

Topic 2: Future climate changes, risks and impacts

Projecting changes in the climate system is done using a hierarchy of simulation models ranging from the simple, through intermediate complexity, to comprehensive Global Climate Models (GCMs), including Earth System Models (ESMs) that simulate the carbon cycle. The models are science-based and extensively tested against historical observations. Climate projections are driven by scenarios of natural and anthropogenic forcings, the standard set for AR5 being the Representative Concentration Pathways (RCPs). *{WGI Box SPM.1}* Impacts and risks are assessed using a variety of methods, including Integrated Assessment Models (IAMs). *{WGII 19.2}* Modelled future impacts assessed in this report are generally based on climate-model projections using the RCPs, and in some cases, the older SRES scenarios. *{WGII 1.1, 1.3, 2.2-3, 19.6, 20.2, 21.3, 21.5, 26.2, Box CC-RC; WGI Box SPM.1}*

Continued emissions of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system. Limiting climate change and associated risks to people and ecosystems will require substantial and sustained reductions of greenhouse gases emissions.

2.1 Drivers and scenarios of future change in climate

Scenarios of greenhouse gas and air pollutant emissions and land-use changes are used to explore how changes in these factors influence the future climate on different timescales. *{WGI 11.3, 12.4; WGIII 6.1}* The effects of CO₂ emissions persist for centuries; depending on the scenario, 15-40% of emitted CO₂ will remain in the atmosphere longer than 1,000 years. *{WGI SPM; Box 6-1; 8.7}* Nitrous oxide has a lifetime of about a century; methane a decade, while air pollutants like ozone and aerosols and their precursors have lifetimes of the order of days to weeks. *{WGI 8.7, 11.3}*

The key factors determining anthropogenic greenhouse gas emissions are population size, economic activity, energy use, land-use patterns, technology change, and climate policy. *{WGIII 5}* Scenarios are generated by a range of approaches, from simple idealised experiments to Integrated Assessment Models (IAMs), which provide comprehensive and internally consistent scenarios of future socio-economic change, emissions and climate response.

The “Representative Concentration Pathways”, or RCPs, describe the 21st century evolution of atmospheric greenhouse gas concentrations, land-use changes and emissions of air pollutants under four very different futures. Developed using IAMs, the RCPs are used as input to a wide range of climate model simulations to project their consequences for the climate system. *{WGI 11-14}* These climate projections are then used for impacts and adaptation assessment. *{WGII 19}* The RCPs can also be compared to a wider set of scenarios to assess the costs associated with emission reductions consistent with these concentration pathways. *{WGIII 6.3.2, 6.3.6}*

RCP8.5 represents a high emission scenario with no climate mitigation policies; RCP6.0 represents many middle-of-the-road scenarios with very modest or no climate policies; RCP4.5 represents a medium mitigation scenario; while RCP2.6 represents more aggressive mitigation scenarios which aim to keep global warming below 2°C above pre-industrial temperatures. Many models indicate that meeting the RCP2.6 scenario will require substantial net negative emissions by 2100, in some cases of about 2 GtCO₂/yr. *{WGIII 6.3.2; WGI 6}* Land-use changes in the RCPs range from strong reforestation to further deforestation. For air pollution, the RCP scenarios point to more consistent improvements in air quality as a consequence of assumed air pollution control and greenhouse gas mitigation policy (Figure 2.1). For each scenario, there is significant uncertainty in the response to aerosol emissions.

Compared with the SRES scenarios used in previous Assessments, the RCPs cover a wider range of possible outcomes for greenhouse gas and overall forcing levels. In terms of overall forcing, RCP8.5 is broadly comparable to the SRES A2 scenario, RCP6.0 to B2 and RCP4.5 to B1. For RCP2.6, there is no equivalent scenario in SRES.

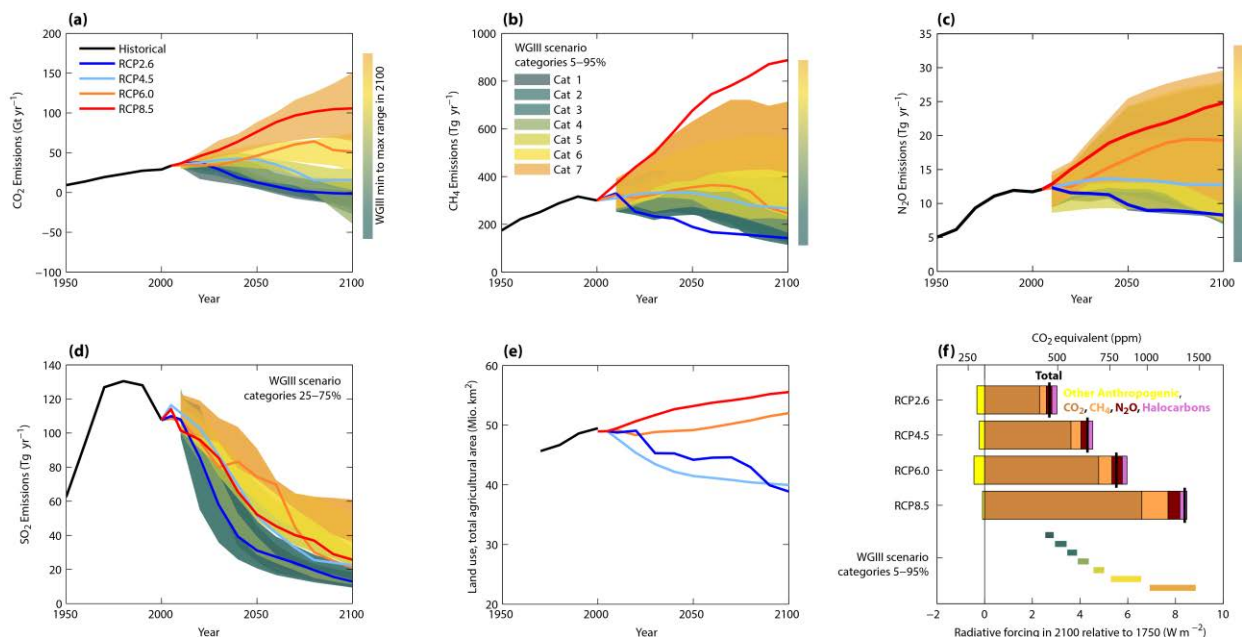


Figure 2.1: Emission and land use scenarios and the resulting radiative forcing levels included in the RCPs (lines) and the associated scenarios categories used in WGIII which are defined based on CO₂eq concentrations¹⁰ by 2100 (colored areas; Topic 3.2). Panel a-d show the emissions of CO₂, CH₄, N₂O and SO₂. Panel e shows the sum of crop and pasture land for the RCPs. Panel f shows future radiative forcing levels calculated using the MAGICC-6 simple model for the RCPs (by forcing agent) and for the WGIII scenario categories (total). {WG1 8.2, 8.5, Annex II, WG III Tables SPM.1 and 6.3}

Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. {WGII SPM} Alternative development paths influence risk by changing the likelihood of climatic events and trends, through their effects on greenhouse gases, pollutants and land use, and by altering vulnerability and exposure. {WGII 19.2.4, Figure 19-1, Box 19-2} Understanding future vulnerability, as well as exposure, of interlinked human and natural systems is challenging due to the number of socioeconomic factors that must be considered, including wealth and its distribution across society, patterns of aging, access to technology and information, labour force participation, the quality of adaptive responses, societal values, and mechanisms and institutions to resolve conflicts. These factors have been incompletely considered to date. {WGII 11.3, 21.3-5, 25.3-4, 25.11, 26.2}

2.2 The methods used to make projections

Climate and impact models have improved since the AR4. In particular, confidence in projections of sea level rise has increased.

¹⁰ CO₂-equivalent concentrations are different from CO₂-equivalent emissions.

Equivalent carbon dioxide (CO₂) emissions:

The amount of carbon dioxide emission that would cause the same integrated radiative forcing, over a given time horizon, as an emitted amount of a greenhouse gas or a mixture of greenhouse gases. The equivalent carbon dioxide emission is obtained by multiplying the emission of a greenhouse gas by its Global Warming Potential for the given time horizon. For a mix of greenhouse gases it is obtained by summing the equivalent carbon dioxide emissions of each gas. Equivalent carbon dioxide emission is a common scale for comparing emissions of different greenhouse gases but does not imply equivalence of the corresponding climate change responses.

Equivalent carbon dioxide (CO₂) concentrations:

The concentration of carbon dioxide that would cause the same radiative forcing as a given mixture of carbon dioxide and other forcing components. Those values may consider only greenhouse gases concentrations, or a combination of greenhouse gases and aerosols concentrations. Equivalent carbon dioxide concentration is a metric for comparing radiative forcing of a mix of different greenhouse gases at a particular time but does not imply equivalence of the corresponding climate change responses nor future forcing. There is generally no connection between equivalent carbon dioxide emissions and resulting equivalent carbon dioxide concentrations

2.2.1 *Models of the Earth System: atmosphere, ocean and land*

Climate models are mathematical representations of processes important to the simulation of the Earth's climate system. They are based on verifiable physical and biogeochemical principles and are evaluated by comparison with observed climate. They simulate many aspects of climate, including the temperature of the atmosphere and ocean, precipitation, winds, clouds, aerosols, ocean currents, and sea-ice extent. When combined with future climate forcings, they are used to make projections of future climate. {WGI 1, 9}

Improvements in climate models since the AR4 are evident in simulations of continental-scale surface temperature and precipitation, the monsoon, Arctic sea ice, ocean heat content, some extreme events, the carbon cycle, atmospheric chemistry and aerosols, the effects of stratospheric ozone, and the El Niño-Southern Oscillation. Climate models reproduce the observed continental-scale surface temperature patterns and trends over many decades, including the more rapid warming since the mid-20th century and the cooling immediately following large volcanic eruptions (*very high confidence*). {WGI SPM, 7.3, 7.6, 9.5-7, 10.3} The ability to simulate ocean thermal expansion, glaciers and ice sheets and thus sea-level has improved since the AR4, but significant challenges remain in representing the dynamics of the Greenland and Antarctic ice sheets. *Confidence* in the representation of processes involving clouds and aerosols remains low. {WGI SPM, 7.3, 7.6, 9.1, 9.2, 9.4, 9.6, 9.8}

2.2.2 *Models and methods for estimating the risks, vulnerability and impacts of climate change*

The experiments, observations and models used to estimate risks and future impacts have all improved since the AR4. In most instances, the range of future uncertainty has narrowed. In some cases, new knowledge has revealed previously unaccounted sources of uncertainty. {WGII 4.3.2.5}

Future risks, vulnerabilities and impacts of climate change are estimated in the AR5 and previous assessments through experiments, analogies and models. “Experiments” involve deliberately changing one or more climate-system factors affecting a subject of interest to reflect anticipated future conditions, while holding the other factors affecting the subject constant. For instance, the Free Air Concentration Experiments or Free Ocean Concentration Experiments reveal the effects of rising CO₂ and O₃ on ecosystems, species or crops. “Analogies” are ‘natural’ experiments, used when controlled experiments are impractical due to ethical constraints, the large area or long time required, or high system complexity. Two types of analogies are used in projections. Spatial analogies identify another part of the world currently experiencing similar conditions to those anticipated to be experienced in the future. For example, niche envelope models project future distributions of species based on their current distribution. Temporal analogies are changes in the past that are used to make inferences about changes in the future. Conditions in the past are sometimes inferred from paleo-ecological data. Models in this context are typically numerical simulations of simplified systems, calibrated and validated using observations from experiments or analogies, and then run using input data representing future climates. Models can also include largely descriptive narratives of possible futures, such as those used in scenario construction; quantitative, process-based models and descriptive models are often used together. Models, including those with socio-economic components, are not independent of the value judgments, world views, or preferences of the modeller. The impacts are modelled for water resources, biodiversity and ecosystem services on land, for inland water and the oceans, agricultural productivity, health, economic growth and poverty. {WGII 2.2.1, 2.4.2, 3.4.1, 4.2.2, 5.4.1, 6.5, 7.3.1, 11.3.6, 13.2.2}

