Topic 3 – Climate change and its impacts in the near and long term under different scenarios
(31 August 2007)

3.1 Emission scenarios

There is *high agreement* and *much evidence*[7] that with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades. Baseline emissions scenarios published since the IPCC Special Report on Emissions Scenarios (SRES) are comparable in range to those presented in SRES (Figure 3.1).[8] {WGIII 1.3, 3.2, SPM}

SRES scenarios

SRES refers to the scenarios described in the IPCC Special Report on Emission Scenarios (IPCC, 2000). The SRES scenarios are grouped into four scenario families (A1, A2, B1, and B2) that explore alternative development pathways in the absence of climate policies, covering a wide range of demographic, economic, and technological driving forces and resulting GHG emissions. The emission projections are widely used in the assessments of future climate change, and their underlying assumptions with respect to socio-economic, demographic and technological change serve as inputs to many recent climate change vulnerability and impact assessments. {WGI 10.1; WGII 2.4; WGIII SPM, TS.1}

The A1 storyline describes a world of very rapid economic growth, a global population that peaks in mid-century and rapid introduction of new and more efficient technologies. A1 is divided into three groups that describe alternative directions of technological change: fossil intensive (A1FI), non-fossil energy resources (A1T), and a balance across all sources (A1B). B1 describes a convergent world, with the same global population as A1, but with more rapid changes in economic structures toward a service and information economy. B2 describes a world with intermediate population and economic growth, emphasising local solutions to economic, social, and environmental sustainability. A2 describes a very heterogeneous world with high population growth, slow economic development and slow technological change. No likelihood has been attached to any of the SRES scenarios. {WGIII SPM, TS.1}

The SRES (non-mitigation) scenarios project an increase of baseline global GHG emissions by a range of 9.7 $GtCO_2$-eq to 36.7 $GtCO_2$-eq (25-90%) between 2000 and 2030. In these scenarios, fossil fuels are projected to maintain their dominant position in the global energy mix to 2030 and beyond. Hence CO_2 emissions between 2000 and 2030 from energy use are projected to grow 40 to 110% over that period. {WGIII 1.3, SPM}

Studies since SRES have used lower values for some drivers for emissions, notably population projections. However, for those studies incorporating these new population

[7] Agreement/evidence statements in italics represent calibrated expressions of uncertainty and confidence. See Box 'Treatment of uncertainty' in the Introduction for an explanation of these terms.

[8] Baseline scenarios do not include additional climate policy above current ones; more recent studies differ with respect to UNFCCC and Kyoto inclusion.

projections, changes in other drivers, such as economic growth, result in little change in overall emission levels. Economic growth projections for Africa, Latin America and the Middle East to 2030 in post-SRES baseline scenarios are lower than in SRES, but this has only minor effects on global economic growth and overall emissions. Aerosols have a net cooling effect and the representation of aerosol and aerosol precursor emissions, including sulphur dioxide, black carbon, and organic carbon has improved. Generally, they are projected to be lower than reported in SRES. Available studies indicate that the choice of exchange rate for GDP (MER or PPP) does not appreciably affect the projected emissions, when used consistently. The differences, if any, are small compared to the uncertainties caused by assumptions on other parameters in the scenarios, e.g. technological change. {WGIII 3.2, TS.3, SPM}

While these post-SRES emissions scenarios have not been widely used for projections by either the climate modelling or impacts communities, they are largely consistent with the possible future development pathways and corresponding GHG emission ranges in the absence of climate policies presented in SRES. {WGIII 3.2}

