

Advances since the TAR show that discernible human influences extend beyond average temperature to other aspects of climate. {2.4}

Human influences 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 extreme hot nights, cold nights and cold days
- more likely than not increased risk of heat waves, area affected by drought since the 1970s and frequency of heavy precipitation events.

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

Spatial agreement between regions of significant warming across the globe and locations of significant observed changes in many systems consistent with warming is very unlikely to be due solely to natural variability. Several modelling studies have linked some specific responses in physical and biological systems to anthropogenic warming. {2.4}

More complete attribution of observed natural system responses to anthropogenic warming is currently prevented by the short time scales of many impact studies, greater natural climate variability at regional scales, contributions of non-climate factors and limited spatial coverage of studies. {2.4}

3. Projected climate change and its impacts

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

The IPCC Special Report on Emission Scenarios (SRES, 2000) projects an increase of global GHG emissions by 25-90% (CO₂-eq) between 2000 and 2030 (Figure SPM.5), with fossil fuels maintaining their dominant position in the global energy mix to 2030 and beyond. More recent scenarios without additional emissions mitigation are comparable in range. ^{8,9} {3.1}

Continued GHG 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 (Table SPM.1, 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 SRES emissions scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected. Afterwards, temperature projections increasingly depend on specific emission scenarios. {3.2}

⁸ For an explanation of SRES emission scenarios, see Box 'SRES scenarios' of this Synthesis Report. These scenarios do not include additional climate policy above current ones; more recent studies differ with respect to UNFCCC and Kyoto Protocol inclusion.

⁹ Emission pathways of mitigation scenarios are discussed in Section 5.

Scenarios for GHG emissions from 2000 to 2100 (in the absence of additional climate policies) and projections of surface temperatures

