Topic 3 – Climate change and its impacts in the near and long term under different scenarios (15 May 2007)

3.1 Emission Scenarios

With current climate change mitigation policies and related sustainable development policies, global greenhouse gas emissions will continue to grow over the next few decades. Baseline emissions scenarios published since the IPCC Special Report on Emission Scenarios (SRES)[1], are comparable in range to those presented in SRES[2], ranging from 25 to 135 Gt CO_2-eq/yr in the year 2100. {WGIII 1.3, 3.2}

There is *high agreement and much evidence* that global baseline greenhouse gas emissions may increase by 25-90% by 2030 relative to 2000. 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 from energy use are projected to grow by 40-110% over that period. {WGIII 1.3, 3.2, SPM}

Longer term projections of future climatic changes to 2100 are mostly based on SRES. The SRES emissions projections are widely used in recent assessments of future climate change (Section 3.2), 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 (Section 3.3). {WGI 10.1; WGII 2.4}

Greenhouse gas emissions ranges in recent long-term baseline scenarios are comparable to those presented in the Special Report on Emission Scenarios (SRES). Studies since SRES use lower assumptions for some drivers of emissions. This concerns notably the population projections and short-term economic growth assumptions for some middle and low-income regions (Africa, Middle East and Latin America to 2030). There is *high agreement and much evidence* from recent studies that these changes have only a minor effect on the ranges of global greenhouse gas emissions. Available studies indicate also with *high agreement and much evidence* that the choice of exchange rate for GDP (MER or PPP) does not appreciably affect the projected emissions, when used consistently[3]. The differences, if any, are small

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

[2] The SRES scenario families and illustrative cases are summarised in the Third Assessment Report. The computed radiative forcing due to anthropogenic greenhouse gases and aerosols in 2100 (see p. 823 of the WGI Third Assessment Report) for the SRES B1, A1T, B2, A1B, A2 and A1FI illustrative marker scenarios correspond to approximately 600, 700, 800, 850, 1250 and 1550 ppm CO_2 equivalent respectively. Scenarios B1, A1B, and A2 have been the focus of model inter-comparison studies and many of those results are assessed in this report. {WG1 10.1, SPM; WGII 2.4}

[3] Since the Third Assessment Report, there has been a debate on the use of different exchange rates in emission scenarios. Two metrics are used to compare GDP between countries. Use of Market Exchange Rates (MER) is preferable for analyses involving internationally traded products. Use of Purchasing Power Parity (PPP), is preferable for analyses involving comparisons of income between countries at very different stages of development. Most of the monetary units in this report are expressed in MER. This reflects the large majority of emissions mitigation literature that is calibrated in MER. When monetary units are expressed in PPP, this is denoted by GDP_{ppp}.

compared to the uncertainties caused by assumptions on other parameters, e.g. technological change. {WGIII 3.2, TS.3, SPM}

While these new emissions scenarios were not widely used by either the climate modelling or impacts communities at the time of this assessment, these new projections remain largely consistent with the SRES projections concerning the possible future pathways and corresponding greenhouse gas emission ranges in absence of climate policies. {WGIII 3.2}

3.2 Projections of future changes in climate

A major advance since the Third Assessment Report is the large number of simulations available from a broader range of models. Taken together with the additional information from observations, these provide a quantitative basis for estimating likelihoods for many aspects of future climate change. {WGI 8.3, 9.4, 10.3, SPM}

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 plausible non-mitigation emission scenarios. Beyond the next few decades, projections increasingly depend on scenarios of future greenhouse gas emissions (Figure 3.1). {WGI 1.2, 3.2, 9.4, 10.3, 10.7; WGIII 3.2}

3.2.1 21st century global changes

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. {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. Results for different emission scenarios are provided explicitly in this report to avoid loss of this policy-relevant information. Best estimates and *likely* ranges for globally average surface air warming for six SRES emissions marker scenarios are given in this assessment and are shown in Table 3.1 (including carbon feedbacks). For example, the best estimate for the low scenario (B1) is 1.8°C (*likely* range is 1.1°C to 2.9°C), and the best estimate for the high scenario (A1FI) is 4.0°C (*likely* range is 2.4°C to 6.4°C). {WGI 10.5}

