Summary for Policymakers

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Introduction

This Summary for Policymakers (SPM) presents key findings of the Working Group I (WGI) contribution to the IPCC's Sixth Assessment Report (AR6)[1]. The report builds upon the IPCC's Fifth Assessment Report (AR5), and the three AR6 special reports[2].

This SPM provides an updated assessment[3] of the physical understanding of the current state of the climate, including how it is changing and the role of human influence[4], and of the state of knowledge on our possible climate futures, on physical climate information relevant to regions and sectors, and on limiting climate change.

Some key findings are statements of fact. For other findings, confidence is indicated using the IPCC calibrated language[5].

The underlying scientific basis for each key finding is given by references to the main Report, indicated in curly brackets, and to the integrated synthesis of the Technical Summary in square brackets.

The novel AR6 WGI Interactive Atlas provides access to climate change information, including across the WGI reference regions[6].

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[1] Decision IPCC/XLVI-2.

[2] The three Special reports are : Global warming of 1.5°C: an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (SR15); Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (SRCCL); The Ocean and Cryosphere in a Changing Climate (SROCC).

[3] The assessment covers literature accepted for publication by 31 January 31 2021.

[4] In this Report, human influence on the climate system refers to human-driven activities that lead to changes in the climate system due to perturbations of the Earth's energy budget (also called anthropogenic forcing). Human influence results from emissions of greenhouse gases, aerosols and tropospheric ozone precursors, ozone depleting substances, and land use change.

[5] Each finding is grounded in an evaluation of underlying evidence and agreement. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and typeset in italics, for example, medium confidence. The following terms have been used to indicate the assessed likelihood of an outcome or a result: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10%, exceptionally unlikely 0–1%. Additional terms (extremely likely: 95–100%, more likely than not >50–100%, and extremely unlikely 0–5%) may also be used when appropriate. Assessed likelihood is typeset in italics, for example, *very likely*. This is consistent with AR5.

[6] To access the Interactive Atlas, please copy http://ipcc-atlas.ifca.es in any web browser. You will be asked for your credential login details: user: reviewer password: internalreview

The Current State of the Climate

Since AR5, improvements in observational estimates and information from paleoclimate archives provide a comprehensive view of each component of the climate system and its changes to date. New climate model simulations, as well as new analyses and methods combining multiple lines of evidence lead to improved understanding of human influence on a wider range of climate variables and for climatic impact-drivers[7]*, including weather and climate extremes.*

HS.1. It is an established fact that human influence has warmed the climate system and that widespread and rapid climate changes have occurred.

(Figure SPM.1, SPM.2) {2.2, 2.3, 2.4, 3.3, 3.5, 5.2, 6.4, 7.3, 8.2, 8.3, 8.4, 8.5, 8.6, Box 8.1, 9.2, 9.3, 9.5, 9.6, Cross-Chapter Box 9.1, 12.4}

H.S.1.1 Anthropogenic emissions of well-mixed greenhouse gases are responsible for the observed increases in greenhouse gas concentrations. Since AR5, concentrations in well-mixed greenhouse gases have continued to increase in the atmosphere, reaching 410 ppm for CO_2 and 1866 ppb for methane in 2019. {2.2, 5.2} [TS.2.2] **(Figure SPM.1, SPM.2)**

H.S.1.2 Global surface temperature was 1.09 [0.95 to 1.20] °C higher in 2011–2020 than 1850–1900, with stronger warming over land (1.59 [1.34 to 1.83] °C) than over the ocean (0.88 [0.68 to 1.01] °C).[8] From 1850–1900 to 2010–2019, it is *likely* that greenhouse gas forcing contributed 1.0°C–2.0°C of warming, other human-caused forcings (principally aerosols) contributed a cooling of 0.0°C–0.8°C, and contributions from natural forcings were smaller than 0.1°C. The *likely* range of net human-caused surface warming is 0.8°C–1.3°C, with a central estimate of 1.07 °C. {2.3, 3.3, 6.4, 7.3} [Cross-Section Box TS.1] **(Figure SPM.1, SPM.2)**

H.S.1.3 Since the 1950s, the troposphere has warmed and it is *virtually certain* that the stratosphere has cooled. It is *very likely* that human-caused greenhouse gas increases were the main driver[9] of tropospheric warming since 1979, and *extremely likely* that human-caused stratospheric ozone depletion was the main driver of lower stratospheric cooling between 1979 and the mid-1990s. {2.3, 2.4, 3.3} [TS.2.3]

H.S.1.4 Human influence *likely* contributed to increases in atmospheric moisture and *extremely likely* contributed to changes in ocean salinity. Globally averaged land precipitation has *likely* increased since 1950, with a faster increase since the 1980s (*medium confidence*), and with *likely* human influence on the pattern of observed precipitation changes. There is *high confidence* that storm tracks and associated precipitation in the Southern Hemisphere have shifted poleward in summer since the 1970s, associated with the poleward shift of the extratropical jet that was *very likely* caused in part by human influence. {2.3, 3.3, 8.2, 8.3, 8.4, 8.5, 8.6, Box 8.1, 9.2} [TS.2.3, TS.2.4, Box TS.6]

H.S.1.5 Human influence is *very likely* the main driver of the global retreat of glaciers since the 1990s and of observed reductions in Arctic sea ice since the late 1970s, and *very likely* contributed to the observed decrease in Northern Hemisphere spring snow cover since 1950. Antarctic sea-ice area has experienced no significant overall change since 1979. {2.3, 3.4, 8.3, 9.3, 9.5} [TS.2.5]

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[7] Physical climate system conditions (e.g., means, events, extremes) that can be directly connected with having impacts on human or ecological systems.

[8] In this report, square brackets are used to provide the assessed *very likely* range, or 90% uncertainty interval.

[9] Throughout this SPM, 'main driver' means responsible for more than 50% of the change.

H.S.1.6 It is *virtually certain* that the global ocean has warmed over the past five decades and *extremely likely* that human influence is the main driver of this warming. It is *virtually certain* that CO_2 emissions are the main driver of global ocean acidification. There is *high confidence* that oxygen levels have dropped in many ocean regions since the mid-20th century and that the geographic range of many marine organisms has changed over the last two decades. {2.3, 3.5, 3.6, 5.3, 9.2} [TS.2.4]

H.S.1.7 Global mean sea level increased by 0.20 [0.15 to 0.25] m between 1901 and 2018. The rate of rise was 1.35 [0.78 to 1.92] mm yr^{-1} between 1901 and 1990, increasing to 3.7 [3.2 to 4.2] mm yr^{-1} between 2006 and 2018 (*high confidence*). Human activity was *very likely* the main driver of observed global mean sea level rise since at least 1970. {2.3, 3.5, 9.6, Cross-Chapter Box 9.1} [Box TS.4]

H.S.1.8 Over the past half century, the land biosphere has changed in ways that are consistent with large-scale warming: climate zones have shifted poleward and the growing season has lengthened in the Northern Hemisphere extratropics (*high confidence*). Regional greening (increases in plant production) and browning (decreases) have been observed since the 1980s, with an overall global average greening (*high confidence*). {2.3, 5.2, 12.4} [TS.2.6]

[START FIGURE SPM.1 HERE]

Figure SPM.1: **Panel a):** Changes in global surface temperature reconstructed from paleoclimate archives (solid grey line) extending back 2000 years (1–2020 Common Era, relative to 1850–1900) (10-year smoothed). The vertical bar on the left shows the estimated multi-century peak global surface temperature during the Holocene, the warmest interval of the current interglacial period prior to industrialization. The grey shade with white diagonal lines shows the *very likely* range of the multi-method reconstruction ensembles. Observed temperature for the past 170 years (black line) is the same in panels a) and b). **Panel b):** Changes in global surface temperature observed over the past 170 years (black line) relative to 1850–1900, compared to CMIP6 climate model simulations of the temperature response to both human and natural drivers (brown), and to only natural drivers (solar and volcanic activity, green). Solid coloured lines show the multi-model average, and coloured shades show the 5-95% range of individual simulations. {2.3.1, 3.3, Cross-Section Box TS.1, Figure 1a}

[END FIGURE SPM.1 HERE]

[START FIGURE SPM.2 HERE]

Figure SPM.2: Assessed contributions to observed warming. The grey bar shows observed increase of global surface temperature in 2010–2019 relative to 1850–1900 and its *very likely* range. **Panel a):** Temperature change in 2010–2019 relative to 1850–1900 attributed to net human influence, well-mixed greenhouse gases, other human drivers (aerosols, ozone, and land-use change), natural drivers (solar and volcanic), and internal climate variability and their *likely* ranges. **Panel b):** Warming and cooling from emissions and land-use change due to human activities, quantified over 1750 to 2019. Estimates account for both direct emissions into the atmosphere and their effect, if any, on other climate drivers. For example, emissions of methane increase its atmospheric concentration, enhance its own lifetime, cause ozone and CO_2 production, enhance stratospheric water vapor, and influence aerosols. {3.3.1, 6.4.2, 7.3}

[END FIGURE SPM.2 HERE]

HS.2. Large-scale indicators of climate change in the atmosphere, ocean, and cryosphere are reaching levels, and changing at rates, unseen in centuries to many thousands of years (*high confidence*).

(Figure SPM.1) {2.2, 2.3, 5.1}

H.S.2.1 Atmospheric concentrations of CO_2, methane and N_2O are higher than at any time in at least 800 thousand years, and current CO_2 concentrations have not been experienced for at least 2 million years (*high confidence*). Since 1850, CO_2 and methane have increased at a rate, and by an amount, that exceed the natural changes between glacial and interglacial periods over at least the past 800 thousand years (*very high confidence*). {2.2, 5.1} [TS.2.2]

H.S.2.2 Over the last 50 years, observed global surface temperature has increased at a rate unprecedented in at least the last 2000 years (*medium confidence*). It is *more likely than not* that the most recent decade was globally warmer than any multi-centennial period since the peak of the last interglacial, about 125 thousand years ago. {2.3} [Cross-Section Box TS.1, TS.2.1] **(Figure SPM.1)**

H.S.2.3 During the last decade, annual Arctic sea ice coverage reached its lowest level since at least 1850 (*high confidence*), and late summer coverage was less than anytime during at least the past 1000 years (*medium confidence*). Recent global glacier retreat is unprecedented in at least the last 2000 years (*medium confidence*). {2.3} [TS.2.5]

H.S.2.4 The rate of global mean sea level rise beginning around 1900 has risen faster than over any preceding century in at least the last 3 thousand years (*high confidence*). The rate of ocean heat content gain was greater over the past century than at any time since the ending of the last ice age (*medium confidence*). Acidification of the open surface ocean is greater now, and has been increasing faster, than anytime in at least 26 thousand years (*very high confidence*). {2.3} [TS.2.4, Box TS.4]

HS.3. Climate change is already affecting every region across the globe, with human influence contributing to many observed changes in extremes and other climatic impact-drivers.

(Figure SPM.3) {2.3, 3.3, 8.2, 8.3, 8.4, 8.5, 8.6 Box 8.1, Box 8.2, Box 9.2, 10.6, 11.2, 11.3, 11.4, 11.6, 11.7, 11.8, 11.9}

H.S.3.1 The attribution of observed changes in extremes to human influence has substantially advanced since AR5, in particular for extreme precipitation, droughts, tropical cyclones and compound events[10] (*high confidence*). It is *virtually certain* that the frequency and intensity of hot extremes and the intensity and duration of heatwaves have increased across most land regions since 1950, while cold extremes have become less frequent and severe. Marine heatwaves have become more frequent in the 20th century (*high confidence*), and human-influence has *very likely* contributed to 84–90% of them since at least 2006. A subset of recently observed hot extremes would have been *extremely unlikely* to occur without human influence on the climate system. {Box 9.2, 11.2, 11.3, 11.4, 11.6, 11.8} [TS.2.4, TS.2.6, Box TS.10] **(Figure SPM.3)**

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[10] Compound events are multivariate or concurrent extremes. For example, compound flooding (e.g., a storm surge in combination with extreme rainfall and/or river flow) or compound fire weather conditions (hot, dry, and windy).

H.S.3.2 The frequency and intensity of heavy precipitation events have increased over the majority of land regions with good observational coverage (*high confidence*), and human influence is *likely* the main driver. Human influence has contributed to drought in particular during the dry season over most land areas due to increases in atmospheric evaporative demand (*medium confidence*). {11.4, 11.6, 11.7, 11.9} [TS.2.6] **(Figure SPM.3)**

H.S.3.3 Global land monsoon precipitation decreased during 1950–1980, partly due to increases in anthropogenic aerosols, but has subsequently increased as a result of greenhouse gas forcing and large-scale multi-decadal variability (*medium confidence*). Increases of Northern Hemispheric anthropogenic aerosols weakened the regional monsoon circulations in South Asia, East Asia and West Africa during the second half of the 20th century, offsetting the expected strengthening of monsoon precipitation in response to greenhouse gas-caused warming (*high confidence*). {2.3, 3.3, 8.2, 8.3, 8.4, 8.5, 8.6 Box 8.1, Box 8.2, 10.6} [Box TS.13]

H.S.3.4 It is *likely* that the proportion of tropical cyclones that are categorized as intense has increased over the last four decades; this change cannot be explained by natural variability alone (*medium confidence*). Event attribution studies provide *high confidence* for human-caused increases in heavy precipitation associated with tropical cyclones. {11.7} [Box TS.10]

H.S.3.5 The probability of compound events has *likely* increased since 1950. This includes increases in the frequency of concurrent heatwaves and droughts (*high confidence*), fire weather in the Mediterranean region, northern Eurasia, the United States, and Australia (*medium confidence*), and compound flooding (*high confidence*). The land area affected by concurrent extremes has increased (*high confidence*). {11.6, 11.7, 11.8} [Box TS.10]

[START FIGURE SPM.3 HERE]

Figure SPM.3: Synthesis of assessed observed changes and human influence for **(panel a)** hot extremes, **(panel b)** heavy rainfall and **(panel c)** agricultural and ecological drought, for the IPCC AR6 regions displayed as hexagons with identical size. The colours in each panel represent the four outcomes of the assessment on the observed changes: red/green for an observed increase with at least *medium confidence*; blue/yellow for a decrease with at least *medium confidence*; white for no significant change for the region as a whole; and grey when the evidence in this region is insufficient due to lack of data and/or literature preventing the assessment of the region as a whole. All assessments are made for each AR6 region as a whole and for the timeframe from 1950 to present thus, more local or assessment made on shorter time scales might differ from what is shown in the figure. The confidence level for the human influence on these changes is based on trend detection and attribution and event attribution literature, and it is indicated by the number of dots: three dots for *high confidence*; two dots for *medium confidence*; and one dot for *low confidence.* Horizontal bars indicate when an assessment is not possible due to insufficient evidence for the specific region.

For hot extremes, the evidence is mostly drawn from changes in metrics based on daily maximum temperatures, regional studies using other metrics (heatwave duration, frequency and intensity) are used in addition. For heavy precipitation, the evidence is mostly drawn from changes in metrics based on one-day or five-day precipitation amounts using global and regional studies. Agricultural and ecological droughts are assessed based on observed and projected changes in total column soil moisture, complemented by evidence on changes in surface soil moisture, water-balance (precipitation minus evapotranspiration) and metrics driven by precipitation and atmospheric evaporative demand. {11.9, Table TS.5, Box TS.10, Figure 1}

[END FIGURE SPM.3 HERE]

HS.4. Our understanding of how much the climate system warms in response to greenhouse gas increases has been strengthened through improved quantification of climate drivers, feedbacks, and the observed energy increase in the climate system.