Risks are evaluated based on the interaction of projected changes in the Earth system with the many dimensions of vulnerability in societies and ecosystems. The data are seldom sufficient to allow direct estimation of probabilities of a given outcome; therefore expert judgment is used to integrate the diverse information sources and likelihoods into an evaluation of risk. An example is the calibrated language on uncertainty used by the IPCC over the past three assessments, and its extension into the evaluation of risk as a function of hazards, exposure, and vulnerability in the AR5 WGII. {WGII 19.2, 21.1}

2.3 Confidence in projections

While relevant scientific understanding and capability has advanced since the last report {WGI 1.1, 12.1, FAQ 1.1, FAQ 9.1; WGII 21.3 21.5}, the degree of confidence in climate change projections and associated impacts varies, depending on which aspect of the future is considered. Confidence varies because the quality, amount and degree of agreement among different sources of evidence for particular projections and impacts vary. Some projected changes and impacts are provided as statements of fact, while others are assigned confidence levels ranging from very high to very low. {WGI 1.4, 11.2, 11.3, 12.2; WGII 1.1, Box 1-1} For example, “continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system” is stated as a fact. {WGI SPM} There is *high confidence* that an increase in high sea level extremes will primarily be the result of an increase in mean sea level {WGI SPM} and in the assessment that global temperature increases of ~4°C or more above late-20th-century levels, combined with increasing food demand, would pose large risks to food security globally and regionally. {WGII SPM, Chapter7 ES} There is *medium confidence* that risks of global aggregate impacts are moderate for additional warming between 1-2°C, reflecting impacts to both Earth’s biodiversity and the overall global economy {WGII SPM}; but there is only *low confidence* in projected changes in the frequency of tropical cyclones at the regional scale {WGI 14}. All of the assessments of confidence are based on the opinions of the expert authors, informed by the best available information. {WG 1 SPM, 1}

2.4 Projected changes in the climate system

Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system across the globe.

Projected changes described below are for 2081-2100 relative to 1986-2005 unless otherwise indicated. The period 1986-2005 is approximately 0.61°C [0.55 to 0.67] °C warmer than 1850-1900. {WGI SPM}

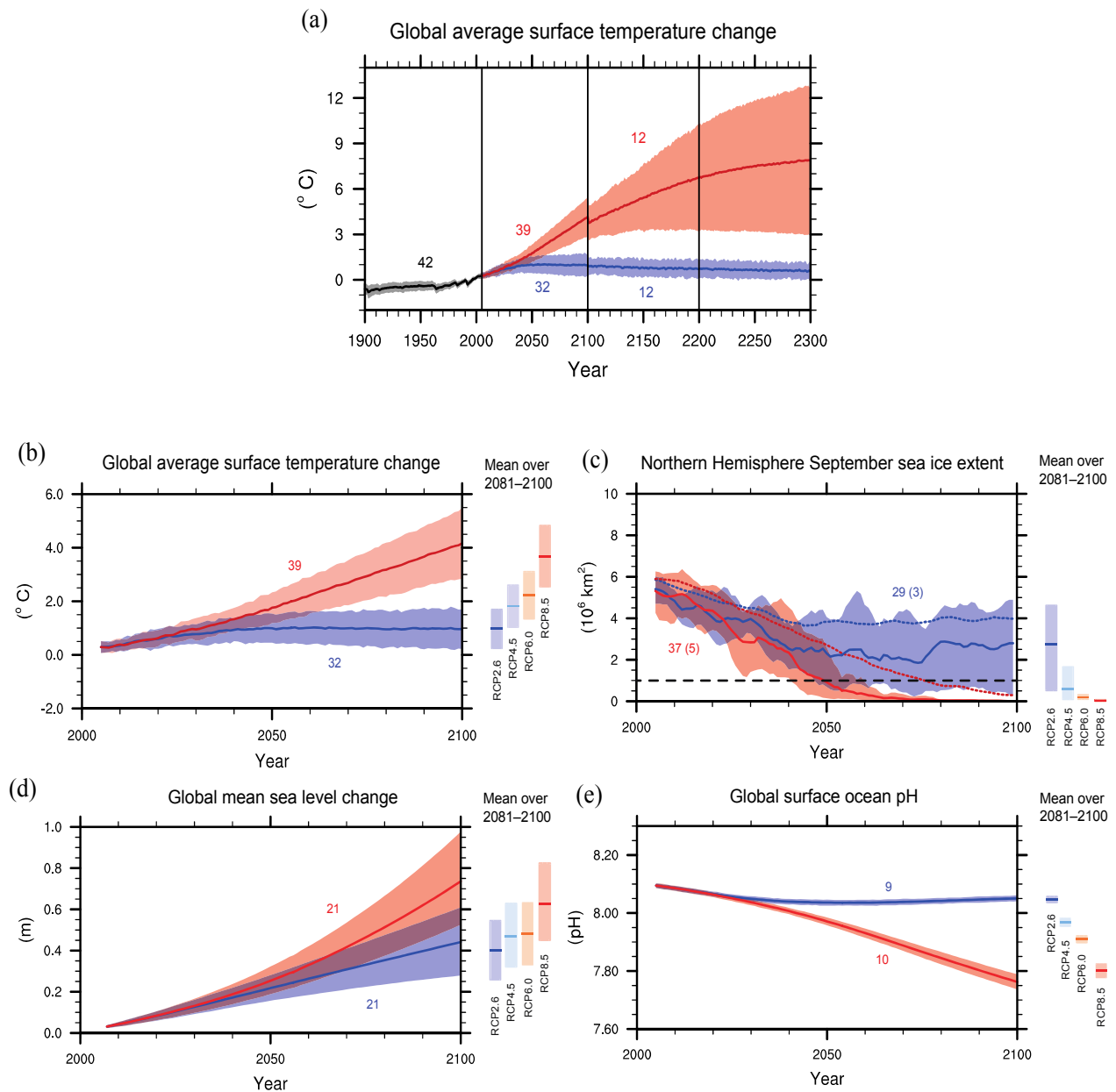
2.4.1 Air Temperature

Global-mean surface air temperature is projected to rise over the 21st century under all of the GHG concentration pathways represented by the RCPs. The projected increase will occur in conjunction with naturally occurring climatic variability. {WGI 11.3, 12.4}

The global mean surface air temperature change for the period 2016-2035 will *likely* be in the range 0.3°C–0.7°C (*medium confidence*). By mid-21st century, the rate of global warming begins to be more strongly dependent on the emissions scenario. {WGI SPM, 11.3, 12.3}

Global-mean surface air temperature change for 2081–2100 will *likely* be 0.3°C–1.7°C (under RCP2.6) to 2.6°C–4.8°C (under RCP8.5) (Figure 2.2, Table 2.1). {WGI SPM, 11.3, 12.3}

Global surface air temperature change for the end of the 21st century is *likely* to exceed 1.5°C relative to 1850-1900 for all RCP scenarios except RCP2.6. It is *likely* to exceed 2°C for RCP6.0 and RCP8.5, *more likely than not* to exceed 2°C for RCP4.5, but *unlikely* to exceed 2°C for RCP2.6 (*medium confidence*). {WGI SPM, 12.3}



colored vertical bars at the right end side of each panel. The number of CMIP5 models used to calculate the multi-model mean is indicated. For sea ice extent (c), the projected mean and uncertainty (minimum-maximum range) of the subset of models that most closely reproduce the climatological mean state and 1979-2012 trend of the Arctic sea ice is given (number of models given in brackets). For completeness, the CMIP5 multi-model mean Arctic sea-ice is also indicated with dotted lines. {WGI Figure SPM.7} For sea level (d), based on current understanding, only the collapse of marine-based sectors of the Antarctic ice sheet, if initiated, could cause global mean sea level to rise substantially above the *likely* range during the 21st century. However, there is *medium confidence* that this additional contribution would not exceed several tenths of a meter of sea level rise during the 21st century.

Table 2.1: Projected change in global mean surface air temperature and global mean sea level rise for the mid and late 21st century relative to the reference period (1986-2005). {WGI SPM, 12.4, Table 12.2, Table 13.5}

	Scenario	2045-2065		2081-2100	
		Mean	Likely range	Mean	Likely range
Global Mean Surface Temperature Change (°C)	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
	Scenario	Mean	Likely range	Mean	Likely range
Global Mean Sea Level Rise ^a (m)	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

Notes:

^a Based on current understanding, only the collapse of marine-based sectors of the Antarctic ice sheet, if initiated, could cause global mean sea level to rise substantially above the *likely* range during the 21st century. However, there is *medium confidence* that this additional contribution would not exceed several tenths of a meter of sea level rise during the 21st century.

The Arctic region will warm more rapidly than the global mean, and warming will be larger over the land than over the ocean (*very high confidence*) (Figure 2.3). {WGI SPM, 11.3, 12.3, 12.4, 14.8}

It is *virtually certain* that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales, as global mean temperatures increases. It is *very likely* that heat waves will tend to occur more often and last longer. Occasional cold winter extremes will continue to occur. {WGI SPM, 12.4}

