Climate Change 2014: Impacts, Adaptation, and Vulnerability

SUMMARY FOR POLICYMAKERS

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INTRODUCTION

Human interference with the climate system is occurring,[1] and climate change poses risks for human and natural systems (Figure SPM.1). The assessment of impacts, adaptation, and vulnerability in the Working Group II contribution to the IPCC's Fifth Assessment Report (WGII AR5) evaluates how patterns of risks and potential benefits are shifting due to climate change and how risks can be reduced through mitigation and adaptation.

Compared to past WGII reports, the WGII AR5 assesses a substantially larger knowledge base of relevant scientific, technical, and socioeconomic literature. Increased literature from all regions has facilitated comprehensive assessment across a broader set of topics and sectors, with expanded treatment of human systems, adaptation, and the ocean. [1.1, Figure 1-1]

Section A of this summary characterizes observed impacts, vulnerability and exposure, and responses to date. Section B examines the range of future risks and potential benefits. Section C considers principles for effective adaptation and the broader interactions among adaptation, mitigation, and sustainable development. Box SPM.1 defines central concepts, and Box SPM.2 introduces terms used to convey the degree of certainty in key findings. Chapter references in square brackets and in footnotes indicate support for findings, paragraphs of findings, figures, and tables in this summary.

Figure SPM.1: Climate-related hazards, exposure, and vulnerability interact to produce risk. Changes in both the climate system (left) and development processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability. [19.2, Figure 19-1]

Boxes SPM.1 and SPM.2 are included at the end of the SPM text.

A) IMPACTS, VULNERABILITY, AND ADAPTATION IN A COMPLEX AND CHANGING WORLD

A-1. Observed Impacts, Vulnerability, and Exposure

Observed impacts of climate change are widespread and consequential. Recent changes in climate have caused impacts on natural and human systems on all continents and across the oceans.[2] Evidence of climate change impacts is strongest and most comprehensive for natural systems, although some impacts in human systems have also been attributed to climate change. See Figure SPM.2 for a summary of observed impacts and indicators of a changing climate, illustrating broader trends presented in this section.[3]

Figure SPM.2: Widespread indicators of a changing climate. (A) Global patterns of observed climate change impacts, at regional, subregional, and more local scales. For categories of attributed impacts, symbols indicate affected systems and sectors, the relative contribution of climate change (major or minor) to the observed change, and confidence in attribution. (B) Glacier mass budgets from all published measurements for Himalayan glaciers, also showing global average glacier mass budget estimates from WGI AR5 4.3 with shading indicating ±1 standard deviation. The blue box for each Himalaya measurement has a height of ±1 standard deviation centered on its average (and ±1 standard error for multi-annual measurements). Himalaya-wide measurement (red) was made by satellite laser altimetry. (C) Locations of substantial drought- and heat-induced tree mortality around the globe over 1970-2011. (D) Average rates of change in distribution (km per decade) for marine taxonomic groups based on observations over 1900-2010. Positive distribution changes are consistent with warming (moving into previously cooler waters, generally poleward). The number of responses analyzed is given for each category. (E) Summary of estimated impacts of observed climate changes on yields over 1960-2013 for four major crops in temperate and tropical regions, with the number of data points analyzed given for each category. [Figures 3-3, 4-7, 7-2, 18-3, and MB-2]

[1] WGI AR5 2.2, 6.3, 10.3-6, 10.9
[2] Attribution of observed impacts in the WGII AR5 links responses of natural and human systems to climate change, not to anthropogenic climate change, unless explicitly indicated.
[3] 18.1, 18.3-6

In response to ongoing climate change, terrestrial and marine species have shifted their ranges, seasonal activities, migration patterns, and abundance, and have demonstrated altered species interactions (*high confidence*). Increased tree mortality, observed in many places worldwide, has been attributed to climate change in some regions. While recent warming contributed to the extinction of many species of Central American amphibians (*medium confidence*), most recent observed terrestrial-species extinctions have not been attributed to recent climate change, despite some speculative efforts (*high confidence*). Natural climate change at rates much slower than current anthropogenic change has led to significant ecosystem shifts, including species emergences and extinctions, in the past millions of years.[4]

In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources and quality (*medium confidence*). Glaciers continue to shrink in many regions due to climate change (*high confidence*). Climate change has caused permafrost warming and thawing in high-latitude and high-elevation mountain regions.[5]

Negative impacts of climate change on crop and terrestrial food production have been more common than positive impacts, which are evident in some high-latitude regions (*high confidence*). Recent periods of rapid food and cereal price increases have indicated that current markets in key producing regions are sensitive to climate extremes.[6]

In recent decades, climate change has *likely* contributed to human ill-health although the present world-wide burden of ill-health from climate change is relatively small compared with effects of other stressors and is not well quantified. There has been increased heat-related mortality and decreased cold-related mortality in some regions as a result of warming (*medium confidence*).[7]

Vulnerability and exposure

Differences in vulnerability and exposure arise from non-climatic stressors and multidimensional inequalities, which shape differential risks from climate change (*very high confidence*). See Box SPM.3.[8]

Impacts from recent extreme climatic events, such as heat waves, droughts, floods, and wildfires, demonstrate significant vulnerability and exposure of some ecosystems and many human systems to climate variability (*very high confidence*). These experiences are consistent with a significant adaptation deficit in developing and developed countries for some sectors and regions.[9]

Climate-related hazards constitute an additional burden to people living in poverty, acting as a threat multiplier often with negative outcomes for livelihoods (*high confidence*). Climate-related hazards affect poor people's lives directly through impacts on livelihoods, such as reductions in crop yields or destruction of homes, and indirectly through increased food prices and food insecurity. Limited positive observed impacts on poor people include isolated cases of social asset accumulation, agricultural diversification, disaster preparedness, and collective action.[10]

Violent conflict strongly influences vulnerability to climate change impacts for people living in affected places (*medium evidence, high agreement*). Large-scale violent conflict harms assets that facilitate adaptation, including infrastructure, institutions, natural capital, social capital, and livelihood opportunities.[11]

Box SPM.3. Multidimensional Inequality and Vulnerability to Climate Change

[4] 4.2-4, 5.3-5, 6.1, 6.3-5, 18.3, 18.5, 22.3, 24.4, 25.6, 28.2, 30.4-5, Boxes 4-2, 4-3, 25-3, CC-CR, and CC-MB
[5] 3.2, 4.3, 18.3, 18.5, 24.4, 26.2, 28.2, Tables 3-1 and 25-1, Figures 18-2 and 26-1
[6] 7.3, 18.4, 22.3, 24.4, 26.5, Figures 7-2, 7-3, and 7-7
[7] 11.4-6, 18.4, 22.3, 24.4, 25.8, 26.6, 28.2
[8] 8.2, 9.3, 12.2, 13.1-2, 14.1-3, 19.6, 26.8, Box CC-GC
[9] 3.2, 4.2-3, 8.1, 9.3, 10.7, 11.3, 11.7, 13.2, 14.1, 18.6, 22.3, 25.6-8, 26.6-7, 28.4, 30.5, 30.7, Tables 18-3 and 23-1, Figure 26-2, Boxes 4-3, 4-4, 25-5, 25-6, 25-8, and CC-CR
[10] 8.2-3, 9.3, 11.3, 13.1-3, 22.3, 24.4, 26.8
[11] 12.5, 19.4, 19.6

People who are socially, economically, culturally, politically, institutionally, or otherwise marginalized are often highly vulnerable to climate change and climate change responses (*medium evidence, high agreement*). This heightened vulnerability is rarely due to a single cause. Rather, it is the product of intersecting social processes that result in inequalities in socioeconomic status, income, and exposure, including, for example, discrimination on the basis of gender, class, ethnicity, age, and (dis)ability. The full spectrum of these processes and their context-specific interactions shape multidimensional vulnerability and differential capacities and opportunities of individuals, households, and communities.[12]

A-2. Adaptation Experience

Adaptive human responses can be motivated by observed and projected climate change impacts and by broader vulnerability-reduction and development objectives.

Adaptation is already occurring and is becoming embedded in some planning processes (*high confidence*). Engineered and technological adaptation options are the most commonly implemented adaptive responses. There is increasing recognition of the value of ecosystem-based, institutional, and social measures, including provision of social protection measures, and of linkages with disaster risk reduction. Selection of adaptation options continues to emphasize incremental adjustments and co-benefits and is starting to emphasize flexibility and learning (*medium evidence, medium agreement*). Most evaluations of adaptation have been restricted to impacts, vulnerability, and adaptation planning, with very few assessing the processes of implementation or actual adaptation actions (*medium evidence, high agreement*).[13]

Governments at various scales are starting to develop adaptation plans and policies, and adaptation experience is accumulating across regions (*high confidence*).

- In Africa, most national governments are initiating governance systems for adaptation, and in predominantly isolated efforts, disaster risk management, adjustments in technologies and infrastructure, ecosystem-based approaches, conservation agriculture, and livelihood diversification are reducing vulnerability.[14]
- In Europe, adaptation policy has been developed across scales, with some adaptation planning integrated into coastal and water management and into disaster risk management.[15]
- In Asia, adaptation practices have sometimes provided livelihood benefits, and adaptation has been facilitated through integrated water resource management.[16]
- In Australasia, planning for sea-level rise and, in southern Australia, for reduced water availability is becoming widely adopted, although implementation faces major constraints, especially for transformational responses at local and community levels.[17]
- In North America, governments are engaging in incremental adaptation assessment and planning, particularly at the municipal level, with some proactive adaptation anticipating future impacts for longer-term investments in energy and public infrastructure.[18]
- In Central and South America, ecosystem-based adaptation including protected areas, conservation agreements, and community management of natural areas is increasingly common, with benefits for improvements in livelihoods and preservation of traditional cultures.[19]
- In the Arctic, residents have a history of adapting to change, but the rate of climate change and complex inter-linkages with societal, economic, and political factors represent unprecedented challenges for northern communities.[20]
- In small islands, diverse physical and human attributes and their sensitivity to climate-related drivers have been inconsistently integrated into adaptation planning.[21]

[12] 8.1-2, 8.5, 9.3-4, 10.9, 11.1, 11.3-5, 12.2-5, 13.2-3, 14.6, 18.4, 19.6, 23.5, 25.8, 26.6, 26.8, 28.4, Box CC-GC
[13] 4.4, 5.5, 6.4, 8.3, 9.4, 11.7, 14.1, 14.3-4, 15.2-4, 17.2-3, 21.3, 21.5, 22.3-5, 23.7, 25.4, 26.8-9, 30.6, Boxes 25-1, 25-2, 25-9, and CC-EA
[14] 11.7, 22.4, Box CC-EA
[15] 11.7, 23.7, Box 23-3
[16] 11.7, 24.4
[17] 25.4, 25.10, Table 25-2, Boxes 25-1, 25-2, and 25-9
[18] 26.7-9
[19] 27.3
[20] 28.2, 28.4
[21] Table 29-3, Figure 29-1

A-3. The Decision-making Context

Responding to climate-related risks involves making decisions and taking actions in the face of continuing uncertainty about the extent of climate change and the severity of impacts in a changing world, with potential limits to the effectiveness of incremental approaches (*high confidence*). Iterative risk management is a useful framework for decision-making in situations characterized by large potential consequences, persistent uncertainties, long timeframes, potential for learning, and multiple influences changing over time, such as climate and non-climatic stressors. See Figure SPM.3. Assessment of the full range of potential future impacts, including low-probability outcomes with large consequences, is central to understanding future risks and the benefits and tradeoffs of alternative risk management actions. The increasing complexity of adaptation actions across scales and contexts means that institutional learning and monitoring are important components of effective adaptation.[22]

Figure SPM.3: Illustration of iterative risk management. [Figure 2-1]

The benefits of mitigation and adaptation occur over different timeframes (*high confidence*). Figure SPM.4 illustrates projected climate futures under scenarios RCP2.6 and 8.5, along with observed temperature changes. Projected global temperature increase over the next few decades is similar across emission scenarios (Figure SPM.4B).[23] During this near-term era of committed climate change, risks will evolve as socioeconomic trends interact with the changing climate. Societal responses, particularly adaptations, will influence near-term outcomes. In the second half of the 21st century and beyond, global temperature increase diverges across emission scenarios (Figure SPM.4B and 4C).[24] For this longer-term era of climate options, near-term and longer-term mitigation and adaptation, as well as development pathways, will determine the risks of climate change. Near-term choices thus affect the risks of climate change throughout the 21st century.[25]

Figure SPM.4: Observed and projected changes in annual average temperature. (A) Observed temperature trends from 1901-2012 determined by linear regression. Trends have been calculated where sufficient data permit a robust estimate (i.e., only for grid boxes with greater than 70% complete records and more than 20% data availability in the first and last 10% of the time period). Other areas are white. Solid colors indicate areas where change is significant at the 10% level. Diagonal lines indicate areas where change is not significant. Observed data (range of grid-point values: -0.53 to 2.50°C over period) are from WGI AR5 Figures SPM.1 and 2.21. (B) Observed and simulated variations in past and projected future global annual average temperature relative to 1986-2005. Black lines show the GISTEMP, NCDC-MLOST, and HadCRUT4.2 estimates from observational measurements. Blue and red shading denotes the ±1.64 standard deviation range based on simulations from 32 models for RCP2.6 and 39 models for RCP8.5; blue and red lines denote the ensemble mean for each scenario. For future projections, light-gray vertical bands specify an indicative timeframe (2030-2040) for the near-term era of committed climate change and an indicative timeframe (2080-2100) for the longer-term era of climate options. [Box CC-RC; WGI AR5 Figures SPM.1 and SPM.7] (C) CMIP5 multi-model mean projections of annual average temperature changes for 2081-2100 under RCP2.6 and 8.5, relative to 1986-2005. Solid colors indicate areas with very strong agreement, where the multi-model mean change is greater than twice the baseline variability and >90% of models agree on sign of change. Colors with white dots indicate areas with strong agreement, where >66% of models show change greater than the baseline variability and >66% of models agree on sign of change. Gray indicates areas with divergent changes, where >66% of models show change greater than the baseline variability, but <66% agree on sign of change. Colors with diagonal lines indicate areas with little or no change, where >66% of models show change less than the baseline variability, although there may be significant change at shorter timescales such as seasons, months, or days. Analysis uses model data (range of grid-point values across RCP2.6 and 8.5: 0.06 to 11.71°C) from WGI AR5 Figure SPM.8, with full description of methods in Box CC-RC. See also Annex I of WGI AR5. [Boxes 21-2 and CC-RC]