(Figure SPM.2) {2.2, 2.3, 4.3, 4.6, 6.2, 6.3, 6.4, 7.1, 7.2, 7.3, 7.4, 7.5, Box 7.1, Box 7.2, 9.2, 9.4, 9.5, 9.6, Cross-Chapter Box 9.1}

H.S.4.1 Since 1750, changes in climate drivers[11] have been dominated by increasing greenhouse gas concentrations that have led to an accumulation of energy in the climate system. The combined effect of climate drivers in 2019 was a rate of energy increase of 2.72[12] [1.96 to 3.48] W m^{-2} (*high confidence*) that is 20% larger than the value for 2011 assessed by AR5. The climate system energy gain is less than that associated directly with climate drivers because as the Earth warms it emits more energy to space. {2.2, 6.2, 6.3, 6.4, 7.2, 7.3, Box 7.1} [TS.2.2] **(Figure SPM.2)**

H.S.4.2 For the period 1971–2018, the average rate of energy gain in the climate system was 0.57 [0.43 to 0.72] W m^{-2}, with a higher rate of 0.79 [0.52 to 1.06] W m^{-2} during 2006–2018 that is equivalent to about 20 times the rate of global primary energy consumption in 2018. Ocean warming accounts for about 90% of the energy gain, with land warming, melting of ice and atmospheric warming accounting for about 5%, 3% and 1%, respectively (*high confidence*). {2.3, 7.2, 9.2, 9.4, 9.5} [TS.3.1]

H.S.4.3 New observational evidence presents a consistent picture of the processes of global sea level rise since the early 20th century and strengthens confidence in the assessed energy changes. For the period 1901–2018, glacier mass loss accounts for about 41% of the observed sea level rise, with ocean warming, ice sheet mass loss and changes in land water storage accounting for about 38%, 29% and -8%, respectively. Greenland and Antarctic Ice Sheet mass loss was four times larger during 2010–2019 than 1992–1999. (*high confidence*). (2.3, 9.2, 9.4, 9.5, 9.6, Cross-Chapter Box 9.1, Table 9.5, Table 9.A.1} [Box TS.4]

H.S.4.4 Improved knowledge of climate feedbacks, past climate states and the observed energy gain have led to a reduction in uncertainty in equilibrium climate sensitivity,[13] with an assessed *likely* range of 2.5°C to 4°C compared to the AR5 *likely* range of 1.5°C to 4.5°C. The assessed *very likely* range for equilibrium climate sensitivity is 2°C to 5°C, with a central estimate of 3°C. {7.1, 7.2, 7.3, 7.4, 7.5, Box 7.1, Box 7.2} [TS.3.2]

H.S.4.5 The assessed range of equilibrium climate sensitivity from multiple lines of evidence is narrower and has a lower mean value than that of the latest generation of climate models. This leads to an assessed range of future warming that is narrower than the spread of model projections. A key advance in this report is the development of projections of surface warming, ocean warming and sea level rise that are fully consistent with the assessment of climate sensitivity. {4.3, 4.6, 7.5, 9.2, 9.6} [TS.3.2]

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[11] An agent or process climate system that influences a component of a human or natural system.

[12] Expressed relative to 1750 and per unit area of Earth's surface.

[13] The equilibrium (steady state) change in the surface temperature following a doubling of the atmospheric CO_2 concentration from pre-industrial conditions.

Our Possible Climate Futures

A core set of five new emission scenarios is used consistently across this report to explore the climate response to a broader range of greenhouse gas, land use and air pollutant futures than assessed in the AR5. This set of scenarios drives projections of changes in the climate system made with a hierarchy of models ranging from simple climate models to complex Earth system models. These projections also account for solar activity and long-term background forcing from volcanoes.

[START SPM BOX.1 HERE]

Box SPM.1: The Basis for WGI AR6 Climate Projections: Climate Models and Scenarios

Developments in the latest generation of global climate models coordinated by the Coupled Model Intercomparison Project Phase 6 (CMIP6) of the World Climate Research Programme, which include new and better representation of physical, chemical and biological processes, as well as higher resolution, have improved the simulation of the recent mean state of most large-scale indicators of climate change (*high confidence*). While past warming is generally well simulated by the new generation of models, some individual models simulate past surface warming that is either below or above that observed. Information about how well models simulate past warming, as well as other insights from observations and theory, are used to assess projections of global warming. {1.5, 3.1, 3.8.2, 4.3.1, 4.3.4, 7.5} [TS.1.2.2, Cross-Section Box TS.1]

The core set of five scenarios used in this report comprises greenhouse gases, aerosols and land-use patterns. These scenarios span a broader range of greenhouse gas and air pollutant futures than assessed in earlier WGI reports. This set includes high CO_2-emission pathways[14] (SSP3-7.0 and SSP5-8.5) without any climate change mitigation, intermediate CO_2-emission pathways (SSP2-4.5) as well as low CO_2-emission pathways in which CO_2 emissions decline to net zero around or after 2050, followed by varying levels of net negative emissions (SSP1-1.9 and SSP1-2.6). Non-CO_2 emissions vary between scenarios and depend on levels of climate change mitigation and air pollution control. This Report focuses on the climate response to this set of scenarios, whereas the feasibility or likelihood of individual scenarios is not part of the assessment. {1.6, Cross-Chapter Box 1.4} [TS.1.3.1] **(Figure SPM.4)**

[START FIGURE SPM.4 HERE]

Figure SPM.4: Future emissions of main drivers of climate change and their respective contributions to global warming for the core set of five scenarios used in this report (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5). **Panel a):** Annual emissions over the 2015–2100 period. Shown are emissions trajectories for carbon dioxide (CO_2, $GtCO_2$/yr) (left graph) and for three of the non-CO_2 drivers considered in the scenarios: methane (CH_4, Mt CH_4/yr, top-right graph), nitrous oxide (N_2O, Mt N_2O/yr, middle-right graph) and sulfur dioxide (SO_2, Mt SO_2/yr, bottom-right graph). **Panel b):** Warming contribution from different emissions shown as change in global surface temperature (°C) in 2100 relative to 1850–1900 by driver and scenario. Bars and whiskers represent median values and the *very likely range.* Within each scenario bar plot, the grey bar represents total global warming (°C), followed by three bars on warming contributions (°C) from CO_2, from other greenhouse gases (GHGs) and from anthropogenic aerosols (see Figure SPM.2 for the warming contributions to date for CO_2 and for individual non-CO_2 drivers). {Cross-Chapter Box 1.4, 4.6, Figure 4.35, 6.7, Figure 6.18, 6.22 and 6.24, 7.3, Figure 7.7, Box TS.7, Figures TS.4 and TS.15}

[END FIGURE SPM.4 HERE]

[END SPM BOX.1 HERE]

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[14] Throughout this report, scenarios are referred to as SSPx-y, where 'SSPx' refers to the Shared Socio-economic Pathway or "SSP" describing the socio-economic trends underlying the scenario and 'y' refers to the approximate level of radiative forcing (in W m^{-2}) resulting from the scenario in the year 2100.

HS.5. Global surface temperature around 2050 will be higher than today under all emission scenarios considered in this Report. Global warming levels of 1.5°C and 2°C above pre-industrial levels will be exceeded by the end of the 21st century under all but the two lowest CO_2 emission scenarios.
(Figure SPM.4, SPM.8, Table SPM.1) {2.3, Cross-Chapter Box 2.3, Cross-Chapter Box 2.4, 4.3, 4.4, 4.5}

H.S.5.1 Compared to 1850–1900[15], global surface temperature averaged over 2081–2100 is *very likely* to be higher by 1.0°C–1.8°C under the lowest CO_2 emission scenario considered in this report (SSP1-1.9) and by 3.3°C–5.7°C under the highest CO_2 emission scenario (SSP5-8.5). Sustained global warming levels of more than 2.5°C higher than 1850–1900 have not occurred since over 3 million years ago, when major elements of the climate system were very different from now. {2.3, Cross-Chapter Box 2.4, 4.3, 4.5} [Figure TS.1, Box TS.2, Box TS.4, Cross-Section Box TS.1, Cross-Section Box TS.1] **(Table SPM.1)**

[START TABLE SPM.1 HERE]

Table SPM.1: Changes in global surface temperature, for selected time periods and the emission scenarios used in this report. Changes are given in °C relative to the average global surface temperature of the period 1850–1900. [Cross-Section Box TS.1, Table.1]

	Near term, 2021–2040		**Mid-term, 2041–2060**		**Long term, 2081–2100**	
Scenario	Central estimate (°C)	*Very likely* range (°C)	Central estimate (°C)	*Very likely* range (°C)	Central estimate (°C)	*Very likely* range (°C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

[END TABLE SPM.1 HERE]

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[15] The multi-century period prior to the onset of large-scale industrial activity around 1750. The reference period 1850–1900 is used to approximate pre-industrial global surface temperature.

H.S.5.2 Global warming of 2°C, relative to 1850–1900, is *extremely likely* to be exceeded during the 21st century under the three scenarios that do not decline greenhouse gas emissions before mid-century (SSP2-4.5, SSP3-7.0, SSP-8.5). Under the lowest assessed CO_2 emission scenario (SSP1-1.9) – with declining global greenhouse gas emissions from the 2020s onwards and reaching net zero CO_2 emissions in the 2050s – global warming during the 21st century is *extremely likely* to remain below 2°C, with a more than 50% likelihood of staying below 1.6°C, implying a potential temporary overshoot of no more than 0.1°C above 1.5°C global warming. {4.3} [Cross-Section Box TS.1] **(Table SPM.1, Figure SPM.4)**

H.S.5.3 In all scenarios considered in this report except SSP5-8.5, the central estimate of crossing the 1.5°C global warming level lies in the early 2030s[16]. This is about ten years earlier than the midpoint of the *likely* range (2030–2052) assessed in the SR1.5. Roughly half of this ten-year difference arises because, owing to progress in methods, AR6 assesses larger historical warming than SR1.5; the other half arises because AR6 also assesses larger near-term future warming than the recent trends extrapolated in SR1.5 (*medium confidence*). Global surface temperature in any individual year could exceed 1.5°C relative to 1850–1900 by 2030 with a likelihood between 40% and 60%, across the scenarios considered in this report (*medium confidence*). {Cross-Chapter Box 2.3, 4.3, 4.4} [Cross-Section Box TS.1] **(Table SPM.1, Figure SPM.8)**

HS.6. Many changes in the climate system, such as heat waves over land and ocean, heavy precipitation, droughts, and loss of Arctic sea ice, snow cover and permafrost, become larger with increasing global warming.

(Figure SPM.5, SPM.6, SPM.8) {4.5, 4.6, 8.2, 8.4, Box 8.2, 9.5, 11.2, 11.3, 11.4, 11.6, 11.8, 11.9, Cross-Chapter Box 11.1, 12.4, 12.5, Cross-Chapter Box 12.1, 12.4, Atlas.4-Atlas.11}

H.S.6.1 Changes in mean climate, the intensity and frequency of extremes and other climatic impact-drivers become larger with additional global warming. It is *virtually certain* that the land surface will continue to warm more than the ocean surface with increasing global warming and that the surface warming in the Arctic will continue to exceed the global average warming over the 21st century. {4.5, 4.6, 11.3, 11.4, 11.9, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4-Atlas.11} [TS.2.6] **(Figure SPM.5)**

H.S.6.2 Every additional half a degree of global warming causes statistically significant increases in temperature extremes (*likely*), the intensity of heavy precipitation (*high confidence*) and the severity of droughts in some regions (*high confidence*). The occurrence of extreme events that are rare in present-day climate will increase with additional global warming, even at 1.5°C of global warming. Projected percentage changes in frequency are higher for rarer extreme events (*high confidence*). {11.2, 11.3, 11.4, 11.6, Cross-Chapter Box 11.1} [TS.2.6] **(Figure SPM.6)**

H.S.6.3 The frequency and intensity of hot extremes and the intensity and duration of heat waves will increase even if global warming is stabilised at 1.5°C. Changes in the intensity of temperature extremes will *very likely* be proportional to changes in global warming, and in some regions up to 2–3 times larger (*high confidence*). The highest increase in temperature of the hottest days is projected in some mid-latitude and semi-arid regions, at about 1.5 to 2 times the rate of global warming (*high confidence*). The highest increase in temperature of the coldest days is projected in Arctic regions, at about 3 times the rate of global warming (*high confidence*). With additional global warming, the frequency of marine heatwaves will continue to increase (*high confidence*). {Box 9.2, 11.2, 11.3, 11.4, 11.6, 11.8, 11.9, CC-Box 11.1, Table 11.1; Cross-Chapter Box 12.1, 12.4} [TS.2.4, TS.2.6] **(Figure SPM.6)**

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[16] The crossing time is defined as the midpoint of the first 20-year period during which the average global surface temperature exceeds the global warming level.

H.S.6.4 Heavy precipitation events will intensify and become more frequent with additional global warming. At the global scale, heavy precipitation events will intensify by about 7% for each degree of global warming, as a warmer atmosphere is able to hold more moisture (*high confidence*). The proportion of intense tropical cyclones and peak wind speeds of the most intense tropical cyclones will increase on the global scale with increasing global warming (*high confidence*). The land area affected by increasing drought frequency and severity will expand with increasing global warming (*high confidence*). {8.2, 11.4, 11.6, 11.7, 11.9, CC-Box 11.1}[Box TS.6, TS.4.3.1] **(Figure SPM.6)**

H.S.6.5 Additional warming will lead to permafrost thawing, loss of seasonal snow cover, and melting of sea ice, the Greenland Ice Sheet and glaciers (*high confidence*). The Arctic Ocean will become practically sea ice-free in late summer by the end of the 21st century under all but the lowest two CO_2 emissions scenarios (*high confidence*). There is *low confidence* in the projected decrease of Antarctic sea ice. {3.4, 4.3, 4.5, 7.4, 8.2, 8.4, Box 8.2, 9.5, 12.4, Cross-Chapter Box 12.1, Atlas.11.1, Atlas.11.2} [TS.2.5] **(Figure SPM.8)**

[START FIGURE SPM.5 HERE]

Figure SPM.5: **Panel a):** The left map shows annual mean surface temperature anomalies linearly regressed against global surface temperature (°C/°C) in the period 1850–2020. Observed temperature data from Berkeley Earth, the dataset with the largest coverage and highest horizontal resolution. Linear regression is applied to all years for which data at the corresponding grid point is available. White indicates areas where time coverage was 100 years or less and thereby too short to calculate a reliable linear regression. The right map shows simulated annual mean temperature at a global warming level of 1°C relative to 1850–1900.
Simulated annual mean **(Panel b)** temperature (°C), **(Panel c)** precipitation (%) and **(Panel d)** soil moisture (standard deviation of interannual variability 1850-1900) at global warming levels of 1.5°C, 2°C and 4°C relative to 1850–1900. Simulated changes correspond to CMIP6 multi-model mean change (median change for soil moisture) at the corresponding global warming level (20-yr mean global surface temperature change relative to 1850–1900). Results from all models reaching the corresponding warming level in any of the five core scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) are averaged. {TS.1.3.2, Figure TS.5, 4.6.1, Figure 4.31, Figure 4.32, Cross-Chapter Box 11.1, Figure 11.19}

[END FIGURE SPM.5 HERE]

[START FIGURE SPM.6 HERE]

Figure SPM.6: Projected changes in the intensity and frequency of extreme temperature, extreme precipitation and droughts for global warming levels of 1°C, 1.5°C, 2°C, and 4°C, relative to their respective 1851–1900 reference period (1850–1900 for drought). Extreme temperature events are defined as the daily maximum temperatures that were exceeded on average once in a decade (10-year event) or once in 50 years (50-year event) during the 1851–1900 reference period. Extreme precipitation events are defined as the daily precipitation amount that was exceeded on average once in a decade during the 1851–1900 reference period. Drought events are defined as the annual average of total column soil moisture that was below its 10th percentile during the 1850–1900 base period. For extreme temperature and extreme precipitation, results are shown for the global land. For drought, results are shown for the AR6 regions in which there is at least *medium confidence* in a projected increase in agriculture/ecological drought at the 2°C warming level compared to the 1850–1900 base period. These regions include W. North-America, C. North-America, N. Central-America, S. Central-America, N. South-America, N.E. South-America, South-American-Monsoon, S.W.South-America, S.South-America, West & Central-Europe, Mediterranean, W. Southern-Africa, E. Southern-Africa, Madagascar, E. Australia, S. Australia. The dots and bars show the medians and their respective *very likely* range based on the multi-model ensemble from simulations of CMIP6 under different SSP scenarios. Dark dots indicate years in which the extreme threshold is exceeded. Light dots are years when threshold is not exceeded. Changes in the intensity of drought are expressed as fractions of standard deviation of annual soil moisture. {11.1, 11.3, 11.4, 11.6, Figure 11.12, Figure 11.15, Figure 11.6, Figure 11.7, Figure 11.18}

[END FIGURE SPM.6 HERE]

HS.7. Further global warming will intensify changes in the water cycle, including the year-to-year variability and severity of wet and dry events.

