Climate Change 2014: Impacts, Adaptation, and Vulnerability

TECHNICAL SUMMARY

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INTRODUCTION

Human interference with the climate system is occurring. [WGI AR5 2.2, 6.3, 10.3-6, 10.9] Climate change poses risks for human and natural systems (Figure TS.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. It recognizes that risks of climate change will vary across regions and populations, through space and time, dependent on myriad factors including the extent of mitigation and adaptation.

[INSERT FIGURE TS.1 HERE
Figure TS.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]]

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 across sectors and regions, highlighting where choices matter for reducing risks through mitigation and adaptation. Section C considers principles for effective adaptation and the broader interactions among adaptation, mitigation, and sustainable development.

Box TS.1 introduces the context of the WGII AR5, and Box TS.2 defines central concepts. To accurately convey the degree of certainty in key findings, the report relies on the consistent use of calibrated uncertainty language, introduced in Box TS.3. Chapter references in square brackets indicate support for findings, paragraphs of findings, figures, and tables in this summary.

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Box TS.1. Context for the Assessment

For the past two decades, IPCC's Working Group II has developed assessments of climate change impacts, adaptation, and vulnerability. The WGII AR5 builds from the WGII contribution to the IPCC's Fourth Assessment Report (WGII AR4), published in 2007, and the Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX), published in 2012. The WGII AR5 is presented in two volumes, reflecting an expanded literature basis and multidisciplinary approach, increased focus on societal impacts and responses, and continued comprehensive regional coverage. [1.1]

The number of scientific publications available for assessing climate change impacts, adaptation, and vulnerability more than doubled between 2005 and 2010, allowing for a more robust assessment that supports policymaking (*high confidence*). The diversity of the topics and regions covered has similarly expanded, as has the geographic distribution of the authors contributing to the knowledge base for climate change assessments (Box TS.1 Figure 1). Authorship of climate-change publications from developing countries has increased, although it still represents a small fraction of the total. The unequal distribution of publications presents a challenge to the production of a comprehensive and balanced global assessment. [1.1, Figure 1-1]

[INSERT BOX TS.1 FIGURE 1 HERE
Box TS.1 Figure 1: Number of climate-change publications listed in the Scopus bibliographic database. (A) Number of climate-change publications in English (as of July 2011) summed by country affiliation of all authors of the publications and sorted by region. Each publication can be counted multiple times (i.e., the number of different countries in the author affiliation list). (B) Number of climate-change publications in English with individual countries mentioned in title, abstract, or key words (as of July 2011) sorted by region for the decades 1981-1990, 1991-2000, and 2001-2010. Each publication can be counted multiple times if more than one country is listed. [Figure 1-1]]

Adaptation has emerged as a central area in climate change research, in country-level planning, and in implementation of climate change strategies (*high confidence*). The body of literature, including government and private sector reports, shows an increased focus on adaptation opportunities and the interrelations between adaptation, mitigation, and alternative sustainable pathways. The literature shows an emergence of studies on transformative processes that take advantage of synergies between adaptation planning, development strategies, social protection, and disaster risk reduction and management. [1.1]

As a core feature and innovation of IPCC assessment, major findings are presented with defined, calibrated language that communicates the strength of scientific understanding, including uncertainties and areas of disagreement (Box TS.3). Each finding is supported by a traceable account of the evaluation of evidence and agreement. [1.1, Box 1-1]

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Box TS.2. Terms Critical for Understanding the Summary

Core concepts defined in the WGII AR5 glossary and used throughout the report include the following terms. Reflecting progress in science, some definitions differ in breadth and focus from the definitions used in the AR4 and other IPCC reports.

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.

> ***Incremental adaptation:*** Adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale.
>
> ***Transformational adaptation:*** Adaptation that changes the fundamental attributes of a system in response to 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.