Adaptation planning and implementation at a range of scales are contingent on values, objectives, and risk perceptions (*high confidence*). Some types of adaptation options, such as insurance or large-scale infrastructure

[22] 2.1-4, 3.6, 14.1-3, 15.2-3, 15.5, 16.2-4, 17.2, 20.6, 22.4, 25.4, 25.10, Figure 1-5, Boxes 16-1 and 25-2
[23] WGI AR5 11.3
[24] WGI AR5 12.4 and Table SPM.2
[25] 2.5, 21.2-3, 21.5, Box CC-RC

projects, may differentially affect stakeholders. Recognition of diverse interests, values, and expectations, including local and indigenous knowledge, can benefit decision-making processes.[26]

Decision support is most effective when it is sensitive to context, taking into account the diversity of different types of decisions, decision processes, and constituencies (*robust evidence, high agreement*). Organizations bridging science and policy play an important role in the communication and transfer of climate-related knowledge, such as information on risks combining physical climate science and assessments of impacts, adaptation, and vulnerability (*medium evidence, high agreement*).[27]

Scenarios are useful tools for characterizing possible future socioeconomic pathways, climate change and its risks, and policy implications (*high confidence*). Climate change risks vary substantially across plausible alternative development pathways, and the relative importance of development and climate change varies by sector, region, and time period. Both development and climate change are important determinants of possible outcomes. Modeled future impacts assessed in this report are generally based on climate-model projections using the Representative Concentration Pathway (RCP) and the older IPCC Special Report on Emission Scenarios (SRES) scenarios.[28]

Uncertainties about future vulnerability, exposure, and responses of human and natural systems can be larger than uncertainties in regional climate projections, and they are beginning to be incorporated in assessments of future risks (*high confidence*). Understanding future vulnerability, as well as exposure, of interlinked human and natural systems is challenging due to the number of relevant socioeconomic factors, which have been incompletely considered to date. These factors include wealth and its distribution across society, patterns of aging, access to technology and information, labor force participation, the quality of adaptive responses, societal values, and mechanisms and institutions to resolve conflicts. Cross-regional phenomena are also important for understanding the ramifications of climate change at regional scales.[29]

B) FUTURE RISKS AND OPPORTUNITIES FOR ADAPTATION

This section presents future risks and more limited potential benefits across sectors and regions, examining how they are affected by the magnitude and rate of climate change and by development choices. It also points to opportunities for reducing risks through mitigation and adaptation. The section describes risks and potential benefits over the next few decades, the near-term era of committed climate change, and in the second half of the 21st century and beyond, the longer-term era of climate options.

B-1. Key Risks across Sectors and Regions

Many risks of climate change warrant consideration. Key risks, in particular, are potentially severe impacts relevant to "dangerous anthropogenic interference with the climate system," as described in Article 2 of the United Nations Framework Convention on Climate Change. Key risks can involve potentially large or irreversible consequences, high probability of consequences, and/or limited adaptive capacity. Key risks are integrated into five overarching reasons for concern (RFCs) in Box SPM.4.

Key risks that span sectors and regions (*high confidence*) include the following, each of which contributes to one or more RFC.[30]

i. Risk of death, injury, and disrupted livelihoods in low-lying coastal zones and small island developing states, due to sea-level rise, coastal flooding, and storm surges.[31] [RFC 1-5]
ii. Risk of food insecurity linked to warming, drought, and precipitation variability, particularly for poorer populations.[32] [RFC 2-4]

[26] 2.2-4, 12.3, 15.2, 16.2-4, 16.5-7, 17.2-3, 21.3, 22.4, 25.4, 25.8, 26.7, 26.9, 28.2, 28.4, Table 15-1, Boxes 16-1, 16-4, and 25-7
[27] 2.1-4, 8.4, 14.4, 16.2-3, 16.5, 21.2-3, 21.5, 22.4, Box 9-4
[28] 1.1, 1.3, 2.2-3, 19.6, 20.2, 21.3, 21.5, 26.2, Box CC-RC; WGI AR5 Box SPM.1
[29] 11.3, 21.3-5, 25.3-4, 25.11, 26.2
[30] 19.2-4, 19.6, Table 19-4, Boxes 19-2 and CC-KR
[31] 5.4, 8.1-2, 13.1-2, 19.2-4, 19.6-7, 24.4-5, 26.7-8, 29.3, 30.3, Tables 19-4 and 26-1, Figures 7-4 and 26-2, Boxes 25-1, 25-7, and CC-KR
[32] 3.5, 7.4-5, 11.3, 11.6, 13.2, 19.3-4, 19.6, 22.3, 24.4, 25.5, 25.7, 26.5, 26.8, 27.3, Table 19-4, Boxes CC-KR and CC-VW

iii. Risk of severe harm for large urban populations due to inland flooding.[33] [RFC 2 and 3]
iv. Risk of loss of rural livelihoods and income due to insufficient access to drinking and irrigation water and reduced agricultural productivity, particularly for farmers and pastoralists with minimal capital in semi-arid regions.[34] [RFC 2 and 3]
v. Systemic risks due to extreme events leading to breakdown of infrastructure networks and critical services.[35] [RFC 2-4]
vi. Risk of loss of marine ecosystems and the services they provide for coastal livelihoods, especially for fishing communities in the tropics and the Arctic.[36] [RFC 1-5]
vii. Risk of loss of terrestrial ecosystems and the services they provide for terrestrial livelihoods.[37] [RFC 1, 3, and 4]
viii. Risk of mortality, morbidity, and other harms during periods of extreme heat, particularly for vulnerable urban populations.[38] [RFC 2 and 3]

Mitigation of greenhouse gas emissions over the next few decades can substantially reduce risks of climate change in the second half of the 21st century (*high confidence*). Examples include reduced risk of negative agricultural yield impacts, of water scarcity, of major challenges to urban settlements and infrastructure from sea-level rise, and of adverse impacts from heat extremes, floods, and droughts in areas where increased occurrence of these extremes are projected. Under all assessed scenarios for mitigation and adaptation, some risk from residual damages is unavoidable (*very high confidence*).[39]

Large magnitudes of warming increase the likelihood of severe, pervasive, and challenging impacts. Risks associated with global temperature rise in excess of 4°C relative to preindustrial levels include potential adverse impacts on agricultural production worldwide, potentially extensive ecosystem impacts, and increasing species extinction risk (*high confidence*), as well as possible crossing of thresholds that lead to disproportionately large earth system responses (*low confidence*). The precise levels of climate change sufficient to trigger tipping points (critical thresholds) remain uncertain, but the likelihood of crossing tipping points in the earth system or interlinked human and natural systems decreases with reduced greenhouse gas emissions (*medium confidence*).[40]

Box SPM.4. Human Interference with the Climate System

Human interference with the climate system is occurring, yet determining whether this interference is dangerous, as relevant to Article 2 of the UNFCCC, involves both risk assessment and value judgments. This report assesses risks across contexts and through time, providing a basis for value judgments about the level of climate change at which risks become dangerous.

Five integrative reasons for concern (RFCs) provide a framework for summarizing key risks across sectors and regions. First identified in the IPCC Third Assessment Report, the reasons for concern illustrate the implications of warming and of adaptation limits for people, economies, and ecosystems. They provide one starting point for evaluating dangerous anthropogenic interference with the climate system. An updated assessment of risks for each reason for concern is presented below and in Box SPM.4 Figure 1. All temperature changes are given relative to 1986-2005 ("recent").[41]

(1) ***Unique and threatened systems:*** Some unique and threatened systems, including ecosystems and cultures, are at risk from climate change at recent temperatures. The number of such systems at risk of severe consequences increases at warming of 1°C. Many species and systems with limited adaptive capacity are subject to very high risks at warming of 2°C, particularly Arctic sea ice systems and coral reefs (*high confidence*).
(2) ***Extreme weather events:*** Climate-change-related risks from extreme events, such as heat waves, extreme precipitation, and coastal flooding, are moderate at recent temperatures (*high confidence*) and high at 1°C warming (*medium confidence*).

[33] 3.2, 3.4-5, 8.1-2, 13.2, 19.6, 25.10, 26.3, 26.7-8, 27.3, Tables 19-4 and 26-1, Boxes 25-8 and CC-KR
[34] 3.2, 3.4-5, 8.2, 9.3, 12.2, 13.2, 19.3, 19.6, 24.4, 25.7, 26.8, Table 19-4, Boxes 25-5 and CC-KR
[35] 8.1-2, 10.2-3, 12.6, 19.6, 23.9, 25.10, 26.7-8, 28.3, Table 19-4, Boxes CC-KR and CC-HS
[36] 5.4, 6.3, 7.4, 9.3, 19.5-6, 22.3, 25.6, 27.3, 28.2-3, 29.3, 30.5-7, Table 19-4, Boxes CC-OA, CC-CR, CC-KR, and CC-HS
[37] 4.3, 19.3-6, 22.3, 25.6, 27.3, 28.2-3, Tables 19-4 and 23-2, Boxes CC-KR and CC-WE
[38] 8.1-2, 11.3-4, 13.2, 19.3, 19.6, 23.5, 24.4, 25.8, 26.6, 26.8, Tables 19-4 and 26-1, Boxes CC-KR and CC-HS
[39] 3.4-5, 16.3, 16.6, 17.2, 19.7, 20.3, 25.10, Tables 3-2, 8-3, and 8-5, Boxes 13-2, 16-3, and 25-1
[40] 4.2-3, 11.8, 19.5, 19.7, 26.5, Box CC-HS
[41] 18.6, 19.6

(3) ***Distribution of impacts:*** Risks for disproportionately affected people and communities are generally greatest in low-latitude, less-developed areas, and are moderate at recent temperatures because of regionally differentiated climate-change impacts on food production (*medium* to *high confidence*). Developed countries also have highly vulnerable populations. Based on risks for regional crop production and water resources in some countries, risks become high for warming above 2°C (*medium confidence*).

(4) ***Global aggregate impacts:*** Risks to the overall global economy and Earth's biodiversity become moderate for warming between 1-2°C (*medium confidence*) and high around 3°C, reflecting warming-dependent increases in risks of economic impacts (*low confidence*) and extensive biodiversity loss with concomitant loss of ecosystem services (*high confidence*).

(5) ***Large-scale singular events:*** With increasing warming, some physical systems or ecosystems may be at risk of abrupt and drastic changes. Risks of such tipping points become moderate between 0-1°C, due to early warning signs that both coral reef and Arctic systems are already experiencing irreversible regime shifts. Risks become high between 1-4°C, with a disproportionate increase in risks as temperature increases between 1-2°C, due to the potential for commitment to a large and irreversible sea-level rise from ice sheet loss (*medium confidence*).

Box SPM.4 Figure 1: (Right panel) The dependence of risks associated with reasons for concern on the level of climate change, updated based on assessment of the literature and expert judgments. Purple shading, introduced in this assessment, indicates very high risk of severe impacts and the presence of significant irreversibilities combined with limited adaptive capacity. [Figure 19-4] (Left panel) Observed and simulated variations in past and projected future global annual average temperature relative to 1986-2005, as in Figure SPM.4. [Figure RC-1, Box CC-RC; WGI AR5 Figures SPM.1 and SPM.7]

B-2. Sectoral Risks and Potential for Adaptation

Climate change will amplify climate-related risks to natural and human systems. Some of these risks will be limited to a particular sector or region, and others will have cascading effects. To a lesser extent, climate change will also reduce some climate-related risks and have some potential benefits.