(Figure SPM.5, SPM.6) {4.3, 4.4, 4.5, 4.6, 8.2, 8.3, 8.4, 8.5, 8.6, Box 8.1, Box 8.2, 10.6, 11.4, 11.6, 11.9, 12.4, Atlas.3}

H.S.7.1 As global surface temperature increases, the average annual global land precipitation will increase (*high confidence*). Precipitation will *very likely* increase over high latitudes and the tropical oceans, but *likely* decrease over large parts of the subtropics. The area of the global land experiencing statistically significant increases or decreases in seasonal mean precipitation will expand (*medium confidence*), with increased year-to-year variability (*medium confidence*). {4.3, 4.5, 4.6, 8.2, 8.4, 11.6, Atlas.3} [Box TS.6, TS.4.3.1] **(Figure SPM.5)**

H.S.7.2 A warmer climate will increase the severity of very wet or very dry seasons and extreme weather events (*high confidence*). The severity of these extremes will increase in the 21st century, but their location and frequency will depend on projected changes of the large-scale circulation. {4.5, 4.6, 8.2, 8.3, 8.4, 8.5, 8.6, 11.4, 11.6, 11.9, 12.4} [TS.2.6, Box TS.6] **(Figure SPM.5, SPM.6)**

H.S.7.3 During the 21st century, global land monsoon precipitation is projected to increase in response to global warming (*high confidence*). Monsoon precipitation is projected to increase over South and Southeast Asia, East Asia and the central Sahel, and decrease over North America and the far western Sahel (*medium confidence*). {4.4, 4.5, 8.2, 8.3, 8.4, 8.5, Box 8.1, Box 8.2, 10.6} [Box TS.13]

H.S.7.4 In the long term (2081–2100), it is *likely* that the summer extratropical jet, storm tracks and associated precipitation will intensify and shift poleward in the Southern Hemisphere under high CO_2 emission scenarios. However, in the near term (2021–2040), the human influence on the jet is *likely* to be reduced under all scenarios assessed, because of opposing effects of stratospheric ozone recovery and increases in other greenhouse gases (*high confidence*). {4.4, 4.5, 8.4} [TS.2.3]

H.S.7.5 Over the 21st century and beyond, abrupt and irreversible regional changes in the water cycle, including changes in seasonal precipitation, streamflow and aridity, cannot be excluded (*medium confidence*). {4.3, 4.4, 4.5, 4.6, 8.2, 8.3, 8.4, 8.5, 8.6} [Box TS.6]

HS.8. Under high CO_2 emission scenarios, the ocean and land carbon sinks are projected to become less effective at slowing the growth rate of atmospheric CO_2 (*high confidence*).

(Figure SPM.7) {5.2, 5.4, 5.6}

H.S.8.1 Land and ocean CO_2 sinks have removed on average 56% of all anthropogenic CO_2 emissions over the past six decades *(high confidence)*. Projections show that these sinks will take up a larger amount of CO_2 under high compared to low CO_2 emission scenarios. However, the fraction of emissions removed from the atmosphere by land and oceans will decrease with higher cumulative CO_2 emissions, resulting in a higher proportion of remaining CO_2 in the atmosphere (*high confidence*). {5.2, 5.4} [Box TS.5] **(Figure SPM.7)**.

H.S.8.2 Under CO_2 emission scenarios that stabilize atmospheric CO_2 concentrations this century (SSP2-4.5), the growth rates of CO_2 removed by the land and oceans are expected to decrease in the second half of the century (*high confidence*). Under the two lowest CO_2 emission scenarios (SSP1-1.9, SSP1-2.6), where CO_2 concentrations peak and decline during the 21st century, land and oceans begin to take up less carbon in response to declining atmospheric CO_2 concentrations (*high confidence*). The land sink eventually turns into a source under SSP1-1.9 (*medium confidence*). {5.4, 5.6} [Box TS.5], TS.3.3.2]

H.S.8.3 Climate model projections show that the overall uncertainty of atmospheric CO_2 concentrations by 2100 is dominated by the choice of emission scenarios rather than by the feedbacks between climate change and the carbon cycle (*high confidence*), but these feedbacks become more important and more uncertain in high CO_2 emission scenarios. Additional ecosystem responses to warming, including those associated with emissions from wetlands and permafrost thaw, further amplify warming (*medium confidence*). {5.4} [Box TS.5, TS.3.2.2]

[START FIGURE SPM.7 HERE]

Figure SPM.7: **Panel a):** Projected change in the combined land and ocean carbon storage under the five core scenarios: SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5. Values are plotted as the cumulative change since 1850 simulated by CMIP6 Earth system models from the concentration-driven simulations. Values are calculated from net biome productivity on land and net ocean CO_2 flux. Values are shown in PgC and $GtCO_2$ (in parentheses). Solid lines show multi-model averages; shadings show 1 standard deviation from the average. Black line and grey shading correspond to the historical period (1850–2019). SSP1-1.9 considers 5 models, while the other four scenarios have 9 models each. **Panel b):** The share of cumulative anthropogenic CO_2 emissions taken up by the land and ocean sinks under the five core scenarios from 1850 to 2100. Values are calculated by dividing the land, ocean and atmosphere budgets by the total anthropogenic CO_2 fossil fuel and land-use emissions. Fossil fuel emissions are calculated as the residual of the land and ocean sinks and prescribed concentration changes in the CMIP6 simulations, and land-use emissions are taken from the International Institute for Applied Systems Analysis scenario database. Land-use emissions are also added to the net biome productivity for the land uptake so that all changes in carbon stores are accounted for. Values in % are combined projected sink fractions from 1850 to 2100 and represent the projected values as of 2100. The cumulative anthropogenic CO_2 emission under each scenario is visualised as the area of the pie and indicated in $GtCO_2$. {Box TS.5, Box TS.5 Figure 1, 5.2.1,Table 5.1, 5.4.5, 5.5.1; Figure 5.25; Figure 5.31}

[END FIGURE SPM.7 HERE]

HS.9. Many consequences of ongoing climate change are irreversible on centennial to millennial time scales, especially for changes in the ocean, ice sheets and global sea level.

(Figure SPM.8) {2.2, 2.3, Cross-Chapter Box 2.4, 4.3, 4.5, 5.3, 9.2, 9.4, 9.5, 9.6, Box 9.4, Cross-Chapter Box 12.1}

H.S.9.1 Past emissions have led to unavoidable future changes in ocean temperature and sea level rise from ocean thermal expansion, which are irreversible on centennial to millennial time scales (*high confidence*). Over the rest of the 21st century, projected ocean warming ranges from double (SSP1-2.6) to 4–8 times (SSP5-8.5) the observed change during 1971–2018. Ocean stratification (*virtually certain*), acidification (*virtually certain*) and deoxygenation (*high confidence*) will continue to increase in the 21st century, at a rate depending on the future emission scenario. {4.3, 5.3, 9.2} [TS.2.4, Box TS.4] **(Figure SPM.8)**

H.S.9.2 Glaciers will continue to lose mass for at least several decades even if global temperature is stabilized (*very high confidence*). There is *high confidence* that both Greenland and Antarctic Ice Sheets will continue to lose mass throughout this century. Poorly understood ice-sheet destabilization processes could contribute more than one additional meter of sea level increase by 2100 in addition to the *likely* projected global mean sea level rise (*low confidence*). {4.3, 4.5, 9.4, 9.5, Box 9.4} [TS.2.5, Box TS.4]

H.S.9.3 It is *virtually certain* that global mean sea level will continue to rise over the 21st century, with a *likely* rise of 0.28-0.55 m under SSP1-1.9 and 0.63-1.02 m under SSP5-8.5 relative to the 1995–2014 average (*medium confidence*). Over the 21st century, the majority of coastal locations have a median projected regional sea-level rise within ±20% of the projected global mean sea level increase (*medium confidence*). The frequency of extreme sea level events will increase in the 21st century, so that once-per-century extreme sea level events will occur annually in 2100 at 60% (SSP1-2.6) or 80% (SSP5-8.5) of tide gauge locations (*medium confidence*). Beyond 2100, sea level will continue to rise for centuries to millennia due to continuing deep ocean heat uptake and mass loss from ice sheets, and will remain elevated for thousands of years (*high confidence*). {2.3, 9.6, Cross-Chapter Box 12.1} [Box TS.4] **(Figure SPM.8)**

H.S.9.4 Estimates of future committed multi-millennial sea level rise for sustained global warming levels are consistent with evidence from past warm climate states. There is *medium confidence* that sea level was *likely* 5–10 m higher around 125 thousand years ago, when global surface temperature was *very likely* 0.5°C–1.5°C higher than during 1850–1900. Sea level was *very likely* 5–25 m higher roughly 3 million years ago, when atmospheric CO_2 levels were at levels comparable to today and temperatures were *very likely* 2.5°C–4°C higher than during 1850–1900 (*medium confidence*). {2.2, 2.3, Cross-Chapter Box 2.4, 9.6} [Box TS.2, Box TS.4, Box TS.9]

[START FIGURE SPM.8 HERE]

Figure SPM.8: Selected indicators of global climate change under five core scenarios. **Panel a):** Historical and future assessed global surface temperature changes relative to 1850-1900. The assessed changes were constructed by combining scenario-based projections with observational constraints based on past simulated warming, as well as an updated assessment of equilibrium climate sensitivity and transient climate response. Anomalies relative to 1850–1900 are calculated by adding 0.85°C (observed surface temperature increase from 1850-1900 to 1995-2014) to simulated anomalies relative to 1995–2014. **Panel b):** September Arctic sea ice area based on CMIP6 models**. Panel c):** Global surface pH, a measure of acidity, based on CMIP6 models. **Panel d):** Global mean sea level changes from 1950–2100 relative to 1900. The historical changes are observed (tide gauges before 1992 and altimeters afterwards) and the future changes are assessed consistently with observational constraints. The dashed line shows a *likely* upper limit if *low confidence* processes (primarily Marine Ice Cliff Instability) are included in the assessment. **Panel e):** Global mean sea level changes at 2300 relative to 1900 (only SSP1-2.6 and SSP5-8.5 are projected at 2300 due to limited modelling beyond 2100). Shadings in all panels show selected *very likely* ranges, except panels d and e which show assessed *likely* ranges. {Figure TS.8, Figure TS.11, Box TS.4 Figure 1, Box TS.4 Figure 1, 4.3, 9.6, Figure 4.2, Figure 4.8, Figure 4.11, Figure 9.27}

[END FIGURE SPM.8 HERE]

Climate Information for Risk Assessment and Regional Adaptation

Climate change information on global and regional scales is constructed from multiple lines of evidence. The generation of such information to support decision-making, for example as part of climate services, has increased significantly due to scientific and technological advancements and growing user awareness, requirements and demand[17]*. Regional climate information encompasses the interplay between regional responses to natural and human-caused forcings, responses to internal variability whose influence is larger at regional scale than at global scale, and local processes and feedbacks. This Report contributes to the IPCC risk framing through the assessment of relevant climate information, including climatic impact-drivers and low-likelihood, high impact outcomes.*

HS.10. Both human influence and natural climate variability affect near-term climate on global to regional scales.

{Cross-Chapter Box 1.1, 2.3, Cross-Chapter Box 3.1, 4.4, 4.6, Cross-Chapter Box 4.1, 7.2, 8.2, 8.3, 8.4, 8.5, 8.6, 10.4, 10.6, Cross-Chapter Box 9.1, 11.1, 11.3, 12.5}

H.S.10.1 Internal variability and variations in solar and volcanic forcings partly offset the human-caused global surface temperature trend over the 1998–2012 period, with pronounced regional and seasonal signatures (*high confidence*). However, global ocean heat content continued to increase throughout this period, indicating continuous warming of the entire climate system (*very high confidence*). One to two decades of both reduced and increased trends in global surface temperature, relative to human-caused warming, will continue to occur through the 21st century (*very high confidence*). {2.3, Cross-Chapter Box 3.1, 4.4, 7.2, Cross-Chapter Box 9.1} [Cross-Section Box TS.1]

H.S.10.2 It is *likely* that at least one large volcanic eruption will occur during the 21st century. Such an eruption is expected to reduce global surface temperature and land precipitation for several years, alter the monsoon circulation, modify extreme precipitation and change the profile of many climatic impact-drivers (*medium confidence*). If it occurs in the near term, this could delay the emergence of human influence on some regional changes. {4.4, Cross-Chapter Box 4.1, 8.5} [TS.2.1]

H.S.10.3 In the near term, internal variability and local feedbacks will continue to either intensify or obscure human-caused changes in mean and extreme climate and climatic impact-drivers at regional scale. A small fraction of the surface can therefore show cooling, so near-term cooling at any given location is fully consistent with global surface temperature increase due to human influence (*high confidence*). {Cross-Chapter Box 1.1, 11.1, 4.6, 11.3} [TS.4.2]

H.S.10.4 Projected precipitation changes in the near term and at regional scales largely depend on internal variability and uncertainty related to model physics and natural and anthropogenic aerosol forcings (*medium confidence*). These contribute to the delayed or reduced signal of human-caused changes in many land regions (*high confidence*). However, some aspects of water cycle changes that are already discernible from internal variability will become more pronounced in the near term (*high confidence*). {4.4, 4.6, 8.2, 8.3, 8.4, 8.5, 8.6, 10.4, 10.6, 12.5} [Box TS.6]

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[17] The decision-making context, level of user engagement and co-production between scientists, practitioners and intended users are key to climate service utility to support timely adaptation, mitigation and risk management decisions.

HS.11. Every region will increasingly experience concurrent changes in multiple climatic impact-drivers during the next 30 years. A wider set of changes would occur at 2°C compared to 1.5°C in the majority of regions. (*high confidence*)
(Figure SPM.9) {8.1, 8.2, 9.3, 9.6, Box 10.3, 11.3, 11.7, 11.8, 11.9, Box 11.3, Box 11.4, 12.3, 12.4, Cross-Chapter Box 12.1, Atlas.4-Atlas.11}

H.S.11.1 All regions[18] will experience further climate changes in the near to mid term (next 30 years) (*high confidence*). For 1.5°C of global warming, regional changes include: increases in annual surface temperature and consequently longer warm seasons and shorter cold seasons, increased hot extremes (e.g., heat waves, warm spells) and decreased cold extremes (e.g., cold spells, frosts) (*high confidence*). These changes would be larger with higher warming; for example, by 2050 if 2°C of global warming is reached, extreme heat thresholds known to be critical for health, agriculture and other sectors will be more frequently exceeded (*high confidence*). In regions outside of Antarctica with permafrost, snow, lake and sea ice, further decreases are projected. (*medium/high confidence*)[19]. {9.3, 11.9, 12.3, 12.4, Atlas.4-Atlas.11} [TS.4.3] **(Figure SPM.9)**

H.S.11.2 At 1.5°C of global warming, heavy precipitation and pluvial flooding are projected to increase with respect to the last 20–40 years in most regions in Africa, Asia (*high confidence*), North America (*high/medium confidence*) and Europe (*medium confidence*). From 2°C, confidence is higher for the above regions, and these changes are also seen in some regions in Australasia and Central and South America (*medium confidence*). At 1.5°C of global warming, more frequent and/or severe agricultural and ecological droughts are projected in a few regions in all continents except Asia compared to 1850–1900 (*medium confidence*) and in more regions at 2°C, some with *high confidence*. Few regions are projected to experience significant changes in mean precipitation at 1.5°C, while mean precipitation is projected to increase with respect to the last 20-40 years in polar regions, regions of northern Eurasia and North America, and two regions of South America with *high confidence* at 2°C of global warming. {Tables 11.4–11.21, 12.4, Atlas.5, Atlas.7-Atlas.9, Atlas.11} [TS.4.3, Table TS.5] **(Figure SPM.9)**

H.S.11.3 If 2°C of global warming or higher is reached by mid-century, most regions will experience additional changes in climatic impact-drivers that will accumulate in each region (*high confidence*). Region-specific changes could include increases in tropical cyclone intensity or extratropical storms (*medium confidence*), increases in river floods (*high/medium confidence*), reductions in mean precipitation and increases in aridity (*high/medium confidence*), increases in fire weather (*medium/high confidence*) and increasing hydrological droughts (*high/medium confidence*). Future regional risk can also be substantially influenced by other changes (e.g., hail, ice storms, severe storms, dust storms, heavy snowfall, and avalanches) but they cannot currently be projected with *high confidence*. {11.7, 11.9, 12.4, Atlas.4, Atlas.6-Atlas.8, Atlas.10} [TS.4.3.1, TS.4.3.2] **(Figure SPM.9)**

H.S.11.4 Except in a few regions with substantial land uplift, relative sea level rise is *very likely* to *virtually certain* to continue throughout the 21st century, contributing to increases in the frequency and severity of coastal flooding in low-lying areas and to coastal erosion along most sandy coasts and (*high confidence*). {9.6, 12.4, Cross-Chapter Box 12.1} [TS.4.3] **(Figure SPM.9)**

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[18] 'Regions here refer to the WGI AR6 reference regions used in this report to summarize information on sub-continental and oceanic regions {1.4, Atlas.1, Interactive Atlas}.