Although these projections are broadly consistent with the span quoted in the Third Assessment Report (1.4 to 5.8°C), they are not directly comparable (see Figure 3.1 middle). Assessed upper ranges for temperature projections are larger than in the Third Assessment Report (see Table 3.1) mainly because the broader range of models now available suggests stronger climate-carbon cycle feedbacks. For the A2 scenario, for example, the climate-carbon cycle feedback increases the corresponding global average warming at 2100 by more than 1°C. Carbon feedbacks are discussed in topic 2.3. {WGI 7.3, 10.5, SPM}

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

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999) [a] Best estimate	Temperature Change (°C at 2090-2099 relative to 1980-1999) [a] *Likely* range	Sea Level Rise (m at 2090-2099 relative to 1980-1999) 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

Table 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.

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 Third Assessment Report model average for 2090-2099. The ranges are narrower than in the Third Assessment Report mainly because of improved information about some uncertainties in the projected contributions[4]. The models used to make the sea level projections do not include uncertainties in climate-carbon cycle feedback 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. For example, 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 cannot be excluded, but understanding of these effects is too limited to assess their likelihood or provide a best estimate or an upper bound for sea level rise. {WGI 10.6, SPM}

3.2.2 21st century regional changes

The projected patterns 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 ice. {WGI 8.2, 8.3, 8.4, 8.5, 9.4, 9.5, 10.3, 11.1}

[4] Projections in the Third Assessment Report were made for 2100, whereas projections in this Report are for 2090-2099. The Third Assessment Report would have had similar ranges to those in Table 3.1 if it had treated the uncertainties in the same way.

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 (i.e. the oceans near Antarctica) and northern North Atlantic (Figure 3.1 right panels). {WGI 10.3, SPM}

AOGCM projections of surface temperatures

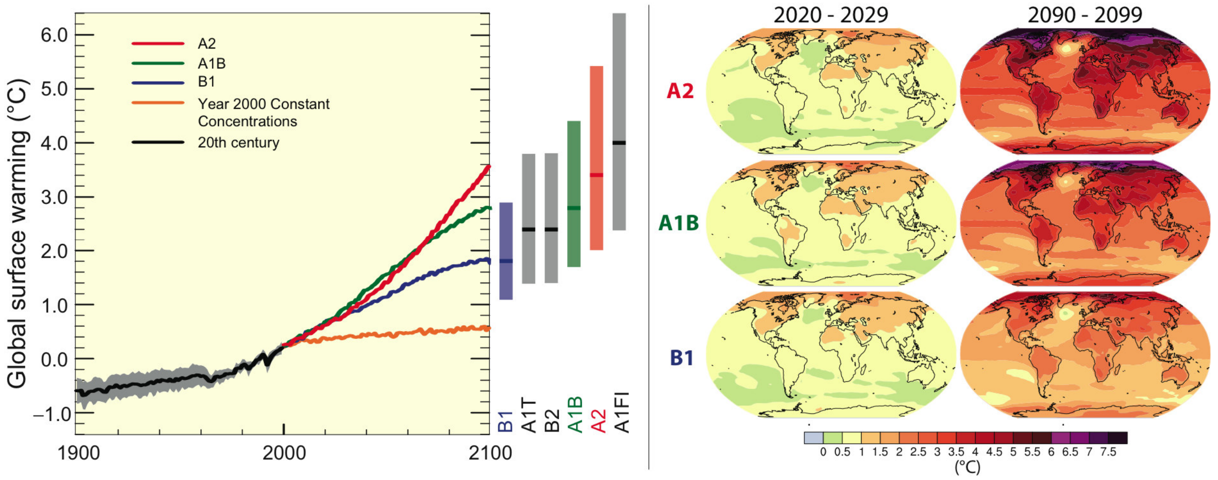

Figure 3.1. For left panel: Solid lines are multi-model global averages of surface warming (relative to 1980-1999) for the SRES scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. The orange line is for the experiment where concentrations were held constant at year 2000 values. The bars in middle of figure indicate the best estimate (solid line within each bar) and the *likely* range assessed for the six SRES marker scenarios. The assessment of the best estimate and *likely* ranges in the bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. For the 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 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}