Freshwater resources

Freshwater-related risks of climate change increase significantly with increasing greenhouse gas emissions (*robust evidence, high agreement*). By the end of the 21st century, the number of people exposed annually to a 20th-century 100-year river flood is projected to be three times greater for RCP8.5 than for RCP2.6. In presently dry regions, drought frequency will *likely* increase by the end of this century under RCP8.5 (*medium confidence*).[42]

Climate change will reduce renewable surface water and groundwater resources significantly in most dry subtropical regions, exacerbating competition for water among sectors (*robust evidence, high agreement*). In contrast, water resources will increase at high latitudes. Each degree of warming is projected to decrease renewable water resources by at least 20% for an additional 7% of the global population. Climate change is projected to reduce raw water quality and pose risks to drinking water quality, due to interacting factors: increased temperature; increased sediment, nutrient, and pollutant loadings from heavy rainfall; reduced dilution of pollutants during droughts; and disruption of treatment facilities during floods (*medium evidence, high agreement*). Adaptive water management techniques, including scenario planning, learning-based approaches, and flexible and low-regret solutions, can address uncertainty due to climate change (*limited evidence, high agreement*).[43]

Terrestrial and freshwater ecosystems

A large fraction of terrestrial and freshwater species faces increased extinction risk under projected climate change during and beyond the 21st century, especially as climate change interacts with other pressures, such as habitat modification, over-exploitation, pollution, and invasive species (*high confidence*). Extinction risk is increased under all RCP scenarios, with risk increasing with both magnitude and rate of climate change. Many species will be unable to move fast enough during the 21st century to track suitable climates under mid- and high-

[42] 3.4-5, 26.3, Tables 3-2 and 25-1, Box 25-8; WGI AR5 12.4
[43] 3.2, 3.4-6, 22.3, 25.5, 26.3, Table 3-2, Boxes 25-2 and CC-WE

range rates of climate change (i.e., RCP4.5, 6.0, and 8.5) (*medium confidence*). See Figure SPM.5. Management actions can reduce, but not eliminate, risks to ecosystems and can increase ecosystem adaptability, for example through reduction of other stresses and habitat fragmentation, maintenance of genetic diversity, assisted translocation, and manipulation of disturbance regimes (*high confidence*).[44]

Within this century, magnitudes and rates of climate change associated with RCP4.5, 6.0, and 8.5 pose high risk of abrupt and irreversible regional-scale change in the composition, structure, and function of terrestrial and freshwater ecosystems, for example in the boreal-tundra Arctic system and the Amazon forest, leading to substantial additional climate change (*medium confidence*). Carbon stored in the terrestrial biosphere is vulnerable to loss to the atmosphere as a result of climate change, deforestation, and ecosystem degradation (*high confidence*). Tree mortality and associated forest dieback will occur in many regions in the next one to three decades (*medium confidence*), with forest dieback posing risks for carbon storage, biodiversity, wood production, water quality, amenity, and economic activity.[45]

Figure SPM.5: Rates of displacement of several terrestrial and freshwater species groups in the absence of human intervention, indicating climate velocities for temperature. White boxes with black bars indicate medians and ranges of observed rates of displacement for trees, plants, mammals, birds, plant-feeding insects, and freshwater mollusks. For RCP2.6, 4.5, 6.0, and 8.5 for 2050-2090, horizontal lines show climate velocity for the global-land-area average and for large flat regions. Species groups with displacement rates below each line are projected to be unable to track climate in the absence of human intervention. [Figure 4-5]

Coastal systems and low-lying areas

Due to sea-level rise throughout the 21st century and beyond, coastal systems and low-lying areas will increasingly experience adverse impacts such as submergence, coastal flooding, and coastal erosion (*very high confidence*). The population and assets exposed to coastal risks as well as human pressures on coastal ecosystems will increase significantly in the coming decades due to population growth, economic development, and urbanization (*high confidence*).[46]

By 2100, due to climate change and development patterns and without adaptation, hundreds of millions of people will be affected by coastal flooding and displaced due to land loss (*high confidence*). The majority affected will be in East, Southeast, and South Asia. The relative costs of adaptation vary strongly among and within regions and countries for the 21st century (*high confidence*). Some low-lying developing countries and small island states are expected to face very high impacts and associated annual damage and adaptation costs of several percentage points of GDP.[47]

Marine systems

By mid 21st century, spatial shifts of marine species will cause species richness to increase at mid and high latitudes (*high confidence*) and to decrease at tropical latitudes (*medium confidence*), resulting in global redistribution of catch potential for fishes and invertebrates, with implications for food security (*medium confidence*). See Figure SPM.6A. Animal displacements are projected to lead to high-latitude invasions and high local-extinction rates in the tropics and semi-enclosed seas. Open-ocean net primary production is projected to redistribute and to fall globally by 2100 under RCP8.5. Climate change adds to the threats of over-fishing and other non-climatic stressors, thus complicating marine management regimes (*high confidence*).[48]

Ocean acidification poses risks to ecosystems, especially polar ecosystems and coral reefs, associated with impacts on the physiology, behavior, and population dynamics of individual species (*medium* to *high confidence*). Highly calcified mollusks, echinoderms, and reef-building corals are more sensitive than crustaceans (*high confidence*) and fishes (*low confidence*), with potential consequences for fisheries and livelihoods. See Figure SPM.6B. Ocean acidification occurs in combination with other environmental changes, both globally (e.g.,

[44] 4.3-4, 25.6, 26.4, Box CC-RF
[45] 4.2-3, 25.6, Figure 4-8, Boxes 4-2, 4-3, and 4-4
[46] 5.3-5, 22.3, 24.4, 25.6, 26.3, 26.8, Table 26-1, Box 25-1
[47] 5.3-5, 24.4
[48] 6.3-5, 7.4, 25.6, 28.3, 30.6-7, Boxes CC-MB and CC-PP

warming, decreasing oxygen levels) and locally (e.g., pollution, eutrophication) (*high confidence*). Simultaneous environmental drivers, such as warming and ocean acidification, can lead to interactive, complex, and amplified impacts for species.[49]

Figure SPM.6: Climate change risks for fisheries. (A) For 2°C increase from preindustrial levels using SRES A1B (≈RCP6.0), projected global redistribution of maximum catch potential of 1000 species of exploited fishes and invertebrates, comparing the 10-year averages 2001-2010 and 2051-2060, without analysis of potential impacts of overfishing. (B) Marine mollusk and crustacean fisheries (estimated catch rates ≥0.005 tonnes per sq. km) and known locations of warm- and cold-water corals, depicted on a global map showing the distribution of ocean acidification in 2100 under RCP8.5. [WGI AR5 Figure SPM.8] The bottom panel compares sensitivity to ocean acidification across corals, mollusks, and crustaceans, vulnerable animal phyla with socioeconomic relevance (e.g., for coastal protection and fisheries). The number of species analyzed across studies is given for each category of elevated CO_2. For 2100, RCP scenarios falling within each pCO_2 category are as follows: RCP4.5 for 500-650 μatm, RCP6.0 for 651-850 μatm, and RCP8.5 for 851-1370 μatm. [6.1, 6.3, 30.5, Figures 6-10 and 6-14; WGI AR5 Box SPM.1]

Food production systems and food security

Without adaptation, local temperature increases of 1°C or more above preindustrial levels are projected to negatively impact yields for the major crops (wheat, rice, and maize) in tropical and temperate regions, although individual locations may benefit (*medium confidence*). With or without adaptation, climate change will reduce median yields by 0 to 2% per decade for the rest of the century, as compared to a baseline without climate change. These projected impacts will occur in the context of rising crop demand, projected to increase by about 14% per decade until 2050. See Figure SPM.7 for a summary of projected changes in crop yields over the 21st century. Risks are greatest for tropical countries, given projected impacts that exceed adaptive capacity and higher poverty rates compared with temperate regions. Climate change will progressively increase inter-annual variability of crop yields in many regions.[50]

On average, adaptation improves yields by the equivalent of ~15-18% of current yields, but the effectiveness of adaptation is highly variable (*medium confidence*). Positive and negative yield impacts projected for local temperature increases of about 2°C above preindustrial levels maintain possibilities for effective adaptation in crop production (*high confidence*). For local warming of about 4°C or more, differences between crop production and population-driven demand will become increasingly large in many regions, posing significant risks to food security even with adaptation.[51]

Figure SPM.7: Summary of projected changes in crop yield as a function of time with and without adaptation, across studies for all regions. Data (n=1090) are plotted in the 20-year period on the horizontal axis that includes the midpoint of each future projection period. [Figure 7-5]

Urban areas

Heat stress, extreme precipitation, inland and coastal flooding, and drought and water scarcity pose risks in urban areas for people, assets, economies, and ecosystems, with risks amplified for those lacking essential infrastructure and services or living in exposed areas (*very high confidence*). Reducing basic service deficits and building resilient infrastructure systems could significantly reduce exposure and vulnerability in cities and urban areas. Urban adaptation benefits from effective multi-level urban risk governance, alignment of policies and incentives, strengthened local government and community adaptation capacity, synergies with the private sector, appropriate financing and institutional development, and increased capacity of low-income groups and vulnerable communities and their partnerships with local governments (*medium confidence*).[52]

Rural areas

[49] 5.4, 6.3, 6.5, 22.3, 25.6, 28.3, 30.5, Boxes CC-CR, CC-OA, and TS.7
[50] 7.4, 22.3, 24.4, 25.7, 26.5, Figures 7-4, 7-5, 7-6, and 7-7
[51] 7.5, 22.3, 25.7, 26.5, Tables 7-2 and 11-3, Figures 7-4, 7-5, 7-7, and 7-8
[52] 3.5, 8.2-4, 22.3, 24.4-5, 26.8, Boxes 25-9 and CC-HS

Major future rural impacts will be felt in the near-term and beyond through impacts on water supply, food security, and agricultural incomes, including shifts in production of food and non-food crops in many areas of the world (*high confidence*). Price rises, which may be induced by climate shocks as well as other factors, have a disproportionate impact on the welfare of the poor in rural areas, such as female-headed households and those with limited access to modern agricultural inputs, infrastructure, and education. Options exist for adaptations within international agricultural trade (*medium confidence*).[53]

Key economic sectors and services

For most economic sectors, the impacts of drivers such as changes in population, age structure, income, technology, relative prices, lifestyle, regulation, and governance will be large relative to the impacts of climate change (*medium evidence, high agreement*). Climate change will reduce energy demand for heating and increase energy demand for cooling in the residential and commercial sectors (*robust evidence, high agreement*). Climate change will affect energy sources and technologies differently, depending on resources (e.g., water flow, wind, insolation), technological processes (e.g., cooling), or locations (e.g., coastal regions, floodplains) involved. More frequent and/or severe weather disasters for some regions and/or hazards will increase losses and loss variability in various regions and challenge insurance systems to offer affordable coverage while raising more risk-based capital, particularly in low- and middle-income countries. Large-scale public-private risk prevention initiatives and government insurance of the non-diversifiable portion of risk offer example mechanisms for adaptation.[54]

Global mean temperature increase of 2.5°C above preindustrial levels may lead to global aggregate economic losses between 0.2 and 2.0% of income (*medium evidence, medium agreement*). Losses increase with greater warming, but little is known about aggregate economic impacts above 3°C. Impact estimates are incomplete and depend on a large number of assumptions, many of which are disputable, and aggregate impacts hide large differences between and within countries. The incremental economic impact of emitting a tonne of carbon dioxide lies between a few dollars and several hundreds of dollars per tonne of carbon (*robust evidence, medium agreement*). Estimates vary strongly with the assumed discount rate, with larger ranges for lower discount rates.[55]

Human health

Until mid-century, climate change will impact human health mainly by exacerbating health problems that already exist (*very high confidence*), and climate change throughout the 21st century will lead to increases in ill-health in many regions, as compared to a baseline without climate change (*high confidence*). Examples include greater likelihood of injury, disease, and death due to more intense heat waves and fires; increased likelihood of under-nutrition resulting from diminished food production in poor regions; risks from lost work capacity and reduced labor productivity in vulnerable populations; and increased risks from food- and water-borne diseases. Positive effects will include modest improvements in cold-related mortality and morbidity in some areas due to fewer cold extremes, shifts in food production, and reduced capacity of disease-carrying vectors (*medium confidence*), but globally, positive impacts will be outweighed by the magnitude and severity of negative impacts (*high confidence*). The most effective adaptation measures for health in the near-term are programs that implement basic public health measures such as provision of clean water and sanitation, secure essential health care including vaccination and child health services, increase capacity for disaster preparedness and response, and alleviate poverty (*very high confidence*). For RCP8.5 by 2100, the combination of high temperature and humidity in some areas for parts of the year will compromise normal human activities, including growing food or working outdoors (*high confidence*).[56]

Human security

Climate change over the 21st century will have significant impacts on forms of migration that compromise human security (*medium evidence, high agreement*). Populations that lack the resources for mobility and

[53] 9.3, 25.9, 26.8, Box 25-5
[54] 3.5, 10.2, 10.7, 10.10, 25.7, 26.7, Box 25-7
[55] 10.9
[56] 8.2, 11.3-8, 19.3, 22.3, 25.8, 26.6, Figure 25-5, Box CC-HS

migration often experience higher exposure to weather-related extremes, in both rural and urban areas, particularly in low-income countries. Expanding opportunities for mobility can reduce vulnerability, but altered migration flows can also create risks as well as potential benefits for migrants and for sending and receiving regions and states.[57]

Climate change indirectly increases risks from violent conflict in the form of civil war, inter-group violence, and violent protests by exacerbating well-established drivers of these conflicts such as poverty and economic shocks (*medium confidence*). Statistical studies show that climate variability is significantly related to these forms of conflict. Poorly designed adaptation and mitigation strategies can increase risks from violent conflict.[58]

Climate change over the 21st century will lead to new challenges to states and will increasingly shape national security policies (*medium evidence, medium agreement*). Small-island states and other states highly vulnerable to sea-level rise face major challenges to their territorial integrity. Some transboundary impacts of climate change, such as changes in sea ice, shared water resources, and migration of fish stocks, have the potential to increase rivalry among states. The presence of robust institutions can manage many of these rivalries to reduce conflict risks.[59]

Livelihoods and poverty

Throughout the 21st century, climate change impacts will slow down economic growth and poverty reduction, further erode food security, and trigger new poverty traps, the latter particularly in urban areas and emerging hotspots of hunger (*medium confidence*). Climate change will exacerbate poverty in low and lower-middle income countries and create new poverty pockets in upper-middle- to high-income countries with increasing inequality. In urban and rural areas, wage-labor-dependent poor households that are net buyers of food will be particularly affected due to food price increases, including in regions with high food insecurity and high inequality (particularly Africa), although the agricultural self-employed could benefit. Insurance programs, social protection measures, and disaster risk management may enhance long-term livelihood resilience among poor and marginalized people, if policies address multidimensional poverty.[60]

B-3. Regional Key Risks and Potential for Adaptation

Risks will vary across regions and populations, through space and time, dependent on myriad factors including the extent of mitigation and adaptation. Key regional risks identified with *medium* to *high confidence* are presented in Table SPM.1. Projected changes in climate and increasing atmospheric CO_2 will have positive effects for some sectors in some locations. For extended summary of regional risks and the more limited potential benefits, see Technical Summary section B-3 and Chapters 21-30.