Scenarios for GHG emissions from 2000 to 2100 in the absence of climate policies

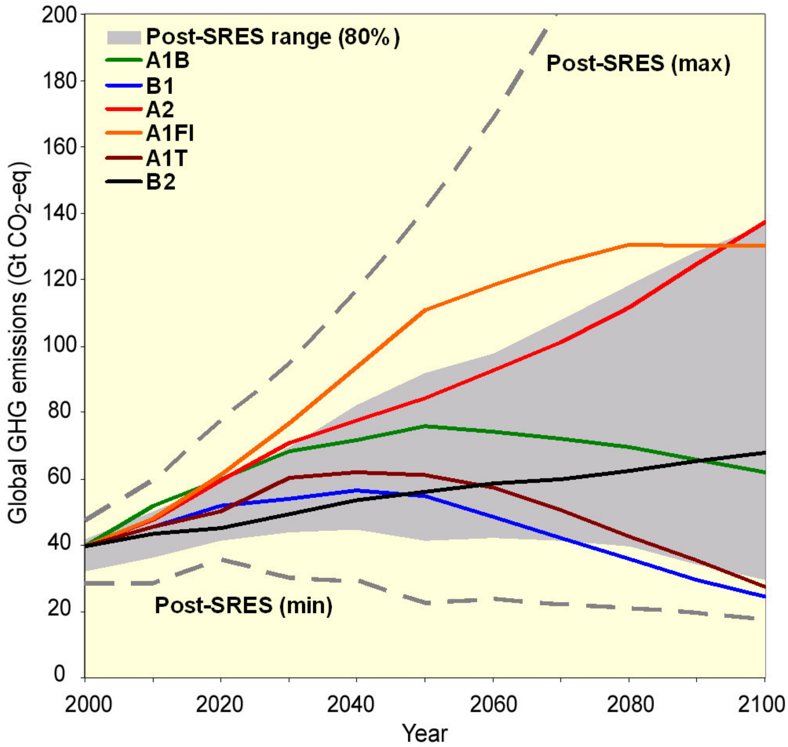


Figure 3.1. Global GHG emissions (in CO_2-eq) in the absence of climate policies: six illustrative SRES marker scenarios (coloured lines) and 80th percentile range of recent post-SRES baseline scenarios (grey shaded area). Dashed lines show the full range of post-SRES scenarios. The emissions include CO_2, CH_4, N_2O, and F-gases. {WGIII 1.3, 3.2, Figure SPM 4}

3.2 Projections of future changes in climate

Since the IPCC's first report in 1990, assessed projections have suggested global averaged temperature increases between about 0.15 and 0.3°C per decade from 1990 to 2005. This can now be compared with observed values of about 0.2°C per decade, strengthening confidence in near-term projections. For the next two decades a warming

of about 0.2°C per decade is projected for a range of SRES emission scenarios. Beyond the next few decades, climate projections increasingly depend on future GHG emission scenarios (Figure 3.2). {WGI 1.2, 3.2, 9.4, 10.3, 10.7; WGIII 3.2}

3.2.1 21st century global changes

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. {WGI 10.3}

Advances in climate change modelling now enable best estimates and *likely* assessed uncertainty ranges to be given for projected warming for different emission scenarios. Table 3.1 shows best estimates and *likely* ranges for global average surface air warming for the six SRES emissions marker scenarios (including climate-carbon cycle feedbacks). {WGI 10.5}

Although these projections are broadly consistent with the span quoted in the TAR (1.4 to 5.8°C), they are not directly comparable[9]. Assessed upper ranges for temperature projections are larger than in the TAR mainly because the broader range of models now available suggests stronger climate-carbon cycle feedbacks. A range of climate models project that by 2100, carbon cycle feedbacks could add between 20 and 220 ppm to atmospheric CO_2 concentration and between 0.1 and 1.5°C to temperature rise. Carbon feedbacks are discussed in topic 2.3. {WGI 7.3, 10.5, SPM}

Table 3.1. Projected global average surface warming and sea level rise at the end of the 21st century. {WGI 10.5, 10.6, Table 10.7, Table SPM.3}

	Temperature change (°C at 2090-2099 relative to 1980-1999) [a, d]		Sea level rise (m at 2090-2099 relative to 1980-1999)
Case	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:
a) These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth Models of Intermediate Complexity, and a large number of Atmosphere-Ocean General Circulation Models (AOGCMs).
b) Year 2000 constant composition is derived from AOGCMs only.
c) All scenarios above are six SRES marker scenarios.
d) Add about half a degree C to the temperature ranges shown to obtain warming relative to pre-industrial.

[9] 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 3.1 if it had treated uncertainties in the same way.

Because understanding of some important effects that determine 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. Instead, model-based projections of global average sea level rise at the end of the 21st century (2090-2099) are shown in Table 3.1. For each scenario, the midpoint of the range in Table 3.1 is within 10% of the TAR model average for 2090-2099. The ranges are narrower than in the TAR mainly because of improved information about some uncertainties in the projected contributions. The sea level projections do not include uncertainties in climate-carbon cycle feedbacks nor do they include the full effects of changes in ice sheet flow, because a basis in published literature is lacking. The projections include a contribution due to increased ice flow from Greenland and Antarctica at the rates observed for 1993-2003, but these flow rates could increase or decrease in the future. If this contribution were to grow linearly with global average temperature change, the upper ranges of sea level rise for SRES scenarios shown in Table 3.1 would increase by 0.1 m to 0.2 m. Larger values for sea level rise cannot be excluded. {WGI 10.6, SPM}

3.2.2 21st century regional changes

The projected patterns of climate change are not uniform across the globe. 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 sea ice. {WGI 8.2, 8.3, 8.4, 8.5, 9.4, 9.5, 10.3, 11.1}

Projected warming in the 21st century shows scenario-independent geographical patterns similar to those observed over the past several decades. Warming is expected to be greatest over land and at most high northern latitudes, and least over the Southern Ocean (near Antarctica) and northern North Atlantic (Figure 3.2 right panels). {WGI 10.3, SPM}