It is *very likely* that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent. {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 Third Assessment Report 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 3.2), 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

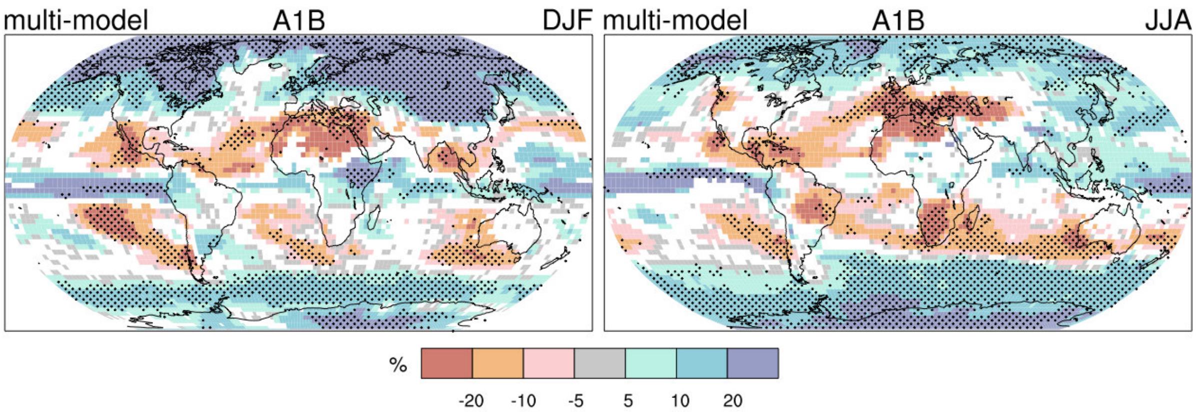

Figure 3.2. Relative changes in precipitation (in percent) for the period 2090-2099, relative to 1980-1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of 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 greenhouse gas concentrations were to be stabilised. {WGI 10.4, 10.5, 10.7, SPM}

Climate carbon cycle coupling is expected to add carbon dioxide to the atmosphere as the climate system warms, but the magnitude of this feedback is uncertain. {WGI 7.3, 10.4, SPM}

If radiative forcing were to be stabilised in 2100 at B1 or A1B levels[1] a further increase in global average temperature of about 0.5°C would still be expected, mostly 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 precipitation and that the surface mass balance becomes negative 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 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 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 in 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 carbon dioxide emissions will continue to contribute to warming and sea level rise for a long period after the emission, because once emitted to the atmosphere about one half remains there for a few centuries and about 20 percent remain there for many thousands of years. {WGI 7.3, 10.3, Figure 7.12, Figure 10.35, SPM}

3.3 Impacts of future climate changes

More specific information is now available across a wide range of systems, sectors and regions of the world concerning the nature of future impacts, including for some fields and places not covered in previous assessments. {WGII TS.4.1, TS.4.2}

The following is a selection of the key findings regarding projected impacts, as well as some findings on vulnerability and adaptation, in each system, sector and region for the range of (unmitigated) climate changes projected by the IPCC over this century judged to be relevant for people and the environment. The magnitude and timing of impacts will vary with the amount and timing of climate change and, in some cases, the capacity to adapt. {WGII SPM}

There is *high confidence* that 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), and other global change drivers (e.g., land use change, pollution, over-exploitation of resources). For increases in global average temperature exceeding 1.5-2.5^{o}C and in concomitant atmospheric CO_2 concentrations, major changes in ecosystem structure and function, with an increasing risk of extinction for many species, are projected, including ecological interactions and geographic ranges of species. Increasing atmospheric carbon dioxide concentrations leads to increasing acidification of the ocean. Projections based on SRES scenarios give significant reductions in average global surface ocean pH over the 21st century. The progressive acidification of oceans is expected, with *medium confidence*, to have negative impacts on marine shell forming organisms (e.g., corals) and their dependent species. {WGI 5.4, Box 7.3, 10.4, SPM; WG II 4.1-4.6, Figure 4.4, Box 4.4, 6.4}.