Table SPM.1: Key regional risks from climate change and the potential for reducing risks through mitigation and adaptation. Risks have been identified based on assessment of the relevant scientific, technical, and socioeconomic literature, as detailed in supporting chapter sections. Each key risk is characterized as very low to very high for three timeframes: the present, near-term (here, assessed over 2030-2040), and longer-term (here, assessed over 2080-2100). Assessed risk levels integrate probability and consequence over the full range of possible outcomes, acknowledging the importance of differences in values and objectives in interpretation of the assessed risk levels. For the near-term era of committed climate change, projected levels of global mean temperature increase do not diverge substantially across emission scenarios. For the longer-term era of climate options, risk levels are presented for global mean temperature increase of 2°C and 4°C above preindustrial levels, illustrating the potential role of mitigation in reducing risks. For the present, risk levels are estimated for current adaptation and a hypothetical highly adapted state, identifying where current adaptation deficits exist. For the future, risk levels are estimated for a continuation of current adaptation and for a highly adapted state, representing the potential for and limits to adaptation. Relevant climate variables are indicated by icons. Risk levels are not necessarily comparable, especially across regions, because the assessment considers potential impacts and adaptation in different physical, biological, and human systems across diverse regional contexts.

[57] 9.3, 12.4, 19.4, 22.3, 25.9
[58] 12.5, 13.2, 19.4
[59] 12.5-6, 23.9, 25.9
[60] 8.1, 8.4, 9.3, 10.9, 13.2-4, 22.3, 26.8

C) MANAGING FUTURE RISKS AND BUILDING RESILIENCE

Managing the risks of climate change involves decisions with implications for future societies, economies, environment, and climate. This section evaluates adaptation as a means to build resilience, as well as limits to adaptation, the role of transformation, and climate-resilient pathways. Figure SPM.8 provides an overview of responses for addressing climate change.

Figure SPM.8: An overview of overlapping entry points and approaches, as well as core considerations, in responding to climate change, as assessed in the WGII AR5. Bracketed references indicate sections of this summary with corresponding assessment findings.

C-1. Principles for Effective Adaptation

Adaptation is highly regionally and context specific, with no single approach for reducing risks appropriate across all settings (*medium confidence*). Effective risk reduction and adaptation strategies consider the dynamics of vulnerability and exposure and their linkages with development and climate change (*high confidence*). Specific examples of responses to climate change are presented in Table SPM.2.[61]

Table SPM.2: Managing the risks of climate change: entry points, strategies, and adaptation options. These approaches should be considered overlapping rather than discrete, and they are often pursued simultaneously. Examples given can be relevant to more than one category. [14.2-3, Table 14-1]

From individuals to governments, actors across scales and regions have complementary roles in enabling adaptation planning and implementation (*high confidence*), for example through increasing awareness of climate change risks, learning from experience with climate variability, and achieving synergies with disaster risk reduction. Local government and the private sector are increasingly recognized as critical to progress in adaptation, given their roles in scaling up adaptation of communities and households and in managing risk information and financing (*medium evidence, high agreement*). National governments can coordinate adaptation by local and subnational governments, creating legal frameworks, protecting vulnerable groups, and providing information, policy frameworks, and financial support (*robust evidence, high agreement*). Public action can influence the degree to which private parties undertake adaptation actions.[62]

In many cases, a first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate through low-regrets measures and actions emphasizing co-benefits (*high confidence*). Available strategies and actions can increase resilience across a range of possible future climates while helping to improve human livelihoods, social and economic well-being, and environmental quality. See Table SPM.2. Integration of adaptation into planning and decision-making can promote synergies with development.[63]

Multiple simultaneous constraints can interact to impede adaptation planning and implementation (*high confidence*). Common constraints on implementation arise from the following: uncertainty about projected impacts; limited financial and human resources; limited integration or coordination of different levels of governance; different perceptions of risks; inadequate responses from political institutions; competing values; absence of adaptation leaders and champions; and limited tools to monitor adaptation effectiveness. Underestimating the complexity of adaptation as a social process can create unrealistic expectations.[64]

Poor planning, overemphasizing short-term outcomes, or discounting or failing to consider all consequences can result in maladaptation (*medium evidence, high agreement*). Maladaptation can increase the vulnerability or exposure of the target group in the future, or the vulnerability of other locations or sectors.[65]

[61] 2.1, 8.3-4, 13.1, 13.3-4, 15.2-3, 15.5, 16.2-3, 16.5, 17.2, 17.4, 19.6, 21.3, 22.4, 26.8-9, 29.6, 29.8
[62] 2.1-4, 3.6, 8.3-4, 9.3-4, 14.2, 15.2-3, 15.5, 16.2-5, 17.2-3, 22.4, 24.4, 25.4, 26.8-9, 30.7, Tables 21-1, 21-5, & 21-6, Boxes 16-1, 16-2, & 25-7
[63] 3.6, 8.3, 9.4, 11.2, 14.3, 15.2-3, 17.2, 20.4, 20.6, 22.4, 24.4-5, 25.4, 25.10, 27.3-5, 29.6, Boxes 25-2 and 25-6
[64] 3.6, 4.4, 8.4, 9.4, 13.2-3, 14.2, 15.2-3, 15.5, 16.2-3, 16.5, 17.2-3, 22.3-5, 23.6-7, 24.5, 25.4, 25.10, 26.8-9, 30.6, Boxes 16-1, 16-3, and CC-EA
[65] 14.6, 15.5, 17.2-3, 22.4

Existing and emerging economic instruments can foster adaptation by providing incentives for anticipating and reducing impacts (*medium confidence*). Instruments include risk sharing and transfer mechanisms, loans, public-private finance partnerships, payments for environmental services, improved resource pricing (e.g., water markets), charges and subsidies including taxes, norms and regulations, and behavioral approaches. Risk financing mechanisms across scales, such as insurance and risk pools, contribute to increasing resilience to climate extremes and climate variability, but can also provide disincentives, cause market failure, and decrease equity. The public sector often plays a key role as regulator, provider, or insurer of last resort.[66]

Global adaptation cost estimates are substantially greater than current adaptation funding and investment, particularly in developing countries, suggesting a funding gap and a growing adaptation deficit (*medium confidence*). The most recent global adaptation cost estimates suggest a range from 70 to 100 US$ billion per year in developing countries from 2010 to 2050 (*low confidence*). Important omissions and shortcomings in data and methods render these estimates highly preliminary (*high confidence*).[67]

C-2. Climate-resilient Pathways and Transformation

Climate-resilient pathways are sustainable-development trajectories that combine adaptation and mitigation to reduce climate change and its impacts. They include iterative processes to ensure that effective risk management can be implemented and sustained (*high confidence*). Prospects for climate-resilient development pathways are related fundamentally to what the world accomplishes with climate change mitigation.[68]

Greater rates and magnitude of climate change increase the likelihood of exceeding adaptation limits that emerge from the interaction among climate change and biophysical and socioeconomic constraints (*high confidence*). Opportunities to take advantage of positive synergies between adaptation and mitigation may decrease with time, particularly if limits to adaptation are exceeded. In some parts of the world, current failures to address emerging impacts are already eroding the basis for sustainable development.[69]

Significant co-benefits, synergies, and tradeoffs exist between mitigation and adaptation and between alternative adaptation responses; interactions occur both within and across regions (*very high confidence*). Increasing efforts to mitigate and adapt to climate change imply an increasing complexity of interactions, particularly at the intersections among water, energy, land use, and biodiversity, but tools to understand and manage these interactions remain limited. For instance, increasing bioenergy crop cultivation poses risks to ecosystems and biodiversity, although contributions of biomass energy to mitigation reduce climate-related risks (*high confidence*). Examples of mitigation actions with adaptation co-benefits include (i) improved energy efficiency and cleaner energy sources, leading to reduced local emissions of health-damaging climate-altering air pollutants, and (ii) reduced energy and water consumption in urban areas through greening cities and recycling water.[70]

Transformations in political, economic, and technological systems resulting from changes in paradigms and goals can facilitate adaptation and mitigation and promote sustainable development (*high confidence*). Transformational adaptation is an important consideration for decisions involving long life- or lead-times, and it can be a response to adaptation limits. It includes adaptation at greater scale or magnitude, introduction of new technologies or practices, formation of new structures or systems of governance, or shifts in the location of activities. Societal debates over risks from forced and reactive transformations as opposed to deliberate transitions to sustainability may place new and increased demands on governance structures to reconcile conflicting goals and visions for the future.[71]

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[66] 10.7, 10.9, 13.3, 17.4-5, Box 25-7
[67] 17.4
[68] 1.1, 2.5, 13.4, 20.2-4, 20.6, Figure 1-5
[69] 1.1, 11.8, 13.4, 16.2-7, 17.2, 20.2-3, 20.5-6, 25.10, 26.5, 26.9, Boxes 16-1, 16-3, and 16-4
[70] 2.5, 3.7, 4.2-4, 8.4, 9.3, 11.9, 13.3, 17.2, 19.3-4, 20.2-5, 21.4, 22.6, 23.8, 24.6, 25.7, 25.9, 26.8-9, 27.3, 29.6-8, Boxes 25-2, 25-9, 25-10, CC-WE, and CC-RF
[71] 1.1, 2.1, 2.5, 8.4, 14.1, 14.3, 16.2-7, 17.3, 20.5, 22.4, 25.4, 25.10, Figure 1-5, Boxes 16-1, 16-4, and TS.8

Box SPM.1. Terms Critical for Understanding the Summary[72]

Climate change: Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.' The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

Exposure: The presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected.

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Impacts: Effects on natural and human systems. In this report, the term *impacts* is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health status, ecosystems, economic, social, and cultural assets, services (including environmental), and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as *consequences* and *outcomes*. The impacts of climate change on geophysical systems, including floods, droughts, and sea-level rise, are a subset of impacts called physical impacts.

Risk: The potential for consequences where something of human value (including humans themselves) is at stake and where the outcome is uncertain. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the consequences if these events occur. This report assesses climate-related risks.

Adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Transformation: A change in the fundamental attributes of a system, often based on altered paradigms, goals, or values. Transformations can occur in technological or biological systems, financial structures, and regulatory, legislative, or administrative regimes.

Box SPM.2. Communication of the Degree of Certainty in Assessment Findings

The degree of certainty in each key finding of the assessment is based on the type, amount, quality, and consistency of evidence (e.g., data, mechanistic understanding, theory, models, expert judgment) and the degree of agreement. The summary terms to describe evidence are: *limited*, *medium*, or *robust*; and agreement: *low*, *medium*, or *high*.

Confidence in the validity of a finding synthesizes the evaluation of evidence and agreement. Levels of confidence include five qualifiers: *very low*, *low*, *medium*, *high*, and *very high*.

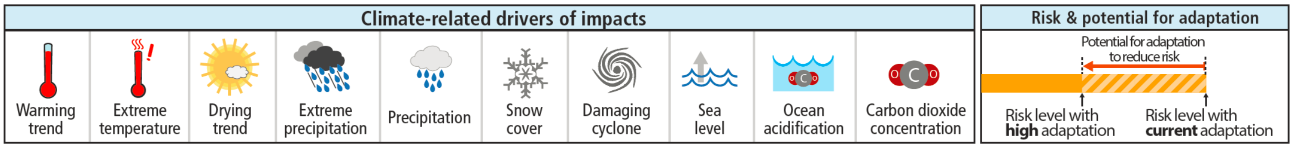
The likelihood, or probability, of some well-defined outcome having occurred or occurring in the future can be described quantitatively through the following terms: v*irtually certain,* 99–100% probability; *extremely likely,* 95–100%; *very likely,* 90–100%; *likely,* 66–100%; *more likely than not,* >50–100%; *about as likely as not,* 33–66%; *unlikely,* 0–33%; *very unlikely,* 0–10%; *extremely unlikely,* 0–5%; and *exceptionally unlikely,* 0–1%. Unless otherwise indicated, findings assigned a likelihood term are associated with *high* or *very high* confidence. Where appropriate, findings are also formulated as statements of fact without using uncertainty qualifiers.

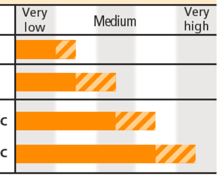
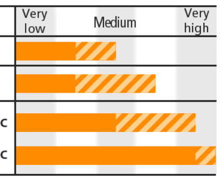
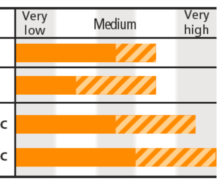
[72] Reflecting progress in science, some definitions differ in breadth and focus from the definitions used in the AR4 and other IPCC reports.

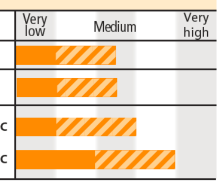
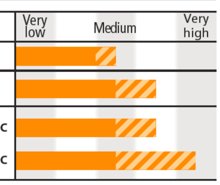
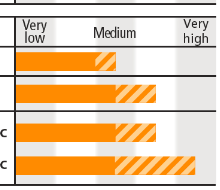
Within paragraphs of this summary, the confidence, evidence, and agreement terms given for a bold key finding apply to subsequent statements in the paragraph, unless additional terms are provided.