Atmosphere-Ocean General Circulation Model projections of surface warming

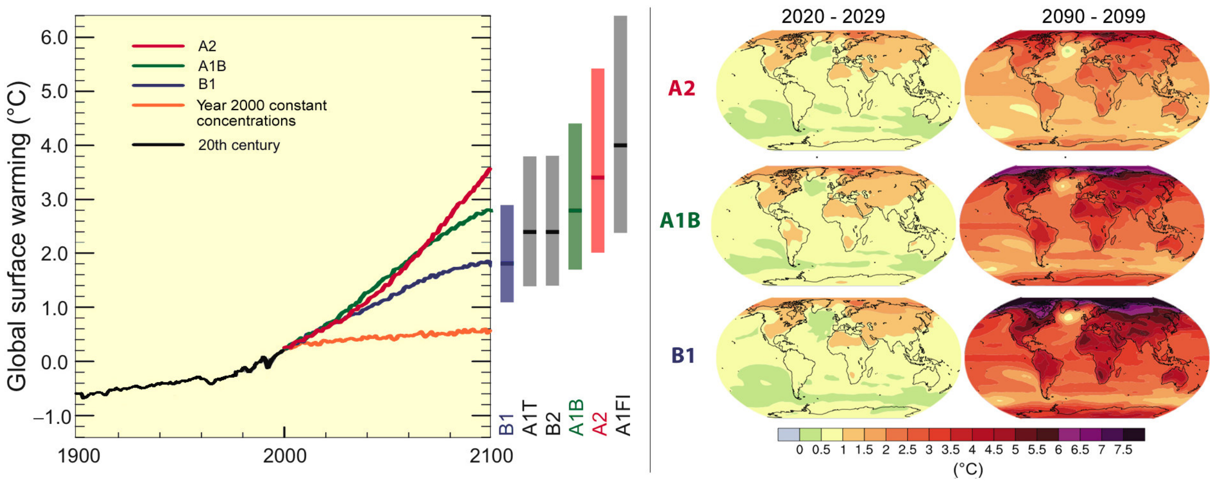


Figure 3.2. Left panel: Solid lines are multi-model global averages of surface warming (relative to 1980-1999) for the SRES scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. The orange line is for the experiment where concentrations were held constant at year 2000 values. The bars in the middle of the figure indicate the best estimate (solid line within each bar) and the *likely* range assessed for the six SRES marker scenarios at 2090-2999 relative to 1980-1999. The assessment of the best estimate and *likely* ranges in the bars includes the Atmosphere-Ocean General Circulation Models (AOGCMs) in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. **Right panels:** Projected surface temperature changes for the early and late 21st century relative to the period 1980-1999. The panels show the multi-AOGCM average projections for the A2 (top), A1B (middle) and B1 (bottom) SRES scenarios averaged over decades 2020-2029 (left) and 2090-2099 (right). {WGI 10.4, 10.8; Figures 10.28, 10.29, SPM}

Snow cover area is projected to contract. Widespread increases in thaw depth are projected over most permafrost regions. Sea ice is projected to shrink in both the Arctic and Antarctic under all SRES scenarios. In some projections, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century. {WGI 10.3, 10.6, SPM; WGII 15.3.4}

It is *very likely* that hot extremes, heat waves, and heavy precipitation events will become more frequent. {SYR Table 3.2; WGI 10.3, SPM}

Based on a range of models, it is *likely* that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea-surface temperatures. There is less confidence in projections of a global decrease in numbers of tropical cyclones. The apparent increase in the proportion of very intense storms since 1970 in some regions is much larger than simulated by current models for that period. {WGI 3.8, 9.5, 10.3, SPM}

Extra-tropical storm tracks are projected to move poleward, with consequent changes in wind, precipitation, and temperature patterns, continuing the broad pattern of observed trends over the last half-century. {WGI 3.6, 10.3, SPM}

Since the TAR there is an improving understanding of projected patterns of precipitation. Increases in the amount of precipitation are *very likely* in high-latitudes, while decreases are *likely* in most subtropical land regions (by as much as about 20% in the A1B scenario in 2100, Figure 3.3), continuing observed patterns in recent trends. {WGI 3.3, 8.3, 9.5, 10.3, 11.2-11.9, SPM}

Projected patterns of precipitation changes

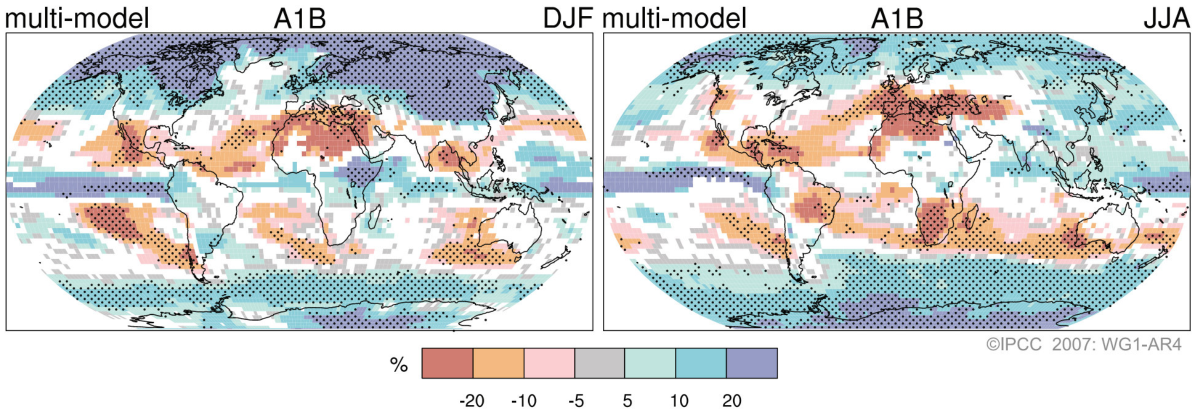


Figure 3.3. Relative changes in precipitation (in percent) for the period 2090-2099, relative to 1980-1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {WGI Figure 10.9, SPM}

