model uncertainties for sea level rise are smaller than in the previous assessment mainly because of improved information about some uncertainties in the projected contributions, but they do not include uncertainties in carbon-cycle feedbacks nor do they include the full effects of changes in ice sheet flow. Understanding of possible future changes in ice sheet flow rates is too limited to assess their likelihood or provide a best estimate or an upper bound for sea level rise. {3.2.1}



Projections of surface temperatures

Figure SPM-5. Left panel: Solid lines are multi-model global averages of surface warming (relative to 1980-99) for the SRES scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. The orange line is for an experiment where concentrations were held constant at year 2000 values. The bars in middle of figure indicate the best estimate (solid line within each bar) and the *likely* range assessed for the six SRES marker scenarios. Right panel: Projected surface temperature changes for the late 21st century (2090-2099) relative to the period 1980–1999. The map shows the multi-AOGCM average projections for the A1B SRES scenario. {Figure 3.1}

There is now higher confidence in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation, and some aspects of extremes and of ice. {3.2.2}

Projected regional-scale changes include: {3.2.2}

- Geographical patterns of warming similar to those observed in recent decades
- Contraction of snow cover and sea ice; almost entire disappearance of Arctic late-summer sea ice by the latter part of the 21st century in some projections using SRES scenarios
- Increased permafrost thaw depth
- Poleward shift of extra-tropical storm tracks with consequent changes in wind, precipitation, and temperature patterns
- *Very likely* increase in frequency of hot extremes, heat waves, and heavy precipitation
- *Likely* increase in tropical cyclone intensity; less confidence in decreasing cyclone numbers
- *Very likely* precipitation increases in high-latitudes and *likely* decreases in most subtropical land regions, continuing observed patterns in recent trends.

Anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilised. {3.2.3}

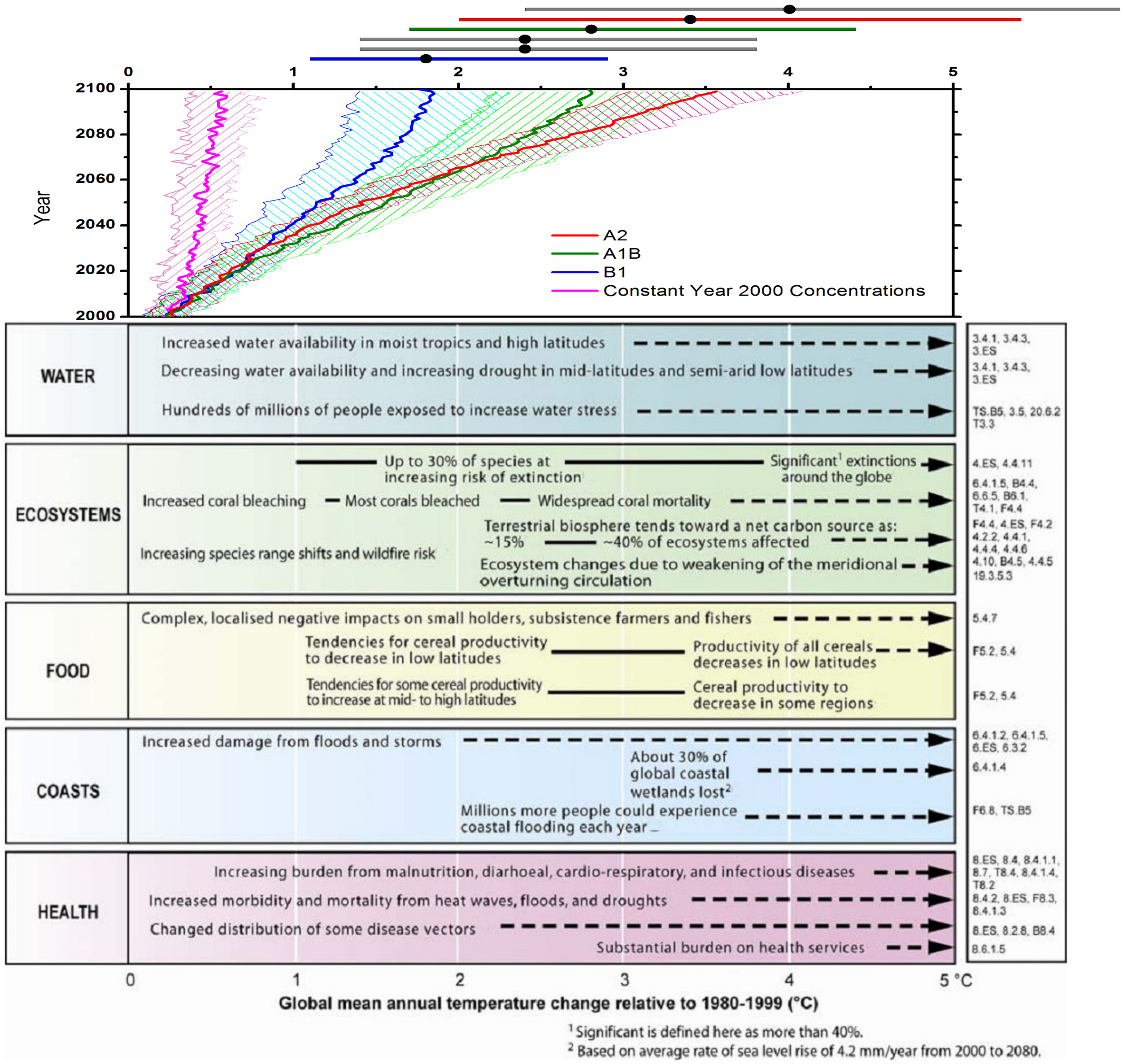
Stabilisation of radiative forcing in 2100 at A1B levels (approximately 850ppm CO_2-equivalent) would lead to further warming of about 0.5°C beyond 2100, mostly by 2200. Thermal expansion of oceans alone would lead to 0.3 to 0.8 m of sea level rise by 2300 (relative to 1980–1999) and continue for many centuries. {3.2.3}