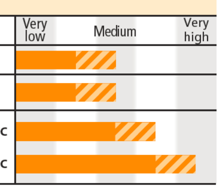
[1.1, Box 1-1]

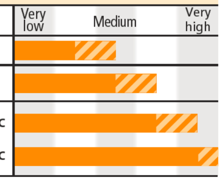
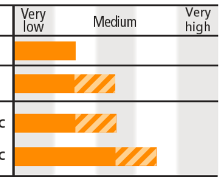
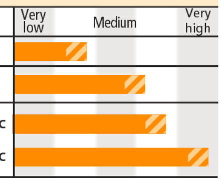
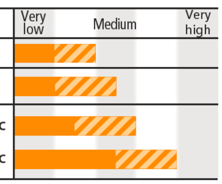
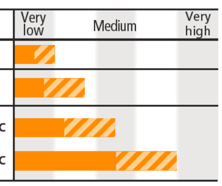
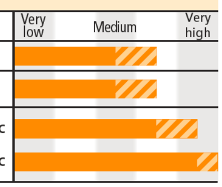
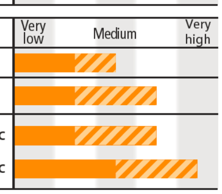
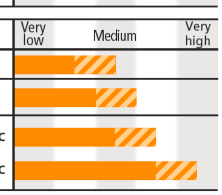
Table SPM.1.



Key risk	Adaptation issues and prospects	Climatic drivers	Supporting ch. sections	Timeframe	Risk for current and high adaptation
Africa					
Compounded stress on water resources facing significant strain from overexploitation and degradation at present and increased demand in the future (*high confidence*)	• Reducing non-climate stressors on water resources • Strengthening institutional capacities for demand management, groundwater assessment, integrated water-wastewater planning, and integrated land and water governance		22.3-4	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Reduced crop productivity with strong adverse effects on regional, national, and household food security, also given increased pest and disease damage and flood impacts on food system infrastructure (*high confidence*)	• Technological adaptation responses (e.g., stress-tolerant crop varieties, irrigation) • Enhancing smallholder access to credit and other critical production resources and diversifying livelihoods • Strengthening institutions at local to regional levels to support agriculture and gender-oriented policy support		22.3-4	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Changes in the incidence and geographic range of vector- and water-borne diseases due to changes in the mean and variability of temperature and precipitation, particularly along the edges of their distribution (*medium confidence*)	• Achieving development goals, particularly improved access to safe water and improved sanitation, and enhancement of public health functions such as surveillance • Vulnerability mapping and early warning systems • Coordination across sectors		22.3	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	

Key risk	Adaptation issues and prospects	Climatic drivers	Supporting ch. sections	Timeframe	Risk for current and high adaptation
Europe					
Increased economic losses and people affected by flooding in river basins and coasts, driven by increasing urbanization and by increasing sea levels and peak river discharges (*high confidence*)	Adaptation can prevent most of the projected damages (*high confidence*). • Significant experience in hard flood-protection technologies • High costs for increasing flood protection • Potential barriers to implementation: demand for land in Europe and environmental and landscape concerns		23.2-3, 23.7	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Increased water restrictions. Significant reduction in water availability from river abstraction and from groundwater resources, combined with increased water demand (e.g., for irrigation, energy and industry, domestic use) and with reduced water drainage and runoff as a result of increased evaporative demand (*high confidence*)	• Proven adaptation potential from adoption of more water-efficient technologies and of water-saving strategies (e.g., for irrigation, crop species, land cover, industries, domestic use) • Further adaptation possible through solar desalinization with mitigation co-benefits		23.4, 23.7	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Increased economic losses and people affected by extreme heat events: impacts on health and well-being, labor productivity, crop production, and air quality (*medium confidence*)	• Implementation of warning systems • Adaptation of dwellings and workplaces and of transport and energy infratructure • Reductions in emissions to improve air quality • Improved wildfire management		23.3, 23.5-7	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	

Key risk	Adaptation issues and prospects	Climatic drivers	Supporting ch. sections	Timeframe	Risk for current and high adaptation
Asia					
Increased flooding leading to widespread damage to infrastructure and settlements in Asia (*medium confidence*)	• Exposure reduction via effective land-use planning, selective relocation, and structural measures • Reduction in the vulnerability of lifeline infrastructure and services (e.g., water, energy, waste management, food, biomass, mobility, local ecosystems, telecommunications) • Assistance to vulnerable sectors and households		24.4	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	

Key risk	Adaptation issues and prospects	Climatic drivers	Supporting ch. sections	Timeframe	Risk for current and high adaptation
Asia (continued)					
Increased risk of heat-related mortality (*high confidence*)	• Heat health warning systems • Urban planning to reduce heat islands • Improvement of the built environment		24.4	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Increased risk of drought-related water and food shortage causing malnutrition (*high confidence*)	• Disaster preparedness including early-warning systems and local response strategies		24.4	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Australasia					
Significant change in community composition and structure of coral reefs and montane ecosystems and risk of loss of some native species in Australia (*high confidence*)	• Ability to adapt naturally is limited especially for species that occupy narrow climatic ranges and fragmented habitats. • Main human adaptation options are to reduce other pressures (e.g., pollution, runoff, fishing, tourism, introduced predators and pests) and improve early warning systems. Assisted colonization and other direct interventions such as shading of reefs have been proposed but remain untested at scale.		25.6, 25.10	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Increased frequency and intensity of flood damage to infrastructure and settlements in Australia and New Zealand (*high confidence*)	• Significant adaptation deficit in some regions to current flood risk. • Effective adaptation includes land-use controls and relocation as well as protection and accommodation of increased risk to ensure flexibility.		Table 25-1, Boxes 25-8 and 25-9	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Increasing risks to coastal infrastructure and low-lying ecosystems in Australia and New Zealand, with widespread damage towards the upper end of projected sea-level-rise ranges (*high confidence*)	• Adaptation deficit in some locations to current coastal erosion and flood risk. Successive building and protection cycles constrain flexible responses. • Effective adaptation includes land-use controls and ultimately relocation as well as protection and accommodation.		25.6, 25.10, Box 25-1	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
North America					
Loss of ecosystem integrity, property loss, human morbidity, and mortality due to wildfires (*high confidence*)	• Some ecosystems are more fire-adapted than others. Forest managers and municipal planners are increasingly incorporating fire protection measures (e.g., prescribed burning, introduction of resilient vegetation). Institutional capacity to support ecosystem adaptation is limited. • Adaptation of human settlements is constrained by rapid private property development in high-risk areas and by limited household-level adaptive capacity.		26.4, 26.8, Box 26-2	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Heat-related human mortality (*high confidence*)	• Residential air conditioning (A/C) can effectively reduce risk. However, availability and usage of A/C is often limited among the most vulnerable individuals and is subject to complete loss during power failures. Vulnerable populations include athletes and outdoor workers for whom A/C is not available. • Community- and household-scale adaptations have the potential to reduce exposure to heat extremes via family support, heat warnings, cooling centers, greening, and high albedo surfaces.		26.6, 26.8	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Property and infrastructure damage; supply chain, ecosystem, and social system disruption; public health impacts; and water quality impairment from river and coastal urban floods (*high confidence*)	• Implementing management of urban drainage is expensive and disruptive to urban areas. • Low-regret strategies with co-benefits include less impervious surfaces leading to more groundwater recharge, green infrastructure, and rooftop gardens. • Sea-level rise increases water elevations in coastal outfalls, which impedes drainage. In many cases, older rainfall design standards are being used that need to be updated to reflect current climate conditions.		26.2-4, 26.8	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	

Key risk	Adaptation issues and prospects	Climatic drivers	Supporting ch. sections	Timeframe	Risk for current and high adaptation
Central and South America					
Water availability in semi-arid and glacier-melt-dependent regions and flooding in urban areas due to extreme precipitation (*high confidence*)	• Water-supply deficit replacement and improved land use • Urban flood management (including infrastructure), early warning systems, better weather and runoff forecasts, and infectious disease control		27.3	Present Near-term (2030-2040) Long-term (2080-2100) 2°C / 4°C	Very low / Medium / Very high
Decreased food production and food quality (*medium confidence*)	• Development of new crop varieties more adapted to changes in CO_2, temperature, and drought • Offsetting of human and animal health impacts of reduced food quality • Offsetting of economic impacts of land use change		27.3	Present Near-term (2030-2040) Long-term (2080-2100) 2°C / 4°C	Very low / Medium / Very high

Key risk	Adaptation issues and prospects	Climatic drivers	Supporting ch. sections	Timeframe	Risk for current and high adaptation
Small Islands					
Loss of livelihoods, coastal settlements, and infrastructure in small islands (*high confidence*)	• Significant potential exists for adaptation in islands, but additional external resources and technologies will enhance response. • Efficacy of traditional community coping strategies is expected to be substantially reduced in the future.		Figure 29-4	Present Near-term (2030-2040) Long-term (2080-2100) 2°C / 4°C	Very low / Medium / Very high
The interaction of rising global mean sea level in the 21st century with high-water-level events will threaten low-lying coastal areas in small islands (*high confidence*)	• High ratio of coastal area to land mass will make adaptation a significant financial and resource challenge for islands. • Adaptation options include maintenance and restoration of coastal landforms and ecosystems, improved management of soils and freshwater resources, and appropriate building codes and settlement patterns.		29.4, Table 29-1; WGI AR5 13.5, Table 13.5	Present Near-term (2030-2040) Long-term (2080-2100) 2°C / 4°C	Very low / Medium / Very high

Key risk	Adaptation issues and prospects	Climatic drivers	Supporting ch. sections	Timeframe	Risk for current and high adaptation
The Ocean					
Distributional shift in fish and invertebrate species, and decrease in fishery catch potential at low latitudes, e.g., in equatorial upwelling and coastal boundary systems and sub-tropical gyres (*high confidence*)	• Evolutionary adaptation potential of fish and invertebrate species to warming is limited as indicated by their ongoing latitudinal shifts. • Human adaptation options: Large-scale translocation of industrial fishing activities following the regional decreases (low latitude) vs. possibly transient increases (high latitude) in catch potential; Flexible management that can react to variability and change; Improvement of fish resilience to thermal stress by reducing other stressors such as pollution and eutrophication; Expansion of aquaculture.		6.3, Box CC-MB	Present Near-term (2030-2040) Long-term (2080-2100) 2°C / 4°C	Very low / Medium / Very high
Reduced biodiversity, fisheries abundance, and coastal protection by coral reefs due to heat-induced mass coral bleaching and mortality increases, e.g., in coastal boundary systems and sub-tropical gyres (*high confidence*)	• Evidence of rapid evolution by corals is very limited. Some corals may migrate to higher latitudes, but entire reef systems are not expected to be able to track the high rates of temperature shifts. • Human adaptation options are limited to reducing other stresses, mainly by enhancing water quality, and limiting pressures from tourism and fishing. These options will delay human impacts of climate change by a few decades, but their efficacy will be severely reduced as thermal stress increases.		5.4, 6.4, 30.3, 30.5, Box CC-CR	Present Near-term (2030-2040) Long-term (2080-2100) 2°C / 4°C	Very low / Medium / Very high
Coastal inundation and habitat loss due to sea-level rise and intensified precipitation events, e.g., in coastal boundary systems and sub-tropical gyres (*medium to high confidence*)	• Human adaptation options are limited to reducing other stresses, mainly by reducing pollution and limiting pressures from tourism, fishing, and aquaculture. • Loss of ecosystems such as sea grass, mangroves, and coral reefs can be reduced by reducing deforestation and increasing reforestation of river catchments and coastal areas to retain sediments and nutrients.		5.5, 30.5-6, Box CC-CR	Present Near-term (2030-2040) Long-term (2080-2100) 2°C / 4°C	Very low / Medium / Very high

Table SPM.2.