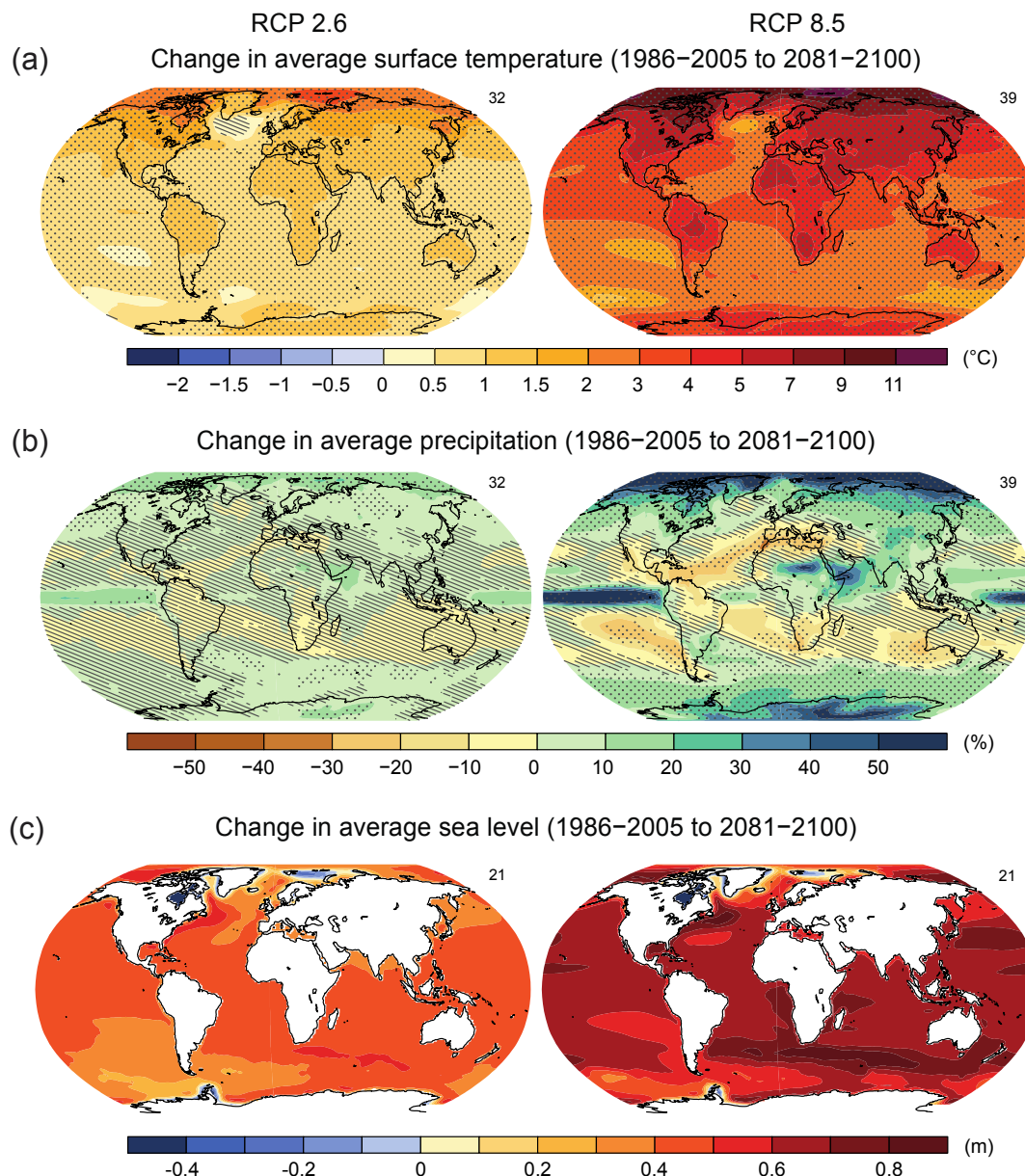


Figure 2.3: CMIP5 multi-model mean projections 2081–2100 under the RCP2.6 (left) and RCP8.5 (right) scenarios for (a) annual mean surface temperature change and (b) average percent change in annual mean precipitation and (c) average sea level. Changes are shown relative to 1986–2005. The number of CMIP5 models used to calculate the multi-model mean is indicated in the upper right corner of each panel. Hatching on (a) and (b) shows regions where the multi-model mean is small compared to internal variability (i.e., less than one standard deviation of internal variability in 20-year means). Stippling on (a) and (b) indicates regions where the multi-model mean is large compared to internal variability (i.e., greater than two standard deviations of internal variability in 20-year means) and where 90% of models agree on the sign of change. See WGI, Box 12.1). {WGI Figure SPM.8, Figure 13.20}

2.4.2 Water cycle

Changes in precipitation in a warming world will not be uniform. The high latitudes and the equatorial Pacific are *likely* to experience an increase in annual mean precipitation by the end of this century under the RCP8.5 scenario. In many mid-latitude and subtropical dry regions, mean precipitation will *likely* decrease, while in many mid-latitude wet regions, mean precipitation will *likely* increase under the RCP8.5 scenario (Figure 2.3). {WGI 7.6, 12.4, 14.3}

Extreme precipitation events over most mid-latitude land masses and over wet tropical regions will *very likely* become more intense and more frequent as global mean surface temperature increases. {WGI SPM, 7.6, 12.4}

Globally, it is *likely* that the area encompassed by monsoon systems will increase and monsoon precipitation is *likely* to intensify due to the increase in atmospheric moisture. {WGI 14.2} Due to the increase in moisture availability, El Niño-Southern Oscillation (ENSO) related precipitation variability on regional scales will *likely* intensify. {WGI 14.4}

It is *likely* that the number of tropical cyclones across the globe will either decrease or remain essentially unchanged, concurrent with a *likely* increase in both global mean tropical cyclone maximum wind speed and rain rates. There is low confidence in projected regional changes in tropical cyclones. {WGI 14.6, 14.8}

2.4.3 Ocean, Cryosphere and Sea-Level

The global ocean will continue to warm during the 21st century. The strongest ocean warming is projected for the surface in tropical and Northern Hemisphere subtropical regions. At greater depth the warming will be most pronounced in the Southern Ocean (*high confidence*). {WGI 12.4}

Year-round reductions in Arctic sea ice are projected for all RCP scenarios. Based on an assessment of the subset of models that most closely reproduce the observations¹¹, a nearly ice-free Arctic Ocean¹² in September before mid-century is *likely* for RCP8.5 (*medium confidence*) (Figure 2.2). In the Antarctic, a decrease in sea ice extent and volume is projected with *low confidence*. {WGI 12.4}

The area of Northern Hemisphere spring snow cover is projected to decrease by 7% for RCP2.6 and by 25% in RCP8.5 (*medium confidence*). {WGI 12.4}

It is *virtually certain* that near-surface permafrost extent at high northern latitudes will be reduced as global mean surface temperature increases. The area of permafrost near the surface (upper 3.5 m) is projected to decrease by between 37% (RCP2.6) to 81% (RCP8.5) (*medium confidence*). {WGI 12.4}

The global glacier volume, excluding glaciers on the periphery of Antarctica, is projected to decrease by 15 to 55% for RCP2.6, and by 35 to 85% for RCP8.5 (*medium confidence*). {WGI 13.4, 13.5}

Global mean sea level will continue to rise during the 21st century and beyond. Under all RCP scenarios, the rate of sea level rise will *very likely* exceed that observed during 1971–2010. {WGI 13.3–5}

Global mean sea level rise will *likely* be in the ranges of 0.26 to 0.55 m for RCP2.6 to 0.45 to 0.82 m for RCP8.5. For RCP8.5, the rise by the year 2100 is 0.52 to 0.98 m, with a rate during 2081–2100 of 8 to 16 mm yr⁻¹ (*medium confidence*). (Figure 2.2, Table 2.1). {WGI 13.5} Based on current understanding, only the collapse of marine-based sectors of the Antarctic ice sheet, if initiated, could cause global mean sea level to rise substantially above the *likely* range during the 21st century. However, there is *medium confidence* that this additional contribution would not exceed several tenths of a meter of sea level rise during the 21st century. {WGI, 13.4, 13.5}

Sea level rise will not be uniform. By the end of the 21st century, it is very likely that sea level will rise in more than about 95% of the ocean area. About 70% of the coastlines worldwide are projected to experience sea level change within 20% of the global mean sea level change (Figure 2.3). {WGI 13.1, 13.6}

2.4.4 Carbon cycle

There is *high confidence* that the feedback between climate and the carbon cycle is positive in the 21st century. Climate change will partially offset increases in land and ocean carbon sinks caused by rising atmospheric CO₂. As a result, more of the emitted anthropogenic CO₂ will remain in the atmosphere. {WGI 6.4} Earth System Models project a global increase in ocean acidification for all RCP scenarios, with a

¹¹ climatological mean state and 1979 to 2012 trend of the Arctic sea ice extent

¹² when sea ice extent is less than 10⁶ km² for at least five consecutive years

decrease in surface ocean pH below present-day values in the range of 0.06 to 0.07 for RCP2.6, to 0.30 to 0.32 for RCP8.5 (Figure 2.2). {WGI 6.4}

2.4.5 Climate system responses

Climate system properties that determine the response to external forcing have been estimated both from climate models and from analysis of past and recent climate change. {WGI 10.8, Box 12.2} The equilibrium climate sensitivity (ECS)¹³ is *likely* in the range 1.5°C–4.5°C, *extremely unlikely* less than 1 °C, and *very unlikely* greater than 6°C. {WGI Box 12.2}

Cumulative emissions of CO₂ are the dominant factor determining the global mean surface warming by the late 21st century. {WGI 12.5} There is a strong and consistent relationship between projected cumulative CO₂ emissions and projected 21st century temperature change in both the RCPs and the wider set of mitigation scenarios analyzed in WGI. Uncertainty in the carbon cycle and climate responses and in emissions of other gases and aerosols both contribute to the uncertainty in this relationship (Figure 2.4).

The transient climate response to cumulative carbon emissions (TCRE)¹⁴ is *likely* in the range of 0.8°C to 2.5°C, and applies for cumulative emissions up to about 2000 GtC until the time temperatures peak. {WGI 12.5, Box 12.2}

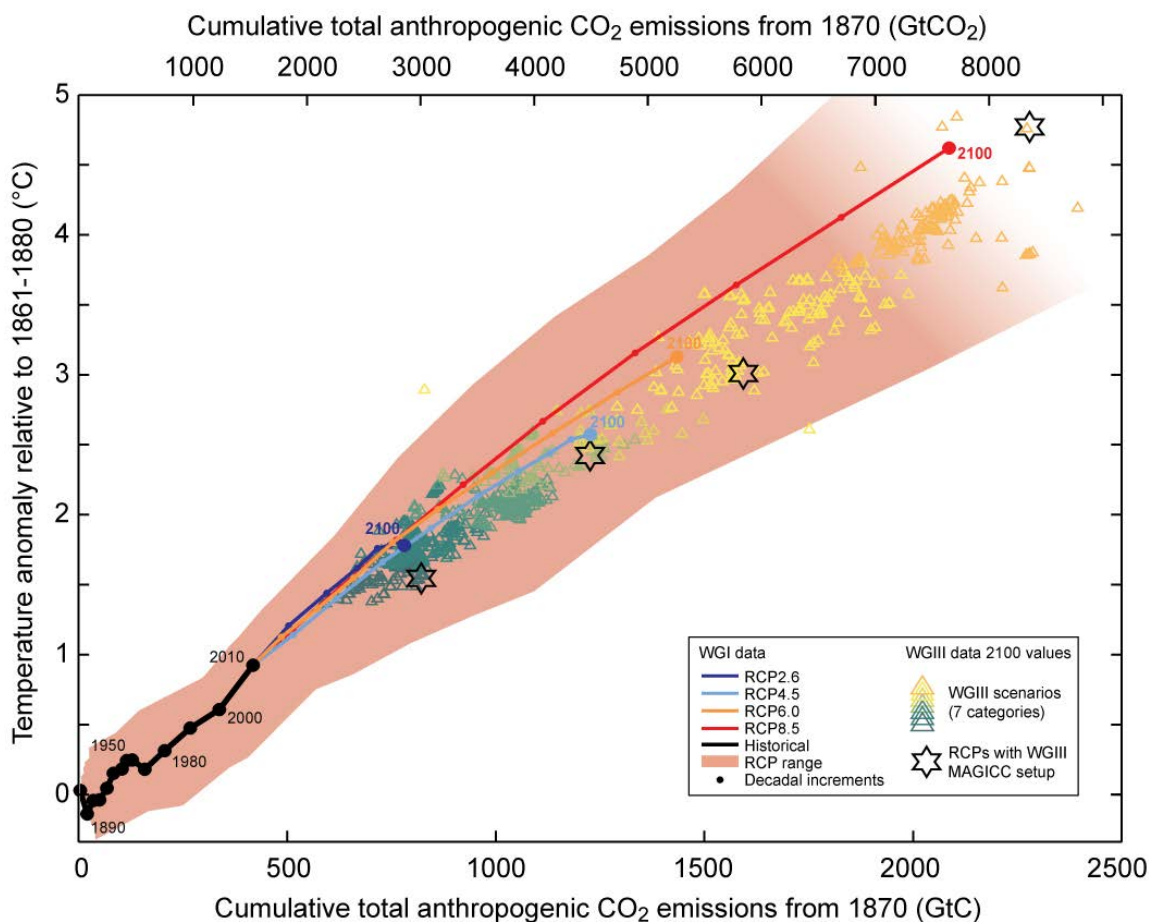


Figure 2.4: Global mean surface temperature increase as a function of cumulative total global CO₂ emissions from various lines of evidence. Multi-model results from a hierarchy of climate-carbon cycle models for each RCP until 2100 are shown (coloured lines). Model results over the historical period (1860 to 2010) are indicated in black. The coloured plume illustrates the multi-model spread over the four RCP scenarios and fades with the decreasing number of available models in RCP8.5. Decadal averages are labelled using dots with the label referring to the year ending the decade. Triangles correspond to estimates for the year 2100 under 962 scenarios evaluated by WGI, divided into the 7

¹³ defined as the equilibrium global average surface warming following a doubling of CO₂ concentration (relative to pre-industrial).