3.2.3 Beyond 21st century changes

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. {WGI 10.4, 10.5, 10.7, SPM}

If radiative forcing were to be stabilised, keeping all the radiative forcing agents constant at B1 or A1B levels in 2100, model experiments show that a further increase in global average temperature of about 0.5°C would still be expected by 2200. In addition, thermal expansion alone would lead to 0.3 to 0.8 m of sea level rise by 2300 (relative to 1980-1999). Thermal expansion would continue for many centuries, due to the time required to transport heat into the deep ocean. {WGI 10.7, SPM}

Contraction of the Greenland ice sheet is projected to continue to contribute to sea level rise after 2100. Current models suggest ice mass losses increase with temperature more rapidly than gains due to increased precipitation and that the surface mass balance becomes negative (net ice loss) at a global average warming (relative to pre-industrial values) in excess of 1.9 to 4.6°C. If a negative surface mass balance were sustained for millennia, that would lead to virtually complete elimination of the Greenland ice sheet and a resulting contribution to sea level rise of about 7 m. The corresponding future temperatures in Greenland (1.9 to 4.6°C global) 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. {WGI 6.4, 10.7, SPM}

Dynamical processes related to ice flow – which are not included in current models but suggested by recent observations – could increase the vulnerability of the ice sheets to warming, increasing future sea level rise. Understanding of these processes is limited and there is no consensus on their magnitude. {WGI 4.6, 10.7, SPM}

Current global 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. {WGI 10.7, SPM}

Both past and future anthropogenic CO_2 emissions will continue to contribute to warming and sea level rise for more than a millennium, due to the time scales required for the removal of this gas from the atmosphere. {WGI 7.3, 10.3, Figure 7.12, Figure 10.35, SPM}

3.3 Impacts of future climate changes

The following is a selection of key findings[10] regarding the impacts of climate change on systems, sectors and regions, as well as some findings on vulnerability[11], for the range of climate changes projected over the 21st century. {WGII SPM}

The magnitude and timing of projected impacts depend on the amount and timing of climate change, the development pathway, i.e., projected social and economic changes, and in some cases, the capacity to adapt. {WGII 2.4, 19.4.1, SPM}

[10] Criteria of choice: magnitude and timing of impact, confidence in the assessment, representative coverage of the system, sector and region.

[11] Vulnerability to climate change is the degree to which systems are susceptible to, and unable to cope with, adverse impacts.

In the selected examples below, quantitative information is available and impacts are judged to be relevant for people and the environment, in the absence of adaptation. Unless otherwise stated, the confidence level in the projections is *high*. Global average temperature increases are given relative to 1980-1999. Additional information on impacts can be found in the WG II report. {WGII SPM}

3.3.1 Impacts on systems and sectors

Ecosystems:

- The resilience of many ecosystems is *likely* to be exceeded this century by an unprecedented combination of climate change, associated disturbances (e.g. flooding, drought, wildfire, insects, ocean acidification), and other global change drivers (e.g. land-use change, pollution, fragmentation of natural systems, over-exploitation of resources). {WGII 4.1-4.6, SPM}
- Over the course of this century, net carbon uptake by terrestrial ecosystems is likely to peak before mid-century and then weaken or even reverse[12], thus amplifying climate change. {WGII 4.ES, Figure 4.2, SPM}
- For increases in global average temperature exceeding 1.5-2.5°C and in concomitant atmospheric CO_2 concentrations, there are projected to be major changes in ecosystem structure and function, species' ecological interactions, and shifts in species' geographical ranges, with predominantly negative consequences for biodiversity and ecosystem goods and services, e.g. water and food supply. {WGII Box TS.6, 4.4, SPM}
- The progressive acidification of oceans due to increasing atmospheric CO_2 is expected to have negative impacts on marine shell-forming organisms (e.g. corals) and their dependent species (*medium confidence*). {WGI 5.4, Box 7.3, 10.4, SPM; WGII Box 4.4, 6.4, TS.4.1, SPM}

Food:

- Crop productivity is projected to increase slightly at mid- to high latitudes for local mean temperature increases of up to 1-3°C depending on the crop, and then decrease beyond that in some regions (*medium confidence*). {WGII 5.4, SPM}
- At lower latitudes, especially in seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1-2°C), which would increase the risk of hunger (*medium confidence*). {WGII 5.4, SPM}
- Globally, the potential for food production is projected to increase with increases in local average temperature over a range of 1-3°C, but above this it is projected to decrease (*medium confidence*). {WGII 5.4, 5.5, SPM}

Coasts:

- Coasts are projected to be exposed to increasing risks, including coastal erosion, due to climate change and sea level rise. The effect will be exacerbated by increasing human-induced pressures on coastal areas (*very high confidence*). {WGII 6.3, 6.4, SPM}
- By the 2080s, many millions more people than today are projected to experience floods every year due to sea level rise. The numbers affected will be largest in the

[12] Assuming continued GHG emissions at or above current rates and other global changes including land-use changes.