Overlapping Entry Points	Category	Examples	Chapter Reference(s)
Vulnerability reduction through development & planning ***Including many low-regrets measures***	**Human development**	Improved access to education, nutrition, health facilities, energy, safe settlement structures, & social support structures; Reduced gender inequality & marginalization in other forms.	8.3, 9.3, 13.1-3, 14.2-3, 22.4
	Poverty alleviation	Insurance schemes; Social safety nets & social protection; Disaster risk reduction; Improved access to & control of local resources, land tenure, & storage facilities.	8.3, 9.3, 13.1-3, Box 8-4
	Livelihood security	Income, asset, & livelihood diversification; Improved infrastructure; Access to technology & decision-making fora; Enhanced agency; Changed cropping, livestock, & aquaculture practices; Reliance on social networks.	7.5, 13.1-3, 22.3-4, 23.4, 26.5, 27.3, 29.6, Table 24-7
	Disaster risk management	Early warning systems; Hazard & vulnerability mapping; Improved drainage; Flood & cyclone shelters; Building codes; Storm & wastewater management; Transport & road infrastructure improvements.	8.2-4, 11.7, 14.3, 15.3-4, 22.4, 24.4, 25.4, 26.6, 28.4
	Ecosystem management	Maintaining wetlands & urban green spaces; Coastal afforestation; Dam management; Reduction of other stressors on ecosystems & of habitat fragmentation; Maintenance of genetic diversity; Assisted translocation; Manipulation of disturbance regimes; Community-based natural resource management.	4.3-4, 8.3, 22.4, Table 3-3, Boxes 4-2, 4-3, 8-2, 15-1, 25-8, 25-9, & CC-EA
	Spatial or land-use planning	Provisioning of adequate housing, infrastructure, & services; Managing development in flood prone & other high risk areas; Urban upgrading programs; Land zoning laws; Easements; Protected areas.	4.4, 8.1, 8.3-4, 22.4, 23.7-8, 27.3, Box 25-8
Adaptation ***Including incremental & transformational adjustments***	**Structural/ physical**	***Engineered & built-environment options:*** Sea walls & coastal protection structures; Flood levees; Water storage; Improved drainage; Flood & cyclone shelters; Building codes; Storm & wastewater management; Transport & road infrastructure improvements; Floating houses; Power plant & electricity grid adjustments.	3.5-6, 5.5, 8.2-3, 10.2, 11.7, 23.3, 24.4, 25.7, 26.3, 26.8, Boxes 15-1, 25-1, 25-2, & 25-8
		Technological options: New crop & animal varieties; Traditional technologies & methods; Efficient irrigation; Water-saving technologies; Conservation agriculture; Food storage & preservation facilities; Hazard mapping & monitoring; Early warning systems; Building insulation; Mechanical & passive cooling.	7.5, 8.3, 9.4, 10.3, 15.3-4, 22.4, 24.4, 26.3, 26.5, 27.3, 28.2, 28.4, 29.6-7, Table 25-2, Boxes 20-5 & 25-2
		Ecosystem-based options: Ecological restoration; Afforestation & reforestation; Mangrove conservation & replanting; Green infrastructure (e.g., shade trees, green roofs); Controlling overfishing; Fisheries co-management; Assisted migration or managed translocation; Ecological corridors; Ex situ conservation & seed banks; Community-based natural resource management.	4.4, 5.5, 8.3, 9.4, 11.7, 15.3-4, 22.4, 23.6-7, 24.4, 25.6, 26.4, 27.3, 28.2, 29.7, 30.6, Boxes 15-1, 22-2, 25-9, 26-2, & CC-EA
		Services: Social safety nets & social protection; Food banks & distribution of food surplus; Municipal services including water & sanitation; Vaccination programs; Essential public health services; Enhanced emergency medical services.	3.5-6, 8.3, 9.3-4, 11.7, 11.9, 22.4, 29.6, Box 13-2
	Institutional	***Economic options:*** Financial incentives including taxes & subsidies; Insurance; Catastrophe bonds; Payments for ecosystem services; Water tariffs; Microfinance; Disaster contingency funds; Cash transfers.	8.3-4, 9.4, 10.7, 11.7, 13.3, 15.4, 17.5, 22.4, 26.7, 27.6, 29.6, Box 25-7
		Laws & regulations: Land zoning laws; Building standards; Easements; Water regulations & agreements; Laws to support disaster risk reduction; Laws to encourage insurance purchasing; Defined property rights & land tenure security; Protected areas; Fishing quotas; Patent pools & technology transfer.	4.4, 8.3, 9.3, 10.5, 10.7, 15.2, 15.4, 17.5, 22.4, 23.4, 23.7-8, 24.4, 25.4, 26.3, 27.3, Table 25-2, Box CC-CR
		Government policies & programs: National & regional adaptation plans including mainstreaming; Sub-national & local adaptation plans; Urban upgrading programs; Municipal water management programs; Disaster planning & preparedness; Integrated water resource management; Integrated coastal zone management; Ecosystem-based management; Community-based adaptation.	2.2-4, 3.6, 4.4, 5.5, 6.4, 7.5, 8.3, 11.7, 15.2-4, 22.4, 23.7, 25.4, 25.8, 26.8-9, 27.3-4, 29.6, 30.6, Boxes 25-1, 25-2, & 25-9
	Social	***Educational options:*** Awareness raising & integrating into education; Gender equity in education; Extension services; Sharing local & traditional knowledge; Participatory action research & social learning; Knowledge-sharing & learning platforms.	8.3-4, 9.4, 11.7, 12.3, 15.2-4, 22.4, 25.4, 28.4, 29.6, Table 25-2
		Informational options: Hazard & vulnerability mapping; Early warning & response systems; Systematic monitoring & remote sensing; Climate services; Use of indigenous climate observations; Participatory scenario development.	2.4, 5.5, 8.3-4, 9.4, 11.7, 15.2-4, 22.4, 23.5, 24.4, 25.8, 26.6, 26.8, 27.3, 28.2, 28.5, Table 25-2, Box 26-3
		Behavioral options: Household preparation & evacuation planning; Migration; Soil & water conservation; Storm drain clearance; Livelihood diversification; Changed cropping, livestock, & aquaculture practices; Reliance on social networks.	5.5, 7.5, 9.4, 11.7, 12.4, 22.3-4, 23.4, 23.7, 25.7, 26.5, 27.3, 29.6, Table SM24-7, Box 25-5
Transformation	**Spheres of change**	***Practical:*** Social & technical innovations, behavioral shifts, or institutional & managerial changes that produce substantial shifts in outcomes.	8.3, 20.5, Box 25-5
		Political: Changes in the political, social, cultural, & ecological systems or structures that currently contribute to risk & vulnerability or impede practical transformations.	14.2-3, 20.5, 25.4, Table 14-1
		Personal: Changes in individual & collective assumptions, beliefs, values, & worldviews that influence climate change responses.	14.2-3, 20.5, 25.4, Table 14-1
Mitigation	See WGIII AR5.		

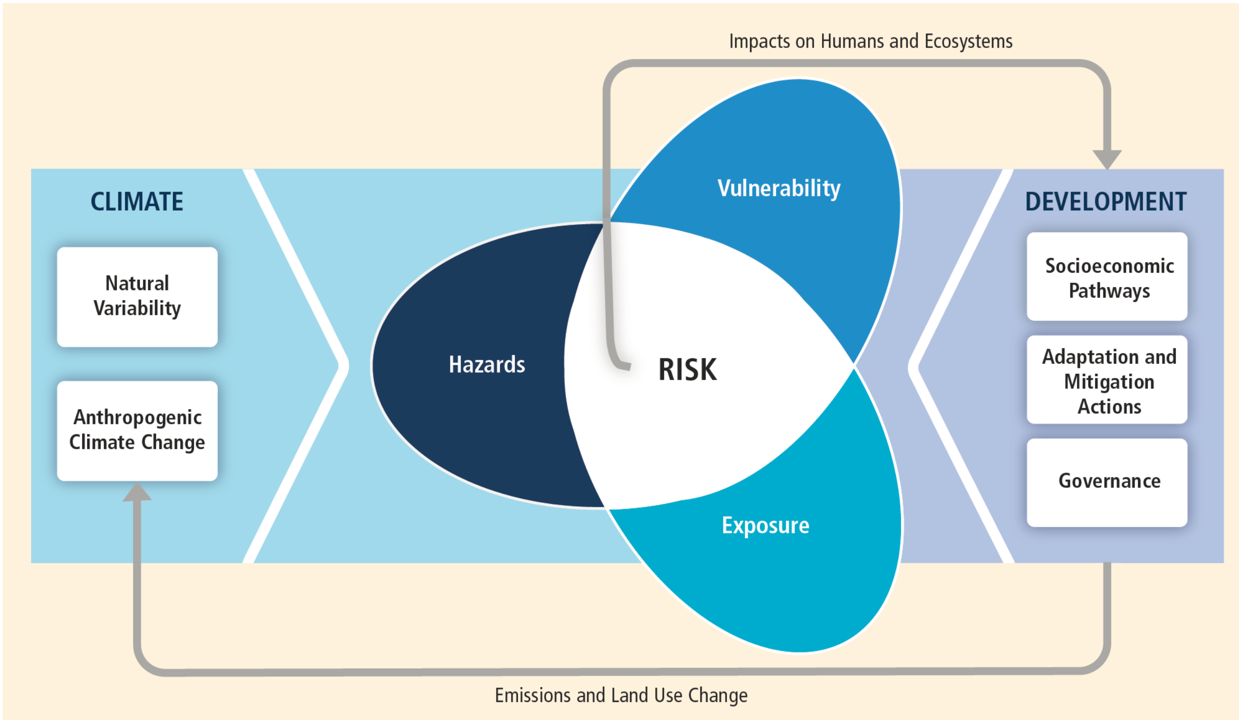

Impacts on Humans and Ecosystems
CLIMATE
Natural Variability
Anthropogenic Climate Change
Vulnerability
Hazards
RISK
Exposure
DEVELOPMENT
Socioeconomic Pathways
Adaptation and Mitigation Actions
Governance
Emissions and Land Use Change

Figure SPM.1.

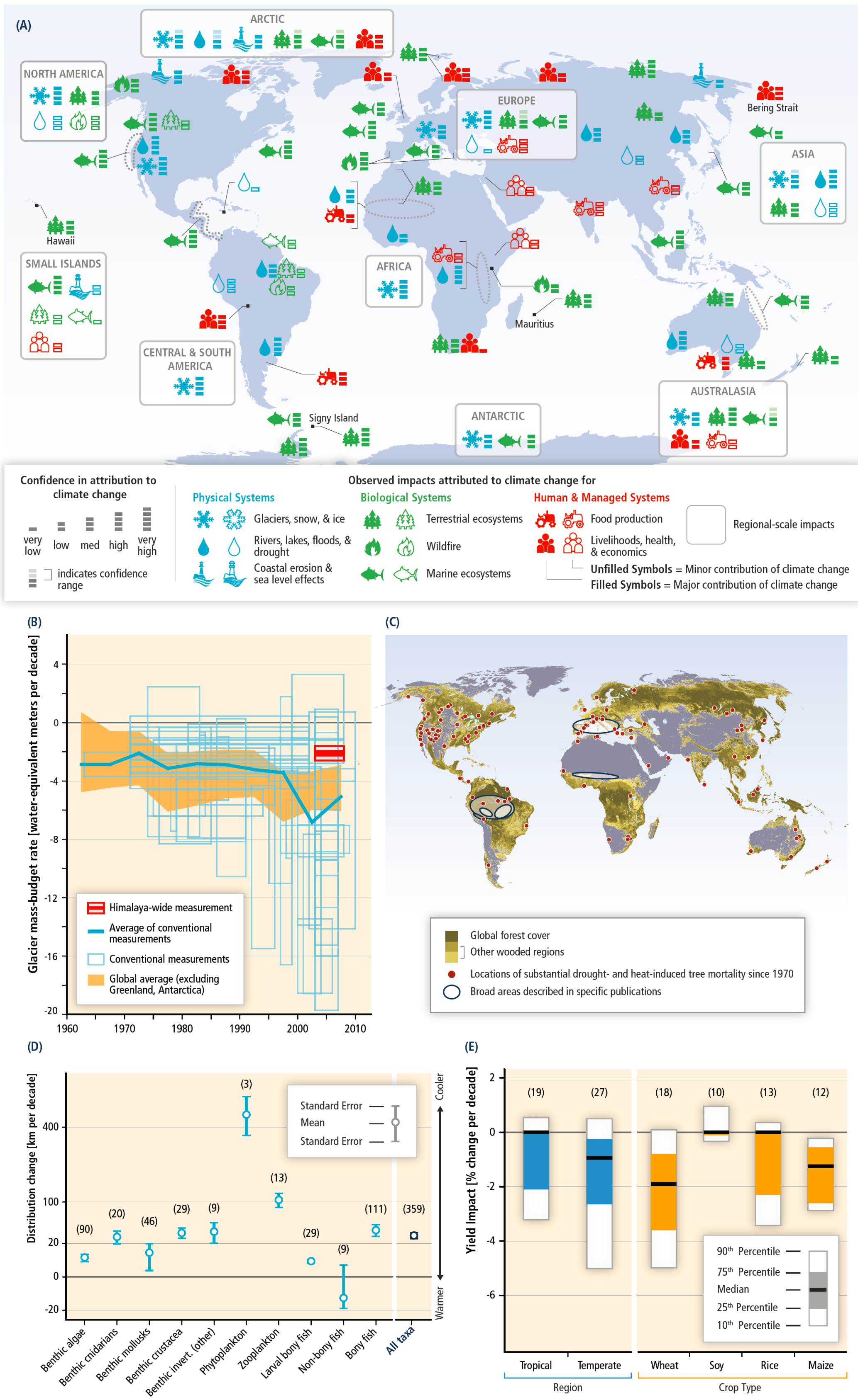

(A)
ARCTIC
NORTH AMERICA
EUROPE
ASIA
Bering Strait
Hawaii
SMALL ISLANDS
AFRICA
Mauritius
CENTRAL & SOUTH AMERICA
AUSTRALASIA
ANTARCTIC
Signy Island
Confidence in attribution to climate change
very low
low
med
high
very high
indicates confidence range
Observed impacts attributed to climate change for
Physical Systems
Glaciers, snow, & ice
Rivers, lakes, floods, & drought
Coastal erosion & sea level effects
Biological Systems
Terrestrial ecosystems
Wildfire
Marine ecosystems
Human & Managed Systems
Food production
Livelihoods, health, & economics
Regional-scale impacts
Unfilled Symbols = Minor contribution of climate change
Filled Symbols = Major contribution of climate change
(B)
Glacier mass-budget rate [water-equivalent meters per decade]
4
0
-4
-8
-12
-16
-20
1960
1970
1980
1990
2000
2010
Himalaya-wide measurement
Average of conventional measurements
Conventional measurements
Global average (excluding Greenland, Antarctica)
(C)
Global forest cover
Other wooded regions
Locations of substantial drought- and heat-induced tree mortality since 1970
Broad areas described in specific publications
(D)
Distribution change [km per decade]
400
100
20
0
-20
(90)
(20)
(46)
(29)
(9)
(3)
(13)
(29)
(9)
(111)
(359)
Standard Error
Mean
Standard Error
Cooler
Warmer
Benthic algae
Benthic cnidarians
Benthic mollusks
Benthic crustacea
Benthic invert. (other)
Phytoplankton
Zooplankton
Larval bony fish
Non-bony fish
Bony fish
All taxa
(E)
Yield Impact [% change per decade]
2
0
-2
-4
-6
(19)
(27)
(18)
(10)
(13)
(12)
90th Percentile
75th Percentile
Median
25th Percentile
10th Percentile
Tropical
Temperate
Region
Wheat
Soy
Rice
Maize
Crop Type

Figure SPM.2.