Contraction of the Greenland ice sheet is projected to continue to contribute to sea level rise after 2100. Current models suggest virtually complete elimination of the Greenland ice sheet and a resulting contribution to sea level rise of about 7 m if global average warming were sustained for millennia in excess of 1.9 to 4.6ºC relative to pre-industrial values. {3.2.3}

Current model studies project that the Antarctic ice sheet will remain too cold for widespread surface melting and is expected to gain mass due to increased snowfall. However, net loss of ice mass could occur if dynamical ice discharge dominates the ice sheet mass balance. {3.2.3}

More specific information on projected impacts of future climate change is now available across a wider range of systems, sectors and regions, including for some fields and places not covered in previous assessments. {3.3}

Additional studies since the previous assessment have enabled a more systematic understanding of the timing and magnitude of impacts related to differing amounts and rates of change in global temperature. Table SPM-2 presents examples of this new information for systems and sectors, selected for their relevance for people and the environment. More comprehensive information and some findings on vulnerability and adaptation, can be found in the longer report, including impacts on specific regions. {3.3}



[1] Significant is defined here as more than 40%.
[2] Based on average rate of sea level rise of 4.2 mm/year from 2000 to 2080.

Table SPM-2. Examples of projected impacts for varying changes in global average surface temperatures. **Lower part of table:** Illustrative examples of global impacts projected for climate changes (and sea-level and atmospheric carbon dioxide where relevant) associated with different amounts of increase in global average surface temperature in the 21st century. The black lines link impacts, dotted arrows indicate impacts continuing with increasing temperature. Entries are placed so that the left hand side of text indicates approximate level of warming that is associated with the onset of a given impact. Quantitative entries for water scarcity and flooding represent the additional impacts of climate change relative to the conditions projected across the range of Special Report on Scenarios (SRES) scenarios A1FI, A2, B1 and B2. Adaptation to climate change is not included in these estimations. Confidence levels for all statements are high. **Upper part of table:** Solid lines are multi-model global averages of surface warming over the course of the 21st century relative to 1980-1999 for the SRES scenarios A2, A1B and B1. Shading denotes the ±1 standard deviation range of individual model annual averages. The purple line is for an experiment where concentrations were held constant at year 2000 values. The bars on top indicate the best estimate (dot within each bar) and the likely range assessed for the six SRES marker scenarios for 2090-2099 relative to 1980-1999. Together, the upper and lower parts of this table demonstrate the influence of different SRES emission scenarios for climate change on the timing and severity of impacts that could occur during the 21st century. To express temperature changes relative to 1850-1899, add about 0.5°C. {Table 3.2}

Impacts due to altered frequencies and intensities of extreme weather, climate, and sea-level events are very likely to change. {3.3}

Projected increases in many extremes over the 21st century are expected to have mostly adverse effects on agriculture, forestry, water resources, human health, industry and settlements. {3.3}

Magnitudes and timing of projected impacts depend not only on climate change but also on development pathways. {3.3}

Impacts of climate change can vary greatly due to the development pathway assumed, e.g. estimates of regional population, income and technological development are strong determinants of vulnerability to climate change. For example, the number of people whose food supply, flood risk or water scarcity would be affected by climate change (see also Table SPM-2) strongly depends on the assumed size of the vulnerable low-income population. {3.3}

Some future impacts already appear unavoidable, owing to the inertia of the climate system. {3.3}

Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.6°C relative to the 1980-1999 average would be expected over the 21st century. This suggests that even under stringent mitigation scenarios some future impacts (see Table SPM-2) are already unavoidable, for example: {3.3}

- increased coral bleaching
- increased species range shifts and risk of wildfire
- decreased water availability and increased drought risk in the tropics and subtropics
- increased coastal damage from floods combined with sea-level rise.