Globally, the potential for food production is projected with *medium confidence* to increase with increases in local average temperature over a range of 1-3°C, but above this it is projected to decrease. At lower latitudes, especially seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1-2°C), which would increase risk of hunger. Adaptations such as altered cultivars and planting times allow cereal yields to be maintained at or above baseline yields for modest warming. {WGII 5.4, 5.5}

Coasts are projected with *very high confidence* to be exposed to increasing risks, including coastal erosion, due to climate change and sea-level rise and the effect will be exacerbated by increasing human-induced pressures on coastal areas. Many millions more people are projected to be flooded every year due to sea-level rise by the 2080s. There is *high confidence* that adaptation for coastal regions will be more challenging in developing countries than developed countries due to constraints on adaptive capacity. {WGII 6.4, 6.5, Table 6.11}

Costs and benefits of climate change for industry, settlement, and society will vary widely by location and scale. In the aggregate, however, there is *high confidence* that net effects will tend to be more negative the larger the change in climate. {WGII 7.4, 7.6}

There is *high confidence* that the health status of millions of people is likely to be affected, through increases in malnutrition and consequent disorders; increased deaths, diseases and injury due to heat-waves, floods, storms, fires and droughts; increased burden of diarrhoeal diseases; the increased frequency of cardio-respiratory diseases due to higher concentrations of ground level ozone in urban areas from climate change; and the altered spatial distribution of some infectious disease vectors. Climate change is projected to bring some benefits in temperate areas, such as fewer deaths from cold exposure, and some mixed effects e.g. for the 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 world-wide, especially in developing countries. Critically important will be factors that directly shape the health of populations such as education, health care, public health prevention and infrastructure and economic development. {WGI 7.6, Box 7.4; WGII 8.2, 8.3, 8.4}

Climate change and water

Climate change is expected to exacerbate current stresses on water resources from population growth, changes in economy and land-use, 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. Over the course of the century, water supplies stored in glaciers and snow cover are projected to decline, reducing water availability and changing seasonality of flows in regions supplied by meltwater from major mountain ranges, 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 3.2) and temperature (Figure 3.1) lead to changes in runoff and water availability which are projected to increase by 10-40% by mid-century at higher latitudes and in some wet tropical areas, including populous areas in E and SE 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. Increased risk of summer droughts in mid-continental areas has potential 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 *likely*. {WGI 8.3, 10.3, 11.2-11.9; WGII 3.4, 3.5}

Available research suggests a significant trend for an 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 current physical infrastructure, water quality and water storage. 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}

Increased temperatures will further affect the physical, chemical, and biological properties of freshwater lakes and rivers, with predominantly adverse impacts on many individual freshwater species, community composition, and water quality. In coastal areas, sea-level rise will exacerbate water resource constraints due to increased salinisation of groundwater supplies. {WGII 3.2, 3.4, 4.4}