densely-populated and low-lying areas megadeltas of Asia and Africa while small islands are especially vulnerable. (*very high confidence*) {WGII 6.4, 6.5, Table 6.11, SPM}

Industry, settlements and society:

- The most vulnerable industries, settlements and societies are generally those in coastal and river flood plains, those whose economies are closely linked with climate-sensitive resources, and those in areas prone to extreme weather events, especially where rapid urbanisation is occurring. {WGII 7.1, 7.3, 7.4, 7.5, SPM}
- Poor communities can be especially vulnerable, in particular those concentrated in high-risk areas. {WGII 7.2, 7.4, 5.4, SPM}

Health:

- The health status of millions of people is projected to be affected through, for example, increases in malnutrition; increased deaths, diseases and injury due to extremes; increased burden of diarrhoeal diseases; increased frequency of cardio-respiratory diseases due to higher concentrations of ground-level ozone in urban areas related to climate change; and the altered spatial distribution of some infectious diseases. {WGI 7.4, Box 7.4; WGII 8.4, 8.ES, 8.2, SPM}
- Climate change is projected to bring some benefits in temperate areas, such as fewer deaths from cold exposure, and some mixed effects such as changes in range and transmission potential of malaria in Africa. Overall it is expected that benefits will be outweighed by the negative health effects of rising temperatures, especially in developing countries. {WGII 8.4, SPM}
- Critically important will be factors that directly shape the health of populations such as education, health care, public health initiatives, and infrastructure and economic development. {WGII 8.3, SPM}

Water:

- Water impacts are key for all sectors and regions. These are discussed below in the Box 'Climate change and water'.

Climate change and water

Climate change is expected to exacerbate current stresses on water resources from population growth and economic and land-use change, including urbanisation. On a regional scale, mountain snow pack, glaciers and small ice caps play a crucial role in fresh water availability. Widespread mass losses from glaciers and reductions in snow cover over recent decades are projected to accelerate throughout the 21st century, reducing water availability, hydropower potential, and changing seasonality of flows in regions supplied by meltwater from major mountain ranges (e.g. Hindu-Kush, Himalaya, Andes), where more than one-sixth of the world population currently lives. {WGI 4.1, 4.5; WGII 3.3, 3.4, 3.5}

Changes in precipitation (Figure 3.3) and temperature (Figure 3.2) lead to changes in runoff (Figure 3.4) and water availability. Runoff is projected to increase by 10-40% by mid-century at higher latitudes and in some wet tropical areas, including populous areas in East and South-East Asia, and decrease by 10-30% over some dry regions at mid-latitudes and dry tropics (Figure 3.3), due to decreases in rainfall and higher rates of evapotranspiration. Drought-affected areas are projected to increase in extent, with the potential for adverse impacts on multiple sectors, e.g. agriculture, water supply, energy production, and health. Regionally, large increases in irrigation water demand as a result of climate changes are projected. {WGI 10.3, 11.2-11.9; WGII 3.4, 3.5, SPM}

The beneficial impacts of increased annual runoff in some areas are likely to be tempered by negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality and flood risk. {WGII TS.4.1}

Available research suggests a significant future increase in heavy rainfall events in many regions, including some in which the mean rainfall is projected to decrease. The resulting increased flood risk poses challenges to society, physical infrastructure and water quality. It is *likely* that up to 20% of the world population will live in areas where river flood potential could increase by the 2080s. Increases in the frequency and severity of floods and droughts are projected to adversely affect sustainable development. {WGI 11.2-11.9; WGII 3.2, 3.3, 3.4}