¹⁴ defined as the global mean surface temperature change per 1000 GtC of carbon dioxide emitted to the atmosphere.

categories described in Section 3.2. The four large star symbols are estimates for the 4 RCPs by the MAGICC6 simple model, with the set up used for the WGIII scenarios estimates. Temperature values are always given relative to the 1861-1880 period, and emissions are cumulative since 1870. {WGI SPM, Figure 12.45; TS TFE.8, Figure 1 and TS Supplementary material, WG III Tables SPM.1 and 6.3}

If total accumulated CO₂ emissions from all anthropogenic sources remain below about 3665 GtCO₂ over the 21st century, then warming, relative to 1861-1880, will *likely* be less than 2°C. This figure is reduced to about 2895 GtCO₂ when accounting for non-CO₂ forcings as in RCP2.6. An amount of 1890 [1630 to 2145] GtCO₂ has already been emitted by 2011 (Table 2.2). {WGI 12.5}

Table 2.2: Cumulative CO₂ emission budgets consistent with limiting warming to less than stated temperature goals at different levels of probability. {WGI, 12.5; WGIII}

Cumulative carbon budgets consistent with temperature goals ^a									
Assessed probability, multiple lines of evidence, CO ₂ -induced warming alone ^b	Likely less than 2°C			About as likely as not <2°C			Unlikely less than 2°C		
	3665 GtCO ₂ (1000 GtC)			4435 GtCO ₂ (1210 GtC)			5760 GtCO ₂ (1570 GtC)		
Cumulative CO ₂ emissions from 1870 in GtCO ₂									
Fraction of simulations	66%			50%			33%		
Net anthropogenic warming	<1.5°C	<2°C	<3°C	<1.5°C	<2°C	<3°C	<1.5°C	<2°C	<3°C
Complex models, RCP scenarios only ^c	2250	2900	4200	2250	3000	4500	2550	3300	4850
Simple model, multiple parameters & WGIII scenarios ^d	2400-2850	2900-3600	4300-5400	2500-2950	3100-3800	4850-5950	2600-3100	3350-4050	5200-6550
Cumulative CO ₂ emissions from 2011 in GtCO ₂ ^e									
Simple model, multiple parameters & WGIII scenarios ^d	550-1000	1050-1750	2450-3550	650-1100	1250-1950	3000-4100	750-1250	1500-2200	3350-4700

^a Temperature values are given relative to the 1861-1880 base period, and emissions are cumulated from 1870; cumulative CO₂ emissions are rounded to the nearest 50GtCO₂.

^b Based on the assessed likely range for Transient Climate Response to Emissions (TCRE) of 0.8-2.5°C per 1000GtC cumulative emissions, modelled as the 1-standard deviation range of a Gaussian distribution.

^c The figures show cumulative CO₂ emissions at the time the temperature threshold is exceeded that are required for 66%, 50% or 33% of the CMIP5 ESM and EMIC simulations, assuming non-CO₂ forcing follows the RCP8.5 scenario. Lower non-CO₂ forcing would imply a higher CO₂ budget consistent with a given temperature threshold, but comparing budgets implied by RCP2.6 with RCP8.5 suggests this is a limited effect if attention is restricted to RCP scenarios alone. Note that for most scenario/threshold combinations, emissions and warming continue after the threshold is exceeded: nevertheless, because of the cumulative nature of CO₂ emissions, these figures provide an indication of the CO₂ emission budgets implied by the CMIP5 models simulations consistent with meeting various climate targets.

^d As note c, but showing the impact of variation in CO₂ budgets across scenarios. For each WGIII scenario, cumulative CO₂ emission budgets were diagnosed (with the simple model used by WGIII) that would cause temperatures to exceed the given threshold for 66%, 50% or 33% of simulations in an ensemble representing climate system and carbon cycle uncertainty. Figures show 5%-95% range of cumulative CO₂ emission budgets across the 962 scenarios considered by WGIII, accounting for variations across scenarios in non-CO₂ emissions and the (small) impact of the timing of CO₂ emissions. Note that these figures do not account for uncertainty in model structure.

^e Provided for information, assuming 1850GtCO₂ for anthropogenic CO₂ emissions over the 1870-2010 period.

2.5 Future risks and impacts caused by a changing climate

Climate change is projected to amplify existing climate-related risks and create new risks for natural and human systems. Some of these risks will be limited to a particular sector or region, and others will have cascading effects. Large magnitudes of warming often increase the likelihood of more severe and pervasive impacts (Figure 2.5, Table 2.3). To a lesser extent, climate change is also projected to have some potential benefits. The precise levels of climate change that breach critical thresholds in the earth system, including its coupled human and natural subsystems, remain uncertain.

Increasing magnitudes of warming increase the likelihood of severe, pervasive, and irreversible impacts. Some risks of climate change are considerable at 1 or 2°C above preindustrial levels. Global climate change risks are high to very high with global mean temperature increase of 4°C or more above preindustrial levels in all reasons for concern, and include severe and widespread impacts on unique and threatened systems, substantial species extinction, large risks to global and regional food security, and the combination of high temperature and humidity compromising normal human activities, including growing food or working outdoors in some areas for parts of the year (high confidence). The precise levels of climate change sufficient to trigger tipping points (thresholds for abrupt and irreversible change) remain uncertain, but the risk associated with crossing multiple tipping points in the earth system or in interlinked human and natural systems increases with rising temperature (*medium confidence*). {WGII SPM}

Risks caused by a changing climate depend on the magnitude and rate of climate change, but also on the exposure, vulnerability, and ability of affected systems to adapt. Risk levels are considered low when climate change-induced impacts remain within the range of natural variability characterizing pre-industrial climates. Risks are considered high or very high once projected impacts become widespread and detrimental for present-day natural or human systems. Adaptation has the potential to reduce climate change impacts significantly, but its potential differs between sectors and there are constraints and limits to adaptation. Such constraints and limits vary significantly among global regions, institutions, sectors, communities, and ecological systems. Constraints and limits to adaptation depend on other stresses, change over time, and are closely linked to socioeconomic development pathways. Greater rates and magnitude of climate change increase the likelihood of exceeding adaptation limits (*high confidence*). For each key risk in Figure 2.5, risk levels were assessed for three timeframes with current and high adaptation levels, considering the potential for and limits to adaptation. {WGII TS Table 4}

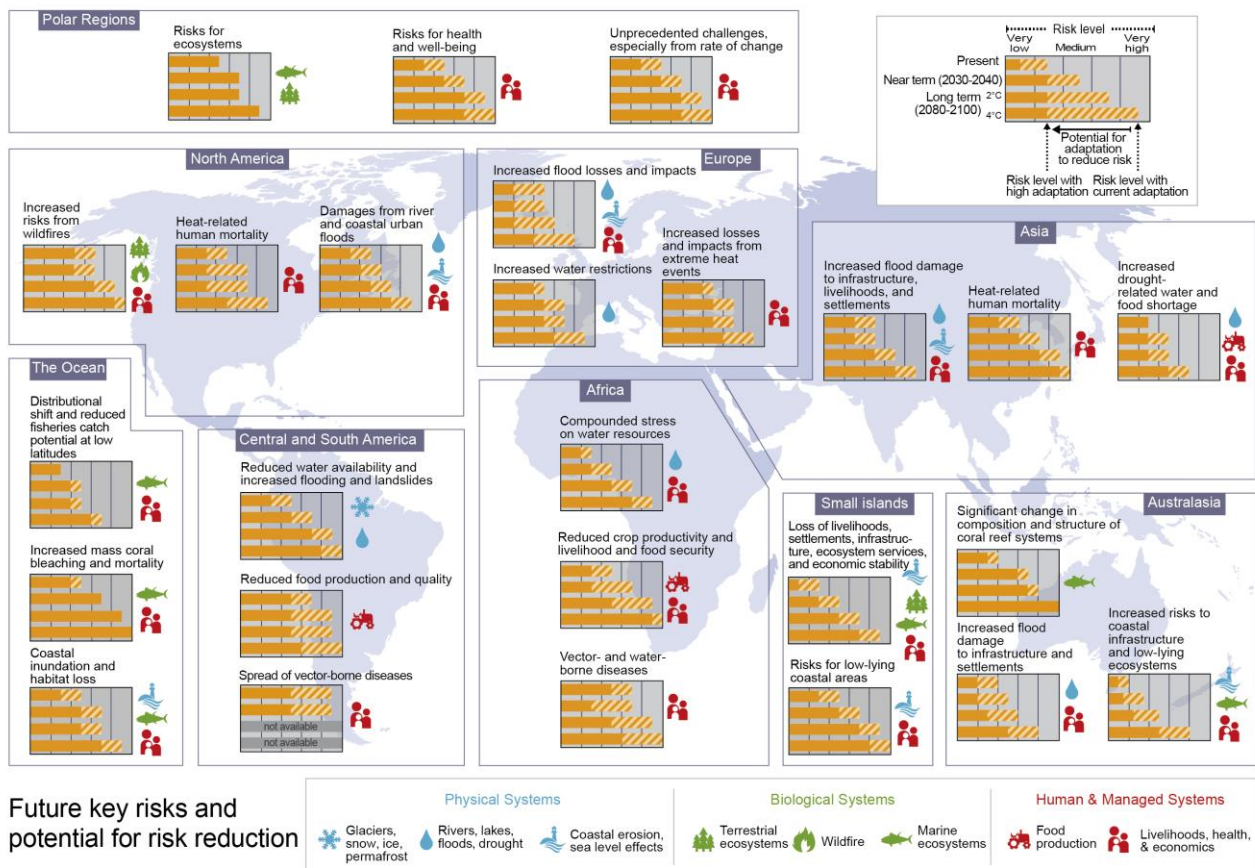


Figure 2.5: Example of regional key risks for physical, biological, and human and managed systems, and potential for risk reduction through adaptation. Key risks are identified based on assessment of the literature and expert judgment. Each risk is characterized as very low, low, medium, high, or very high. Risk levels are presented at three time frames: present, near-term (2030-2040), and long-term (2080-2100). Near-term indicates that projected levels of global mean temperature do not diverge substantially across emission scenarios. Long-term differentiates between a global mean temperature increase above 2°C and 4°C above pre-industrial levels. For each timeframe, risk levels are estimated for a continuation of current adaptation and for a high adaptation state. {WGII TS Table 4}

2.5.1 Ecosystems and their services in the oceans, at coasts, in freshwater and on land

There is high risk of substantive impacts on terrestrial and aquatic ecosystems as result of climate change, causing mostly negative consequences for biodiversity and ecosystem services (*high confidence*). Risks of harmful effects on ecosystems and human systems increase with the rate of warming, the magnitudes of ocean acidification and warming and the rates and magnitudes of sea level rise (Figure 2.6).