Projected relative changes in runoff

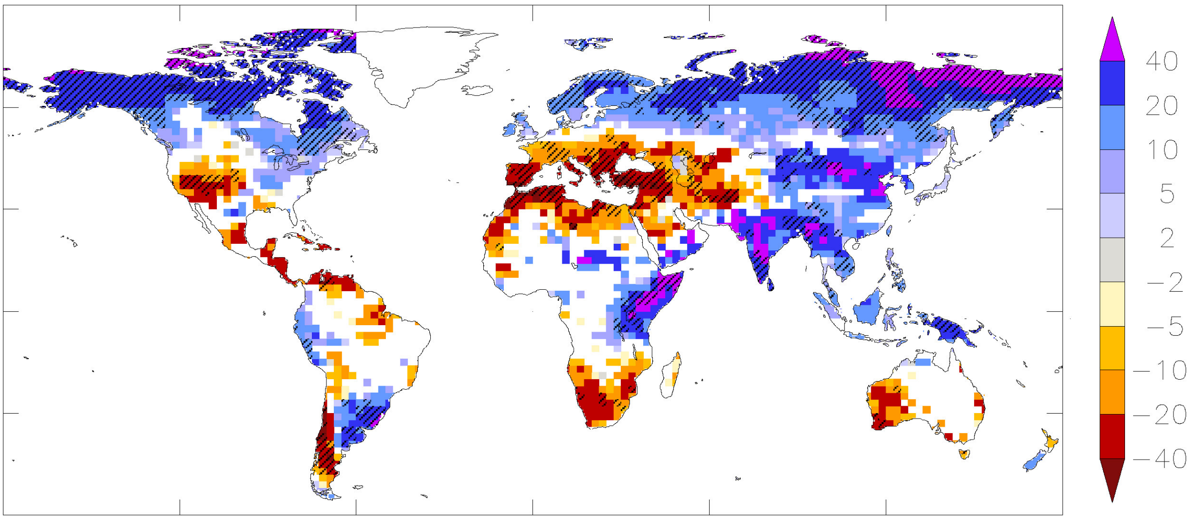

Figure 3.3. Relative changes in annual runoff (in %) for the period 2090-2099, relative to 1980-1999. Values are obtained from the median model in the multi-model dataset and are based on the SRES A1B scenario. White areas are where less than 66% of the models agree in the sign of change and stippled areas are where more than 90% models agree in the sign of change. {WGII Figure 3.4, technically adjusted to match the assumptions of Figure SYR 3.2}

Africa: By 2020, between 75 and 250 million people are projected with *high confidence* to be exposed to an increase of water stress due to climate change. Agricultural production, including access to food, in many African countries and regions is projected to be severely compromised by climate variability and change. In some countries, yields from rain-fed agriculture could be reduced by up to 50% by 2020. Some adaptation to current climate variability is taking place, however, this may be insufficient for future changes in climate. {WGII 8.2, 8.4, 8.5}

Asia: There is *high confidence* that climate change would compound pressures on natural resources and the environment associated with rapid urbanisation, industrialisation, and economic development in Asia. Freshwater availability in Central, South, East and Southeast Asia particularly in large river basins is projected with *high confidence* to become more variable seasonally in the decades to come and would decrease during dry seasons due to climate change. This, along with population growth and increasing demand arising from higher standards of living, could adversely affect more than a billion people by the 2050s. Glacier melt in the Himalayas is projected with *medium confidence* to increase flooding and rock avalanches over the next few decades, followed by decreases in flows as glaciers recede.

Crop yields are projected with *medium confidence* to increase up to 20% in East and Southeast Asia while it could decrease up to 30% in Central and South Asia by the mid-21st century. {WGII 10.2, 10.4, 10.5}

Australia and New Zealand: Water security problems are projected with *high confidence* to intensify by 2030 in southern and eastern Australia and, in New Zealand, in Northland and some eastern regions, while ongoing coastal development and population growth are projected to exacerbate risks from sea-level rise. Significant loss of biodiversity is projected with *very high confidence* to occur by 2020 in some ecologically-rich sites. The region has substantial adaptive capacity due to well-developed economies and scientific and technical capabilities, but natural systems have limited adaptive capacity. {WGII 11.2, 11.4, 11.5, 11.6}

Europe: Nearly all European regions are anticipated, with *very high confidence*, to be negatively affected by some future impacts of climate change, which would magnify regional differences in Europe's natural resources and assets. Negative impacts include with *high confidence* increased risk of inland flash floods, more frequent coastal flooding and increased erosion, and in Southern, Eastern and Central Europe, increased water stress, drought risk and heat waves. In Northern Europe, climate change is initially projected to bring mixed effects, but the negative impacts are likely to outweigh its benefits as climate change continues. Adaptation to climate change is likely to benefit from experience gained in reaction to extreme climate events, and by specifically implementing proactive climate change risk management adaptation plans. {WGII 12.2, 12.3, 12.4, 12.5, 12.7}