Projected relative changes in runoff by the end of the 21st century

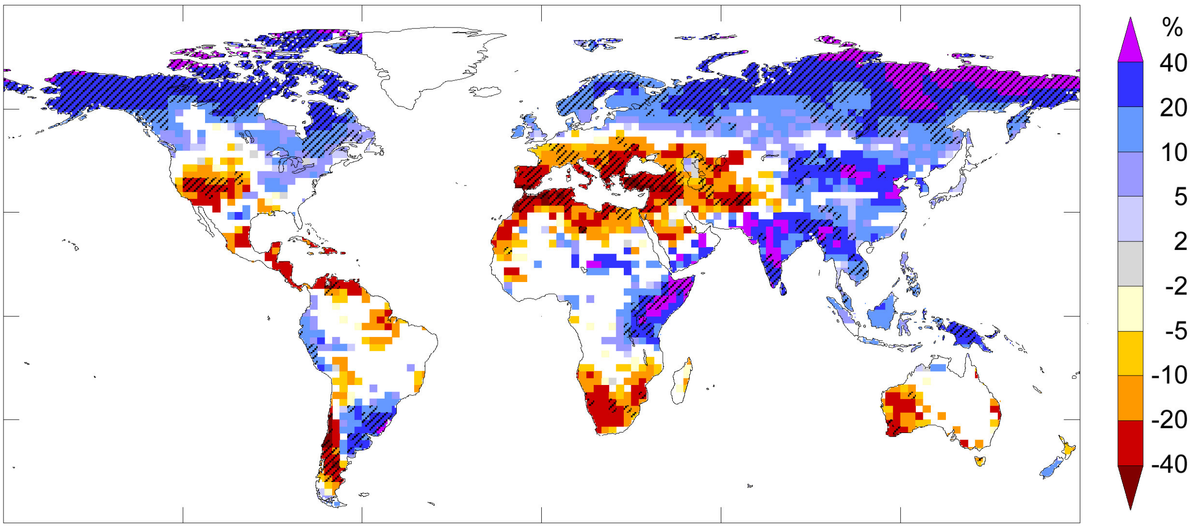
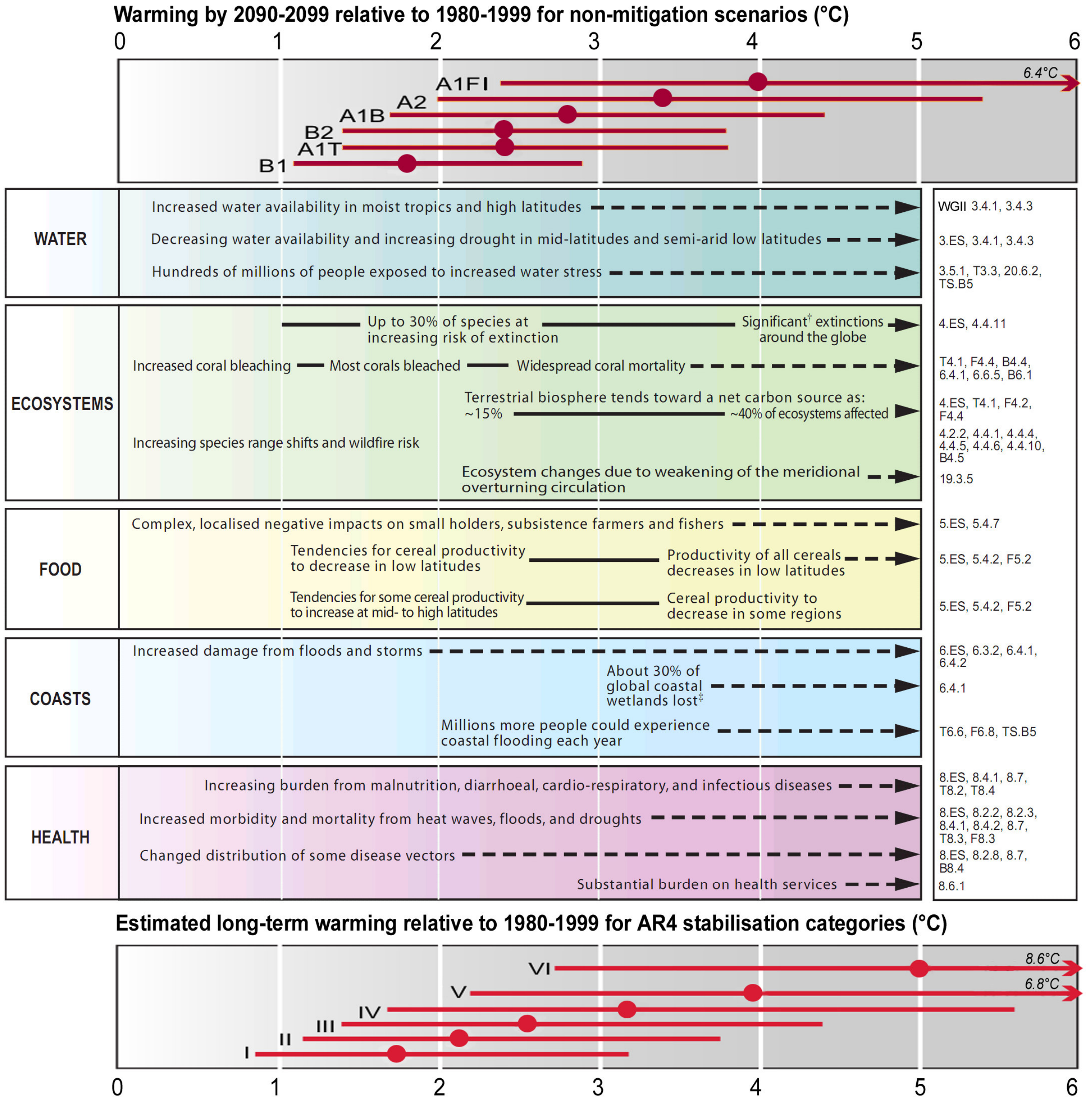


Figure 3.4. Relative changes in annual runoff (in %) for the period 2090-2099, relative to 1980-1999. Values are derived from a multi-model ensemble and are based on the SRES A1B scenario. White areas are where less than 66% of the 12 considered models agree on the sign of change and stippled areas are where more than 90% models agree on the sign of change. The global map of annual runoff illustrates a broad future but it is not intended to refer to smaller temporal and spatial scales. In some areas with projected increases in annual runoff, different seasonal effects are expected, such as increased wet season runoff and decreased dry season runoff. Hence dry season problems would increase in severity if the extra water in the wet season is not stored. Many national studies have been based on results of one or two climate models, which can be considerably different from the median of a multi-model ensemble. {WGII Figure 3.4, adjusted to match the assumptions of Figure SYR 3.3; WGII 3.3.1, 3.4.1, 3.5.1}