Resilience: The capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

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_____ START BOX TS.3 HERE _____

Box TS.3. Communication of the Degree of Certainty in Assessment Findings

Based on the Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties, the WGII AR5 relies on two metrics for communicating the degree of certainty in key findings:

- Confidence in the validity of a finding, based on the type, amount, quality, and consistency of evidence (e.g., data, mechanistic understanding, theory, models, expert judgment) and the degree of agreement. Confidence is expressed qualitatively.
- Quantified measures of uncertainty in a finding expressed probabilistically (based on statistical analysis of observations or model results, or both, and expert judgment).

Each finding has its foundation in evaluation of associated evidence and agreement. The summary terms to describe evidence are: *limited*, *medium*, or *robust*; and agreement: *low*, *medium*, or *high*. These terms are presented with some key findings. In many cases, assessment authors additionally evaluate their confidence about the validity of a finding, providing a synthesis of the evaluation of evidence and agreement. Levels of confidence include five qualifiers: *very low*, *low*, *medium*, *high*, and *very high*. Box TS.3 Figure 1 illustrates the flexible relationship between the summary terms for evidence and agreement and the confidence metric. For a given evidence and agreement statement, different confidence levels could be assigned, but increasing levels of evidence and degrees of agreement are correlated with increasing confidence.

[INSERT BOX TS.3 FIGURE 1 HERE
Box TS.3 Figure 1: Evidence and agreement statements and their relationship to confidence. The shading increasing towards the top right corner indicates increasing confidence. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality evidence. [Figure 1-3]]

When assessment authors evaluate the likelihood, or probability, of some well-defined outcome having occurred or occurring in the future, a finding can include likelihood terms (see below) or a more precise presentation of probability. Use of likelihood is not an alternative to use of confidence. Unless otherwise indicated, findings assigned a likelihood term are associated with *high* or *very high* confidence.

Term	**Likelihood of the outcome**
Virtually certain	99–100% probability
Extremely likely	95– 100% probability
Very likely	90–100% probability
Likely	66–100% probability
More likely than not	>50–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Extremely unlikely	0–5% probability
Exceptionally unlikely	0–1% probability

Where appropriate, findings are also formulated as statements of fact without using uncertainty qualifiers.

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]

_____ END BOX TS.3 HERE _____

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

This section presents observed effects of climate change, building from understanding of vulnerability, exposure, and climate-related hazards as determinants of impacts. The section considers the factors, including development and non-climatic stressors, that influence vulnerability and exposure, evaluating the sensitivity of systems to climate change. The section also identifies challenges and options based on adaptation experience, looking at what has motivated previous adaptation actions in the context of climate change and broader objectives. It examines current understanding of decision-making as relevant to climate change.

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.[1] This conclusion is strengthened by more numerous and improved observations and analyses since the AR4. For many natural systems on land and in the ocean, new or stronger evidence exists for substantial and wide-ranging climate change impacts. For human systems, effects of changing social and economic factors have often been larger than climate-change-related impacts, but despite this, some impacts in human systems have also been attributed to climate change. In many regions, impacts on natural and human systems are now detected even in the presence of strong confounding factors such as pollution or land use change. See Table TS.1 and Figure TS.2 for a summary of observed impacts and indicators of a changing climate, illustrating broader trends presented in this section. Most reported impacts of climate change are attributed to warming and/or to shifts in precipitation patterns. There is also emerging evidence of impacts of ocean acidification. Few robust attribution studies and meta-analyses have linked impacts in physical and biological systems to anthropogenic climate change. [18.1, 18.3-6]

[INSERT TABLE TS.1 HERE
Table TS.1: Examples of observed impacts attributed to climate change with *medium* (M) or *high* (H) confidence, indicating the relative contribution of climate change (major [C] or minor [c]) to the observed change, for natural and human systems across eight major world regions over the past several decades. [Tables 18-5, 18-6, 18-7, 18-8, and 18-9]]

[INSERT FIGURE TS.2 HERE
Figure TS.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]]

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 TS.4. Vulnerability and exposure vary over time and across geographic contexts. Changes in poverty or socioeconomic status, ethnic composition, age structure, and governance have had a significant influence on the outcome of past crises associated with climate-related hazards. [8.2, 9.3, 12.2, 13.1-2, 14.1-3, 19.6, 26.8, Box CC-GC]

[1] 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.