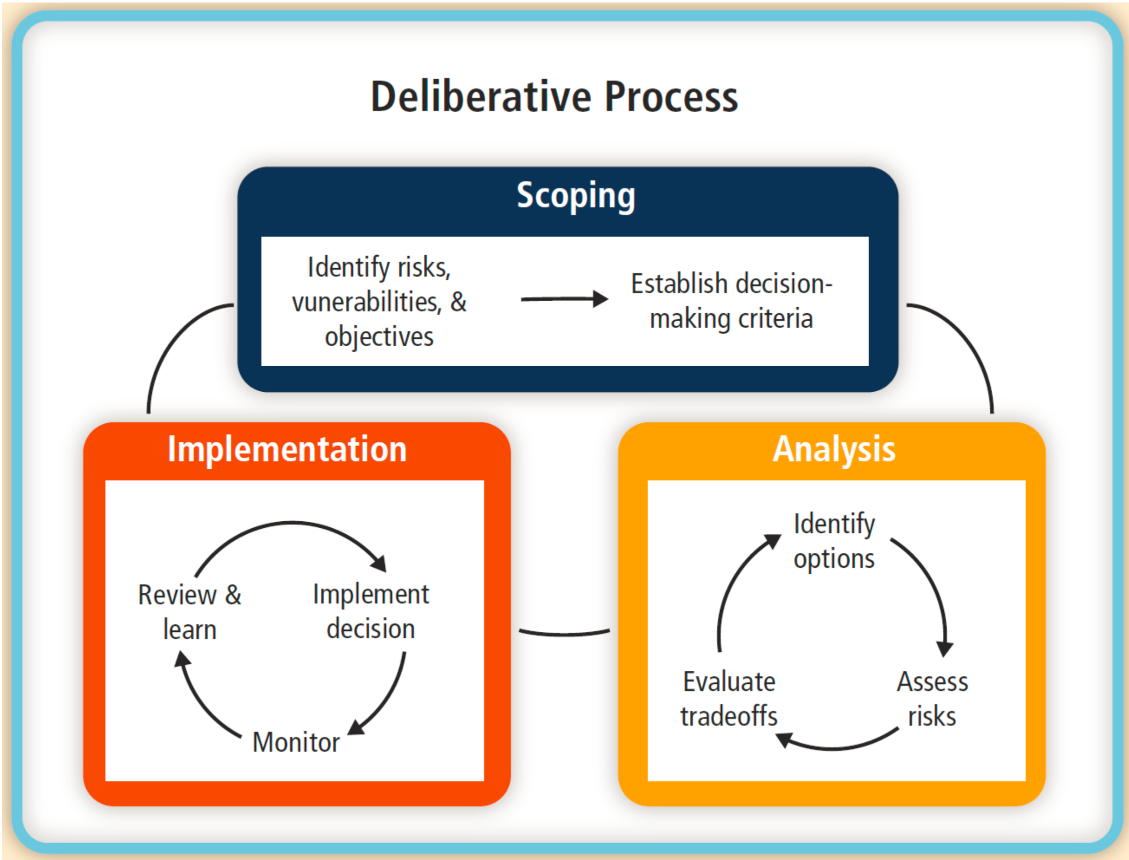

Deliberative Process
Scoping
Identify risks, vulnerabilities, & objectives
Establish decision-making criteria
Implementation
Review & learn
Implement decision
Monitor
Analysis
Identify options
Assess risks
Evaluate tradeoffs

Figure SPM.3.

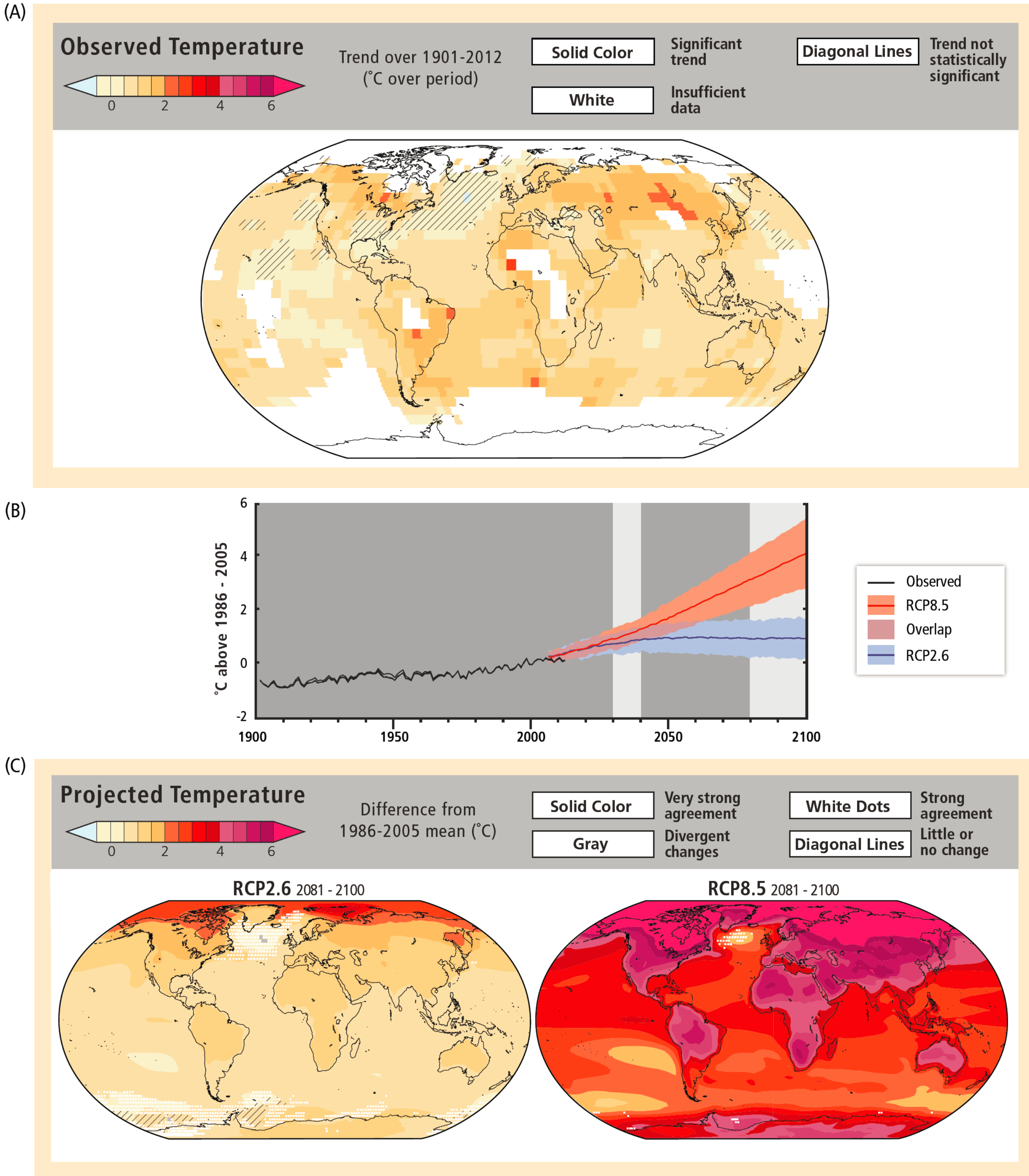
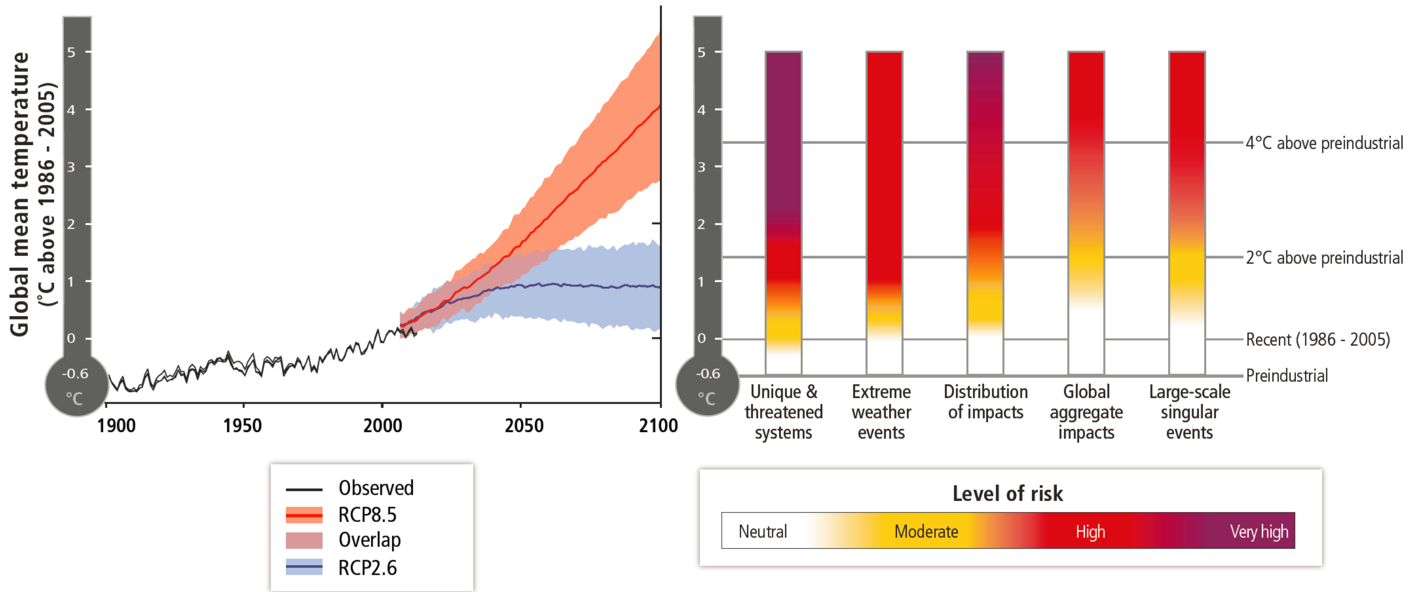

(A)
Observed Temperature
0 2 4 6
Trend over 1901-2012
(˚C over period)
Solid Color
Significant trend
White
Insufficient data
Diagonal Lines
Trend not statistically significant
(B)
°C above 1986 - 2005
6
4
2
0
-2
1900
1950
2000
2050
2100
Observed
RCP8.5
Overlap
RCP2.6
(C)
Projected Temperature
0 2 4 6
Difference from
1986-2005 mean (˚C)
Solid Color
Very strong agreement
Gray
Divergent changes
White Dots
Strong agreement
Diagonal Lines
Little or no change
RCP2.6 2081 - 2100
RCP8.5 2081 - 2100

Figure SPM.4.



Box SPM.4 Figure 1.

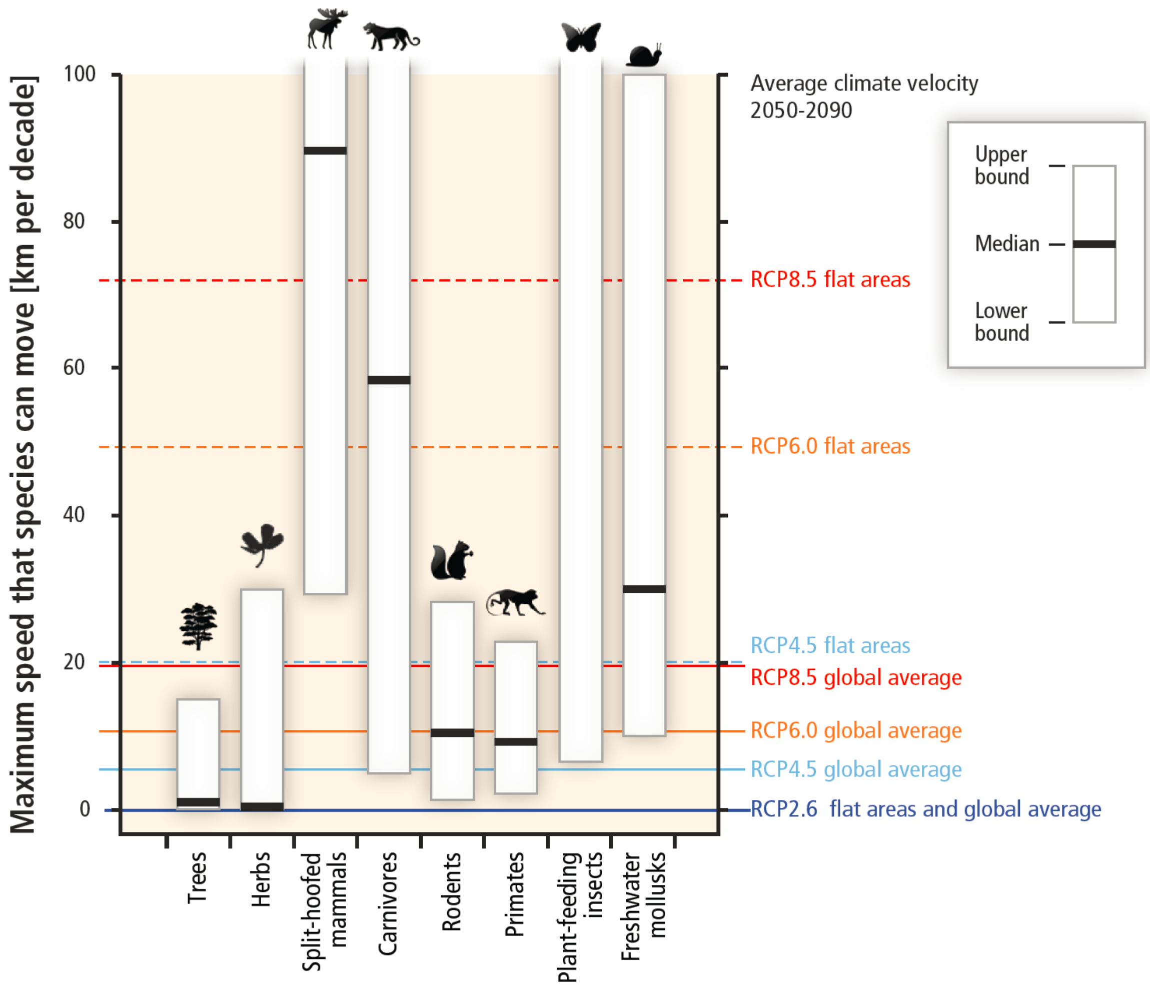
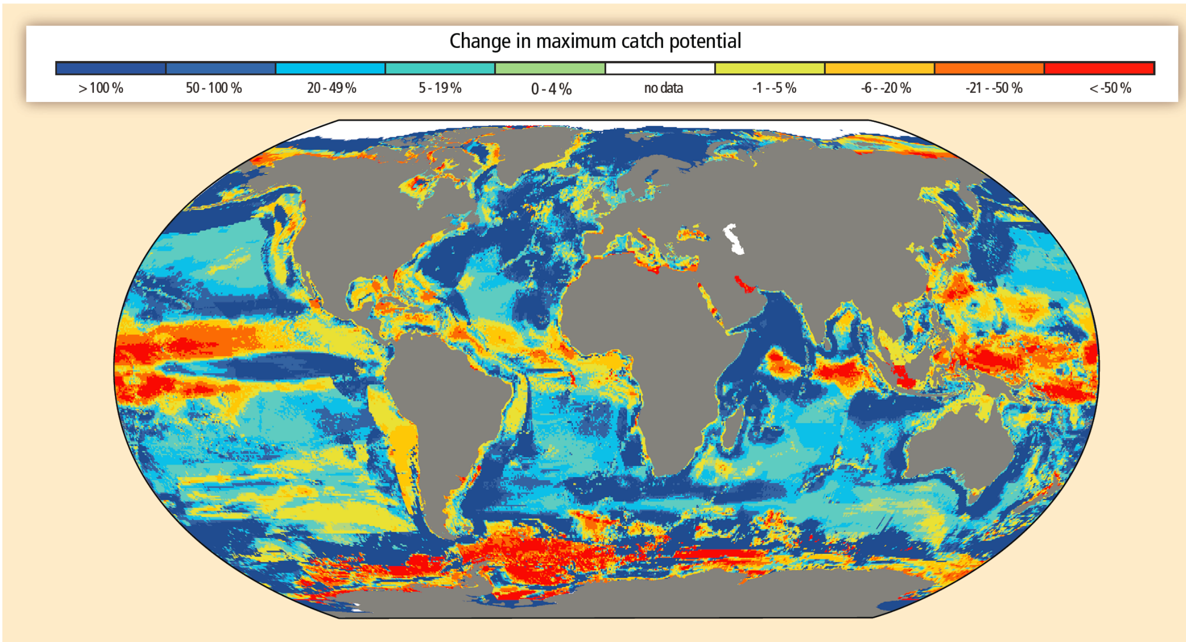