[19] The level of confidence is dependent on the specific region and can be found in the Technical Summary and underlying report.

H.S.11.5 Predominantly at night, urban areas are generally warmer than their surroundings (*very high confidence*). Urbanization alters the water cycle, generating increased precipitation over and downwind of cities (*medium confidence*), and increasing runoff intensity (*high confidence*). Large implications are expected from the combination of future urban development and the more frequent occurrence of extreme climate events (*very high confidence*). In coastal cities, the combination of extreme sea level and extreme rainfall/riverflow events will increase the probability of flooding (*high confidence*). {8.1, 8.2, Box 10.3, 11.3, 12.4} [Box TS.14]

H.S.11.6 Many regions will experience an increase in the probability of compound events with higher global warming (*high confidence*). At 2°C and higher warming, simultaneous or sequential extremes become more frequent across multiple locations, possibly affecting similar sectors (e.g., critical regions for global food supply) in different regions (*high confidence*). {11.8, Box 11.3, Box 11.4, 12.3, 12.4} [TS.4.3]

[START FIGURE SPM.9 HERE]

Figure SPM.9: **Panel a):** geographical location of regions belonging to one of five groups characterised by a specific combination of changing climatic impact-drivers (CIDs). The five groups are represented by five different colours, and the CID combinations associated with each group are represented in the corresponding 'fingerprint' and text below the map. Each fingerprint comprises a set of CIDs projected to change with *high confidence* in every region in the group, and a second set of CIDs, one or more of which are projected to change in each region with *high* or *medium confidence*. The CID combinations follow a progression from those becoming hotter and drier (group 1) to those becoming hotter and wetter (group 5). In between (groups 2–4), the CIDs that change include some becoming drier and some wetter and always include a set of CIDs which are getting hotter. Tropical cyclones and severe wind CID changes are represented on the map with black dots in the regions affected. Regions affected by coastal CID changes are described by text on the map. The five groups are chosen to provide a reasonable level of region-specific detail whilst not overwhelming the map with all aspects of the assessment, which is available in Table TS.5. The CID changes summarized in the figure represent *high* and *medium confidence* changes projected for around 2050 if 2ºC of global warming is reached. **Panel b):** numbers of regions where each CID is increasing or decreasing with *medium* or *high confidence* for all land regions reported in the map of panel a) as well as for the ocean regions. The regions coloured in the map are WGI AR6 reference regions with an additional non-continuous Pacific Islands region labelled PAC. Definitions of the acronyms of the other regions are provided in Atlas.1 and the Interactive Atlas. {Table TS.5, Figure TS.24}

[END FIGURE SPM.9 HERE]

HS.12. Low-likelihood outcomes leading to substantially larger global or regional changes than assessed for the *very likely* range of projections cannot be ruled out and complement climate information for risk assessment.

(Table SPM.1) {4.3, 4.4, 4.7, 4.8, Cross-Chapter Box 4.1, 7.3, 7.4, 7.5, 8.6, 9.3, 9.6, Box TS.4, Box 9.4, 11.8, Box 11.2, Cross-Chapter Box 12.1}

H.S.12.1 If global warming exceeds the assessed *very likely* range for a given emission scenario, including low CO_2 emission scenarios and near-term projections, then global and regional changes in many aspects of the climate system, including climatic impact-drivers,would be larger than described for their assessed *very likely* ranges. Such high-warming outcomes are associated with potentially largest impacts and high risks for human and ecological systems.{4.3, 4.4, 4.8, Cross-Chapter Box 4.1, 7.3, 7.4, 7.5, 9.6, Box TS.4, Box 9.4, Box 11.2, Cross-Chapter Box 12.1} [Box TS.3] **(Table SPM. 1)**

H.S.12.2 For global warming within the *very likely* range for a particular emission scenario, low-likelihood, high-impact outcomes[20] might occur at global and regional scales that include large precipitation changes, additional sea level rise associated with collapsing ice sheets, or abrupt ocean circulation changes. {4.3, 4.4, 4.8, Cross-Chapter Box 4.1, 7.3, 7.4, 7.5, 9.6, Box TS.4, Box 9.4, Cross-Chapter Box 12.1} [Box TS.3, Box TS.4, TS.2.5] **(Table SPM.1)**

H.S.12.3 The chance of low-likelihood, high impact outcomes increases with higher global warming levels. As global warming increases, some compound events with low likelihood in past and current climate will become more frequent, and there is a higher chance that events unprecedented in the observational record occur (*high confidence*). {4.8, 11.8, Box 11.2, Cross-Chapter Box 12.1} [Box TS.3, Box TS.9]

H.S.12.4 It is *very likely* that Atlantic Meridional Overturning Circulation will decline over the 21st century, but there is only *medium confidence* that it will not experience an abrupt collapse before 2100. If an abrupt collapse were to occur, it would *very likely* cause abrupt shifts in weather patterns and the regional water cycle. {4.7, 8.6, 9.3, Cross-Chapter Box 12.1} [Box TS.3, Box TS.9, Box TS.12]

H.S.12.5 Low-likelihood, high impact outcomes may also result from a series of very large volcanic eruptions that could substantially alter the 21st century climate trajectory compared to the core set of emission scenarios assessed in this Report. {Cross-Chapter Box 4.1} [Box TS.3]

Limiting Climate Change

Estimates of remaining carbon budgets have been strengthened by an improved methodology from SR15, updated evidence, and the integration of results from multiple lines of evidence. A comprehensive range of possible future air pollution management options in scenarios has been used to consistently assess the effects of various pathways on climate and air pollution. A key development since the AR5 has been the quantification of when climate responses to emissions reductions would emerge above natural variability.

HS.13. Limiting human-induced global warming at any level requires achieving net zero CO_2 emissions. Furthermore, stringent methane emissions reductions would limit additional non-CO_2 warming and improve air quality.
(Figure SPM.10, Table SPM.2) {4.6, 5.1, 5.5, 5.6, Box 5.2, 6.7, 7.6}

H.S.13.1 This report reaffirms with *high confidence* the AR5 finding that there is a near-linear relationship between cumulative CO_2 emissions and the global warming they cause. Each 1000 PgC (3664 $GtCO_2$) of cumulative CO_2 emissions is assessed to *likely* cause a 1.0°C–2.3°C increase in global surface temperature. This quantity is referred to as the Transient Climate Response to Cumulative CO_2 Emissions (TCRE). This relationship implies that stabilizing human-induced global temperature increase at any level requires net anthropogenic CO_2 emissions to become zero. It further implies that requirements for limiting warming to specific levels can be quantified in terms of a carbon budget (*high confidence*). {5.5} [TS.1.3.2, TS.3.3.1] **(Figure SPM.10)**

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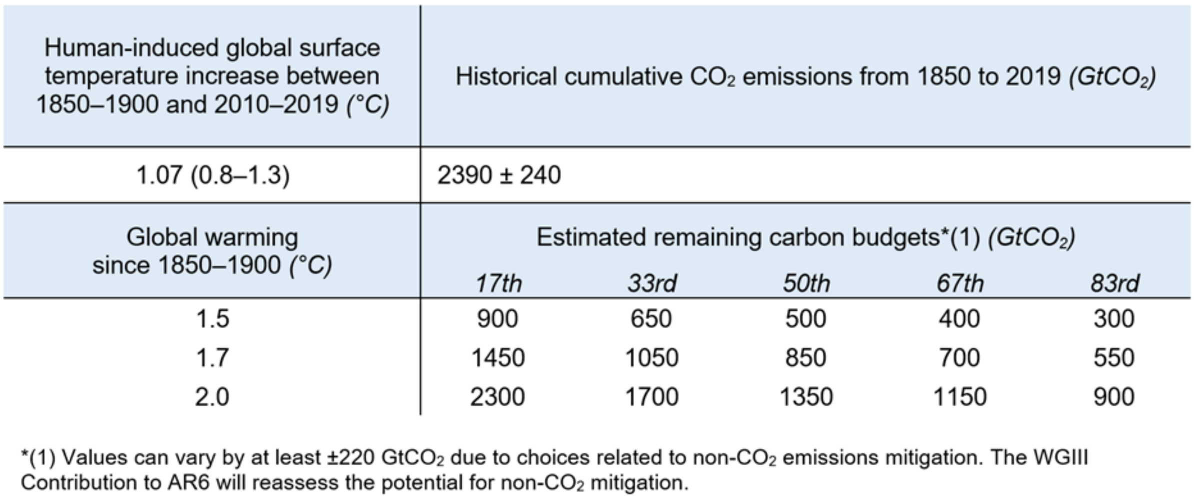
[20] Outcomes or events whose probability of occurrence is low or not well known (as in the context of deep uncertainty) but whose potential impacts on society and ecosystems could be high.

H.S.13.2 Over the period 1850–2019, a total of 2390 ± 240 (1 standard deviation) $GtCO_2$ of anthropogenic CO_2 had been emitted. Remaining carbon budgets for limiting warming to specified levels have been quantified and depend on the chosen warming level, the percentile of TCRE and other uncertainties. These estimates take into account projected warming of associated non-CO_2 emissions, and possible differences in the future level of these non-CO_2 emissions could increase or decrease remaining carbon budget estimates by at least 220 $GtCO_2$. {5.1, 5.5.2, Box 5.2} [TS.3.3.1] **(Table SPM.2)**

[START TABLE SPM.2 HERE]

Table SPM.2: Estimates of the historical and the remaining carbon budgets.
Estimated remaining carbon budgets starting from 1 January 2020 are assessed for five percentiles of TCRE[21]. {Table 3.1, Table 5.1, Table 5.7, Table 5.8, 5.5.1, 5.5.2, Box 5.2}



Human-induced global surface temperature increase between 1850–1900 and 2010–2019 *(°C)*	Historical cumulative CO_2 emissions from 1850 to 2019 *($GtCO_2$)*				
1.07 (0.8–1.3)	2390 ± 240				
Global warming since 1850–1900 *(°C)*	**Estimated remaining carbon budgets*(1) *($GtCO_2$)***				
	17th	*33rd*	*50th*	*67th*	*83rd*
1.5	900	650	500	400	300
1.7	1450	1050	850	700	550
2.0	2300	1700	1350	1150	900

*(1) Values can vary by at least ±220 $GtCO_2$ due to choices related to non-CO_2 emissions mitigation. The WGIII Contribution to AR6 will reassess the potential for non-CO_2 mitigation.

[END TABLE SPM.2 HERE]

H.S.13.3 Several factors that determine estimates of the remaining carbon budget have been re-assessed since SR1.5 with improved observations and modelling, including estimates of historical warming, TCRE, projected non-CO_2 warming, future emissions from thawing permafrost, and potential further warming after reaching net zero CO_2 emissions. When adjusted for emissions since previous reports, remaining carbon budget estimates are larger compared to AR5 due to methodological improvements, and of similar magnitude compared to SR1.5 as methods are similar and updates to the above-mentioned contributing factors are small. {5.5, Box 5.2} [TS.3.3.1]

H.S.13.4 Deliberate removal of CO_2 from the atmosphere could compensate for some residual emissions to reach net zero CO_2 or greenhouse gas emissions or, if implemented at a large scale, generate net negative emissions. Carbon dioxide removal (CDR) techniques have various potentially wide-ranging side-effects on biogeochemical cycles and climate that can either weaken or strengthen the carbon sequestration and cooling potential of these techniques (*high confidence*)[22]. {5.6, Figure 5.36} [TS.3.3.2]

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[21] Earth system feedbacks are included in the range of remaining carbon budget estimates. Uncertainties affecting remaining carbon budget estimates, such as those related to historical warming and non-CO_2 forcings, are partially covered by the assessed uncertainty in TCRE.

[22] Side-effects of CDR techniques include co-benefits and adverse side effects for biodiversity, water and food production. These are comprehensively assessed in the WGII and WGIII reports

H.S.13.5 A given amount of CO_2 sequestered by CDR will not result in a drop in atmospheric CO_2 of the same magnitude. In a similar way a fraction of historical anthropogenic CO_2 emissions has been taken up by land and ocean carbon stores, net CO_2 removal will be partially counteracted by CO_2 release from these stores (*very high confidence*). {5.6} [TS.3.3.2]

H.S.13.6 CDR could reverse surface warming if global CO_2 emissions become net negative, but other climate changes would continue for decades to millennia. For instance, sea level rise would not be reversed for several centuries to millennia even under large net negative CO_2 emissions (*high confidence*). {4.6} [TS.3.3.2]

H.S.13.7 The choice of emission metric used to aggregate emissions and removals of different greenhouse gases affects whether and when net zero greenhouse gas emissions would be diagnosed, as well as the implications of reaching net zero greenhouse gas emissions for the subsequent evolution of global surface temperature (*high confidence*). Achieving sustained net zero greenhouse gas emissions aggregated with the Global Warming Potential over a 100-year period (GWP-100), typically leads to a peak and decline in global surface temperatures. In contrast, achieving sustained net zero greenhouse gas emissions aggregated according to new metric approaches would lead to approximately stable temperatures. {7.6} [TS.3.3.3]

H.S.13.8 In the core set of scenarios, net zero CO_2 emissions are accompanied by reductions in emissions of aerosols and non-CO_2 greenhouse gases. These reductions lead to warming and cooling, respectively. Their net effect on future global surface temperature is thus determined by their respective contributions, driven by levels of air pollution control and climate change mitigation. {6.7} [Box TS.7] **(Figure SPM.4)**

H.S.13.9 Simultaneous changes in methane, aerosol and ozone precursor emissions lead to a net global surface warming in the near term and by 2100, in all core scenarios (*high confidence*). Air pollution control, combined with stringent methane emission reductions as considered in the scenarios reaching net zero CO_2 emissions, can limit the net warming due to methane, aerosol and ozone, despite the warming due to reduction in aerosols (*high confidence*). Methane mitigation partially counteracts global warming from aerosol reductions by 2100, and reduces global surface ozone, thus contributing to improved air quality (*high confidence*). {6.7} [Box TS.7]

[START FIGURE SPM.10 HERE]

Figure SPM.10: Relationship between cumulative CO_2 emissions and the increase in global surface temperature. Historical data (thin black line) shows historical CO_2 emissions versus observed global surface temperature increase from 1850–1900. The grey range with its central line shows a corresponding estimate of the human-induced share of historical warming (see Figure SPM.1b). Coloured areas show the assessed *very likely* range of global surface temperature projections, and thick coloured central lines show the median estimate as a function of cumulative CO_2 emissions for the core set of scenarios SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 (see Figure SPM.4). Cumulative CO_2 emissions for projections are from the original emissions scenarios, and the global warming shown includes the contribution from non-CO_2 gases as described in each respective scenario. Cumulative carbon emissions are also shown as a link to Figure SPM.7. The bottom panel shows bars of cumulative CO_2 emissions over the historical period and for the respective scenario projections. {Figure TS.18, Figure 5.31}

[END FIGURE SPM.10 HERE]