Impacts from recent extreme climatic events, such as heat waves, droughts, floods, and wildfires, show significant vulnerability and exposure of some ecosystems and many human systems to climate variability (*very high confidence*). Impacts include the alteration of ecosystems and of food production, damage to infrastructure and settlements, morbidity and mortality, and consequences for mental health and human well-being. These experiences are consistent with a significant adaptation deficit in developing and developed countries for some sectors and regions. The following examples illustrate impacts of extreme weather and climate events experienced across regional contexts.

- In Africa, extreme weather and climate events including droughts and floods have significant impacts on economic sectors, natural resources, ecosystems, livelihoods, and human health. The floods of the Zambezi River in Mozambique in 2008, for example, displaced 90,000 people, and along the Zambezi River Valley, with approximately 1 million people living in the flood-affected areas, temporary displacement is taking on permanent characteristics. [22.3-4, 22.6]
- Recent floods in Australia and New Zealand caused severe damage to infrastructure and settlements and 35 deaths in Queensland alone (2011). The Victorian heat wave (2009) increased heat-related morbidity and was associated with more than 300 excess deaths, while intense bushfires destroyed over 2,000 buildings and led to 173 deaths. Widespread drought in south-east Australia (1997-2009) and many parts of New Zealand (2007-2009; 2012-13) resulted in economic losses (e.g., regional GDP in the southern Murray-Darling Basin was below forecast by about 5.7% in 2007/08, and New Zealand lost about NZ$3.6b in direct and off-farm output in 2007-09). [3.2, 13.2, 25.6, 25.8, Table 25-1, Boxes 25-5, 25-6, 25-8]
- In Europe, extreme weather events currently have significant impacts in multiple economic sectors as well as adverse social and health effects (*high confidence*). [Table 23-1]
- In North America, most economic sectors and human systems have been affected by and have responded to extreme weather, including hurricanes, flooding, and intense rainfall (*high confidence*). Extreme heat events currently result in increases in mortality and morbidity (*very high confidence*), with impacts that vary by age, location, and socioeconomic factors (*high confidence*). Extreme coastal storm events have caused excess mortality and morbidity, particularly along the east coast of the United States, and the gulf coast of both Mexico and the United States. Much North American infrastructure is currently vulnerable to extreme weather events (*medium confidence*), with deteriorating water-resource and transportation infrastructure particularly vulnerable (*high confidence*). [3.2, 26.6-7, Figure 26-2]
- In the Arctic, extreme weather events have had direct and indirect adverse health effects for residents (*high confidence*). [28.2]

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Box TS.4. Multidimensional Inequality and Vulnerability to Climate Change

People who are socially, economically, culturally, politically, institutionally, or otherwise marginalized in society 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, race/ethnicity, age, and (dis)ability. See Box TS.4 Figure 1. Understanding differential capacities and opportunities of individuals, households, and communities requires knowledge of these intersecting social drivers, which may be context-specific and clustered in diverse ways (e.g., class and ethnicity in one case, gender and age in another). Few studies depict the full spectrum of these intersecting social processes and the ways in which they shape multidimensional vulnerability to climate change.

Examples of inequality-driven impacts and risks of climate change and climate change responses (*medium evidence, high agreement*):

- Privileged members of society can benefit from climate change impacts and response strategies, due to their flexibility in mobilizing and accessing resources and positions of power, often to the detriment of others. [13.2-3, 22.4, 26.8]
- Differential impacts on men and women arise from distinct roles in society, the way these roles are enhanced or constrained by other dimensions of inequality, risk perceptions, and the nature of response to hazards. [8.2, 9.3, 11.3, 12.2, 13.2, 18.4, 22.4, Box CC-GC]