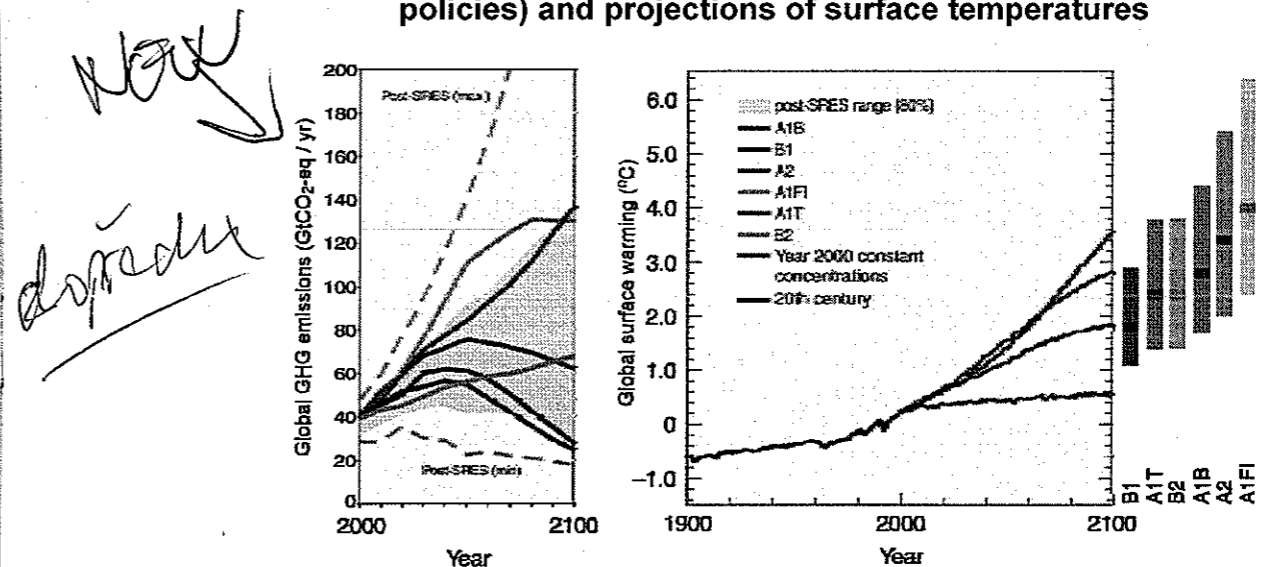


Figure SPM-5. Left Panel: Global GHG emissions (in CO₂-eq) in the absence of climate policies: six illustrative SRES marker scenarios (coloured lines) and the 80th percentile range of recent scenarios published since SRES (post-SRES) (gray shaded area). Dashed lines show the full range of post-SRES scenarios. The emissions cover CO₂, CH₄, N₂O, and F-gases. Right Panel: Solid lines are multi-model global averages of surface warming for scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. These projections also take into account emissions of short-lived GHGs and aerosols. The pink line is not a scenario, but is for AOGCM simulations where atmospheric concentrations are held constant at year 2000 values. The bars at the right of the figure indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios at 2090-2099. All temperatures are relative to the period 1980-1999. (Figure 3.1, Figure 3.2)

Table SPM.1. Projected global 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,d}		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	Not available
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:

- Temperatures are assessed best estimates and likely uncertainty ranges from a hierarchy of models of varying complexity as well as observational constraints.
- Year 2000 constant composition is derived from Atmosphere-Ocean General Circulation Models (AOGCMs) only.
- All scenarios above are six SRES marker scenarios. Approximate carbon dioxide equivalent concentrations corresponding to the computed radiative forcing due to anthropogenic GHGs and aerosols in 2100 (see p. 823 of the TAR) for the SRES B1, A1T, B2, A1B, A2 and A1FI illustrative marker scenarios are about 600, 700, 800, 850, 1250 and 1550 ppm, respectively.
- Temperature changes are expressed as the difference from the period 1980-1999. To express the change relative to the period 1850-1899 add 0.5°C.

The range of projections (Table SPM.1) is broadly consistent with the TAR, but uncertainties and upper ranges for temperature are larger mainly because the broader range of available models suggests stronger climate-carbon cycle feedbacks. Warming reduces terrestrial and ocean uptake of atmospheric CO₂, increasing the fraction of anthropogenic emissions remaining in the atmosphere. The strength of this feedback effect varies markedly among models. {2.3, 3.2.1}

Because understanding of some important effects driving sea level rise is too limited, this report does not assess the likelihood, nor provide a best estimate or an upper bound for sea level rise. Table SPM.1 shows model-based projections of global average sea level rise for 2090-2099. The projections do not include uncertainties in climate-carbon cycle feedbacks nor the full effects of changes in ice sheet flow, therefore the upper values of the ranges are not to be considered upper bounds for sea level rise. They include a contribution from increased Greenland and Antarctic ice flow at the rates observed for 1993-2003, but this could increase or decrease in the future. {3.2.1}

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

Regional-scale changes include: {3.2.2}

- warming greatest over land and at most high northern latitudes and least over Southern Ocean and parts of the North Atlantic Ocean, continuing recent observed trends (Figure SPM.6) in contraction of snow cover area, increases in thaw depth over most permafrost regions, and decrease in sea ice extent; in some projections using SRES scenarios, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century
- very likely increase in frequency of hot extremes, heat waves, and heavy precipitation
- likely increase in tropical cyclone intensity; less confidence in global decrease of tropical cyclone numbers
- poleward shift of extra-tropical storm tracks with consequent changes in wind, precipitation, and temperature patterns
- very likely precipitation increases in high latitudes and likely decreases in most subtropical land regions, continuing observed recent trends

There is high confidence that by mid-century, annual river runoff and water availability are projected to increase at high latitudes (and in some tropical wet areas) and decrease in some dry regions in the mid-latitudes and tropics. There is also high confidence that many semi-arid areas (e.g. Mediterranean basin, western United States, southern Africa and northeast Brazil) will suffer a decrease in water resources due to climate change. {3.2; Figure 3.4}