HS.14. Stringent reductions of CO_2 and non-CO_2 emissions will lead to discernible effects on atmospheric composition and air quality within years. By contrast, the effects on other variables, such as surface temperature, will emerge only after decades or more.
(Figure SPM.7, SPM.8) {4.6, 6.6, 6.7, Cross-Chapter Box 6.1, 9.6, 11.2, 11.4, 11.5, 11.6, 12.4, 12.5, Cross-Chapter Box11.1}

H.S.14.1 Temporary emission reductions in 2020 associated with COVID-19 containment led to a small increase in net radiative forcing, primarily due to reductions in human-caused aerosols, and discernible but temporary effects on atmospheric composition and air pollution. Global and regional climate responses to this forcing are, however, undetectable above internal variability, due to the temporary nature of the emission reductions (*high confidence*). {Cross-Chapter Box 6.1} [TS.3.3.3]

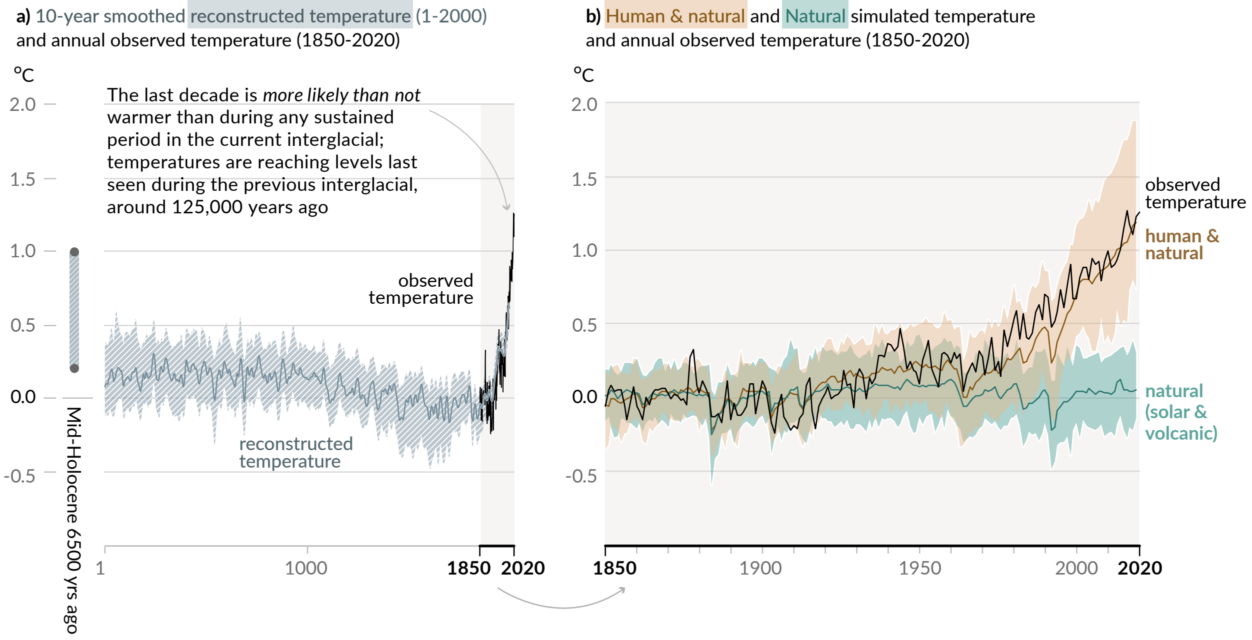
H.S.14.2 Future changes in global air quality (surface ozone and particulate matter) will be mainly driven by emission changes rather than by climate change (*high confidence*). Air quality improvements driven by rapid decarbonization, as in SSP1-1.9 and SSP1-2.6, are not sufficient in the near term to achieve air quality guidelines set by the World Health Organization in some highly polluted regions (*high confidence*). Implementation of air pollution controls, relying on existing technologies, leads to air quality benefits more rapidly than climate mitigation policy. Additional policies envisaged to attain Sustainable Development Goals, such as access to clean energy or waste management, bring complementary reductions in ozone and particulate matter precursor emissions. {6.6, 6.7} [Box TS.7]

H.S.14.3 Stringent emission reductions have immediate and sustained effects on human-caused climate change, even if early responses can be masked by natural variability. If stringent mitigation is implemented, as in the SSP1-1.9 and SSP1-2.6 scenarios, the effect on global surface temperature trends would emerge around 2040, relative to warming from emissions following SSP3-7.0 or SSP5-8.5. The response to mitigation of many other climate variables, such as regional temperature and precipitation, is largely masked by internal variability during the near term (*high confidence*). The mitigation benefits for these quantities emerge only later in the 21st century (*high confidence*). {4.6} [Cross-Section Box TS.1] **(Figures SPM.7, SPM.8)**

H.S.14.4 Stringent emission reductions strongly influence changes in climatic impact-drivers beyond 2040. By the end of the century, such mitigation strongly limits the frequency of extreme sea levels, drastically reduces the frequency of events exceeding dangerous heat thresholds, and limits the number of regions where such exceedances occur (*high confidence*). {9.6, 11.2, 11.4, 11.5, 11.6, 12.4, 12.5, Cross-Chapter Box11.1} [TS.4.3.1, TS.4.3.2]

Human influence has warmed the climate system at a rate that is unprecedented in at least the last 2000 years

Global surface temperature change relative to 1850-1900


a) 10-year smoothed reconstructed temperature (1-2000) and annual observed temperature (1850-2020)

b) Human & natural and Natural simulated temperature and annual observed temperature (1850-2020)

Figure SPM.1: Panel a): Changes in global surface temperature reconstructed from paleoclimate archives (solid grey line) extending back 2000 years (1–2020 Common Era, relative to 1850–1900) (10-year smoothed). The vertical bar on the left shows the estimated multi-century peak global surface temperature during the Holocene, the warmest interval of the current interglacial period prior to industrialization. The grey shade with white diagonal lines shows the *very likely* range of the multi-method reconstruction ensembles. Observed temperature for the past 170 years (black line) is the same in panels a) and b). **Panel b):** Changes in global surface temperature observed over the past 170 years (black line) relative to 1850–1900, compared to CMIP6 climate model simulations of the temperature response to both human and natural drivers (brown), and to only natural drivers (solar and volcanic activity, green). Solid coloured lines show the multi-model average, and coloured shades show the 5-95% range of individual simulations. {2.3.1, 3.3, Cross-Section Box TS.1, Figure 1a}

Observed warming to date has been driven by greenhouse gas emissions, roughly a third of which has been masked by cooling from aerosol emissions

Contributions to global surface temperature increase based on two lines of evidence (panel a and b)

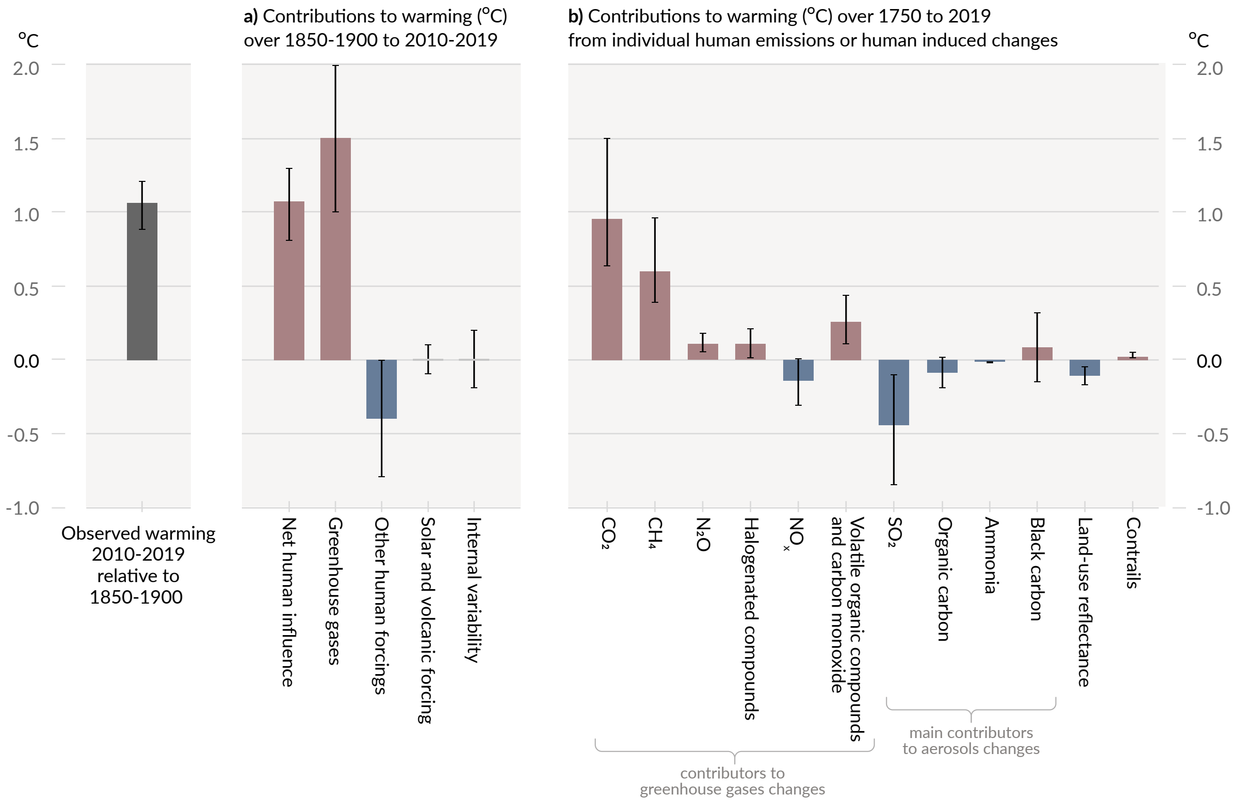
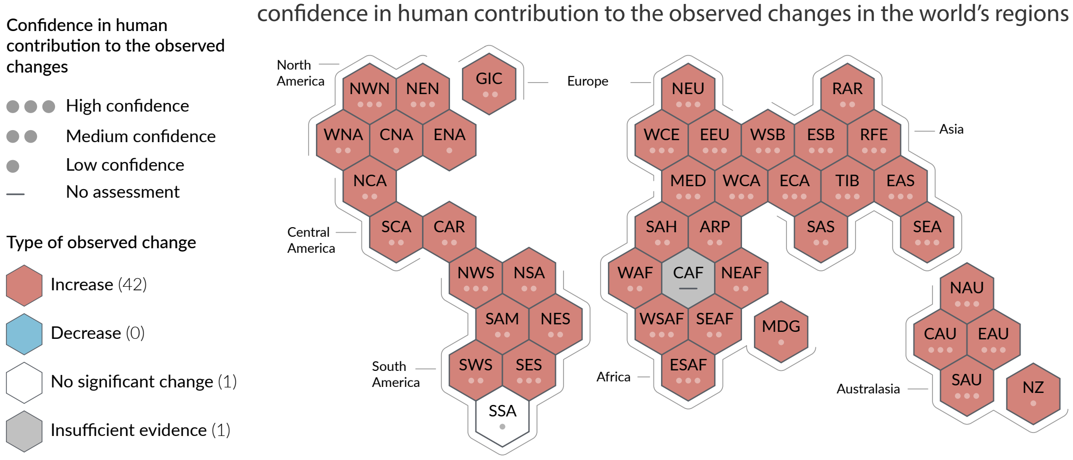


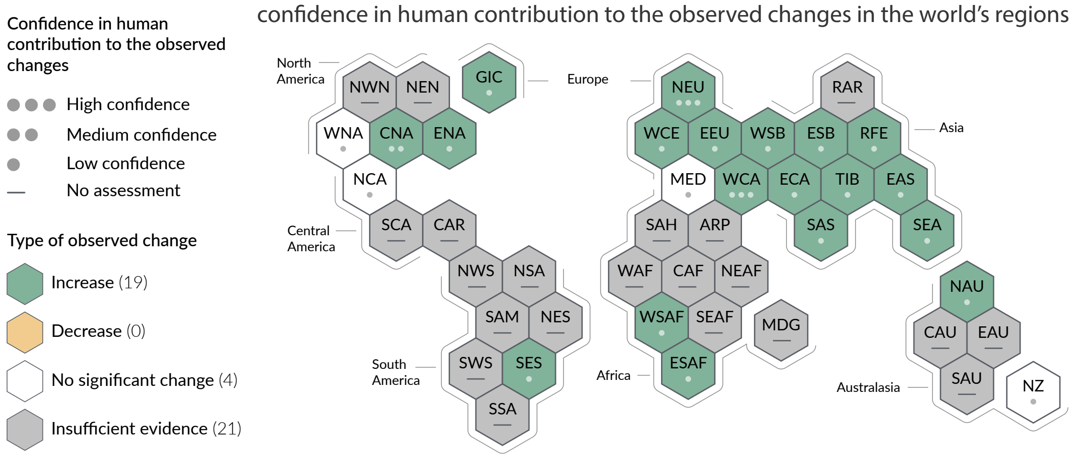
Figure SPM.2: Assessed contributions to observed warming. The grey bar shows observed increase of global surface temperature in 2010–2019 relative to 1850–1900 and its *very likely* range. **Panel a):** Temperature change in 2010–2019 relative to 1850–1900 attributed to net human influence, well-mixed greenhouse gases, other human drivers (aerosols, ozone, and land-use change), natural drivers (solar and volcanic), and internal climate variability and their *likely* ranges. **Panel b):** Warming and cooling from emissions and land-use change due to human activities, quantified over 1750 to 2019. Estimates account for both direct emissions into the atmosphere and their effect, if any, on other climate drivers. For example, emissions of methane increase its atmospheric concentration, enhance its own lifetime, cause ozone and CO2 production, enhance stratospheric water vapor, and influence aerosols. {3.3.1, 6.4.2, 7.3}

Climate change is already affecting every region across the globe with human influence contributing to many observed changes in weather and climate extremes

a) Synthesis of assessment of observed change in **hot extremes** and confidence in human contribution to the observed changes in the world's regions



b) Synthesis of assessment of observed change in **heavy precipitation** and confidence in human contribution to the observed changes in the world's regions



c) Synthesis of assessment of observed change in **agricultural drought** and confidence in human contribution to the observed changes in the world's regions