The current and projected rate of anthropogenic climate change is much faster than natural climate change during the past millions of years, which led to significant ecosystem shifts and species extinctions on land and in the oceans; there is thus a strong basis for expecting major climate change-induced risks to species and ecosystems (*high confidence*). Many species will be unable to adapt locally or move fast enough during the 21st century to track suitable climates under mid- and high-range rates of climate change (RCP4.5, 6.0, and 8.5) (*medium confidence*) (Figure 2.6). {WGII 4.3-4, 6.1, 6.3, 6.5, 25.6, 26.4, Box CC-RF, Box CC-MB}

Increasing risk from RCP 2.6 to RCP 8.5

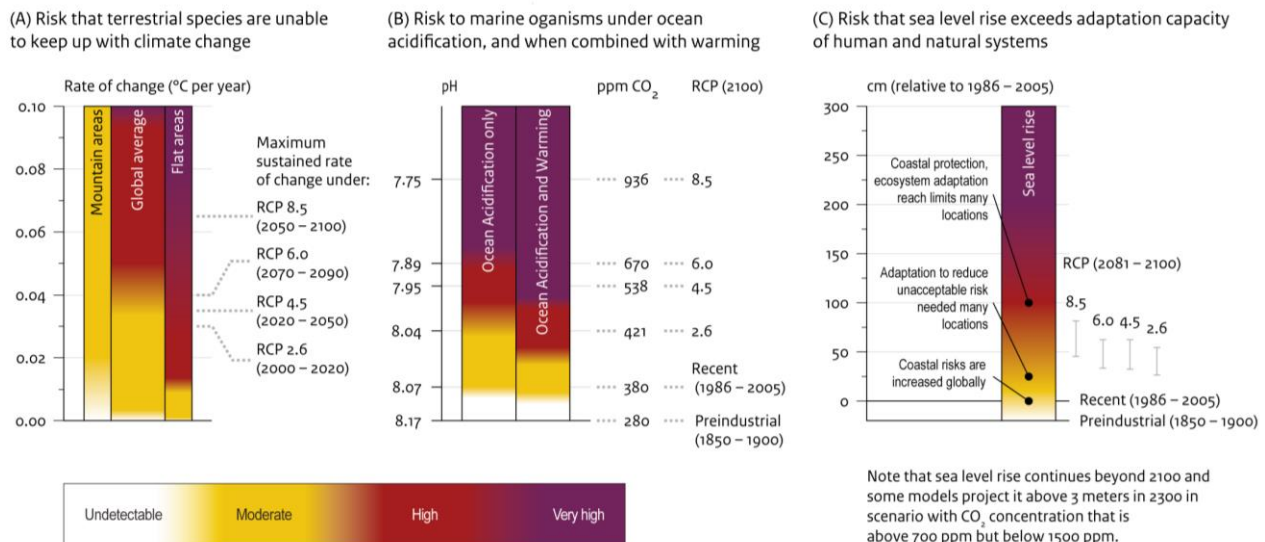


Figure 2.6: [PLACEHOLDER: CAPTION TO BE SHORTENED] There is increasing risk from RCP 2.6 to RCP 8.5 that (A) major groups of terrestrial and freshwater species are unable to move fast enough to stay within the climate envelopes to which they are adapted, (B) that sensitive marine organisms (e.g. those forming a calcium carbonate exoskeleton) are impacted by ocean acidification (OA) and combined OA and warming extremes and (C) that sea level rise exceeds adaptation capacity of human and natural systems. (A) Ember translates RCPs 2.6 to 8.5 to a rate of climate change ($^{\circ}\text{C y}^{-1}$, averaged over the period of 20–30 years during which each RCP showed its maximum rate of change during the 21st century). The ability of various groups of organisms to track this rate of change by following their preferred temperatures is determined from their observed or modelled rates of movement, in km y^{-1} . This is converted to its equivalent in rate of climate change, which differs for flat landscapes and mountainous landscapes, with the global average in between. Zero rate of climate change corresponds to no additional risk (white colour). The yellow colour (moderate risk) begins when the rate of change exceeds the lower bound for trees, which move more slowly and where dieback has been detected on the hot end of their temperature range and accordingly, distributions. The transition to red (high risk) reflects the median limits to movement of several important groups of organisms, including trees, herbs, small mammals, molluscs and certain insects. Transition to purple (very high risk) occurs when none of the assessed groups are able to keep up. Only large, hooved animals are able to keep up with the maximum rates of change shown on this graphic (birds were not assessed), thus all other groups are at high risk below this maximum. (B) Risks of harmful ecosystem effects of ocean acidification (OA) are moderate at present day CO_2 levels (380 ppm) which have caused detectable ocean acidification and a decline in calcification of some foraminifera and pteropods. Studies of sensitivity distribution among species (OA only, warming excluded) reflects onset of significant effects in 20 to 50 % of extant vulnerable taxa (corals, echinoderms, molluscs) beyond about 500 ppm turning risk into high. This percentage is rising progressively as more calcifying taxa are being affected, turning risk into very high beyond about 700 ppm. Current knowledge indicates that the combined pressures of warming extremes and acidification lead to a shift in sensitivity thresholds to lower CO_2 concentrations, as seen in corals and crustaceans. For corals this comes with the risk that OA will increasingly contribute to the marginalization of a whole ecosystem, a process that has already started due to a combination of various stressors (extreme events, predation, bleaching). Knowledge of the capacity for evolutionary adaptation and its limits is scarce (esp. in fishes). (C) For sea level rise, the height of a 50-yr flood event has already increased (by between 2 and 10 cm per decade) in many coastal locations, increasing risks for ecosystems and human systems from coastal floods and coastal erosion, in addition to the impact of population and socio-economic changes and non-climatic man-made stress. A more than 100 fold increase in the frequency of floods in many places would result from a 0.5 m rise in sea level in the absence of adaptation. For a 1 m sea level rise, local adaptation (and in particular protection) will reach limits for ecosystems and human systems in many places. At that point, only a limited number of adaptation options remain, abandoned land will become more widespread, with significant investments in defense of cities and other key coastal infrastructure. {WGI, 3.7.5, Figure 13.25, WGII, Figure 4.5, Figure 6.10, CC-OA, 5.2, 5.3–5, 5.4.4, 5.5.6}

A large fraction of terrestrial, freshwater and marine species face increasing extinction risk, to a large degree due to climate change (high confidence). Extinctions will be driven by several climate-associated drivers (warming, reduced flows in rivers, ocean acidification and hypoxia) and the interactions of these drivers among themselves and with simultaneous habitat modification, over-exploitation of stocks, pollution, eutrophication and invasive species (high confidence). Extinction risk is increased under all RCP scenarios, as a result of both the magnitude and rate of climate change, likely reducing biodiversity and ecosystem services (high confidence). {WGII 4.3–4, 6.1, 6.3, 6.5, 25.6, 26.4, Box CC-RF, Box CC-MB}

Global marine-species redistribution and marine biodiversity reduction in sensitive regions under climate change will challenge the sustained provision of fisheries productivity and other ecosystem services, especially at low latitudes (*medium confidence*). By mid-21st century under 2°C global warming relative to 2001-2010, spatial shifts of marine species will cause species richness and fisheries catch potential to increase, on average, at mid and high latitudes (*high confidence*) and to decrease at tropical latitudes and in semi-enclosed seas (*medium confidence*). The progressive expansion of Oxygen Minimum Zones (OMZs) and anoxic “dead zones” in the oceans will further constrain fish habitat (*medium confidence*). Open-ocean net primary production is projected to redistribute and to fall globally by 2100 under all RCP scenarios (*medium confidence*). Climate change adds to the threats of over-fishing and other non-climatic stressors. {WGII 6.3-5, 7.4, 25.6, 28.3, 30.6-7, Boxes CC-MB and CC-PP}

Marine ecosystems, especially polar ecosystems and coral reefs, are at risk from ocean acidification (*medium to high confidence*). The impacts on individual species and the number of species affected in a group increase from RCP4.5 to 8.5. Highly calcified molluscs, echinoderms, and reef-building corals are more sensitive than crustaceans (*high confidence*) and fishes (*low confidence*). Ocean acidification acts together with other global environmental changes, (e.g., warming, decreasing oxygen levels) and with local changes (e.g., pollution, eutrophication) (*high confidence*), leading to interactive, complex, and amplified impacts for species and ecosystems (Figure 2.6 and 2.7). {WGII 5.4, 6.3, 6.5, 22.3, 25.6, 28.3, 30.5, Figures 6-10, SPM.6B, Boxes CC-CR, CC-OA, and TS.7}