Geographical pattern of surface warming

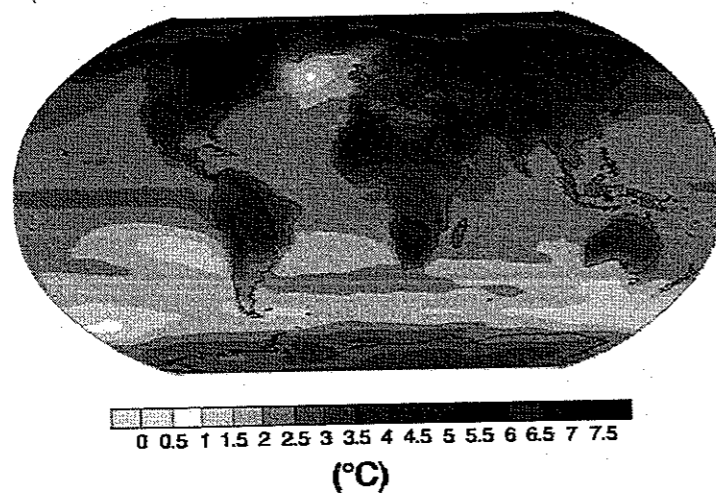


Figure SPM. 6. Projected surface temperature changes for the late 21st century (2090-2099). The map shows the multi-AOGCM average projection for the A1B SRES scenario. All temperatures are relative to the period 1980-1999. {Figure 3.2}

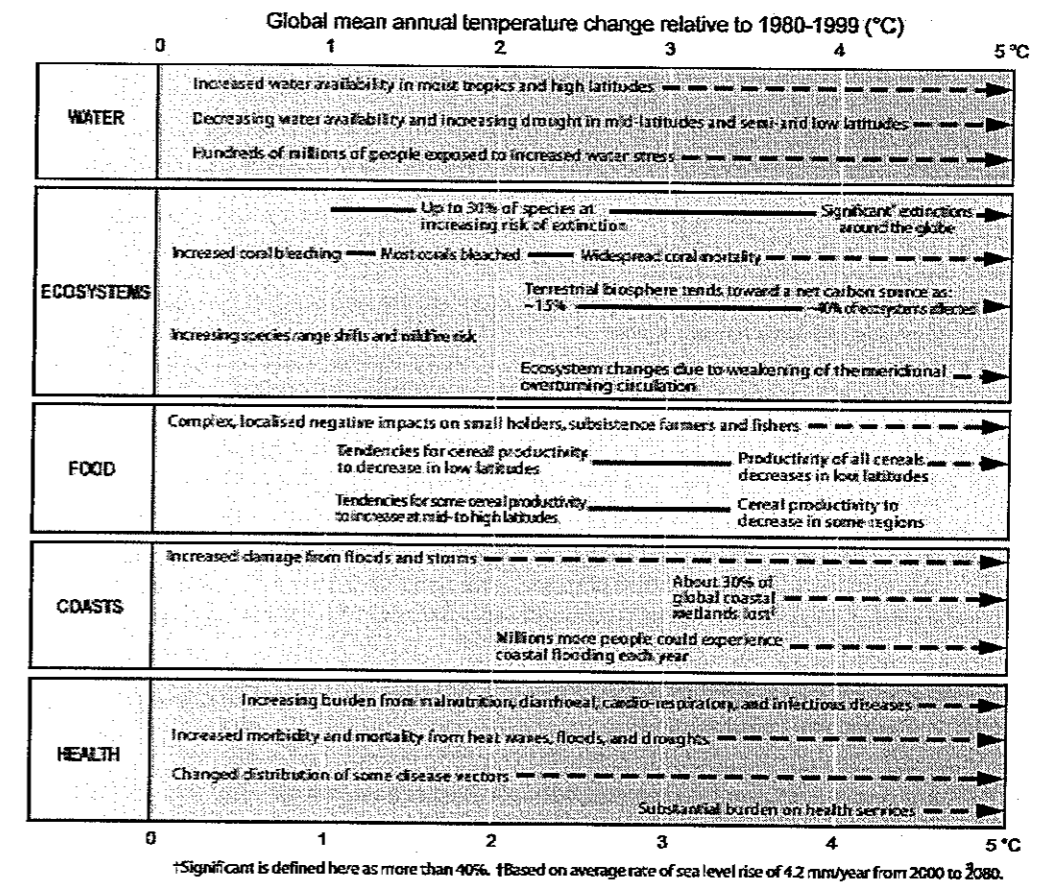
¹⁰ TAR projections were made for 2100, whereas the projections for this report are for 2090-2099. The TAR would have had similar ranges to those in Table SPM.1 if it had treated uncertainties in the same way.