- Both male and female deaths are recorded after flooding, affected by socioeconomic disadvantage, occupation, and culturally imposed expectations to save lives. While women are generally more sensitive to heat stress, more male workers are reported to have died largely due to responsibilities related to outdoor and indoor work. [11.3, 13.2, Box CC-GC]
- Women often experience additional duties as laborers and caregivers as a result of extreme weather events and climate change, as well as responses (e.g., male outmigration), while facing more psychological and emotional distress, reduced food intake, adverse mental health outcomes due to displacement, and in some cases increasing incidences of domestic violence. [9.3-4, 12.4, 13.2, Box CC-GC]
- Children and the elderly are often at higher risk due to narrow mobility, susceptibility to infectious diseases, reduced caloric intake, and social isolation. While adults and older children are more severely affected by some climate-sensitive vector-borne diseases such as dengue, young children are more likely to die from or be severely compromised by diarrheal diseases and floods. The elderly face disproportional physical harm and death from heat stress, droughts, and wildfires. [8.2, 10.9, 11.1, 11.4-5, 13.2, 22.4, 23.5, 26.6]
- In most urban areas, low-income groups, including migrants, face large climate change risks because of poor-quality, insecure, and clustered housing, inadequate infrastructure, and lack of provision for health care, emergency services, flood exposure, and measures for disaster risk reduction. [8.1-2, 8.4-5, 12.4, 22.3, 26.8]
- People disadvantaged by race or ethnicity, especially in high-income countries, experience more harm from heat stress, often due to low economic status and poor health conditions, and displacement after extreme events. [11.3, 12.4, 13.2]
- Livelihoods and lifestyles of indigenous peoples, pastoralists, and fisherfolk, often dependent on natural resources, are highly sensitive to climate change and climate change policies, especially those that marginalize their knowledge, values, and activities. [9.3, 11.3, 12.3, 14.2, 22.4, 25.8, 26.8, 28.2]
- Disadvantaged groups without access to land and labor, including female-headed households, tend to benefit less from climate change response mechanisms (e.g., CDM, REDD+, large-scale land acquisition for biofuels, and planned agricultural adaptation projects). [9.3, 12.2, 12.5, 13.3, 22.4, 22.6]

[INSERT BOX TS.4 FIGURE 1 HERE
Box TS.4 Figure 1: Multidimensional vulnerability driven by intersecting dimensions of inequality. Vulnerability increases when people's capacities and opportunities to adapt to climate change and adjust to climate change responses are diminished. [Figure 13-5]]

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Freshwater resources

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*) (Figure TS.2B). Climate change has caused permafrost warming and thawing in high-latitude and high-elevation mountain regions. There is no evidence that surface water and groundwater drought frequency has changed over the last few decades, although impacts of drought have increased mostly due to increased water demand. [3.2, 4.3, 18.3, 18.5, 24.4, 25.5, 26.2, 28.2, Tables 3-1 and 25-1, Figures 18-2 and 26-1]

Terrestrial and freshwater ecosystems

Many terrestrial plant and animal species have shifted their ranges and seasonal activities and altered their abundance in response to past climate change, and they are doing so now in many regions (*high confidence*). Increased tree mortality, observed in many places worldwide, has been attributed to climate change in some regions (Figure TS.2C). Increases in the frequency or intensity of ecosystem disturbances such as droughts, wind-storms, fires, and pest outbreaks have been detected in many parts of the world and in some cases are attributed to climate change (*medium confidence*). 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*). [4.2-4, 18.3, 18.5, 22.3, 25.6, 26.4, 28.2, Figure 4-10, Boxes 4-2, 4-3, 4-4, and 25-3]

Coastal systems and low-lying areas

Coastal systems are particularly sensitive to changes in sea level and ocean temperature and to ocean acidification (*very high confidence*). Coral bleaching and species range shifts have been attributed to changes in ocean temperature. For many other coastal changes, the impacts of climate change are difficult to identify given other human-related drivers (e.g. land-use change, coastal development, pollution) (*robust evidence, high agreement*). [5.3-5, 18.3, 25.6, 26.4, Box 25-3]