Based on the preceding analysis, some systems, sectors and regions can now be identified as particularly vulnerable to climate change.[2] {3.3}

Particularly vulnerable systems and sectors are: {3.3}

- Some ecosystems
  - Terrestrial: tundra, boreal forest, mountain, mediterranean-type ecosystems
  - Along coasts: mangroves and salt marshes
  - In oceans: coral reefs and the sea ice biome
- Low-lying coastal regions due to the threat of sea-level rise and increased risk from extreme weather events
- Water resources in the dry tropics and subtropics due to decreases in rainfall and higher rates of evapotranspiration
- Agriculture in low-latitude regions due to reduced water availability
- Human health in areas with low adaptive capacity.

Particularly vulnerable regions are: {3.3}

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[2] Criteria used for this conclusion included: magnitude, timing, irreversibility of possible impacts, confidence in assessment, and potential for adaptation.

- The Arctic, because of the impacts of high rates of projected warming on natural systems
- Africa, especially the sub-Saharan region, because of current low adaptive capacity
- Small islands, due to high exposure of population and infrastructure to sea-level rise and increased storm surges
- Asian megadeltas due to large populations and high exposure to sea-level rise, storm surges and river flooding.

It is *very unlikely* that there will be large abrupt climate changes due to changes in the large scale ocean circulation (MOC) or ice sheets over the 21st century. The probability of large abrupt climate changes beyond 2100 cannot be assessed with confidence. {3.4}

Based on current model simulations, it is *very unlikely* that the MOC of the Atlantic Ocean will undergo a large abrupt transition, but it is *very likely* that the MOC will slow down during the 21st century. Longer-term changes in the MOC cannot be assessed with confidence. Impacts of large-scale and persistent changes in the MOC *are likely* to include changes in marine ecosystem productivity, fisheries, ocean CO_2 uptake, oceanic oxygen concentrations and vegetation. {3.4}

Partial deglaciation of polar ice sheets would imply major changes in coastlines and inundation of low-lying areas, with greatest effects in river deltas. Current models project that such changes would occur over millennial time scales. Rapid sea level rise on century time scales cannot be excluded. {3.4}

Gradual climate changes are *likely* to lead to irreversible impacts. {3.4}

There is *medium confidence* that approximately 20-30% of species assessed so far are *likely* to be at increasing risk of extinction if increases in global average warming exceed 1.5-2.5°C, and *high confidence* of significant (>40%) extinctions around the globe for warming above 4°C. {3.4}

Adaptation and mitigation options and responses, the inter-relationship with sustainable development, at global and regional levels

There is *high confidence* that adaptation and mitigation can together reduce risks of climate change and can act as complementary response measures to climate change. {4.1, 4.4}

There is *high confidence* that adaptation can reduce vulnerability, especially in the short-term and where it complements broader development initiatives. {4.2}

Societies across the world have a long record of adapting to the impacts of weather- and climate-related events such as floods, droughts and storms, and some planned adaptation to climate change is already occurring on a limited basis. Many adaptations are embedded within broader development and sectoral planning initiatives. However, vulnerability to climate change can be exacerbated by non-climate stresses such as rapid population growth and urbanisation, construction and settlement in high risk areas, poor management of natural resources and the loss of traditional coping skills. {4.2}

Adaptive capacity is intimately connected to social and economic development, but it is not evenly distributed across and within societies. Even high adaptive capacity and the necessary financial resources do not automatically translate into effective action on adaptation to climate change, variability and extremes. {4.2}

There is *high confidence* that viable adaptation options can be implemented at low cost, and/or with high benefit-cost ratios, in sectors such as sea level rise, agriculture, energy demand for heating and cooling, water resources management and infrastructure. Empirical research also suggests that higher benefit/cost ratios can be achieved by implementing many adaptation measures now compared with the costs of retrofitting long-lived infrastructure at a later date. Knowledge of the global costs and benefits of adaptation is limited. {4.2}

There is *high agreement* and *much evidence* from both bottom-up and top-down studies that there is substantial economic potential for the mitigation of global greenhouse gas emissions over the coming decades that could offset the projected growth of global emissions or reduce emissions below current levels. {4.3}

The global economic potentials found in the top-down studies are in line with bottom-up studies across all sectors (Figures SPM-6 and SPM-7), though there are considerable differences at the sectoral level. {4.3}