Latin America: By mid-century, increases in temperature and associated decreases in soil water are projected with *high confidence* to lead to gradual replacement of tropical forest by savanna in eastern Amazonia. In drier areas, climate change is expected to lead to salinisation and desertification of agricultural land. Changes in precipitation patterns and the disappearance of glaciers are projected to significantly affect water availability. Some countries have made efforts to adapt, but the effectiveness of these efforts is outweighed by informational, institutional and resource constraints, as well as settlements in vulnerable areas. {WGII 13.2, 13.4, 13.7}

North America: Moderate climate change in the early decades of the century is projected with *high confidence* to increase aggregate yields of rain-fed agriculture by 5-20%, but with important regional variability depending on crops and water resources. Warming in western mountains is projected with *very high confidence* to increase winter flooding but reduce summer flows. Disturbances from pests, diseases, and fire are projected to have increasing impacts on forests. Cities vulnerable to heat waves are expected to be further challenged by an increased number, intensity and duration of heat waves. Population growth and the rising value of infrastructure in coastal areas increase vulnerability to climate variability and future climate change, with losses projected to increase if the intensity of tropical storms increases; current adaptation is uneven and readiness for increased exposure is low. {WGII 14.4}

Polar regions: Changes in snow and ice cover in polar regions are projected to affect many natural systems, with detrimental effects on many organisms including migratory birds, mammals and higher predators. For Arctic human communities, impacts are projected to be detrimental to infrastructure and indigenous ways of life, but beneficial in terms of reduced heating costs and more navigable northern sea routes. Already Arctic human communities are adapting to climate change, but some traditional ways of life are being threatened and substantial investments are needed to adapt or re-locate physical structures and communities. {WGII 15.2, 15.3, 15.4, 15.6}

Small islands: Sea-level rise is expected with *very high confidence* to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of island communities. 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. Deterioration in coastal conditions, for example through erosion of beaches and coral bleaching, is expected with *high confidence* to affect local resources, e.g., fisheries, and reduce the value of these destinations for tourism. With higher temperatures, increased invasion by non-native species is expected to occur, particularly on middle and high-latitude islands. {WGII 16.4}

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

Since the previous assessment, many additional studies, particularly in regions that previously had been little researched, have enabled a more systematic understanding of how the timing and magnitude of impacts may be affected by changes in climate and sea level associated with differing amounts and rates of change in global average temperature. {WGII SPM}

Examples of this new information are presented in Table 3.2. Entries have been selected which are judged to be relevant for people and the environment and for which there is *high confidence* in the assessment. {WGII SPM}