Marine systems

Warming has caused and will continue to cause shifts in the abundance, geographic distribution, migration patterns, and timing of seasonal activities of species (*very high confidence*), paralleled by reduction in maximum body sizes in warming waters (*medium confidence*). This has resulted and will further result in changing interactions between species, including competition and predator-prey dynamics (*high confidence*). Numerous observations over the last decades in all ocean basins show global-scale changes including large-scale distribution shifts of species (*very high confidence*) and altered ecosystem composition (*high confidence*) on multidecadal time scales, tracking climate trends. Many fishes, invertebrates, and phytoplankton have shifted their distribution and/or abundance poleward and/or to deeper, cooler waters (Figure TS.2D). Some warm-water corals and their reefs have responded to warming with species replacement, bleaching, and decreased coral cover causing habitat loss. Few field observations to date demonstrate biological responses attributable to anthropogenic ocean acidification, as in many places these responses are not yet outside their natural variability and may be influenced by confounding local or regional factors. See also Box TS.7. Natural climate change at rates slower than current anthropogenic change has led to significant ecosystem shifts, including species emergences and extinctions, in the past millions of years. [5.4, 6.1, 6.3-5, 18.3, 18.5, 22.3, 25.6, 26.4, 30.4-5, Boxes 25-3, CC-OA, CC-CR, and CC-MB]

Vulnerability of most marine organisms to warming is set by their physiology which defines their limited temperature ranges and hence their thermal sensitivity (*high confidence*). See Figure TS.3. Temperature defines the geographic distribution of many species and their responses to climate change. Shifting temperature means and extremes alter habitat (e.g., sea ice and coastal habitat), and cause changes in abundance through local extinctions and latitudinal expansions or shifts of up to hundreds of kilometers per decade (*very high confidence*). Although genetic adaptation occurs (*medium confidence*), the capacity of fauna and flora to compensate for or keep up with the rate of ongoing thermal change is limited (*low confidence*). [6.3, 6.5]

Oxygen minimum zones are progressively expanding in the tropical Pacific, Atlantic, and Indian Oceans, due to reduced ventilation and O_2 solubilities in more stratified oceans at higher temperatures (*high confidence*). In combination with human activities that increase the productivity of coastal systems, hypoxic areas ("dead zones") are increasing in number and size. Regional exacerbation of hypoxia causes shifts to hypoxia-tolerant biota and reduces habitat for commercially relevant species, with implications for fisheries. [6.1, 6.3, 30.3, 30.5-6; WGI AR5 3.8]

[INSERT FIGURE TS.3 HERE
Figure TS.3: Temperature specialization of species (A), which is influenced by other factors such as oxygen, causes warming-induced distribution shifts (B), for example, the northward expansion of warm-temperate species in the Northeast Atlantic (C). These distribution changes depend on species-specific physiology and ecology. Detailed introduction of each panel follows: (A) The temperature tolerance range and performance levels of an organism are described by its performance curve. Each performance (e.g., exercise, growth, reproduction) is highest at optimum temperature (T_{opt}) and lower at cooler or warmer temperatures. Surpassing temperature thresholds (T_p) means going into time-limited tolerance, and more extreme temperature changes lead to exceedance of thresholds that cause metabolic disturbances (T_c) and ultimately onset of cell damage (T_d). These thresholds for an individual can shift (horizontal arrows), within limits, between summer and winter (seasonal acclimatization) or when the species adapts to a cooler or warmer climate over generations (evolutionary adaptation). Under elevated CO_2 levels (ocean acidification) or low oxygen, thermal windows narrow (dashed grey curves). (B) During climate warming, a species follows its normal temperatures as it moves or is displaced, typically resulting in a poleward shift of the biogeographic range (exemplified for the northern hemisphere). The polygon delineates the distribution range in space and seasonal time; the level of grey denotes abundance. (C) Long-term changes in the mean number of warm-temperate pseudo-oceanic copepod species in the Northeast Atlantic from 1958 to 2005. [Figures 6-5, 6-7, and 6-8]]