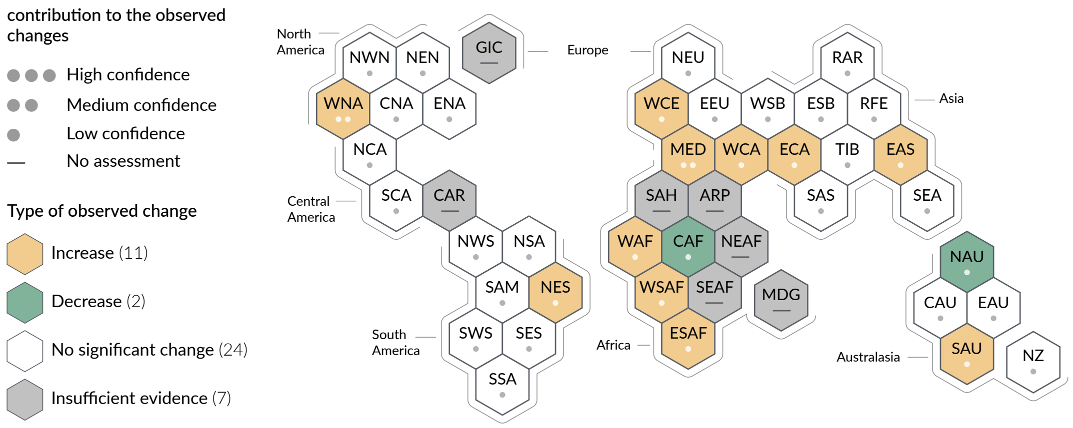
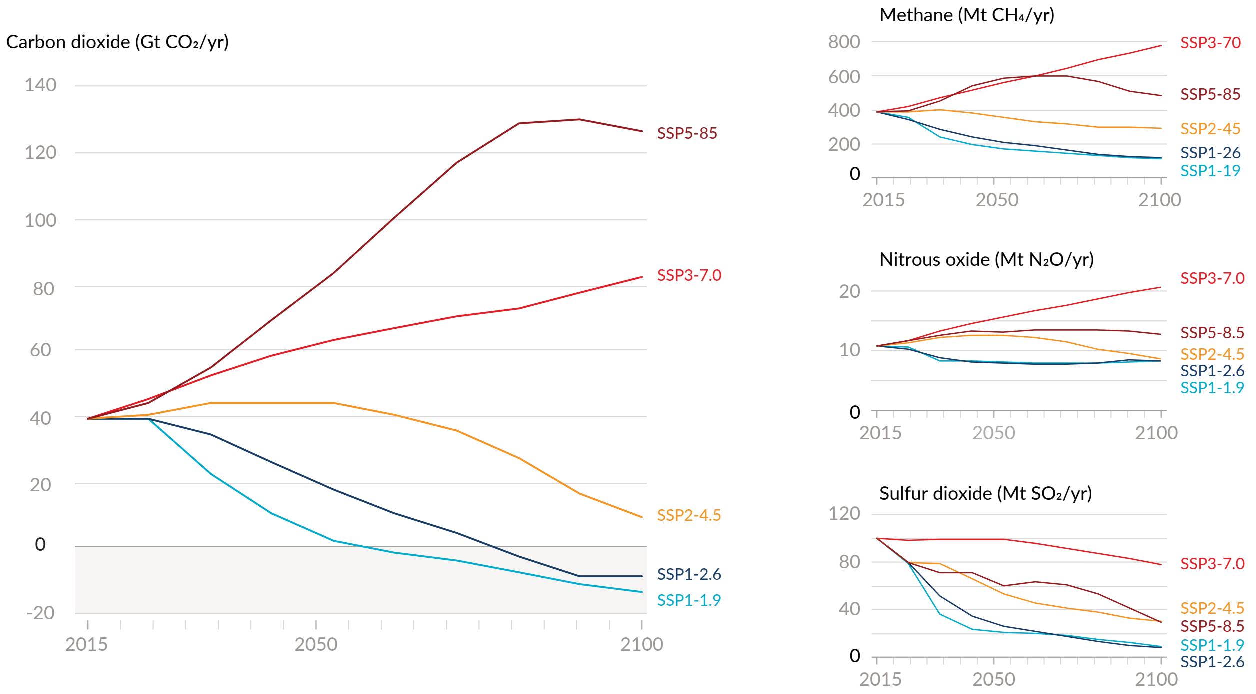


Figure SPM.3: Synthesis of assessed observed changes and human influence for **(panel a)** hot extremes, **(panel b)** heavy rainfall and **(panel c)** agricultural and ecological drought, for the IPCC AR6 regions displayed as hexagons with identical size. The colours in each panel represent the four outcomes of the assessment on the observed changes: red/green for an observed increase with at least *medium confidence*; blue/yellow for a decrease with at least *medium confidence*; white for no significant change for the region as a whole; and grey when the evidence in this region is insufficient due to lack of data and/or literature preventing the assessment of the region as a whole. All assessments are made for each AR6 region as a whole and for the timeframe from 1950 to present thus, more local or assessment made on shorter time scales might differ from what is shown in the figure. The confidence level for the human influence on these changes is based on trend detection and attribution and event attribution literature, and it is indicated by the number of dots: three dots for *high confidence*; two dots for *medium confidence*; and one dot for *low confidence*. Horizontal bars indicate when an assessment is not possible due to insufficient evidence for the specific region.
For hot extremes, the evidence is mostly drawn from changes in metrics based on daily maximum temperatures, regional studies using other metrics (heatwave duration, frequency and intensity) are used in addition. For heavy precipitation, the evidence is mostly drawn from changes in metrics based on one-day or five-day precipitation amounts using global and regional studies. Agricultural and ecological droughts are assessed based on observed and projected changes in total column soil moisture, complemented by evidence on changes in surface soil moisture, water-balance (precipitation minus evapotranspiration) and metrics driven by precipitation and atmospheric evaporative demand. {11.9, Table TS.5, Box TS.10, Figure 1}

Future emissions determine future warming, with CO_2 emissions dominating

a) The key determining factors of scenarios are their CO_2 and non-CO_2 emissions



b) Contribution to Global Surface Temperature increase from different emissions, with a dominant role of CO_2 emissions

Warming in 2100 relative to 1850-1900 (°C)

Total warming, warming from CO_2 emissions and from non-CO_2 emissions (other greenhouse gases and anthropogenic aerosols)

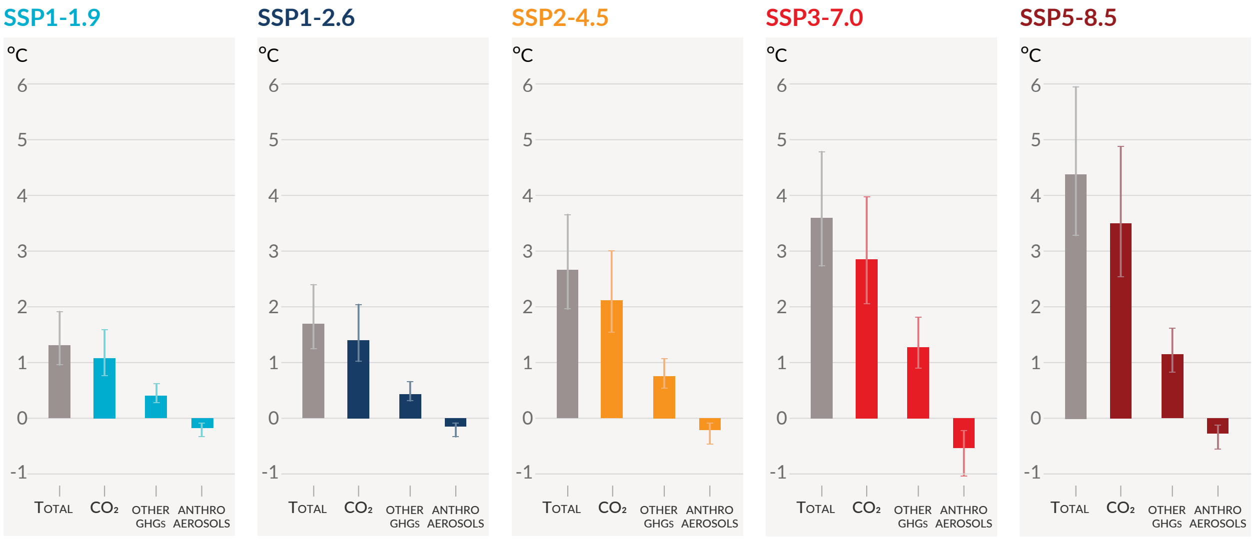


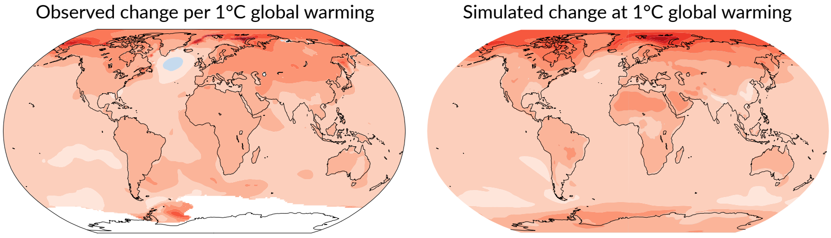
Figure SPM.4: Future emissions of main drivers of climate change and their respective contributions to global warming for the core set of five scenarios used in this report (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5). **Panel a):** Annual emissions over the 2015–2100 period. Shown are emissions trajectories for carbon dioxide (CO_2, $GtCO_2$/yr) (left graph) and for three of the non-CO_2 drivers considered in the scenarios: methane (CH_4, Mt CH_4/yr, top-right graph), nitrous oxide (N_2O, Mt N_2O/yr, middle-right graph) and sulfur dioxide (SO_2, Mt SO_2/yr, bottom-right graph). **Panel b):** Warming contribution from different emissions shown as change in global surface temperature (°C) in 2100 relative to 1850–1900 by driver and scenario. Bars and whiskers represent median values and the *very likely* range. Within each scenario bar plot, the grey bar represents total global warming (°C), followed by three bars on warming contributions (°C) from CO_2, from other greenhouse gases (GHGs) and from anthropogenic aerosols (see Figure SPM.2 for the warming contributions to date for CO_2 and for individual non-CO_2 drivers). {Cross-Chapter Box 1.4, 4.6, Figure 4.35, 6.7, Figure 6.18, 6.22 and 6.24, 7.3, Figure 7.7, Box TS.7, Figures TS.4 and TS.15}

With every increment of global warming, changes in regional mean temperature, precipitation and soil moisture get larger

a) Annual mean temperature change (°C)
at 1°C global warming relative to 1850-1900

Warming at 1°C affects all continents and is generally larger over land, where we live, than over the oceans.

The panels show linearly scaled observed temperature change per 1°C global warming and multi-model mean simulated temperature at a 1°C global warming level.

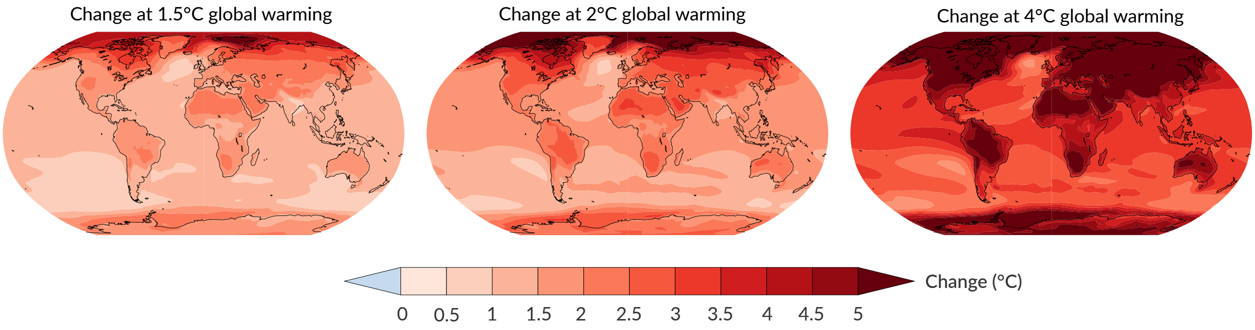


Observed change per 1°C global warming

Simulated change at 1°C global warming

b) Annual mean temperature change (°C)
relative to 1850-1900 at three global warming levels

Across warming levels land areas warm more than oceans, and the Arctic and Antarctica warm more than the tropics.



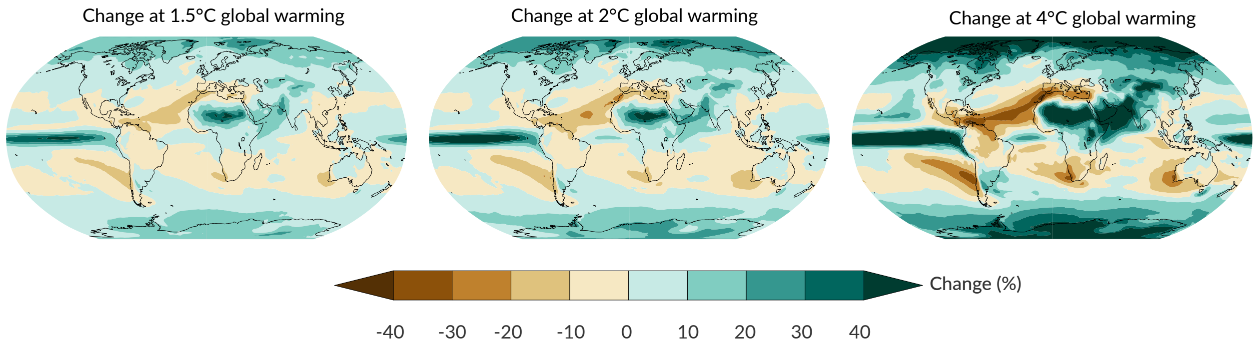
Change at 1.5°C global warming

Change at 2°C global warming

Change at 4°C global warming

c) Annual mean precipitation change (%)
relative to 1850-1900 at three global warming levels

Precipitation increases over high latitudes, tropical oceans and parts of the monsoon regions but decreases over parts of the subtropics.



d) Annual mean soil moisture change (sd)
(standard deviation of interannual variability) relative to 1850-1900 at three global warming levels

Across warming levels changes in soil moisture largely follow changes in precipitation but also show some differences due to the influence of evapotranspiration.

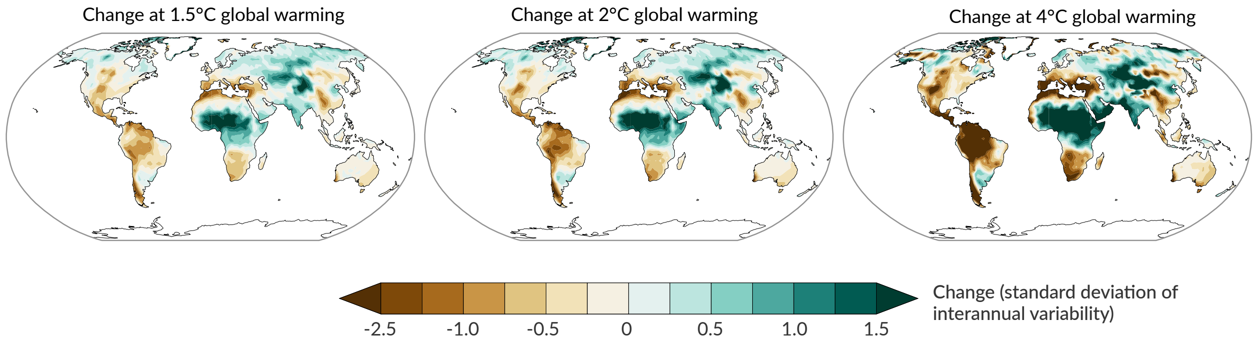


Figure SPM.5: Panel a): The left map shows annual mean surface temperature anomalies linearly regressed against global surface temperature (°C/°C) in the period 1850–2020. Observed temperature data from Berkeley Earth, the dataset with the largest coverage and highest horizontal resolution. Linear regression is applied to all years for which data at the corresponding grid point is available. White indicates areas where time coverage was 100 years or less and thereby too short to calculate a reliable linear regression. The right map shows simulated annual mean temperature at a global warming level of 1°C relative to 1850–1900.
Simulated annual mean **(Panel b)** temperature (°C), **(Panel c)** precipitation (%) and **(Panel d)** soil moisture (standard deviation of interannual variability 1850-1900) at global warming levels of 1.5°C, 2°C and 4°C relative to 1850–1900. Simulated changes correspond to CMIP6 multi-model mean change (median change for soil moisture) at the corresponding global warming level (20-yr mean global surface temperature change relative to 1850–1900). Results from all models reaching the corresponding warming level in any of the five core scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) are averaged. {TS.1.3.2, Figure TS.5, 4.6.1, Figure 4.31, Figure 4.32, Cross-Chapter Box 11.1, Figure 11.19}

Projected changes in extremes are larger in frequency and intensity with every additional increment of global warming