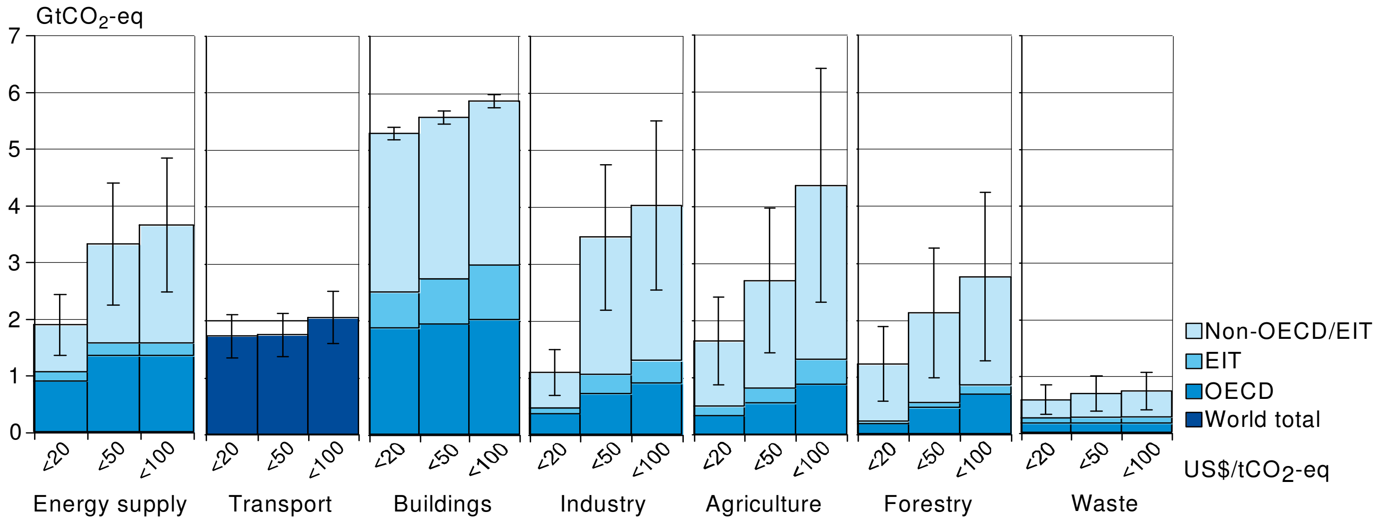

Figure SPM-6. Estimated economic mitigation potential by sector in 2030 from bottom-up studies, compared to the respective baselines assumed in the sector assessments (see longer report for details). The potentials do not include non-technical options such as lifestyle changes. {Figure 4.2}

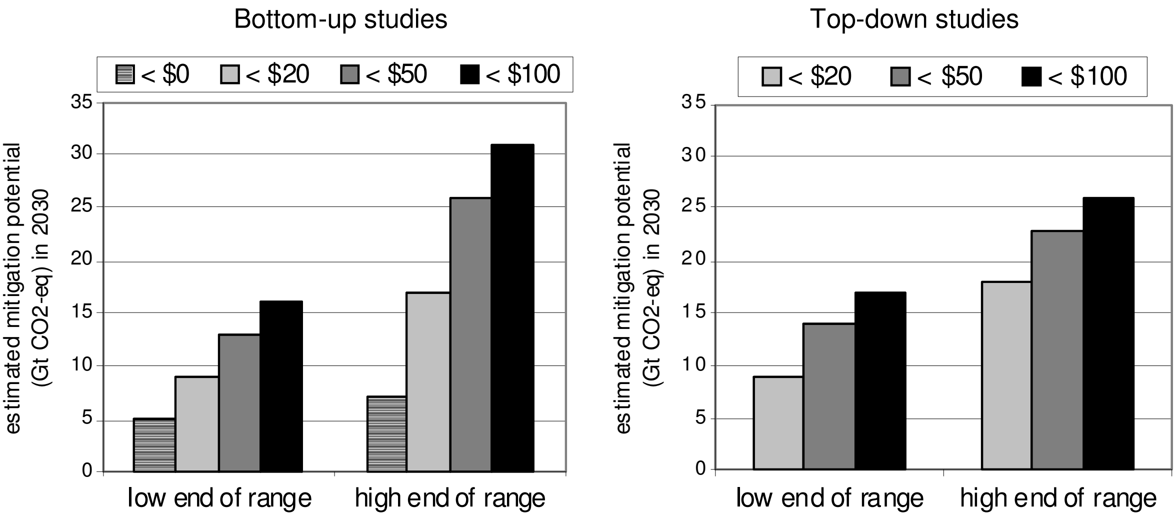

Figure SPM-7. Global economic potential in 2030 estimated from bottom-up and top down studies. Emissions in 2000 were equal to 43 $GtCO_2$-eq, while for 2030 the projected emissions are 49 Gt CO_2-eq/yr (SRES B2) and 68 Gt CO2-eq/yr (SRES A1B). {Figure 4.1}