¹¹ For discussion of the longer term see material below.

Studies since the TAR have enabled more systematic understanding of the timing and magnitude of impacts related to differing amounts and rates of climate change. {3.3.1, 3.3.2}

Figure SPM.7 presents examples of this new information for systems and sectors. The top panel shows impacts increasing with increasing temperature change. Their estimated magnitude and timing is also affected by development pathway (lower panel). {3.3.1, 3.3.2}

Examples of impacts associated with global average temperature change
 (Impacts will vary by extent of adaptation, rate of temperature change, and socio-economic pathway)



Warming by 2090-2099 relative to 1980-1999 for non-mitigation scenarios

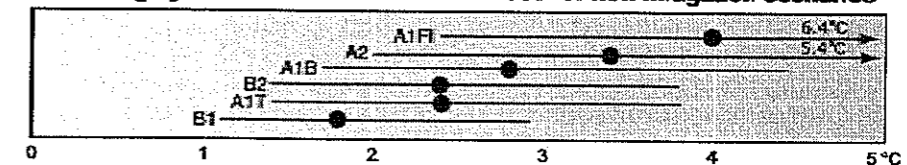


Figure SPM.7. Examples of impacts associated with projected global average surface warming. Upper panel: Illustrative examples of global impacts projected for climate changes (and sea level and atmospheric CO₂ where relevant) associated with different amounts of increase in global average surface temperature in the 21st century. The black lines link impacts. Broken-line arrows indicate impacts continuing with increasing temperature. Entries are placed so that the left hand side of text indicates the 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 SRES scenarios A1FI, A2, B1 and B2. Adaptation to climate change is not included in these estimations. Confidence levels for all statements are high. Lower panel: Dots and bars indicate the best estimate and likely ranges of warming assessed for the six SRES marker scenarios for 2090-2099 relative to 1980-1999. {Figure 3.5}

Examples of some projected impacts for different regions are given in Table SPM.2.