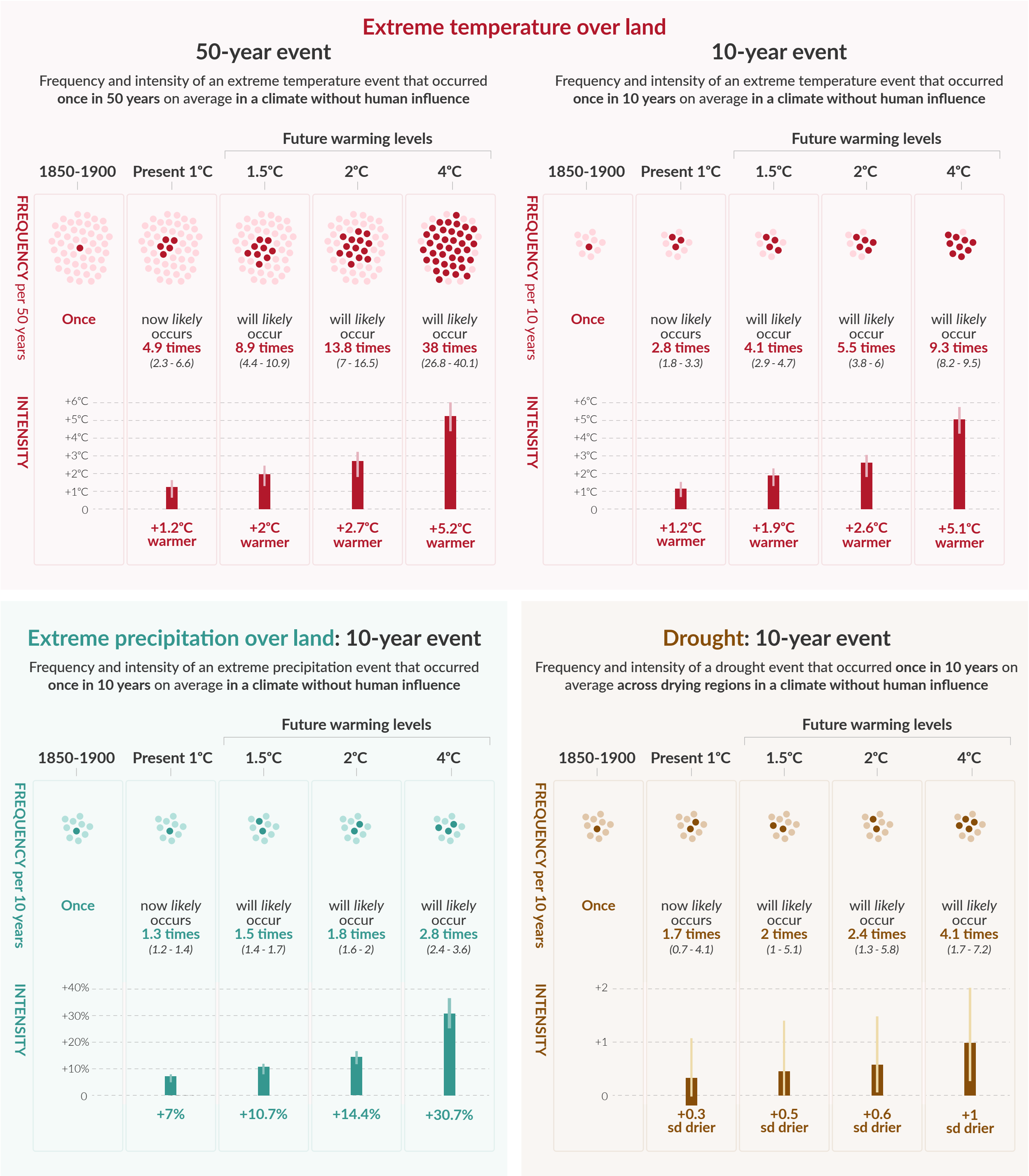
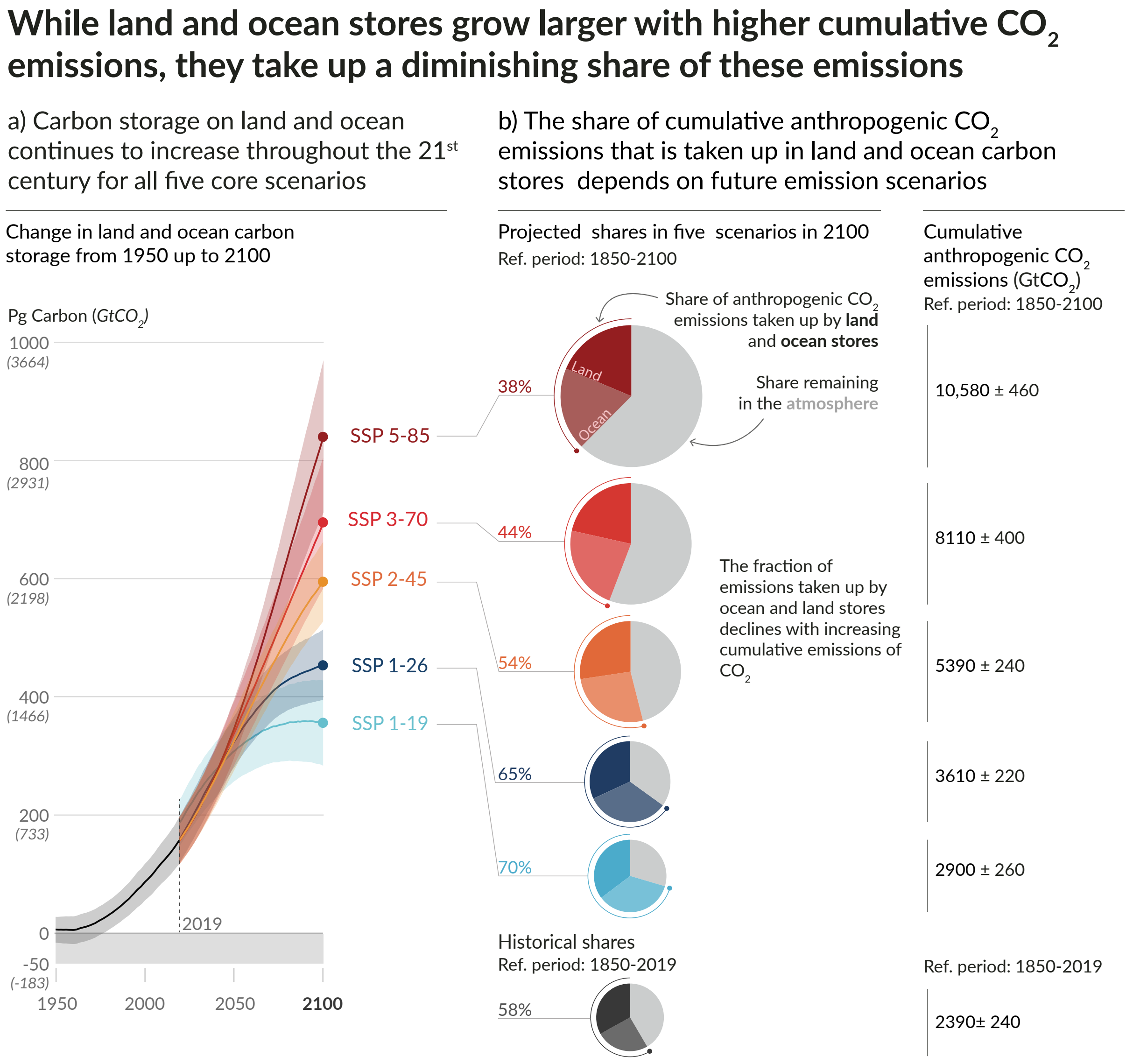


Figure SPM.6: Projected changes in the intensity and frequency of extreme temperature, extreme precipitation and droughts for global warming levels of 1°C, 1.5°C, 2°C, and 4°C, relative to their respective 1851–1900 reference period (1850–1900 for drought). Extreme temperature events are defined as the daily maximum temperatures that were exceeded on average once in a decade (10-year event) or once in 50 years (50-year event) during the 1851–1900 reference period. Extreme precipitation events are defined as the daily precipitation amount that was exceeded on average once in a decade during the 1851–1900 reference period. Drought events are defined as the annual average of total column soil moisture that was below its 10th percentile during the 1850–1900 base period. For extreme temperature and extreme precipitation, results are shown for the global land. For drought, results are shown for the AR6 regions in which there is at least *medium confidence* in a projected increase in agriculture/ecological drought at the 2°C warming level compared to the 1850–1900 base period. These regions include W. North-America, C. North-America, N. Central-America, S. Central-America, N. South-America, N.E. South-America, South-American-Monsoon, S.W.South-America, S.South-America, West & Central-Europe, Mediterranean, W. Southern-Africa, E. Southern-Africa, Madagascar, E. Australia, S. Australia. The dots and bars show the medians and their respective *very likely* range based on the multi-model ensemble from simulations of CMIP6 under different SSP scenarios. Dark dots indicate years in which the extreme threshold is exceeded. Light dots are years when threshold is not exceeded. Changes in the intensity of drought are expressed as fractions of standard deviation of annual soil moisture. {11.1, 11.3, 11.4, 11.6, Figure 11.12, Figure 11.15, Figure 11.6, Figure 11.7, Figure 11.18}



While land and ocean stores grow larger with higher cumulative CO_2 emissions, they take up a diminishing share of these emissions

a) Carbon storage on land and ocean continues to increase throughout the 21st century for all five core scenarios

b) The share of cumulative anthropogenic CO_2 emissions that is taken up in land and ocean carbon stores depends on future emission scenarios

Figure SPM.7: **Panel a):** Projected change in the combined land and ocean carbon storage under the five core scenarios: SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5. Values are plotted as the cumulative change since 1850 simulated by CMIP6 Earth system models from the concentration-driven simulations. Values are calculated from net biome productivity on land and net ocean CO_2 flux. Values are shown in PgC and $GtCO_2$ (in parentheses). Solid lines show multi-model averages; shadings show 1 standard deviation from the average. Black line and grey shading correspond to the historical period (1850–2019). SSP1-1.9 considers 5 models, while the other four scenarios have 9 models each. **Panel b):** The share of cumulative anthropogenic CO_2 emissions taken up by the land and ocean sinks under the five core scenarios from 1850 to 2100. Values are calculated by dividing the land, ocean and atmosphere budgets by the total anthropogenic CO_2 fossil fuel and land-use emissions. Fossil fuel emissions are calculated as the residual of the land and ocean sinks and prescribed concentration changes in the CMIP6 simulations, and land-use emissions are taken from the International Institute for Applied Systems Analysis scenario database. Land-use emissions are also added to the net biome productivity for the land uptake so that all changes in carbon stores are accounted for. Values in % are combined projected sink fractions from 1850 to 2100 and represent the projected values as of 2100. The cumulative anthropogenic CO_2 emission under each scenario is visualised as the area of the pie and indicated in $GtCO_2$. {Box TS.5, Box TS.5 Figure 1, 5.2.1,Table 5.1, 5.4.5, 5.5.1; Figure 5.25; Figure 5.31}

Human activities affect all the major climate system components, with some responding quickly and others on longer timescales

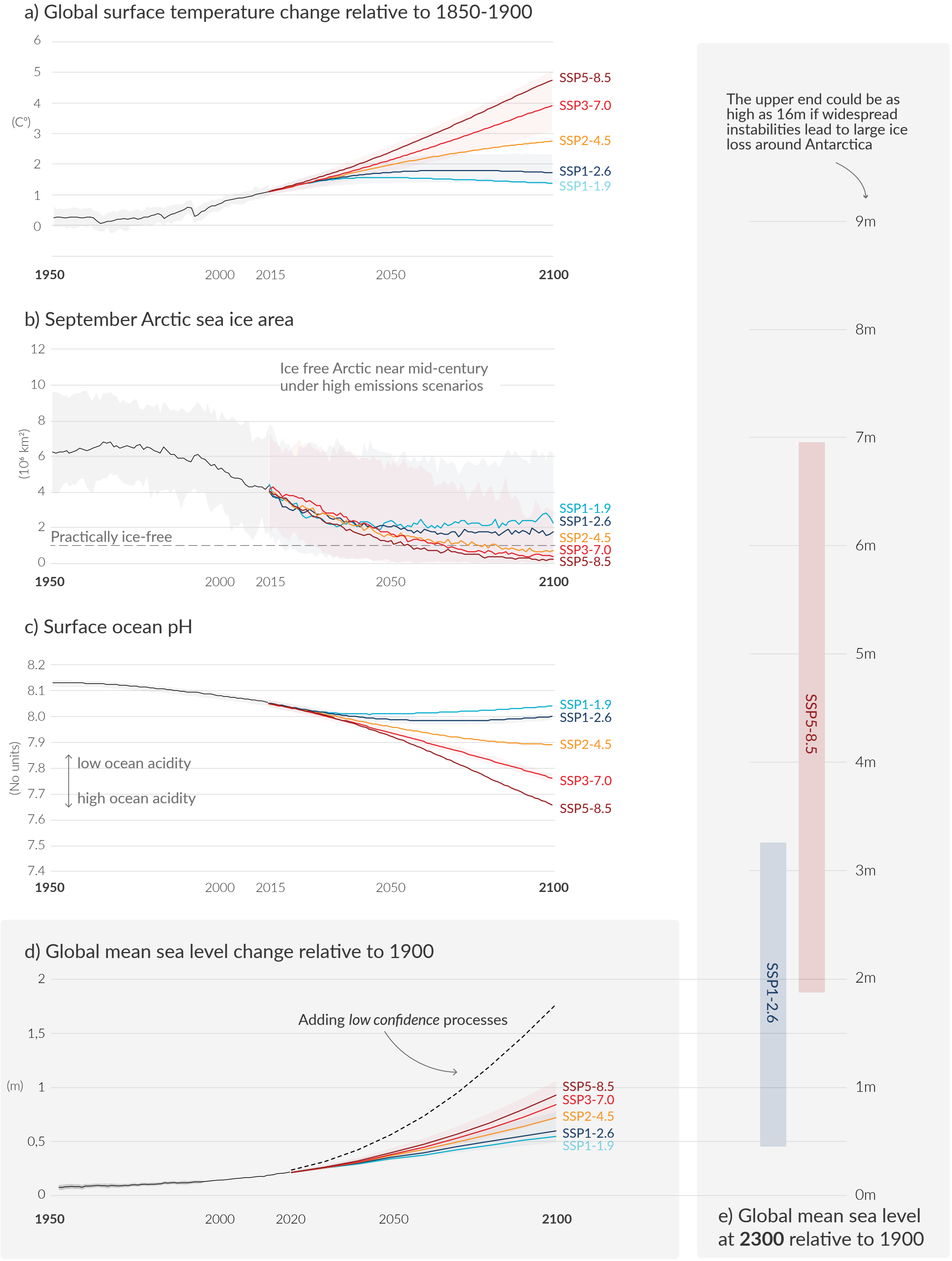
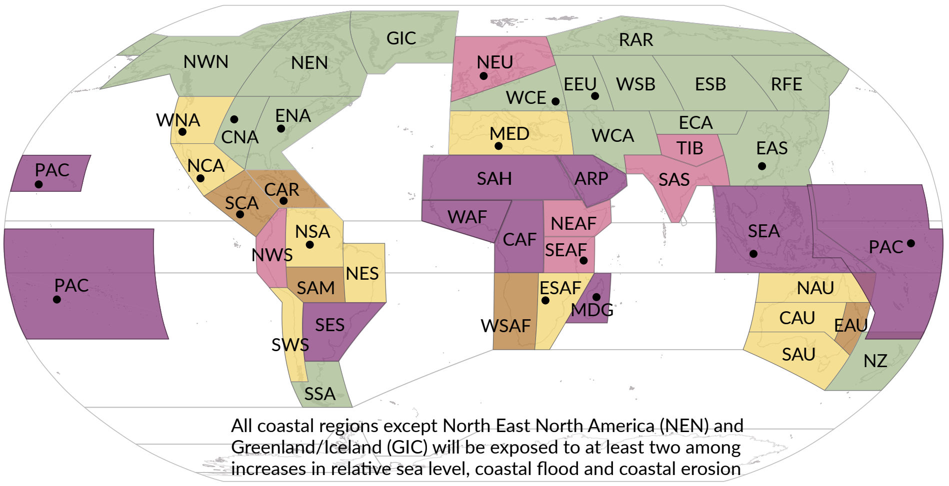


Figure SPM.8: Selected indicators of global climate change under five core scenarios. **Panel a):** Historical and future assessed global surface temperature changes relative to 1850-1900. The assessed changes were constructed by combining scenario-based projections with observational constraints based on past simulated warming, as well as an updated assessment of equilibrium climate sensitivity and transient climate response. Anomalies relative to 1850–1900 are calculated by adding 0.85°C (observed surface temperature increase from 1850-1900 to 1995-2014) to simulated anomalies relative to 1995–2014. **Panel b):** September Arctic sea ice area based on CMIP6 models. **Panel c):** Global surface pH, a measure of acidity, based on CMIP6 models. **Panel d):** Global mean sea level changes from 1950–2100 relative to 1900. The historical changes are observed (tide gauges before 1992 and altimeters afterwards) and the future changes are assessed consistently with observational constraints. The dashed line shows a likely upper limit if low confidence processes (primarily Marine Ice Cliff Instability) are included in the assessment. **Panel e):** Global mean sea level changes at 2300 relative to 1900 (only SSP1-2.6 and SSP5-8.5 are projected at 2300 due to limited modelling beyond 2100). Shadings in all panels show selected *very likely* ranges, except panels d and e which show assessed *likely* ranges. {Figure TS.8, Figure TS.11, Box TS.4 Figure 1, Box TS.4 Figure 1, 4.3, 9.6, Figure 4.2, Figure 4.8, Figure 4.11, Figure 9.27}