A wide variety of national policies and instruments are available to governments to create the incentives for mitigation action, including carbon pricing, regulation, voluntary agreements, RD&D, and information. {4.3}

Future energy infrastructure investment decisions, expected to total over 20 trillion US$[3] between now and 2030, will have long-term impacts on greenhouse gas emissions, because of the long life-times of energy plants and other infrastructure capital stock. The widespread diffusion of low-carbon technologies may take many decades, even if early investments in these technologies are made attractive. {4.3}

There is *high agreement and much evidence* that many mitigation options can provide co-benefits, such as reduced air pollution, which benefits human health, agriculture and general sustainable development, and can offset a substantial fraction of mitigation costs. {4.3}

There is also *high agreement*, but only *medium evidence* that changes in life style and behaviour patterns can contribute to climate change mitigation. {4.3}

Broader sustainable development decisions affect climate change and the capacity to respond through adaptation and mitigation, and vice versa. {4.4}

There is *very high confidence* that enhancing society's response capacity through the pursuit of sustainable development could promote both adaptation and mitigation. Limited studies provide *high agreement* that decisions about fiscal policies, multilateral development bank lending, insurance practices, industrial policies, electricity market liberalisation, energy security, forest conservation, for example, can have profound impacts on greenhouse gas emissions. Conversely, climate policies that implicitly address social, environmental,

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[3] 20 trillion = 20,000 billion= $20*10^{12}$.

economic and security issues may turn out to be important levers for creating a sustainable world. {4.4}

Some specific adaptation and mitigation options exhibit synergies (mainly agriculture, forestry, buildings and urban infrastructure), but trade-offs are possible where adaptation requires additional energy use, e.g. for cooling, irrigation, and coastal protection infrastructure. {4.4}

There is *high agreement* and *much evidence* that there are many options for achieving reductions of global greenhouse gas emissions at the international level through cooperation. {4.5}

The UNFCCC and its Kyoto Protocol stimulated an array of policies, created a global carbon market and established new institutional mechanisms for adaptation and mitigation actions. {4.5}

Greater cooperative efforts will reduce global costs or improve environmental effectiveness. These can include diverse elements such as emissions targets; sectoral, local, sub-national and regional actions; RD&D programmes; adopting common policies; implementing development oriented actions; or expanding financing instruments. {4.5}

The long-term perspective: scientific and socio-economic aspects relevant to adaptation and mitigation, consistent with the objectives and provisions of the Convention, and in the context of sustainable development

Decision-making about the appropriate level of adaptation and global mitigation over time involves an iterative risk management process that includes mitigation and adaptation, taking into account actual and avoided climate change damages, co-benefits, sustainability, equity, and attitudes to risk. {5.1}

The likelihood that any climate impact will be associated with a key vulnerability or important opportunity depends on characteristics of natural and human systems and varies over space, time, sectors and regions. No single metric can adequately describe the diversity of key vulnerabilities or support their ranking. {5.2}

The five "reasons for concern" identified in the Third Assessment Report remain a viable framework to consider key vulnerabilities. Recent research has updated these findings: {5.2}

- **Risks to unique and threatened systems**. New and stronger evidence of observed impacts of regional climate change on unique and vulnerable systems has increased confidence in projected future effects.
- **Risks of extreme weather events.** There is much more evidence of the sensitivity and vulnerability of human and natural systems to extreme events.
- **Distribution of impacts and vulnerabilities.** There is new evidence that low-latitude and less-developed areas generally face the greatest risk due to higher sensitivity, lower adaptive capacity, and greater confidence in projected precipitation patterns.

- **Net aggregate impacts.** There is some evidence that initial net market benefits from climate change will peak at a lower magnitude and therefore sooner, and that damages would be higher for larger magnitudes of global mean temperature increase, than was concluded in the previous assessment.
- **Risks of large scale singularities: abrupt or irreversible changes.** There is now more specific information on levels of warming that would result in at least partial deglaciation of the Greenland ice sheet. The risk of large-scale abrupt changes in ocean circulation during the 21st century is very unlikely.