Table SPM.2. Examples of some projected regional impacts*

Africa	<ul style="list-style-type: none"> By 2020, between 75 and 250 million of people are projected to be exposed to increased water stress due to climate change; By 2020, in some countries, yields from rain-fed agriculture could be reduced by up to 50%. Agricultural production, including access to food, in many African countries is projected to be severely compromised. This would further adversely affect food security and exacerbate malnutrition; Towards the end of the 21st century, projected sea-level rise will affect low-lying coastal areas with large populations. The cost of adaptation could amount to at least 5-10% of Gross Domestic Product (GDP); By 2080, an increase of 5-8% of arid and semi-arid land in Africa is projected under a range of climate scenarios (TS).
Asia	<ul style="list-style-type: none"> By the 2050s, freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease; Coastal areas, especially heavily-populated megadelta regions in South, East and South-East Asia, will be at greatest risk due to increased flooding from the sea and, in some megadeltas, flooding from the rivers; Climate change is projected to compound the pressures on natural resources and the environment, associated with rapid urbanization, industrialization and economic development; Endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected to rise in East, South and South-East Asia due to projected changes in the hydrological cycle.
Australia and New Zealand	<ul style="list-style-type: none"> By 2020, significant loss of biodiversity is projected to occur in some ecologically rich sites including the Great Barrier Reef and Queensland Wet Tropics; By 2030, water security problems are projected to intensify in southern and eastern Australia and, in New Zealand, Northland and some eastern regions; By 2030, production from agriculture and forestry is projected to decline over much of southern and eastern Australia, and over parts of eastern New Zealand, due to increased drought and fire. However, in New Zealand, initial benefits are projected in some other regions.; By 2050, ongoing coastal development and population growth in some areas of Australia and New Zealand are projected to exacerbate risks from sea level rise and increases in the severity and frequency of storms and coastal flooding.
Europe	<ul style="list-style-type: none"> Climate change is expected to magnify regional differences in Europe's natural resources and assets. Negative impacts will include increased risk of inland flash floods, and more frequent coastal flooding and increased erosion (due to storminess and sea-level rise); Mountainous areas will face glacier retreat, reduced snow cover and winter tourism, and extensive species losses (in some areas up to 60% under high emissions scenarios by 2080); In Southern Europe, climate change is projected to worsen conditions (high temperatures and drought) in a region already vulnerable to climate variability, and to reduce water availability, hydropower potential, summer tourism and, in general, crop productivity; Climate change is also projected to increase the health risks due to heat-waves, and the frequency of wildfires.
Latin America	<ul style="list-style-type: none"> By mid century, increases in temperature and associated decreases in soil water are projected to lead to gradual replacement of tropical forest by savanna in eastern Amazonia. Semi-arid vegetation will tend to be replaced by arid-land vegetation. There is a risk of significant biodiversity loss through species extinction in many areas of tropical Latin America; Productivity of some important crops is projected to decrease and livestock productivity to decline, with adverse consequences for food security. In temperate zones soybean yields are projected to increase. Overall, the number of people at risk of hunger is projected to increase (TS; <i>medium confidence</i>). Changes in precipitation patterns and the disappearance of glaciers are projected to significantly affect water availability for human consumption, agriculture and energy generation.
North America	<ul style="list-style-type: none"> Warming in western mountains is projected to cause decreased snowpack, more winter flooding, and reduced summer flows, exacerbating competition for over-allocated water resources; In the early decades of the century, moderate climate change is projected to increase aggregate yields of rain-fed agriculture by 5-20%, but with important variability among regions. Major challenges are projected for crops that are near the warm end of their suitable range or which depend on highly utilized water resources; During the course of this century, cities that currently experience heatwaves are expected to be further challenged by an increased number, intensity and duration of heatwaves during the course of the century, with potential for adverse health impacts; Coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution.
Polar Regions	<ul style="list-style-type: none"> The main projected biophysical effects are reductions in thickness and extent of glaciers and ice sheets and sea ice, and changes in natural ecosystems with detrimental effects on many organisms including migratory birds, mammals and higher predators; For human communities in the Arctic, impacts, particularly those resulting from changing snow and ice conditions are projected to be mixed; Detrimental impacts would include those on infrastructure and traditional indigenous ways of life; In both polar regions, specific ecosystems and habitats are projected to be vulnerable, as climatic barriers to species invasions are lowered.

Table SPM.2. (cont.)

Small Islands	<ul style="list-style-type: none"> Sea-level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of island communities; Deterioration in coastal conditions, for example through erosion of beaches and coral bleaching is expected to affect local resources; By mid-century, climate change is expected to reduce water resources in many small islands, e.g., in the Caribbean and Pacific, to the point where they become insufficient to meet demand during low-rainfall periods. With higher temperatures, increased invasion by non-native species is expected to occur, particularly on mid- and high-latitude islands.
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*Unless stated explicitly, all entries are from WGII SPM text, and are either very high confidence or high confidence statements, reflecting different sectors (Agriculture, Ecosystems, Water, Coasts, Health, Industry and Settlements). The WGII SPM refers to the source of the statements, timelines and temperatures. The magnitude and timing of impacts that will ultimately be realized will vary with the amount and rate of climate change, emission scenarios, development pathways and adaptation.