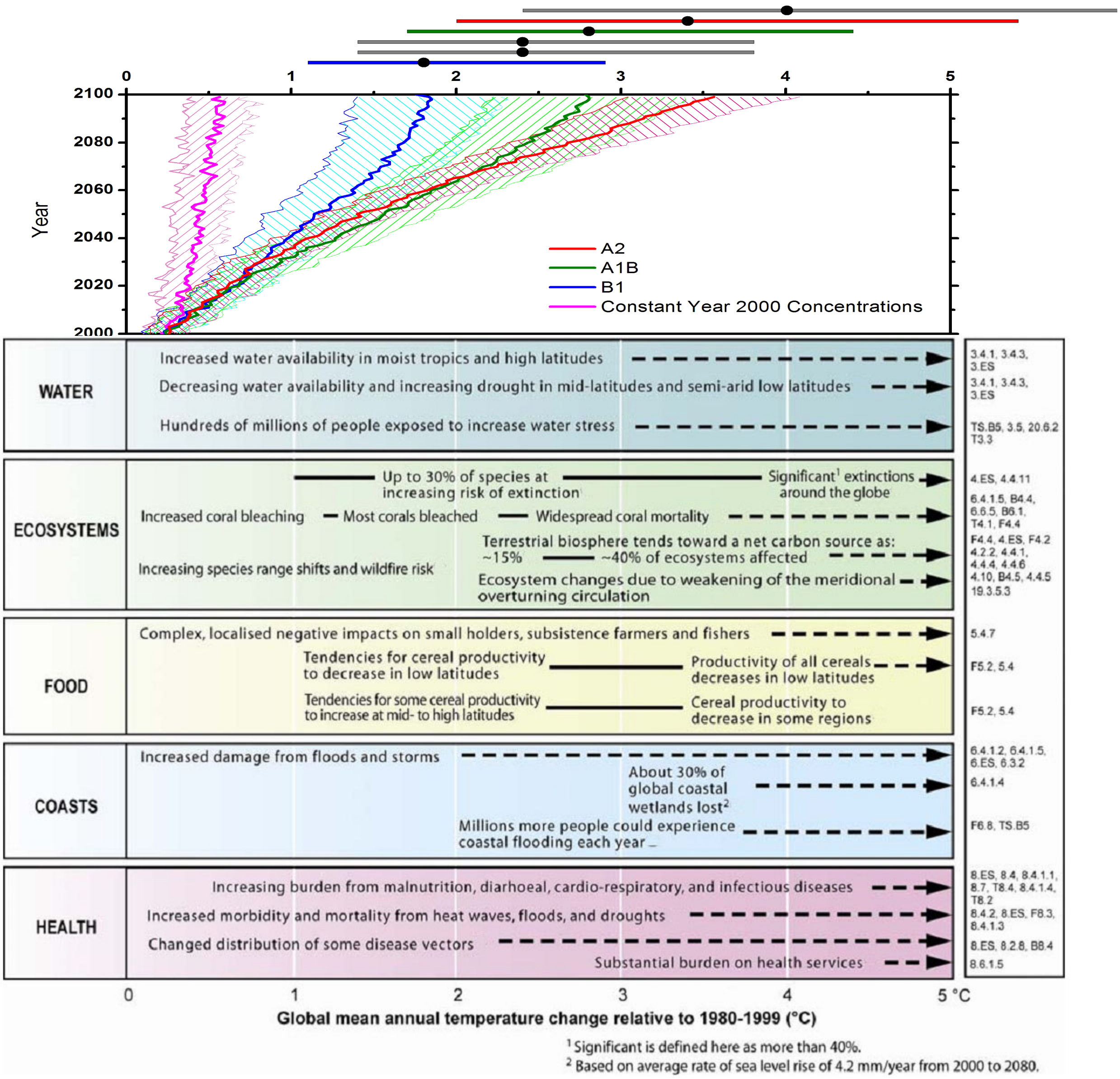

Table 3.2. Examples of projected impacts for varying changes in global average surface temperatures. **Lower part of table:** Illustrative examples of global impacts projected for climate changes (and sea-level and atmospheric carbon dioxide where relevant) associated with different amounts of increase 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. {WGI Figure SPM-5; WGII Table SPM-1}

Impacts due to altered frequencies and intensities of extreme weather, climate, and sea-level events are *very likely* to change. {WGII Table SPM-2}

Since the previous assessment, 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: {WGI Table SPM-2; WGII 3.4, 4.4, 5.4, 7.4, 8.2, Table SPM-2}

- Agriculture, forestry and ecosystems are projected to be negatively affected by increases in heat waves, heavy precipitation events, droughts, or increased tropical cyclone intensity. A reduced frequency of cold days and nights is projected to increase agricultural yields in colder environments but would also increase insect outbreaks. Increased incidence of extreme high sea level is projected to lead to salinisation of irrigation water, estuaries and freshwater systems.
- Water resources are projected to be affected in terms of both demand and supply by an increased frequency of hot extremes and droughts. Increased heavy precipitation would have adverse effects on water quality, but could act to relieve water scarcity if run-off can be stored.
- Heat extremes are expected to impact human health and quality of life, while decreased cold exposure would reduce winter mortality. Increases in other extremes such as heavy precipitation and associated flooding, and intense tropical cyclone activity, are projected to increase risk of death and injuries and post-traumatic stress disorders.
- Many of these changes in extremes would also affect industry, settlements and society. They would also change energy demands for heating and cooling (where such services are available), and impact on transport, water supply, and infrastructure exposed to coastal and/or riverine flooding or cyclone damages.