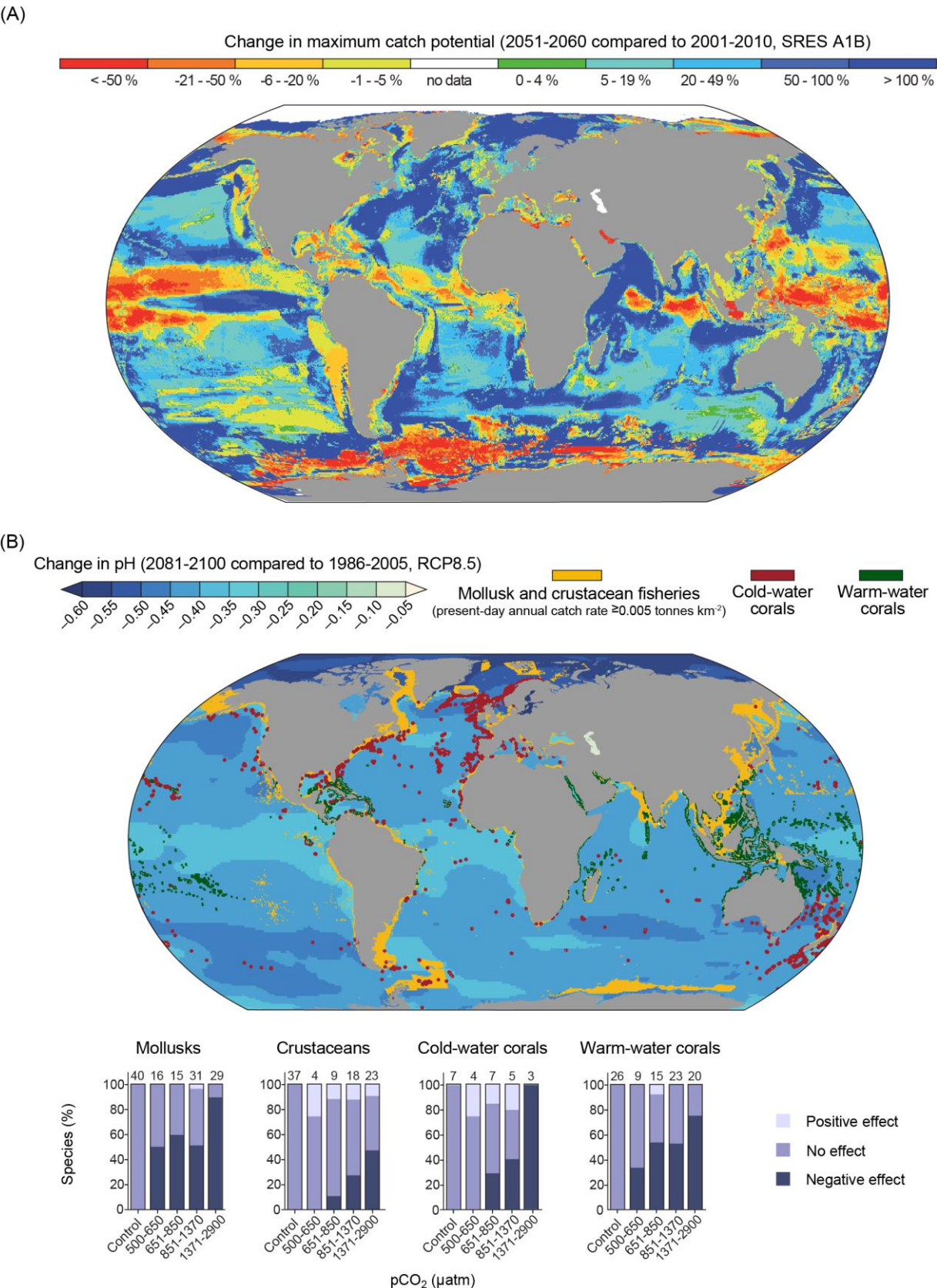


Figure 2.7: Climate change risks for fisheries. (A) For 2°C increase from preindustrial levels using SRES A1B (≈RCP6.0), projected global redistribution of maximum catch potential of 1000 species of exploited fishes and invertebrates, comparing the 10-year averages 2001-2010 and 2051-2060, without analysis of potential impacts of overfishing. (B) Marine mollusc and crustacean fisheries (estimated catch rates ≥ 0.005 tonnes per sq. km) and known locations of warm- and cold-water corals, depicted on a global map showing the distribution of ocean acidification in 2100 under RCP8.5. {WGI AR5 Figure SPM.8} The bottom panel compares sensitivity to ocean acidification across corals, molluscs, and crustaceans, vulnerable animal phyla with socioeconomic relevance (e.g., for coastal protection and fisheries). The number of species analyzed across studies is given for each category of elevated CO₂. For 2100,

RCP scenarios falling within each $p\text{CO}_2$ category are as follows: RCP4.5 for 500-650 μatm , RCP6.0 for 651-850 μatm , and RCP8.5 for 851-1370 μatm . By 2150, RCP8.5 falls within the 1371-2900 μatm category. The control category corresponds to 380 μatm (The unit μatm is more or less equal to the unit ppm, WGII, Figure SPM.6). {6.1, 6.3, 30.5, Figures 6-10 and 6-14; WGI AR5 Box SPM.1}

Carbon stored in the terrestrial biosphere is susceptible to loss to the atmosphere as a result of climate change, deforestation, and ecosystem degradation (*high confidence*). Increased tree mortality and associated forest dieback will occur in many places in the next one to three decades (*medium confidence*), posing risks for carbon storage, biodiversity, wood production, water quality, amenity, and economic activity. {WGII SPM, 4.2-3, 25.6, Figure 4-8, Boxes 4-2, 4-3, and 4-4}

Coastal and low-lying areas will increasingly experience submergence, flooding and erosion throughout the 21st century and beyond, due to sea-level rise (*very high confidence*). The population and assets projected to be exposed to coastal risks as well as human pressures on coastal ecosystems will increase significantly in the coming decades due to population growth, economic development, and urbanization (*high confidence*). Climatic and non-climatic drivers affecting corals and coral reefs will erode habitats, increase coastline exposure to waves and storms, and degrade environmental features important to industries such as fisheries or tourism (*high confidence*). Some low-lying developing countries and small island states are expected to face very high impacts that, in some cases, could have associated damage and adaptation costs of several percentage points of GDP (Figure 2.6). {WGII 5.3-5, 22.3, 24.4, 25.6, 26.3, 26.8, Table 26-1, Boxes 25-1 and CC-CR}

2.5.2 Water, Food and urban systems, human health, security and livelihoods

Throughout the 21st century, climate change will further challenge food, livelihood and human security and wellbeing, not only in low-income countries.

Freshwater-related risks of climate change increase significantly with increasing greenhouse gas concentrations (*robust evidence, high agreement*). The fraction of global population experiencing water scarcity and the fraction affected by major river floods increase with the level of warming in the 21st century. {WGII 3.4-5, 26.3, Table 3-2, Box 25-8}

Climate change over the 21st century is projected to reduce renewable surface water and groundwater resources significantly in most dry subtropical regions (*robust evidence, high agreement*), intensifying competition for water among sectors (*limited evidence, medium agreement*). In presently dry regions, drought frequency will *likely* increase by the end of the 21st century under RCP8.5 (*medium confidence*). In contrast, water resources are projected to increase at high latitudes (*robust evidence, high agreement*). Climate change is projected to reduce raw water quality and pose risks to drinking water quality even with conventional treatment, due to interacting factors: increased temperature; increased sediment, nutrient, and pollutant loadings from heavy rainfall; increased concentration of pollutants during droughts; and disruption of treatment facilities during floods (*medium evidence, high agreement*). {WGII 3.2, 3.4-6, 22.3, 23.9, 25.5, 26.3, Table 3-2, 23-3, Boxes 25-2, CC-RF, and CC-WE; WGI AR5 12.4}

For the major crops (wheat, rice, and maize) in tropical and temperature regions, climate change without adaptation is projected to negatively impact production for local temperature increases of 2°C or more above late-20th-century levels, although individual locations may benefit (*medium confidence*). Projected impacts vary across crops and regions and adaptation scenarios, with about 10% of projections for the period 2030-2049 showing yield gains of more than 10%, and about 10% of projections showing yield losses of more than 25%, compared with the late 20th century. Global temperature increases of ~4°C or more above late-20th-century levels, combined with increasing food demand, would pose large risks to food security globally and regionally (*high confidence*) (Figure 2.5, 2.8). {WGII 6.3-5, 7.4-5, 9.3, 22.3, 24.4, 25.7, 26.5, Tables 7-2 and 7-3, Figures 7-1, 7-4, 7-5, 7-6, 7-7, and 7-8, Box 7-1}

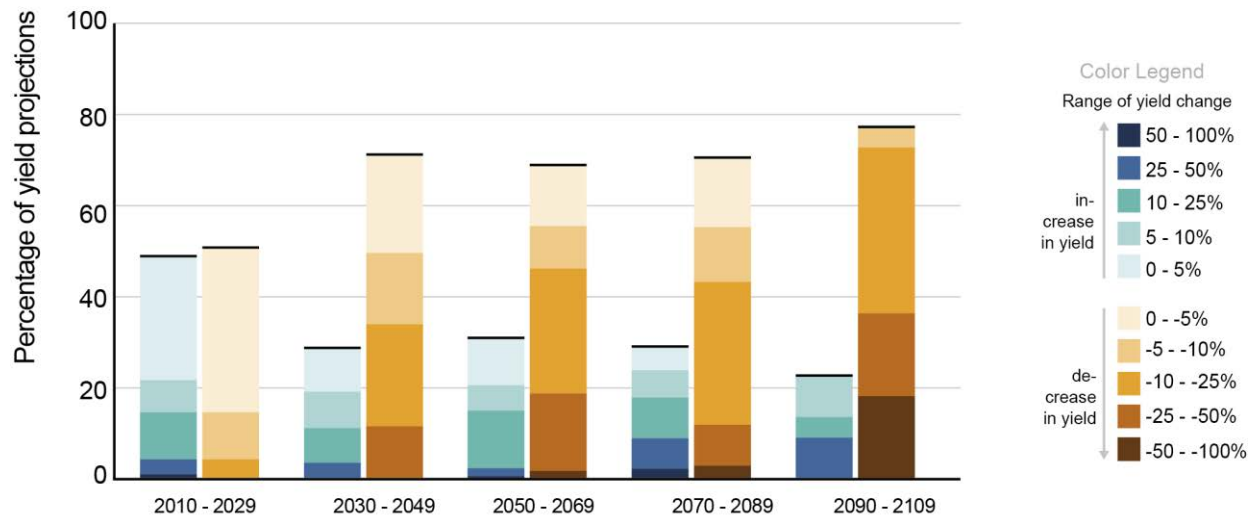


Figure 2.8: Summary of projected changes in crop yields, due to climate change over the 21st century. The figure includes projections for different emission scenarios, for tropical and temperature regions, and for adaptation and no-adaptation cases combined. Relatively few studies have considered impacts on cropping systems for scenarios where global mean temperatures increase by 4°C or more. For five timeframes in the near-term and long-term, data (n=1090) are plotted in the 20-year period on the horizontal axis that includes the midpoint of each future projection period. Changes in crop yields are relative to the late-20th-century levels. Date for each time frame sum to 100%. {WGII, Figure SPM.7}

Heat stress, extreme precipitation, sea level rise, inland and coastal flooding, drought, landslides, air pollution, and water scarcity pose risks in urban areas for people, economies, and ecosystems, with risks amplified for those lacking essential infrastructure and services or living in exposed areas (very high confidence). {WGII 3.5, 8.2-4, 22.3, 24.4, 26.8, Boxes 25-9 and CC-HS}

Rural areas will experience major impacts on water availability and supply, food security, infrastructure, and agricultural incomes, including shifts in the production areas of food and non-food crops around the world (high confidence). These impacts are expected to disproportionately affect the welfare of the poor in rural areas, such as female-headed households and those with limited access to land, modern agricultural inputs, infrastructure, and education. {WGII 9.3, 25.9, 26.8, Box 25-5}

For most economic sectors, the impacts of changes in population, age structure, income, technology, relative prices, lifestyle, regulation, and governance are projected to be large relative to the impacts of climate change (medium evidence, high agreement). Climate change is projected to reduce residential and commercial energy demand for heating and increase it for cooling (*robust evidence, high agreement*). More severe and/or frequent weather hazards are projected to increase disaster losses and loss variability, posing challenges for affordable insurance, particularly in low- and middle-income countries. {WGII 3.5, 10.2, 10.7, 10.10, 25.7, 26.7, Box 25-7}














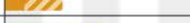



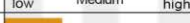

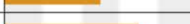
























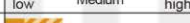



































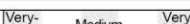
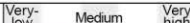







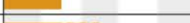




Climate change is expected to lead to increases in ill-health in many regions, especially in developing countries with low income (high confidence). Up to mid-century, the impact will mainly be through exacerbating health problems that already exist (*very high confidence*). Health impacts include greater likelihood of injury, food- and water-borne diseases, malnutrition, and death; and risks from lost work capacity and reduced labor productivity. Fewer cold extremes and reduced capacity of disease-carrying vectors are expected to result in modestly lower cold-related mortality and morbidity in some areas (*medium confidence*). Globally, positive impacts are projected to be outweighed by the magnitude and severity of negative impacts (*high confidence*). {WGII 8.2, 11.3-8, 19.3, 22.3, 25.8, 26.6, Figure 25-5, Box CC-HS}

