Maximum speed that species can move [km per decade]
100
80
60
40
20
0
Trees
Herbs
Split-hoofed mammals
Carnivores
Rodents
Primates
Plant-feeding insects
Freshwater mollusks
Average climate velocity 2050-2090
RCP8.5 flat areas
RCP6.0 flat areas
RCP4.5 flat areas
RCP8.5 global average
RCP6.0 global average
RCP4.5 global average
RCP2.6 flat areas and global average
Upper bound
Median
Lower bound

Figure SPM.5.

(A)



(B)

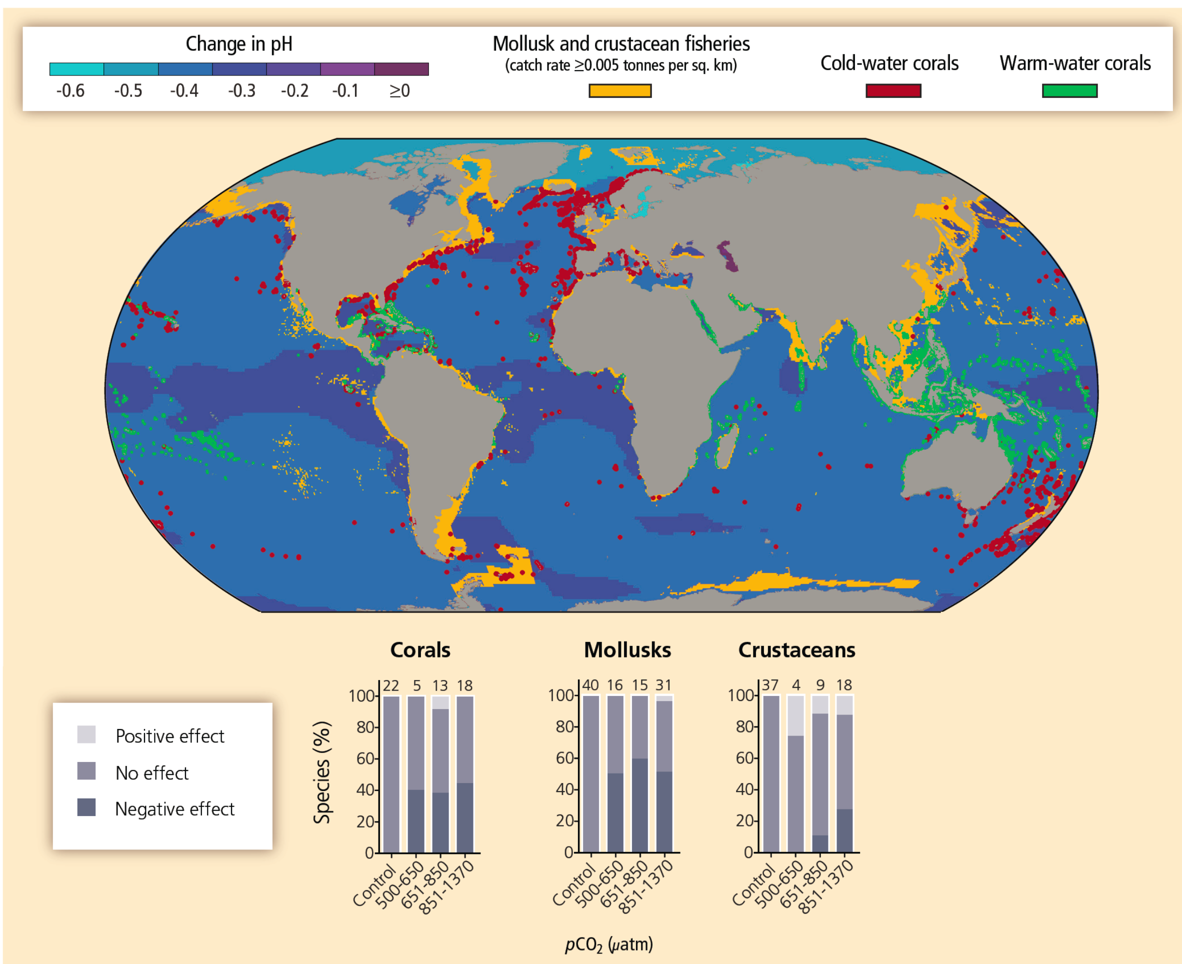
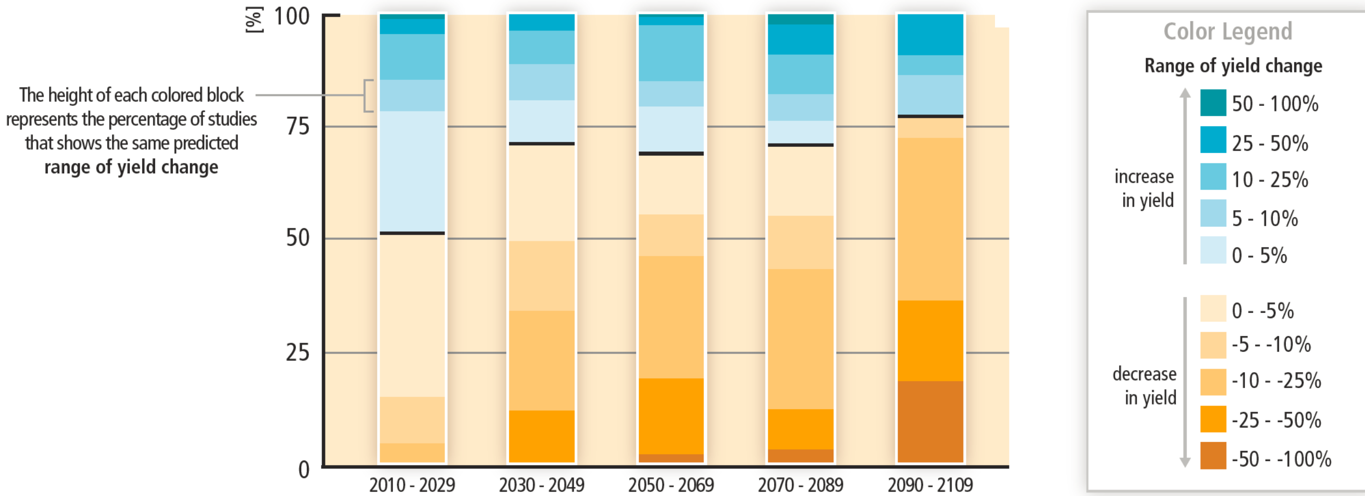


Figure SPM.6.



[%]
100
75
50
25
0
The height of each colored block represents the percentage of studies that shows the same predicted range of yield change
2010 - 2029
2030 - 2049
2050 - 2069
2070 - 2089
2090 - 2109
Color Legend
Range of yield change
increase in yield
50 - 100%
25 - 50%
10 - 25%
5 - 10%
0 - 5%
decrease in yield
0 - -5%
-5 - -10%
-10 - -25%
-25 - -50%
-50 - -100%

Figure SPM.7.

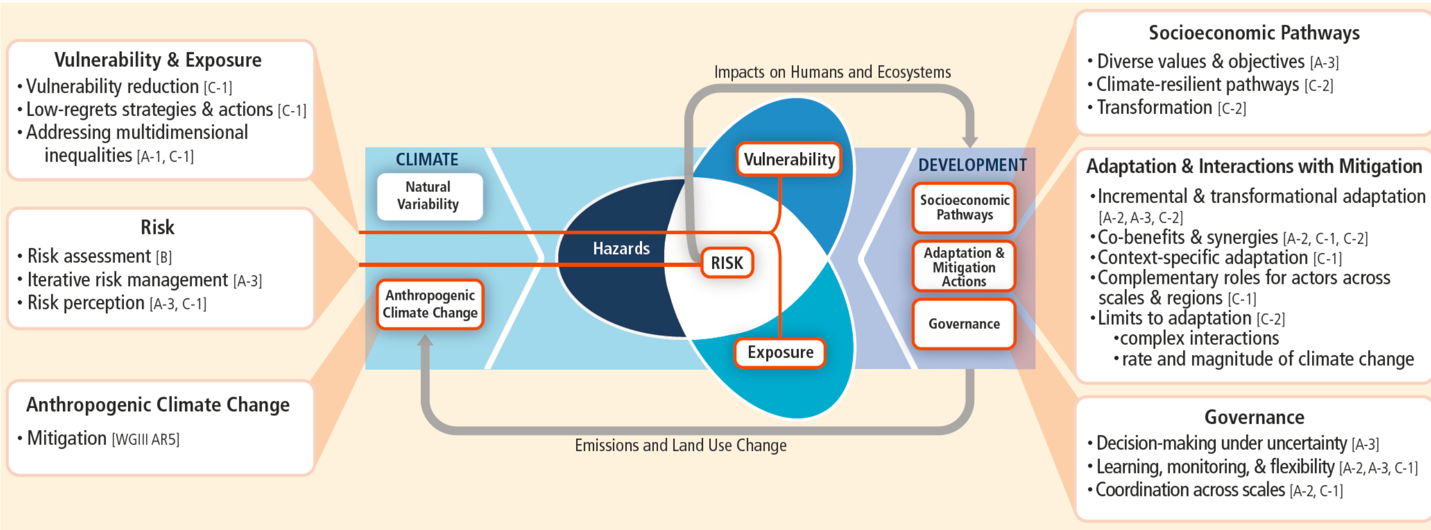

Vulnerability & Exposure
• Vulnerability reduction [C-1]
• Low-regrets strategies & actions [C-1]
• Addressing multidimensional inequalities [A-1, C-1]
Risk
• Risk assessment [B]
• Iterative risk management [A-3]
• Risk perception [A-3, C-1]
Anthropogenic Climate Change
• Mitigation [WGIII AR5]
CLIMATE
Natural Variability
Anthropogenic Climate Change
Impacts on Humans and Ecosystems
Hazards
Vulnerability
RISK
Exposure
Emissions and Land Use Change
DEVELOPMENT
Socioeconomic Pathways
Adaptation & Mitigation Actions
Governance
Socioeconomic Pathways
• Diverse values & objectives [A-3]
• Climate-resilient pathways [C-2]
• Transformation [C-2]
Adaptation & Interactions with Mitigation
• Incremental & transformational adaptation [A-2, A-3, C-2]
• Co-benefits & synergies [A-2, C-1, C-2]
• Context-specific adaptation [C-1]
• Complementary roles for actors across scales & regions [C-1]
• Limits to adaptation [C-2]
• complex interactions
• rate and magnitude of climate change
Governance
• Decision-making under uncertainty [A-3]
• Learning, monitoring, & flexibility [A-2, A-3, C-1]
• Coordination across scales [A-2, C-1]

Figure SPM.8.