Magnitudes of impact can now be estimated more systematically for a range of possible increases in global average temperature. {WGII SPM}

Examples of this new information are presented in Figure 3.5. Depending on circumstances, some of the impacts shown in Figure 3.5 could be associated with ‘key vulnerabilities’, based on a number of criteria in the literature (magnitude, timing, persistence/reversibility, the potential for adaptation, distributional aspects, likelihood and ‘importance’ of the impacts) (see topic 5.2). {WGII SPM}

Examples of impacts associated with projected global average surface warming



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

Figure 3.5. Examples of impacts associated with projected global average surface warming. **Upper 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. Together, the upper and middle parts of this figure demonstrate the influence of different SRES emission scenarios on the severity of the impacts. **Middle panel:** Illustrative examples of global impacts projected for climate changes (and sea level and atmospheric CO_2 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*. The middle right panel gives the WG II references for the statements made in the middle left panel[13]. **Lower panel:** Estimated long term (multi-century) warming corresponding to the six AR4 WG III stabilisation categories

[13] Where ES = Executive Summary, T = Table, B = Box and F = Figure. Thus B4.5 indicates Box 4.5 in Chapter 4 and 3.5.1 indicates Section 3.5.1 in Chapter 3.

(Table 5.1). Warming is reduced by half a degree C compared to Table 5.1 to account approximately for the warming between pre-industrial and 1980-1999. {WGI Figure SPM.5, 10.7; WGII Figure SPM.2; WGIII Table TS.2, Table 3.10}

Some future impacts already appear unavoidable owing to the inertia of the climate system. {WGI 10.3, 10.7, SPM; WGII Figure SPM.2}

Even if the concentrations of all GHGs and aerosols had been kept constant at year 2000 levels, a further warming of about 0.6°C relative to 1980-1999 levels would be expected over the 21st century. Even the most stringent stabilisation scenarios assessed in the AR4 (see topic 5.4) project further increases in GHG concentrations, leading to even higher temperature increases and associated climate changes. {WGI 10.3, 10.7, SPM; WGIII 3.2, 3.3}

This suggests that some future impacts projected to occur at low levels of additional warming over the 21st century (see Figure 3.5) are already unavoidable, even with adaptation, for example increases in:

- coral bleaching
- species range shifts
- drought risk and water scarcity in some regions of the dry tropics and subtropics
- risk of wildfire
- coastal damage from floods combined with sea level rise.

3.3.2 Impacts on regions

Africa:

- Between 75 and 250 million people are projected to be exposed to increased water stress due to climate change by 2020 (a warming of less than 1°C). {WGII 3.4, 8.2, 8.4, 9.4, SPM}
- The area suitable for agriculture, the length of the growing seasons and yield potential, particularly along the margins of semi-arid and arid areas, are expected to decrease. This would further adversely affect food security and exacerbate malnutrition in the continent. {WGII 9.2, 9.4, 9.6, SPM}
- Ecosystems in Africa are projected to experience major shifts in species range and possible extinctions (*medium confidence*). {WGII Box TS.6, Table TS.4, 9.4.5, SPM}

Asia:

- Freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease during the dry season. Along with population growth and increasing demand arising from higher standards of living, this could adversely affect more than a billion people by the 2050s.{WGI 11.4; WGII 10.4, SPM}
- 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 rivers. {WGII 10.2, 10.4, 10.5, SPM}
- It is projected that crop yields could increase up to 20% in East and Southeast Asia, while they could decrease up to 30% in Central and South Asia by the mid-21st century (*medium confidence*). {WGII Box TS.6, Table TS.4, 10.4.1, SPM}

Australia and New Zealand:

- Water security problems are projected to intensify by 2030 in southern and eastern Australia and, in New Zealand, in Northland and some eastern regions. {WGII Box TS.6, 11.4.1, SPM}
- Significant loss of biodiversity is projected to occur by 2020 in some ecologically rich sites including the Great Barrier Reef and Queensland Wet Tropics; other sites are also at risk (*very high confidence*). {WGII Table TS.4, Box TS.6, Box 11.3, SPM}
- Production from agriculture and forestry by 2030 is projected to decline over much of southern and eastern Australia, and over parts of eastern New Zealand, due to increased drought and fire, but initial benefits are projected in some regions of New Zealand. {WGII Box TS.6, 11.4, SPM}

Europe:

- Climate change is expected to magnify regional differences in Europe's natural resources and assets (*very high confidence*). {WGII Box TS.6, Table TS.4, SPM}
- By the 2070s, hydropower potential for the whole of Europe is expected to decline by 6%, varying regionally from a 15 to 30% increase in northern and eastern Europe to a 20 to 50% decrease in the Mediterranean region. {WGII Box TS.6, 12.4.8}
- Mountainous areas will face glacier retreat, reduced snow cover and winter tourism, and extensive species losses (in some areas up to 60% under high-emission scenarios by 2080) (*very high confidence*). {WGII SPM}

Latin America:

- Productivity of some important crops and livestock is projected to decrease, while in temperate zones soybean yields are projected to increase. Overall, the number of people at risk of hunger is projected to increase. {WGII Box TS.6, 13.4, SPM}
- Changes in precipitation patterns and the disappearance of small glaciers are projected to significantly affect water availability for human consumption, agriculture and energy generation. {WGII 13.4, SPM}
- By mid-century, climate change is 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. {WGII 13.4.1, SPM}

North America:

- Warming in the western mountains by the mid-21st century is projected to cause large decreases in the snowpack, more winter flooding and reduced summer flows, thus exacerbating competition for over-allocated water resources (*very high confidence*). {WGII Box TS.6, 14.4, SPM}
- Moderate climate change in the early decades of the century is projected to increase aggregate yields of rain-fed agriculture by 5-20%, but with important variability among regions. {WGII 14.4, SPM}
- Cities that currently experience heatwaves are expected to be further challenged by an increased number, intensity and duration of heatwaves during the 21st century, with potential for adverse health impacts (*very high confidence*). {WGII SPM}

Polar regions:

- Changes in snow and ice cover in polar regions are projected to affect many natural ecosystems, with detrimental effects on many organisms including migratory birds, mammals and higher predators. {WGII Table TS.4, 15.3.4, 15.6, SPM}
- Projected effects on Arctic communities are mixed. Detrimental impacts would include those on infrastructure and traditional indigenous ways of life (*high confidence*); beneficial impacts would include reduced heating costs and more navigable northern sea routes (*medium confidence*). {WGII 15.ES, 15.4, 15.5, 15.7, SPM}
- By the end of the century, for a warming greater than 4°C, 10-50% of Arctic tundra is projected to be replaced by forest, and around 15-25% of polar desert is projected to be replaced by tundra (*medium confidence*). {WGII Table TS.4, 15.4.2}

Small islands:

- 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 (*very high confidence)*. {WGII 16.4, SPM}
- Increased invasion by non-native species is expected to occur, particularly on mid- and high-latitude islands. {WGII 16.4, SPM}
- By mid-century (a warming of 1-3°C), water resources in many small islands, e.g. in the Caribbean and Pacific, are projected to become insufficient to meet demand during low rainfall periods (*very high confidence*). {WGII TS.4.2, 16.4.1, SPM}

3.3.3 Extreme events

Since the TAR, confidence has increased that some weather events and extremes will become more frequent, more widespread and/or more intense during the 21st century, and more is known about the potential effects of such changes (Table 3.2). {WGII SPM}

Table 3.2. 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[a] and direction of trend	Likelihood of future trends based on projections for 21st 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.

3.3.4 Especially affected systems, sectors, and regions

Some systems, sectors and regions are *likely* to be especially affected by climate change. {WGII TS 4.5}

Regarding systems and sectors, these are: {WGII TS 4.5}

- particular ecosystems:
  - terrestrial: tundra, boreal forest, mountain, mediterranean-type ecosystems
  - coastal: mangroves and salt marshes
  - marine: 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 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.

Regarding regions, these are: {WGII TS 4.5}

- the Arctic, because of the impacts of high rates of projected warming on natural systems
- Africa, especially the sub-Saharan region, because of projected climate change impacts and 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.

In all regions there are certain areas, sectors and communities which are particularly at risk, for example the poor, young children, the elderly and the ill. {WGII TS.4.5, 7.1, 7.2, 7.4}

3.4 Risk of abrupt or irreversible changes

Human activities could lead to abrupt or irreversible climate changes and impacts. The risks are related to the rate and magnitude of climate change. {WGII 19.4, 19.5, SPM}

Abrupt climate change on decadal time scales is normally thought of as involving ocean circulation changes. In addition on longer time scales, ice sheet and ecosystem changes may also play a role. If a large scale abrupt climate change were to occur, its impact could be quite high (see topic 5.2). {WGI 8.7, 10.3, 10.7; WGII 4.4, 19.3}

Based on current model simulations, it is *very likely* that the meridional overturning circulation (MOC) of the Atlantic Ocean will slow down during the 21st century. It is *very unlikely* that the MOC will undergo a large abrupt transition during the 21st century. Longer-term changes in the MOC cannot be assessed with confidence. {WGI 10.3, 10.7; WGII Figure SPM.3, Table TS.5}

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 terrestrial vegetation. These changes may then feed back on the climate system. {WGII 12.6, 19.3, Figure SPM.2}

Partial deglaciation of polar ice sheets and/or the thermal expansion of seawater over very long time scales would imply major changes in coastlines and inundation of low-lying areas, with greatest effects in river deltas and low-lying islands. Current models project that such changes would occur over very long time scales (millennial) if a global temperature increase of 1-4°C (relative to 1990-2000) were to be sustained. Rapid sea level rise on century time scales cannot be excluded. {SYR 3.2.3; WGI 6.4, 10.7; WGII 19.3, SPM}

Climate changes are *likely* to lead to some irreversible impacts. There is *medium confidence* that approximately 20-30% of species assessed so far would be at increasing risk of extinction if increases in global average warming exceed 1.5-2.5°C and there is *high confidence* of significant (>40%) extinctions around the globe for warming above 4°C. {WGII 4.4, Figure SPM.2}