Now Ball

Some systems, sectors and regions are likely to be especially affected by climate change.¹²

Systems and sectors: {3.3.4}

- particular ecosystems:
 - terrestrial: tundra, boreal forest and mountain regions because of sensitivity to warming; mediterranean-type ecosystems because of reduction in rainfall; and tropical rainforests where precipitation declines
 - coastal: mangroves and salt marshes due to multiple stresses
 - marine: coral reefs due to multiple stresses; the sea ice biome because of sensitivity to warming
- water resources in some dry regions at mid-latitudes¹³ and in the dry tropics, due to changes in rainfall and evapotranspiration, and in areas dependent on snow and ice melt
- agriculture in low-latitudes, due to reduced water availability
- low-lying coastal systems, due to threat of sea level rise and increased risk from extreme weather events
- human health in populations with low adaptive capacity.

Regions: {3.3.4}

- the Arctic, because of the impacts of high rates of projected warming on natural systems and human communities
- Africa, because of low adaptive capacity and projected climate change impacts
- small islands, where there is high exposure of population and infrastructure to projected climate change impacts
- Asian and African megadeltas, due to large populations and high exposure to sea level rise, storm surges and river flooding.

Within other areas, even those with high incomes, some people (such as the poor, young children, and the elderly) can be particularly at risk, and also some areas and some activities. {3.3.4}

Ocean Acidification

The uptake of anthropogenic carbon since 1750 has led to the ocean becoming more acidic with an average decrease in pH of 0.1 units. Increasing atmospheric CO₂ concentrations lead to further acidification. Projections based on SRES scenarios give a reduction in average global surface ocean pH of between 0.14 and 0.35 units over the 21st century. While the effects of observed ocean acidification on the marine biosphere are as yet undocumented, the progressive acidification of oceans is expected to have negative impacts on marine shell-forming organisms (e.g. corals) and their dependent species. {3.3.1}

¹² Identified on the basis of expert judgement of the assessed literature and considering the magnitude, timing and projected rate of climate change, sensitivity and adaptive capacity.

¹³ Including arid and semi-arid regions.

Altered frequencies and intensities of extreme weather, together with sea level rise, are expected to have mostly adverse effects on natural and human systems. {3.3.3}

Examples for selected extremes and sectors are shown in Table SPM.3. {Table 3.2}

Table SPM.3. Examples of possible impacts of climate change due to changes in extreme weather and climate events, based on projections to the mid- to late 21st century. These do not take into account any changes or developments in adaptive capacity. The likelihood estimates in column 2 relate to the phenomena listed in column 1. {WGII Table SPM.1}

Phenomenon* and direction of trend	Likelihood of future trends based on projections for 21 st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems (WGII 4.4, 5.4)	Water resources (WGII 3.4)	Human health (WGII 8.2, 8.4)	Industry, settlement and society (WGII 7.4)
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	Virtually certain ^b	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks	Effects on water resources relying on snowmelt; effects on some water supplies	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism
Warm spells/heat waves. Frequency increased over most land areas	Very likely	Reduced yields in warmer regions due to heat stress; increased danger of wildfire	Increased water demand; water quality problems, e.g. algal blooms	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor
Heavy precipitation events. Frequency increases over most areas	Very likely	Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding; pressures on urban and rural infrastructures; loss of property
Area affected by drought increases	Likely	Land degradation; lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases	Water shortage for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration
Intense tropical cyclone activity increases	Likely	Damage to crops; windthrow (uprooting) of trees; damage to coral reefs	Power outages causing disruption of public water supply	Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers, potential for population migrations, loss of property
Increased incidence of extreme high sea level (excludes tsunamis) ^c	Likely ^d	Salinisation of irrigation water, estuaries and freshwater systems	Decreased freshwater availability due to saltwater intrusion	Increased risk of deaths and injuries by drowning in floods; migration-related health effects	Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above

Notes:
a) See WGI Table 3.7 for further details regarding definitions.
b) Warming of the most extreme days and nights each year.
c) Extreme high sea level depends on average sea level and on regional weather systems. It is defined as the highest 1% of hourly values of observed sea level at a station for a given reference period.
d) In all scenarios, the projected global average sea level at 2100 is higher than in the reference period (WGI 10.6). The effect of changes in regional weather systems on sea level extremes has not been assessed.