Food production systems and food security

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*). Production of wheat and maize globally and in many regional systems has been impacted by climate change over the past several decades (*medium confidence*). The impacts of climate change on rice and soybean have been small in major production regions and globally. See Figure TS.2E. Recent periods of rapid food and cereal price increases have indicated that current markets in key producing regions are sensitive to climate extremes (*high confidence*). Crop yields have a large negative sensitivity to extreme daytime temperatures around 30°C, throughout the growing season. CO_2 has stimulatory effects on crop yields in most cases, and elevated tropospheric ozone has damaging effects. Interactions among CO_2 and ozone, mean temperature, extremes, water, and nitrogen are non-linear and difficult to predict (*medium confidence*). [7.3, 18.4, 22.3, 24.4, 26.5, Figures 7-2, 7-3, and 7-7, Box 25-3]

Urban areas

Urban areas hold more than half the world's population and most of its built assets and economic activities. A high proportion of the population and economic activities at risk from climate change are in urban areas, and a high proportion of global greenhouse gas emissions are generated by urban-based activities and residents. Cities are composed of complex inter-dependent systems that can be leveraged to support climate change adaptation via effective city governments supported by cooperative multi-level governance (*medium confidence*). This can enable synergies with infrastructure investment and maintenance, land-use management, livelihood creation, and ecosystem services protection. [8.1, 8.3-4]

Rapid urbanization and growth of large cities in low- and middle-income countries have been accompanied by expansion of highly vulnerable urban communities living in informal settlements, many of which are on land exposed to extreme weather (*medium confidence*). [8.2-3]

Rural areas

Climate change in rural areas will take place in the context of many important economic, social, and land-use trends (*very high confidence*). In different regions, absolute rural populations have peaked or will peak in the next few decades. The proportion of the rural population depending on agriculture is varied across regions, but declining everywhere. Poverty rates in rural areas are higher than overall poverty rates, but also falling more sharply, and the proportions of population in extreme poverty accounted for by rural people are also falling: in both cases with the exception of Sub-Saharan Africa, where these rates are rising. Accelerating globalization, through migration, labor linkages, regional and international trade, and new information and communication technologies, is bringing about economic transformation in rural areas of both developing and developed countries. [9.3, Figure 9-2]

For rural households and communities, access to land and natural resources, flexible local institutions, knowledge and information, and livelihood strategies can contribute to resilience to climate change (*high confidence*). Especially in developing countries, rural people are subject to multiple non-climatic stressors, including under-investment in agriculture, problems with land and natural resource policy, and processes of environmental degradation (*very high confidence*). In developed countries, there are important shifts towards multiple uses of rural areas, especially leisure uses, and new rural policies based on the collaboration of multiple stakeholders, the targeting of multiple sectors, and a change from subsidy-based to investment-based policy. [9.3, 22.4, Table 9-3]

Key economic sectors and services

Economic losses due to extreme weather events have increased globally, mostly due to increase in wealth and exposure, with a possible influence of climate change (*low confidence* in attribution to climate change). Flooding can have major economic costs, both in term of impacts (e.g., capital destruction, disruption) and adaptation (e.g., construction, defensive investment) (*robust evidence, high agreement*). Since the mid-20th century, socioeconomic losses from flooding have increased mainly due to greater exposure and vulnerability (*high confidence*). [3.2, 3.4, 10.3, 18.4, 23.2-3, 26.7, Figure 26-2, Box 25-7]

Human health

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*). Local changes in temperature and rainfall have altered distribution of some water-borne illnesses and disease vectors and have reduced food production for some vulnerable populations (*medium confidence*). [11.4-6, 18.4, 22.3, 24.4, 25.8, 26.6, 28.2]

The health of human populations is sensitive to shifts in weather patterns and other aspects of climate change (*very high confidence*). These effects occur directly, due to changes in temperature and precipitation and in the occurrence of heat waves, floods, droughts, and fires. Health may be damaged indirectly by climate-change-related ecological disruptions, such as crop failures or shifting patterns of disease vectors, or by social responses to climate change, such as displacement of populations following prolonged drought. Variability in temperatures is a risk factor in its own right, over and above the influence of average temperatures on heat-related deaths. [11.4, 28.2]