Magnitudes and timing of projected impacts depend not only on climate change but also on development pathway. {WGII SPM}

A number of impacts studies completed since the previous assessment take into account not only projected climate change but also projected social and economic changes. {WGII 2.4}

These studies show that the projected impacts of climate change can vary greatly due to the development pathway assumed, e.g. estimates of regional population, income and technological development. These factors are often a strong determinant of vulnerability to climate change. To illustrate, the projected number of people affected by climate change in terms of food supply, risk of coastal flooding, and water scarcity, is significantly greater under the SRES A2-type scenario of development (characterised by relatively low per capita income and large population growth) than under other SRES futures. This difference is largely explained, not by differences in changes of climate, but by differences in vulnerability. {WGII 2.4, Table 6.6, Table 20.6, SPM}

Some future impacts already appear unavoidable owing to the inertia of the climate system. {WGI 10.3, 10.7, SPM; WGII Table SPM-1}

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 1980-1999 levels would be expected over the 21st century. However, even the most stringent stabilisation scenarios assessed in this report (see topic 5), project further increases in greenhouse gas concentrations, leading to even higher temperature increases and associated climate changes. This suggests that some future impacts projected to occur at low levels of additional warming over the 21st century (see Table 3.2) are already unavoidable, for example: {WGI 10.3, 10.7, SPM; WGII Table SPM-1; WGIII 3.2, 3.3}

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

Some systems, sectors and regions can now be identified as particularly vulnerable to climate change.[5] {WGII SPM}

Particularly vulnerable systems and sectors are:

- Some ecosystems {WGII 4.ES, 4.4, 6.4}
    - 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 {WGII 6.ES}
- Water resources in the dry tropics and subtropics, due to decreases in rainfall and higher rates of evapotranspiration {WGII 3.4}
- Agriculture in low-latitude regions due to reduced water availability {WGII 5.4, 5.3}
- Human health in areas with low adaptive capacity. {WGII 8.3}

Particularly vulnerable regions are:

- The Arctic, because of the impacts of high rates of projected warming on natural systems {WGII 15.3}
- Africa, especially the sub-Saharan region, because of current low adaptive capacity {WGII 9.ES, 9.5}
- Small islands, due to high exposure of population and infrastructure to sea-level rise and increased storm surge {WGII 16.1, 16.2}
- Asian mega-deltas, such as the Ganges-Brahmaputra and the Zhujiang, due to large populations and high exposure to sea-level rise, storm surge and river flooding {WGII Table 10.9, 10.6}.

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

3.4 Risk of abrupt or irreversible changes

It is *very unlikely* that there will be large abrupt climate changes due to changes in the large scale ocean circulation (MOC) or ice sheet over the 21st century. The probability of large abrupt climate changes beyond 2100 cannot be assessed with confidence. {WG 8.7, 10.3, 10.7}

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[5] Criteria used in this conclusion included: magnitude, timing, irreversibility of possible impacts, confidence in assessment, and potential for adaptation. {WGII 19.2}

Abrupt climate change on decadal time scales is normally thought of as involving ocean circulation changes. In addition on longer time scales, ice sheet changes may also play a role. If a large scale abrupt climate change were to occur, its impact could be quite high (See 5.1 for more details). {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. The multi-model average reduction by 2100 is 25% (range from zero to about 50%) for SRES emission scenario A1B. Temperatures in the Atlantic region are projected to increase despite such changes due to the much larger warming associated with projected increases of greenhouse gases. It is *very unlikely* that the MOC will undergo a large abrupt transition during the 21stcentury. Large scale circulation changes beyond the 21st century cannot be assessed because uncertainties in the meltwater supply from the Greenland ice sheet and the model response to warming make the assessment of level of confidence difficult. {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 vegetation. {WGII 12.6, 19.3, Table SPM-1]}

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 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}

Gradual climate changes *are likely* to lead to irreversible and abrupt impacts. 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. {WGII Table SPM-1, WGII 4.4}