Taken together, these findings suggest that there are stronger reasons for concern than in the Third Assessment Report, even though some benefits of climate change can be identified in some regions, systems and sectors. {3.3, 5.2}

Many impacts can be avoided, reduced or delayed by mitigation, but adaptation is also necessary even at the lowest stabilisation levels assessed in this report. {5.3, 5.7}

Alternative emission pathways have an increasing influence on the rate and magnitude of global climate change and the impacts that are consequently incurred or avoided in the second half of the 21st century and beyond. {5.3, 5.7}

Adaptation can significantly reduce risks, but it is either very limited or very costly for some key vulnerabilities, such as loss of biodiversity, melting of mountain glaciers or disintegration of major ice sheets. Reliance solely on adaptation could allow the climate to change so significantly that effective reduction in climate risks would be possible only at very high social, environmental and economic costs. {5.3}

Long-term risks associated with sea-level rise depend on the level at which greenhouse gas concentrations are stabilised beyond 2100. Thermal expansion of the ocean alone will cause an inexorable sea level rise of up to several meters for the higher stabilisation levels as shown in Table SPM-3. The time scales of thermal expansion and melting of ice sheets imply that stabilisation of greenhouse gases at or above present levels would not stabilise sea level rise for more than a millennium. {3.2, 5.3, 5.7}

A scientific assessment of climate change cannot determine what constitutes “dangerous anthropogenic interference” as per Article 2 of the UNFCCC, because this involves value judgements, and perceptions of risks are variable over space and time. However, such considerations can be informed by scientific information such as that presented above. {5.9}

Global emissions must peak and then decline to meet any of the assessed stabilisation levels. Mitigation efforts over the next two to three decades will have a large impact on opportunities to achieve lower stabilisation levels and resulting long term equilibrium temperate changes. {5.4}

Table SPM-3 summarises stabilisation ranges, resulting global average warming at equilibrium, years in which emissions would have to peak and decline to attain the stabilisation level, and equilibrium sea level rise due to thermal expansion. (See also Figure SPM-8.) Stabilisation at lower concentration and related equilibrium temperature levels advances the date when emissions need to peak, and requires greater emissions reductions by 2050. {5.4}

Table SPM-3. Characteristics of post-TAR stabilisation scenarios {Table 5.1}

Category	CO_2 concentration (a)	CO_2-equivalent Concentration (a)	Peaking year for CO_2 emissions (b)	Change in global CO_2 emissions in 2050 (% of 2000 emissions) (b)	Global mean temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity (c), (d)	Global average sea-level rise above pre-industrial at equilibrium from thermal expansion only (e)
	ppm	ppm	year	percent	ºC	metres
I	350 – 400	445 – 490	2000 - 2015	-85 to -50	2.0 – 2.4	0.4 – 1.4
II	400 – 440	490 – 535	2000 - 2020	-60 to -30	2.4 – 2.8	0.5 – 1.7
III	440 – 485	535 – 590	2010 - 2030	-30 to +5	2.8 – 3.2	0.6 – 1.9
IV	485 – 570	590 – 710	2020 - 2060	+10 to +60	3.2 – 4.0	0.6 – 2.4
V	570 – 660	710 – 855	2050 - 2080	+25 to +85	4.0 – 4.9	0.8 – 2.9
VI	660 – 790	855 – 1130	2060 - 2090	+90 to +140	4.9 – 6.1	1.0 – 3.7

Notes:

a) *Atmospheric CO_2 concentrations have increased by about 100 ppm since pre-industrial times, reaching 379 ppm in 2005. The best estimate of total CO_2-equivalent concentration in 2005 for all long-lived greenhouse gases is about 455 ppm, while the corresponding value including the net effect of all anthropogenic forcing agents is 375 ppm CO_2-equivalent.*

b) *Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with CO_2-only scenarios.*

c) *The best estimate of climate sensitivity is 3ºC. {WGI SPM}*

d) *Global mean temperature at equilibrium is different from expected global mean temperature at the time of stabilisation of greenhouse gas concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilisation of greenhouse gas concentrations occurs between 2100 and 2150.*

e) *Values for sea-level rise from thermal expansion are estimated using relatively simple climate models (one low resolution AOGCM and several EMICs). These values result from a relatively uniform warming throughout the deep ocean which is expected at equilibrium. Ranges are based on the best estimate of 3ºC climate sensitivity. Equilibrium sea-level rise is for the contribution from thermal expansion only and does not include contributions from ice sheets, glaciers and ice caps.*