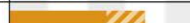


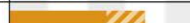


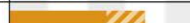












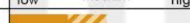


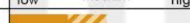


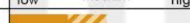


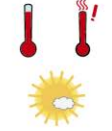









Climate change is projected to increase displacement of people (medium evidence, high agreement). Many populations that lack the resources for mobility and migration experience higher exposure to extreme weather events, particularly in developing countries with low income. Change in the incidence of extreme events is projected to amplify the risks of displacement. Expanding opportunities for mobility can reduce vulnerability, but altered migration flows can also create risks as well as potential benefits for migrants and for sending and receiving regions and states. {WGII 9.3, 12.4, 19.4, 22.3, 25.9}

Climate change can indirectly increase risks of violent conflicts in the form of civil war and intergroup violence by amplifying well-documented drivers of these conflicts such as poverty and economic shocks (*medium confidence*). Multiple lines of evidence relate climate variability to these forms of conflict. *{WGII SPM, 12.5, 13.2, 19.4}*

Climate change impacts are projected to slow economic growth, make poverty reduction more difficult, further erode food security, and prolong existing and create new poverty traps, the latter particularly in urban areas and emerging hotspots of hunger (*medium confidence*). Climate change impacts are expected to exacerbate poverty in most developing countries and create new poverty pockets in countries with increasing inequality, in both developed and developing countries (Figure 2.5). *{WGII 8.1, 8.4, 9.3, 10.9, 13.2-4, 22.3, 26.8}*

Table 2.3: Key sectoral risks from climate change and the potential for reducing risks through mitigation and adaptation. Risks have been identified based on assessment of the relevant scientific, technical, and socioeconomic literature, as detailed in supporting chapter sections. Each key risk is characterized as very low to very high for three timeframes: the present, near-term (here, assessed over 2030-2040), and longer-term (here, assessed over 2080-2100). Assessed risk levels integrate probability and consequence over the full range of possible outcomes, acknowledging the importance of differences in values and objectives in interpretation of the assessed risk levels. In the near-term, projected levels of global mean temperature increase do not diverge substantially across emission scenarios. In the longer-term, risk levels are presented for global mean temperature increase of 2°C and 4°C above preindustrial levels, illustrating the potential role of mitigation in reducing risks. For the present, risk levels are estimated for current adaptation and a hypothetical highly adapted state, identifying current adaptation deficits. For the future, risk levels are estimated for a continuation of current adaptation and for a highly adapted state, representing the potential for and limits to adaptation. Relevant climate variables are indicated by icons. Risk levels are not necessarily comparable across sectors because the assessment considers potential impacts and adaptation across diverse physical, biological, and human systems. *{WGII Table TS.4}*

Climate-related drivers of impacts									Risk & potential for adaptation			
												
Warming trend	Extreme temperature	Drying trend	Extreme precipitation	Damaging cyclone	Flooding	Storm surge	Ocean acidification	Carbon dioxide concentration	Risk level with high adaptation	Risk level with current adaptation		
Key risk			Adaptation issues and prospects				Climatic drivers	Supporting ch. sections	Timeframe	Risk for current and high adaptation		
Global Risks												
Reduction in terrestrial carbon sink: Carbon stored in terrestrial ecosystems is vulnerable to loss back into the atmosphere, resulting from increased fire frequency due to climate change and the sensitivity of ecosystem respiration to rising temperatures (medium confidence)			• Adaptation options include managing land use (including deforestation), fire and other disturbances, and non-climatic stressors.				  	4.2-3		Very-low	Medium	Very high
									Present			
									Near-term (2030-2040)			
									Long-term (2080-2100)			
									2°C			
4°C												
Boreal tipping point: Arctic ecosystems are vulnerable to abrupt change related to the thawing of permafrost, spread of shrubs in tundra, and increase in pests and fires in boreal forests (medium confidence)			• There are few adaptation options in the Arctic.				 	4.3, Box 4-4		Very-low	Medium	Very high
									Present			
									Near-term (2030-2040)			
									Long-term (2080-2100)			
									2°C			
4°C												
Amazon tipping point: Moist Amazon forests could change abruptly to less-carbon-dense, drought- and fire-adapted ecosystems (medium confidence)			• Policy and market measures can reduce deforestation and fire.				  	4.3, Box 4-3		Very-low	Medium	Very high
									Present			
									Near-term (2030-2040)			
									Long-term (2080-2100)			
									2°C			
4°C												
Increased risk of species extinction: A large fraction of the species assessed is vulnerable to extinction due to climate change, often in interaction with other threats. Species with an intrinsically low dispersal rate, especially when occupying flat landscapes where the projected climate velocity is high, and species in isolated habitats such as mountaintops, islands, or small protected areas are especially at risk. Cascading effects through organism interactions, especially those vulnerable to phenological changes, amplify risk (high confidence)			• Adaptation options include reduction of habitat modification and fragmentation, pollution, over-exploitation, and invasive species; protected area expansion; assisted dispersal; and ex situ conservation.				  	4.3-4		Very-low	Medium	Very high
									Present			
									Near-term (2030-2040)			
									Long-term (2080-2100)			
									2°C			
4°C												
Reduced growth and survival of commercially valuable shellfish and other calcifiers (e.g., reef building corals, calcareous red algae) due to ocean acidification (high confidence)			• Evidence for differential resistance and evolutionary adaptation of some species exists but is likely to be limited at higher CO ₂ concentrations and temperatures. • Adaptation options include exploiting more resilient species or protecting habitats with low natural CO ₂ levels, as well as reducing other stresses, mainly pollution, and limiting pressures from tourism and fishing.					5.3, 6.1, 6.3-4, 30.3, Box CC-OA		Very-low	Medium	Very high
									Present			
									Near-term (2030-2040)			
									Long-term (2080-2100)			
									2°C			
4°C												
Marine biodiversity loss with high rate of climate change (medium confidence)			• Adaptation options are limited to reducing other stresses, mainly pollution, and limiting pressures from coastal human activities such as tourism and fishing.				  	6.3-4, Table 30-4, Box CC-MB		Very-low	Medium	Very high
									Present			
									Near-term (2030-2040)			
									Long-term (2080-2100)			
									2°C			
4°C												
Negative impacts on average crop yields and increases in yield variability due to climate change (high confidence)			• With or without adaptation, negative impacts on average yields become likely from the 2030s with median yield impacts of 0 to -2% per decade projected for the rest of the century, and after 2050 the risk of more severe impacts increases.				   	7.2-5, Box 7-1		Very-low	Medium	Very high
									Present			
									Near-term (2030-2040)			
									Long-term (2080-2100)			
									2°C			
4°C												

Key risk	Adaptation issues and prospects	Climatic drivers	Supporting ch. sections	Timeframe	Risk for current and high adaptation																			
Global Risks																								
Urban risks associated with water supply systems (high confidence)	• Adaptation options include changes to network infrastructure as well as demand-side management to ensure sufficient water supplies and quality, increased capacities to manage reduced freshwater availability, and flood risk reduction.		8.2-3	<table><tr><td></td><td>Very low</td><td>Medium</td><td>Very high</td></tr><tr><td>Present</td><td colspan="3"></td></tr><tr><td>Near-term (2030-2040)</td><td colspan="3"></td></tr><tr><td>Long-term (2080-2100)</td><td colspan="3"></td></tr><tr><td></td><td>2°C</td><td></td><td>4°C</td></tr></table>		Very low	Medium	Very high	Present				Near-term (2030-2040)				Long-term (2080-2100)					2°C		4°C
	Very low	Medium	Very high																					
Present																								
Near-term (2030-2040)																								
Long-term (2080-2100)																								
	2°C		4°C																					
Urban risks associated with energy systems (high confidence)	• Most urban centers are energy intensive, with energy-related climate policies focused only on mitigation measures. A few cities have adaptation initiatives underway for critical energy systems. There is potential for non-adapted, centralized energy systems to magnify impacts, leading to national and transboundary consequences from localized extreme events.		8.2, 8.4	<table><tr><td></td><td>Very low</td><td>Medium</td><td>Very high</td></tr><tr><td>Present</td><td colspan="3"></td></tr><tr><td>Near-term (2030-2040)</td><td colspan="3"></td></tr><tr><td>Long-term (2080-2100)</td><td colspan="3"></td></tr><tr><td></td><td>2°C</td><td></td><td>4°C</td></tr></table>		Very low	Medium	Very high	Present				Near-term (2030-2040)				Long-term (2080-2100)					2°C		4°C
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Present																								
Near-term (2030-2040)																								
Long-term (2080-2100)																								
	2°C		4°C																					
Urban risks associated with housing (high confidence)	• Poor quality, inappropriately located housing is often most vulnerable to extreme events. Adaptation options include enforcement of building regulations and upgrading. Some city studies show the potential to adapt housing and promote mitigation, adaptation, and development goals simultaneously. Rapidly growing cities, or those rebuilding after a disaster, especially have opportunities to increase resilience, but this is rarely realized. Without adaptation, risks of economic losses from extreme events are substantial in cities with high-value infrastructure and housing assets, with broader economic effects possible.		8.3	<table><tr><td></td><td>Very low</td><td>Medium</td><td>Very high</td></tr><tr><td>Present</td><td colspan="3"></td></tr><tr><td>Near-term (2030-2040)</td><td colspan="3"></td></tr><tr><td>Long-term (2080-2100)</td><td colspan="3"></td></tr><tr><td></td><td>2°C</td><td></td><td>4°C</td></tr></table>		Very low	Medium	Very high	Present				Near-term (2030-2040)				Long-term (2080-2100)					2°C		4°C
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Long-term (2080-2100)																								
	2°C		4°C																					
Displacement associated with extreme events (high confidence)	• Adaptation to extreme events is well understood, but poorly implemented even under present climate conditions. Displacement and involuntary migration are often temporary. With increasing climate risks, displacement is more likely to involve permanent migration.		12.4	<table><tr><td></td><td>Very low</td><td>Medium</td><td>Very high</td></tr><tr><td>Present</td><td colspan="3"></td></tr><tr><td>Near-term (2030-2040)</td><td colspan="3"></td></tr><tr><td>Long-term (2080-2100)</td><td colspan="3"></td></tr><tr><td></td><td>2°C</td><td></td><td>4°C</td></tr></table>		Very low	Medium	Very high	Present				Near-term (2030-2040)				Long-term (2080-2100)					2°C		4°C
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Violent conflict arising from deterioration in resource-dependent livelihoods such as agriculture and pastoralism (high confidence)	Adaptation options: • Buffering rural incomes against climate shocks, for example through livelihood diversification, income transfers, and social safety net provision • Early warning mechanisms to promote effective risk reduction • Well-established strategies for managing violent conflict that are effective but require significant resources, investment, and political will		12.5	<table><tr><td></td><td>Very low</td><td>Medium</td><td>Very high</td></tr><tr><td>Present</td><td colspan="3"></td></tr><tr><td>Near-term (2030-2040)</td><td colspan="3"></td></tr><tr><td>Long-term (2080-2100)</td><td colspan="3"></td></tr><tr><td></td><td>2°C</td><td></td><td>4°C</td></tr></table>		Very low	Medium	Very high	Present				Near-term (2030-2040)				Long-term (2080-2100)					2°C		4°C
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Declining work productivity, morbidity (e.g., dehydration, heat stroke, and heat exhaustion), and mortality from exposure to heat waves. Particularly at risk are agricultural and construction workers as well as children, homeless people, the elderly, and women who have to walk long hours to collect water (high confidence)	• Adaptation options are limited for people who are dependent on agriculture and cannot afford agricultural machinery. • Adaptation options are limited in the construction sector where many poor people work under insecure arrangements. • Adaptation limits may be exceeded in certain areas in a +4°C world.		13.2, Box 13-1	<table><tr><td></td><td>Very low</td><td>Medium</td><td>Very high</td></tr><tr><td>Present</td><td colspan="3"></td></tr><tr><td>Near-term (2030-2040)</td><td colspan="3"></td></tr><tr><td>Long-term (2080-2100)</td><td colspan="3"></td></tr><tr><td></td><td>2°C</td><td></td><td>4°C</td></tr></table>		Very low	Medium	Very high	Present				Near-term (2030-2040)				Long-term (2080-2100)					2°C		4°C
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Reduced access to water for rural and urban poor people due to water scarcity and increasing competition for water (high confidence)	• Adaptation through reducing water use is not an option for the many people already lacking adequate access to safe water. Access to water is subject to various forms of discrimination, for instance due to gender and location. Poor and marginalized water users are unable to compete with water extraction by industries, large-scale agriculture, and other powerful users.		13.2, Box 13-1	<table><tr><td></td><td>Very low</td><td>Medium</td><td>Very high</td></tr><tr><td>Present</td><td colspan="3"></td></tr><tr><td>Near-term (2030-2040)</td><td colspan="3"></td></tr><tr><td>Long-term (2080-2100)</td><td colspan="3"></td></tr><tr><td></td><td>2°C</td><td></td><td>4°C</td></tr></table>		Very low	Medium	Very high	Present				Near-term (2030-2040)				Long-term (2080-2100)					2°C		4°C
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2.6 Long-term, irreversible and abrupt changes¹⁵