While changes in climatic impact-drivers are projected everywhere, there is a specific combination of changes each region would experience

a) World regions grouped into five clusters, each one based on a combination of changes in climatic impact-drivers

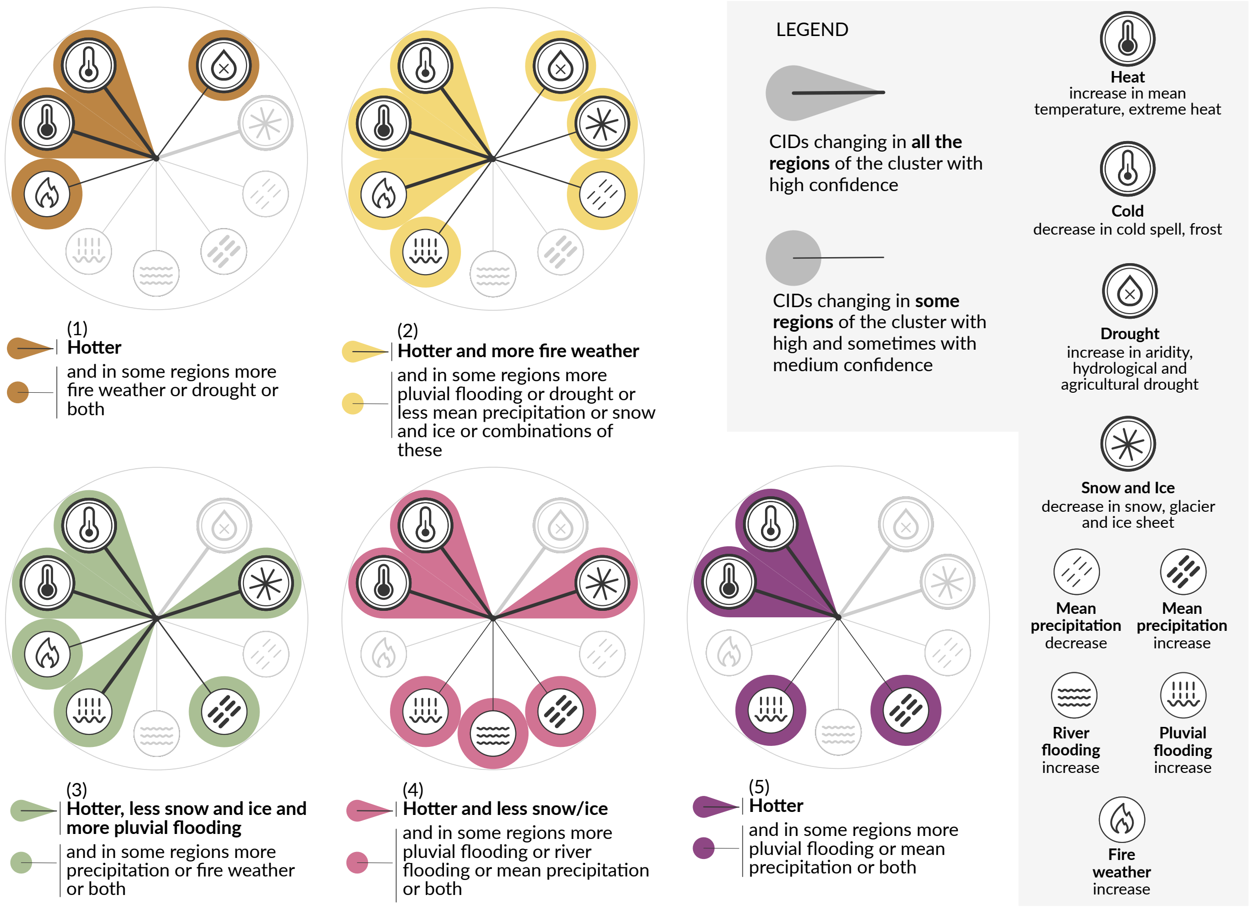
Reference period: Mid 21st century or 2°C GWL compared to a climatological reference period included within 1960-2014



All coastal regions except North East North America (NEN) and Greenland/Iceland (GIC) will be exposed to at least two among increases in relative sea level, coastal flood and coastal erosion

- 🟫 1) Hotter and drier
- 🟨 2) Hotter and drier and in some regions wetter extremes
- 🟩 3) Hotter and wetter extremes and in some regions more precipitation or fire weather
- 🟥 4) Hotter and wetter and in some regions more flooding
- 🟪 5) Hotter and in some regions wetter extremes or more precipitation
- ● 6) Increase in Tropical cyclones intensity or Severe winds

Combinations of future changes in Climatic Impact-Drivers (CIDs)



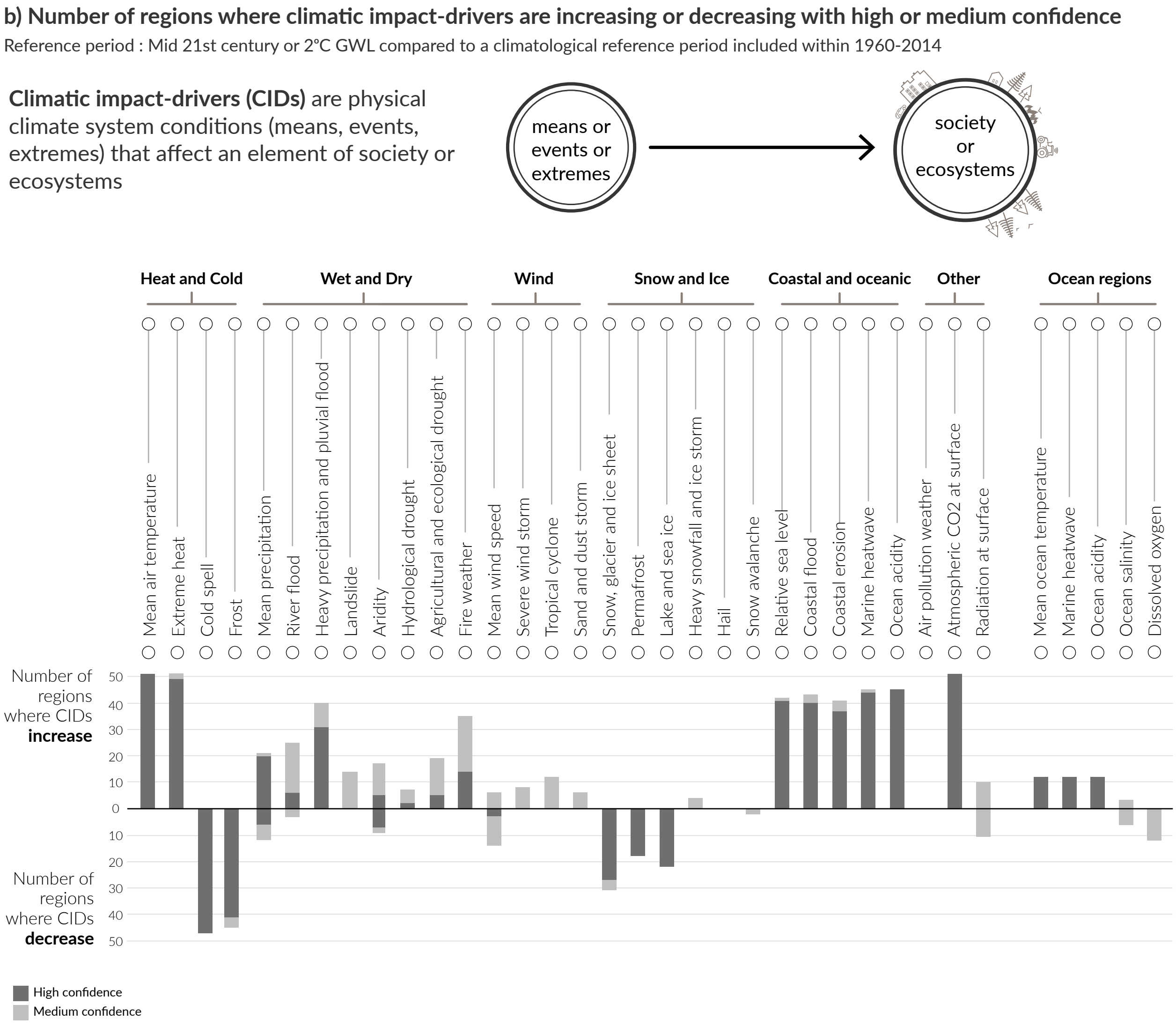
(1)
Hotter
and in some regions more fire weather or drought or both

(2)
Hotter and more fire weather
and in some regions more pluvial flooding or drought or less mean precipitation or snow and ice or combinations of these

(3)
Hotter, less snow and ice and more pluvial flooding
and in some regions more precipitation or fire weather or both

(4)
Hotter and less snow/ice
and in some regions more pluvial flooding or river flooding or mean precipitation or both

(5)
Hotter
and in some regions more pluvial flooding or mean precipitation or both



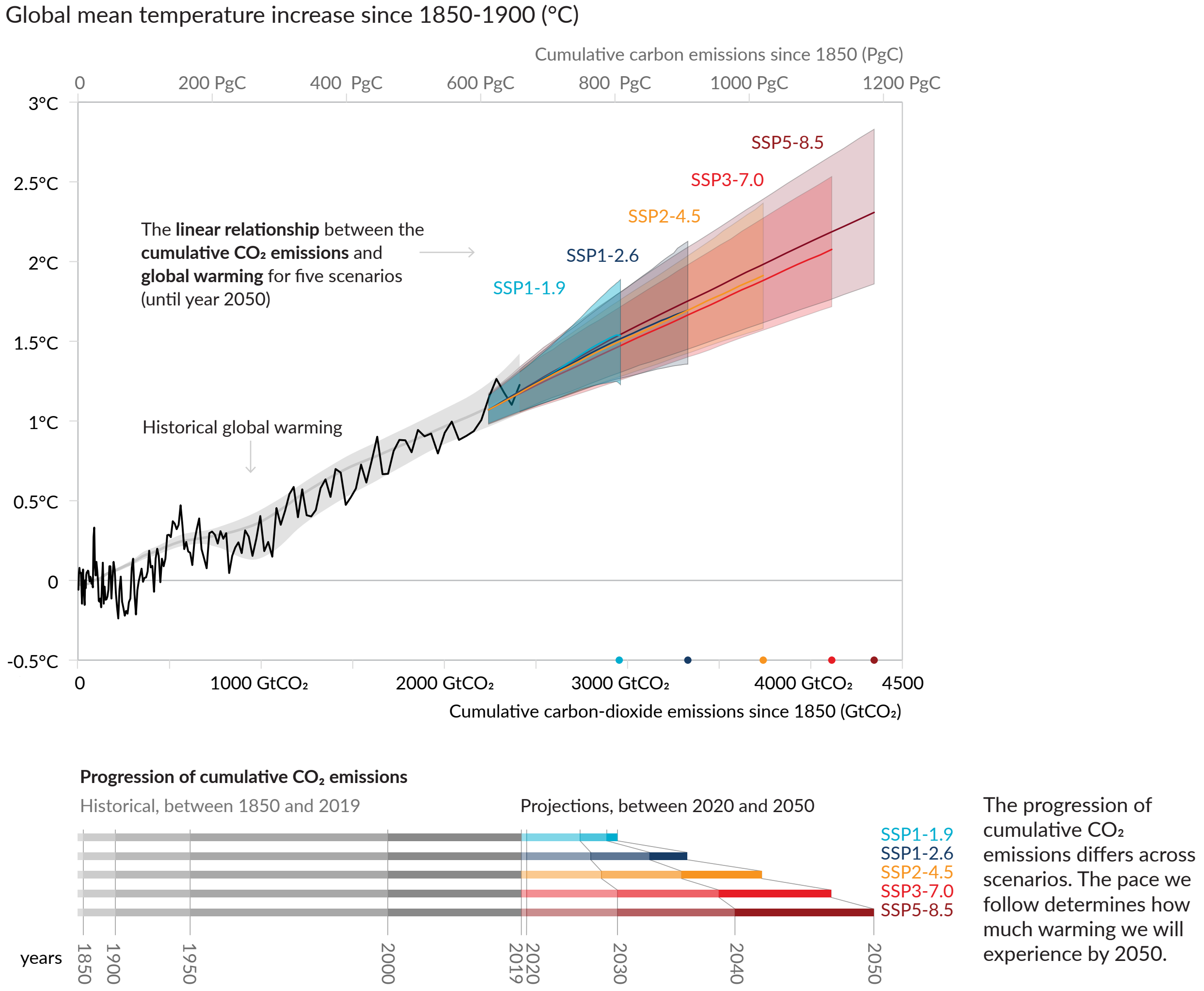
b) Number of regions where climatic impact-drivers are increasing or decreasing with high or medium confidence

Reference period : Mid 21st century or 2°C GWL compared to a climatological reference period included within 1960-2014

Climatic impact-drivers (CIDs) are physical climate system conditions (means, events, extremes) that affect an element of society or ecosystems

Figure SPM.9: Panel a): geographical location of regions belonging to one of five groups characterised by a specific combination of changing climatic impact-drivers (CIDs). The five groups are represented by five different colours, and the CID combinations associated with each group are represented in the corresponding 'fingerprint' and text below the map. Each fingerprint comprises a set of CIDs projected to change with *high confidence* in every region in the group, and a second set of CIDs, one or more of which are projected to change in each region with *high* or *medium confidence.* The CID combinations follow a progression from those becoming hotter and drier (group 1) to those becoming hotter and wetter (group 5). In between (groups 2–4), the CIDs that change include some becoming drier and some wetter and always include a set of CIDs which are getting hotter. Tropical cyclones and severe wind CID changes are represented on the map with black dots in the regions affected. Regions affected by coastal CID changes are described by text on the map. The five groups are chosen to provide a reasonable level of region-specific detail whilst not overwhelming the map with all aspects of the assessment, which is available in Table TS.5. The CID changes summarized in the figure represent *high* and *medium confidence* changes projected for around 2050 if 2ºC of global warming is reached. **Panel b):** numbers of regions where each CID is increasing or decreasing with *medium* or *high confidence* for all land regions reported in the map of panel a) as well as for the ocean regions. The regions coloured in the map are WGI AR6 reference regions with an additional non-continuous Pacific Islands region labelled PAC. Definitions of the acronyms of the other regions are provided in Atlas.1 and the Interactive Atlas. {Table TS.5, Figure TS.24}

Every tonne of CO_2 we put in the atmosphere adds to global warming



The **linear relationship** between the **cumulative CO_2 emissions** and **global warming** for five scenarios (until year 2050)

Historical global warming

Progression of cumulative CO_2 emissions

The progression of cumulative CO_2 emissions differs across scenarios. The pace we follow determines how much warming we will experience by 2050.

Figure SPM.10: Relationship between cumulative CO_2 emissions and the increase in global surface temperature. Historical data (thin black line) shows historical CO_2 emissions versus observed global surface temperature increase from 1850–1900. The grey range with its central line shows a corresponding estimate of the human-induced share of historical warming (see Figure SPM.1b). Coloured areas show the assessed *very likely* range of global surface temperature projections, and thick coloured central lines show the median estimate as a function of cumulative CO_2 emissions for the core set of scenarios SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 (see Figure SPM.4). Cumulative CO_2 emissions for projections are from the original emissions scenarios, and the global warming shown includes the contribution from non-CO_2 gases as described in each respective scenario. Cumulative carbon emissions are also shown as a link to Figure SPM.7. The bottom panel shows bars of cumulative CO_2 emissions over the historical period and for the respective scenario projections. {Figure TS.18, Figure 5.31}