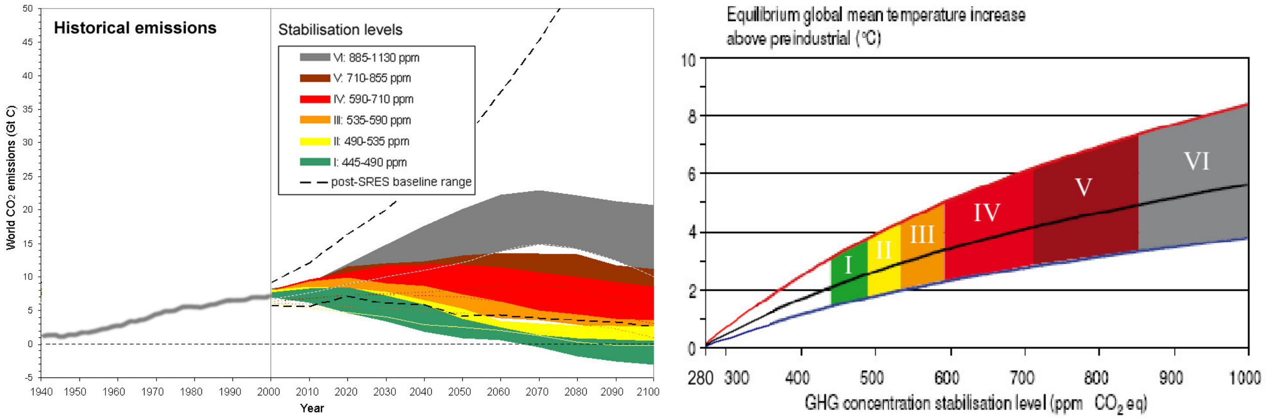

Figure SPM-8. Global CO_2 emissions ranges for alternative groups of stabilisation scenarios (left-hand panel) and the corresponding relationship between the stabilisation target and the likely equilibrium global mean temperature increase above preindustrial (right-hand panel). Coloured shadings show stabilisation scenarios grouped according to different targets (stabilisation category I to VI). Right-hand panel shows ranges of global mean temperature change above pre-industrial, using (i) "best estimate" climate sensitivity of 3°C (black line in middle of shaded area), (ii) upper bound of likely range of climate sensitivity of 4.5°C (red line at top of shaded area) (iii) lower bound of likely range of climate sensitivity of 2°C (blue line at bottom of shaded area). Black dashed lines in the left panel give the emissions range of Post-SRES baseline scenarios. Emissions ranges of the stabilisation scenarios correspond to the 10th – 90th percentile of the full scenario distribution. {Figure 5.2}

The macroeconomic cost of mitigation generally rises with increased stringency of the stabilisation target and is relatively higher from baseline scenarios with high emissions. {5.5}

Table SPM-4 summarises the estimated macro-economic cost of mitigation[4] for a range of stabilisation levels. Estimated GDP losses by 2030 are on average lower and show a smaller spread compared to 2050. For specific countries and sectors, costs vary considerably from the global average. {5.5}

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[4] Most models use a global least cost approach to mitigation portfolios and with universal emissions trading, assuming transparent markets, no transaction cost, and thus perfect implementation of mitigation measures throughout the 21st century. Costs represent global averages and are given for a specific point in time. Estimated costs will increase if some regions, sectors (e.g. land-use options) or gases are excluded. Estimated costs will decrease with lower baselines, use of revenues from carbon taxes and auctioned permits, and if induced technological learning is included. These models do not consider climate benefits and generally also co-benefits of mitigation measures, or equity issues. In models that consider induced technological change, projected costs for a given stabilisation level are reduced; the reductions are greater at lower stabilisation level.

Table SPM-4. Estimated global macro-economic costs in 2030 and 2050. Costs are relative to the baseline for least-cost trajectories towards different long-term stabilisation levels. {Table 5.2}

Stabilisation levels (ppm CO_2-eq)	Median GDP reduction [(a)] (%)		Range of GDP reduction [(b)] (%)		Reduction of average annual GDP growth rates (percentage points) [(b), (c)]	
	2030	*2050*	*2030*	*2050*	*2030*	*2050*
590 – 710	0.2	0.5	-0.6 – 1.2	-1 – 2	< 0.06	< 0.05
535 – 590	0.6	1.3	0.2 – 2.5	slightly negative – 4	< 0.1	< 0.1
445 – 535 [(d)]	Not available		< 3	< 5.5	< 0.12	< 0.12

Notes: Values given in this table correspond to the full literature across all baselines and mitigation scenarios that provide GDP numbers.

a) Global GDP based market exchange rates.

b) The median and the 10th and 90th percentile range of the analyzed data are given.

c) The calculation of the reduction of the annual growth rate is based on the average reduction during the assessed period that would result in the indicated GDP decrease by 2030 and 2050 respectively.

d) The number of studies is relatively small and they generally use low baselines. High emissions baselines generally lead to higher costs.