Many aspects of climate change and its impacts will continue for centuries even if anthropogenic emissions of greenhouse gases cease. The risk of abrupt and irreversible change increases with larger warming.

The climate change already underway represents a substantial multi-century commitment created by human activities today, effectively irreversible over a period of many human generations. {WGI 12.5.2} Stabilization of the radiative forcing would not lead to an instantaneous stabilization of the warming (Figure 2.9). {WGI 12.5.2}

¹⁵ 'Abrupt' refers to a sharp steepening of the rate of change relative to the present and recent past. Abrupt change in slow processes may therefore unfold over decades. Not all irreversible changes are abrupt, nor are all abrupt changes irreversible.

For scenarios driven by carbon dioxide alone, global average temperature is projected to remain above the twentieth century average for many centuries following a complete cessation of emissions. To accelerate the return to past regional temperature regimes, a large fraction of the anthropogenic greenhouse gases already emitted would need to be extracted from the atmosphere. {WGI 12.5.2}

Stabilization of global average surface temperature does not imply stabilization for all aspects of the climate system. Some processes related to shifting biomes, re-equilibrating soil carbon, melting ice sheets, warming of the deep ocean and associated sea level rise have their own intrinsic long timescales which will result in changes detectable hundreds to thousands of years after global surface temperature is stabilized. {WGI 12.5.2}

Ocean acidification will affect marine ecosystems for centuries if emissions continue (*high confidence*). Ocean acidification is caused by rising atmospheric CO₂, and has impacts on physiology, behaviour and population dynamics of organisms (*medium to high confidence*). {WGI 3.8.2, 6.4.4, WGII 6.3.2, CC-OA}

It is *very likely* that the Atlantic Meridional Overturning Circulation (AMOC) will weaken over the 21st century, with best estimates and model ranges for the reduction of 11% (1-24%) for the RCP2.6 scenario, 34% (12-54%) for the RCP8.5. Nevertheless, it is *very unlikely* that the AMOC will undergo an abrupt collapse in the 21st century, and it is *unlikely* that the AMOC will collapse beyond the 21st century for the scenarios considered. {WGI SPM, 12.4.7}

There is little evidence in global climate models of a threshold in the transition from a perennially ice-covered to a seasonally ice-free Arctic Ocean beyond which further sea ice loss is unstoppable and irreversible. {WGI 12.5.5}

Global mean sea level rise will continue for many centuries beyond 2100 (*virtually certain*). {WGI 6.4.9, 12.5.2, 13.5.2} The few available analyses that go beyond 2100 indicate sea level rise to be less than 1 m above the pre-industrial level by 2300 for greenhouse gas concentrations that peak and decline and remain below 500 ppm CO₂eq, as in scenario RCP2.6. For a radiative forcing that corresponds to a CO₂eq concentration in 2100 that is above 700 ppm, as in scenario RCP8.5, the projected rise is 1 m to more than 3 m by 2300 (*medium confidence*) (Figure 2.9). There is *low confidence* in the available models' ability to project solid ice discharge from the Antarctic ice sheet. Hence, these models *likely* underestimate the Antarctica ice sheet contribution, resulting in an underestimate of projected sea level rise beyond 2100. {WGI 13.5}

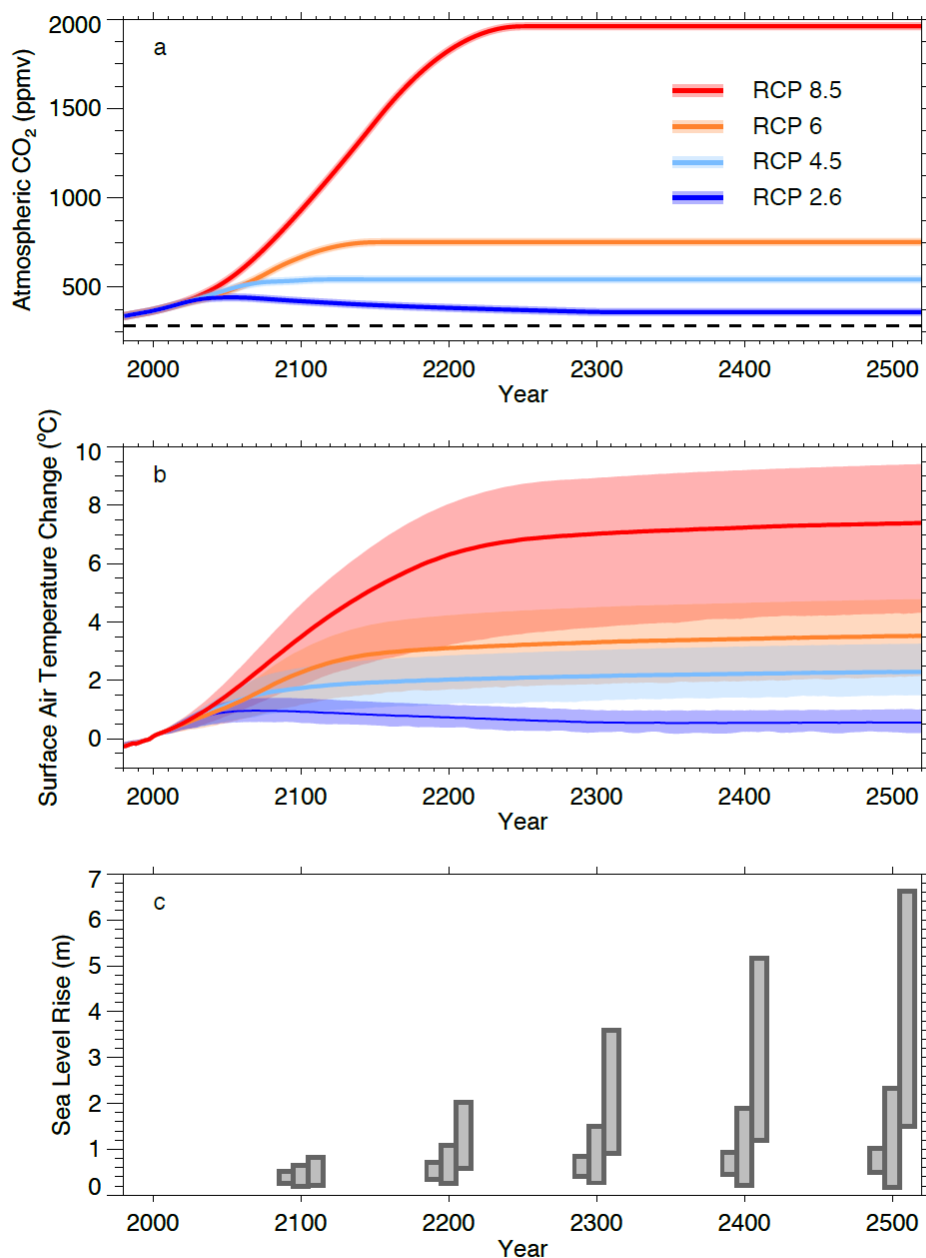


Figure 2.9: (a) Atmospheric CO₂ and (b) projected global mean surface temperature change as simulated by Earth System Models of Intermediate Complexity (EMICs) for the 4 RCPs up to 2300 followed by a constant (year 2300 level) radiative forcing. A 10-year smoothing was applied. Shadings and bars denote the minimum to maximum range. The dashed line on (a) indicates the pre-industrial CO₂ concentration. (c) Sea level change projections grouped into three categories according to the concentration of GHG (in CO₂-eq) in the year 2100 (left: concentrations that peak and decline and remain below 500 ppm, as in scenario RCP2.6; Centre: 500–700 ppm, including RCP4.5; right: concentrations that are above 700 ppm, as in scenario RCP6.0 and RCP8.5). The bars show the maximum possible spread that can be obtained with the few available model results (and should not be interpreted as uncertainty ranges). These models likely underestimate the Antarctica ice sheet contribution, resulting in an underestimate of projected sea level rise beyond 2100. {WGI Figure 12.43 and Table 13.8}

Sustained mass loss by ice sheets would cause larger sea level rise, and some part of the mass loss might be irreversible. There is *high confidence* that sustained global mean warming greater than some threshold would lead to the near-complete loss of the Greenland ice sheet over a millennium or more, causing a sea level rise of up to 7 m. Current estimates indicate that the threshold is greater than 1°C (*low confidence*) but less than about 4°C (*medium confidence*) with respect to pre-industrial temperatures. Abrupt and irreversible ice loss from a potential instability of marine-based sectors of the Antarctic ice sheet in response to climate forcing is possible, but current evidence and understanding is insufficient to make a quantitative assessment. {WGI 5.8, 13.4, 13.5}

1 **Within the 21st century, magnitudes and rates of climate change associated with medium- to high-**
2 **emission scenarios (RCP4.5, 6.0, and 8.5) pose a high risk of abrupt and irreversible regional-scale**
3 **change in the composition, structure, and function of terrestrial and freshwater ecosystems, including**
4 **wetlands (*medium confidence*).** Examples that could lead to substantial impact on climate are the boreal-
5 tundra Arctic system (*medium confidence*) and the Amazon forest (*low confidence*). {WGII 4.3.3.1, Box 4-3,
6 Box 4-4}

7
8 **An effectively irreversible reduction in permafrost extent is *virtually certain* with continued rising**
9 **global temperatures.** Carbon accumulated over hundreds to thousands of years in frozen soils could be lost
10 through decomposition within decades as a result of permafrost thaw. Current permafrost areas are projected
11 to become a net emitter of carbon during the 21st century under future warming scenarios. {WGI 12.5.5,
12 WGII 4.3.3.4, 28.2}