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

Estimated long term (multi-century) warming corresponding to the six AR4 WG III stabilisation categories is shown in Figure SPM.8.

Estimated multi-century warming relative to 1980-1999 for AR4 stabilisation categories

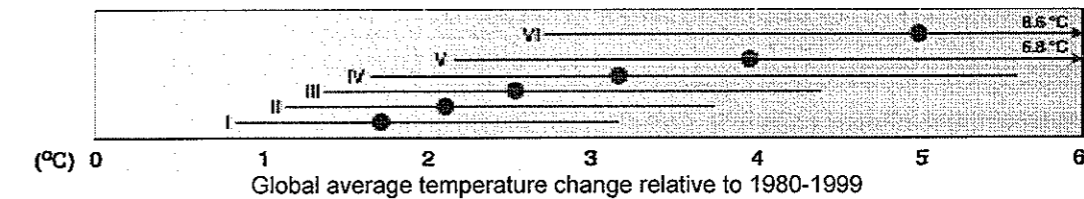


Figure SPM.8. Estimated long term (multi-century) warming corresponding to the six AR4 WGIII stabilisation categories (Table SPM.3). Temperature scale has been shifted by -0.5°C compared to Table SPM.3 to account approximately for the warming between pre-industrial and 1980-1999. For most stabilisation levels global average temperature is approaching the equilibrium level over a few centuries. For GHG emission scenarios that lead to stabilisation by 2100 at levels comparable to SRES B1 and A1B (600 and 850 CO₂-eq. ppm; category IV and V) assessed models project that about 65-70% of the estimated global equilibrium temperature increase assuming a climate sensitivity of 3°C would be realised at the time of stabilisation (WGI 10.7.2). For the much lower stabilisation scenarios (category I and II), the equilibrium temperature may be reached earlier (Figure SPM.11).

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 4.6°C relative to pre-industrial values. The corresponding future temperatures in Greenland are comparable to those inferred for the last interglacial period 125,000 years ago, when paleoclimatic information suggests reductions of polar land ice extent and 4 to 6 m of sea level rise. {3.2.3}

Current global model studies project that the Antarctic ice sheet will remain too cold for widespread surface melting and 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}

Anthropogenic warming could lead to some impacts that are abrupt or irreversible, depending upon the rate and magnitude of the climate change. {3.4}

Partial loss of ice sheets on polar land could imply metres of sea level rise, major changes in coastlines and inundation of low-lying areas, with greatest effects in river deltas and low-lying islands. Such changes are projected to occur over millennial time scales, but more rapid sea level rise on century time scales cannot be excluded. {3.4}

Climate change is likely to lead to some irreversible impacts. There is medium confidence that approximately 20-30% of species assessed so far are likely to be at increased risk of extinction if increases in global average warming exceed 1.5-2.5°C (relative to 1980-1999). As global average temperature increase exceeds about 3.5°C, model projections suggest significant extinctions (40-70% of species assessed) around the globe. {3.4}

Based on current model simulations, the meridional overturning circulation (MOC) of the Atlantic Ocean will very likely slow down during the 21st century; nevertheless temperatures over the Atlantic and Europe are projected to increase. The MOC is very unlikely to undergo a large abrupt transition during the 21st century. Longer-term MOC changes 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 CO₂ uptake, oceanic oxygen concentrations and terrestrial vegetation. Changes in terrestrial and ocean CO₂ uptake may feed back on the climate system. {3.4}