There is *high agreement* and *much evidence* that the range of stabilisation levels assessed can be achieved by deployment of a portfolio of technologies that are currently available and those that are expected to be commercialised in coming decades. This assumes that appropriate and effective incentives are in place for development, acquisition, deployment and diffusion of technologies and for addressing related barriers. {5.6}

The lower the stabilisation levels, especially those of 550 ppm CO_2-eq or lower, the greater the need for more efficient RD&D efforts and investment in new technologies during the next few decades. {5.6}

The contribution of individual technologies varies over time and region and depends on the baseline scenario and the analyzed stabilisation level (Figure SPM-9). Despite large uncertainties concerning the contribution of individual technologies, the majority of the emissions reductions are estimated to come from the energy sector (60-80 % of total emissions reductions), in particular, energy efficiency. For lower stabilisation levels, scenarios put more emphasis on the use of low carbon energy sources and the use of CO_2 capture and storage (CCS). Inclusion of non-CO_2 and CO_2 land-use and forestry mitigation options provides greater flexibility and cost-effectiveness. {5.6}

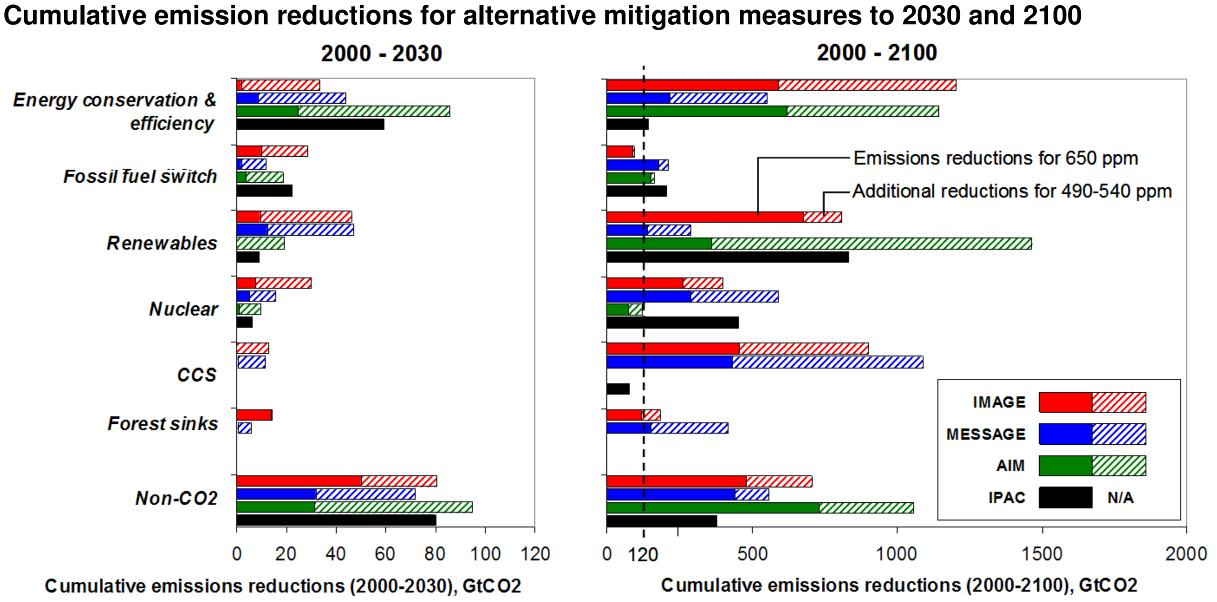

Figure SPM-9. Cumulative emissions reductions for alternative mitigation measures for 2000 to 2030 (left-hand panel) and for 2000-2100 (right-hand panel). The figure shows illustrative scenarios from four models (AIM, IMAGE, IPAC and MESSAGE) aiming at the stabilisation at low (490-540 ppm CO_2-eq) and intermediate levels (650 ppm CO_2-eq) respectively. Dark bars denote reductions for a target of 650 ppm CO_2-eq and light bars the additional reductions to achieve 490-540 ppm CO_2-eq. Note that some models do not consider mitigation through forest sink enhancement (AIM and IPAC) or CCS (AIM) and that the share of low-carbon energy options in total energy supply is also determined by inclusion of these options in the baseline. CCS includes carbon capture and storage from biomass. Forest sinks include reducing emissions from deforestation. Mitigation from baseline scenarios with intermediate emissions between 6000 to 7000 $GtCO_2$ (2000-2100). {Figure 5.3}

It is very likely that anthropogenic climate change will result in net damage costs into the future and can impede nations' abilities to achieve sustainable development pathways. On the other hand, there is *high agreement* and *much evidence* that making development more sustainable can significantly reduce vulnerability to climate change by promoting effective mitigation and adaptation. {5.8}

Both adaptive and mitigative capacities can be enhanced by making development more sustainable. Sustainable development can, thereby, reduce vulnerability to climate change by reducing sensitivities (through adaptation) and/or exposure (through reduced emissions). {5.8}

Climate change will interact with major global environmental concerns, including water, soil and air pollution, health hazards, and deforestation. Their combined impacts will likely be compounded in the future in the absence of integrated mitigation and adaptation measures. {5.8}

The fact that societies have to cope with multiple stresses calls for complementary activities in promoting mitigation, adaptation, and sustainable development. {5.8}