Human security

Challenges for vulnerability reduction and adaptation actions are particularly high in regions that have shown severe difficulties in governance (*high confidence*). 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. [12.5, 19.4, 19.6]

Livelihoods and poverty

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. Urban and rural transient poor who face multiple deprivations can slide into chronic poverty as a result of extreme events, or a series of events, when unable to rebuild their eroded assets (*limited evidence, high agreement*). Limited positive observed impacts on poor people include isolated cases of social asset accumulation, agricultural diversification, disaster preparedness, and collective action. [9.3, 11.3, 13.1-3, 22.4, 24.4, 26.8]

Livelihoods of indigenous peoples in the Arctic have been altered by climate change, through impacts on food security and traditional and cultural values (*medium confidence*). There is emerging evidence of climate change impacts on livelihoods of indigenous people in other regions. [18.4, Table 18-9, Box 18-5]

A-2. Adaptation Experience

This section focuses on adaptive human responses to climate change and its impacts. People cope with climate variability, extremes, and change, and they manage risks through adaptation. Adaptive human responses can be motivated by observed and projected climate change impacts and by broader vulnerability-reduction and development objectives, such as reducing existing adaptation deficits to current climate.

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. Governments at various scales are starting to develop adaptation plans and policies. Selection of adaptation options continues to emphasize incremental adjustments and co-benefits and is starting to emphasize flexibility and learning (*medium evidence, medium agreement*). [4.4, 5.5, 6.4, 8.3, 9.4, 11.7, 14.1, 14.3, 15.2-4, 17.2-3, 22.3-5, 23.7, 25.4, 25.10, 26.8-9, 27.3, 30.6, Boxes 25-1, 25-2, 25-9, and CC-EA]

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*). Vulnerability indicators define, quantify, and weight aspects of vulnerability across regional units, but methods of constructing indices are subjective, often lack transparency, and can be difficult to interpret. There are conflicting views on the choice of adaptation metrics, given differing values placed on needs and outcomes, many of which cannot be captured in a comparable way by metrics. Indicators proving most useful for policy learning are those that track not just process and implementation, but also the extent to which targeted outcomes are occurring. Multi-metric evaluations including risk and uncertainty are increasingly used, an evolution from a previous focus on cost-benefit analysis and identification of "best economic adaptations" (*high confidence*). Adaptation assessments best suited to delivering effective adaptation measures often include both top-down assessments of biophysical climate changes and bottom-up assessments of vulnerability targeted towards local solutions to globally derived risks and towards particular decisions. [4.4, 14.4-5, 15.2-3, 17.2-3, 21.3, 21.5, 22.4, 25.4, 25.10, 26.8-9, Box CC-EA]

Specific examples of adaptation actions across regions and contexts include the following:

- Urban adaptation has emphasized city-based disaster risk management such as early warning systems and infrastructure investments; ecosystem-based adaptation and green roofs; enhanced storm and wastewater management; urban and peri-urban agriculture improving food security; enhanced social protection; and good-quality, affordable, and well-located housing (*high confidence*). [8.3-4, 15.4, 26.8, Boxes 25-9, CC-UR, and CC-EA]
- There is a growing body of literature on adaptation practices in both developed- and developing-country rural areas, including documentation of practical experience in agriculture, water, forestry, and biodiversity and, to a lesser extent, fisheries (*very high confidence*). Public policies supporting decision-making for adaptation in rural areas exist in developed and, increasingly, developing countries, and there are also examples of private adaptations led by individuals, companies, and NGOs (*high confidence*). Adaptation constraints, particularly pronounced in developing countries, result from lack of access to credit, land, water, technology, markets, information, and perceptions of the need to change. [9.4, 17.3, Tables 9-7 and 9-8]
- In Africa, most national governments are initiating governance systems for adaptation (*high confidence*). Progress on national and sub-national policies and strategies has initiated the mainstreaming of adaptation into sectoral planning, but evolving institutional frameworks cannot yet effectively co-ordinate the range of adaptation initiatives being implemented. Disaster risk management, social protection, adjustments in technologies and infrastructure, ecosystem-based approaches, conservation agriculture, and livelihood diversification are reducing vulnerability, but largely in isolated initiatives. [11.7, 22.4, Box CC-EA]
- In Europe, adaptation policy has been developed at international (EU), national, and local government levels, with limited systematic information on current implementation or effectiveness (*high confidence*). Some adaptation planning has been integrated into coastal and water management and into disaster risk management, but there is *limited evidence* of adaptation planning in rural development or land-use planning. [11.7, 23.7, Box 23-3]
- In Asia, community-based approaches are a means to address poverty and livelihoods as well as facilitate integration of disaster risk reduction, development, and climate change adaptation (*limited evidence, high agreement*). Adaptation practices have sometimes provided unexpected livelihood benefits, as with the introduction of traditional flood mitigation measures in China, which have led to reductions in the physical and economic vulnerabilities of communities. Adaptation has also been expedited though integrated water resource management. [11.7, 24.4]
- In Australasia, planning for sea-level rise and, in southern Australia, for reduced water availability is becoming widely adopted, although implementation of specific policies remains piecemeal, subject to political changes, and open to legal challenges (*high confidence*). Adaptive capacity is generally high in many human systems, but implementation faces major constraints especially for transformational responses at local and community levels. [25.4, 25.10, Table 25-2, Boxes 25-1, 25-2, and 25-9]
- 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 (*high confidence*). [26.8-9]
- In Central and South America, ecosystem-based adaptation practices, such as adaptive management and establishment of protected areas, conservation agreements, and community management of natural areas, are

increasingly common, with potential for balancing biodiversity conservation, improving livelihoods, and preserving traditional cultures (*high confidence*). [27.3]

- 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 (*high confidence*). [28.2, 28.4]
- In small islands, diverse physical and human attributes and their sensitivity to climate-related drivers have been inconsistently integrated into adaptation planning (*high confidence*). [Table 29-3, Figure 29-1]
- Observed coastal adaptation includes major projects (e.g., Thames Estuary, Venice Lagoon, Delta Works) and specific practices in some countries (e.g., Netherlands, Australia, Bangladesh) (*high confidence*). [5.5, 7.3, 15.4, Box CC-EA]
- Ocean adaptation strategies beyond coastal areas are generally poorly developed (*high confidence*). [30.6]

Table TS.2 presents examples of how climate extremes and change, as well as exposure and vulnerability at the scale of risk management, shape adaptation actions and approaches to reducing vulnerability and enhancing resilience.

[INSERT TABLE TS.2 HERE
Table TS.2: Illustrative examples of adaptation experience, as well as approaches to reducing vulnerability and enhancing resilience. Adaptation actions can be influenced by climate variability, extremes, and change, and by exposure and vulnerability at the scale of risk management. Many examples and case studies demonstrate complexity at the level of communities or specific regions within a country. It is at this spatial scale that complex interactions between vulnerability, exposure, and climate change come to the fore. [Table 21-4]]

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 TS.4. 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. [2.1-4, 3.6, 14.1-5, 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]

[INSERT FIGURE TS.4 HERE
Figure TS.4: Illustration of iterative risk management. [Figure 2-1]]

The benefits of mitigation and adaptation occur over different timeframes (*high confidence*). Figure TS.5 illustrates projected climate futures under scenarios RCP2.6 and 8.5, along with observed temperature and precipitation changes. Projected global temperature increase over the next few decades is similar across emission scenarios. [WGI AR5 11.3] 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. [WGI AR5 12.4 and Table SPM.2] For this longer-term era of climate options, near-term and ongoing mitigation and adaptation, as well as development pathways, will determine the risks of climate change. Present-day choices thus affect the risks of climate change throughout the 21st century. [2.5, 21.2-3, 21.5, Box CC-RC]

[INSERT FIGURE TS.5 HERE
Figure TS.5: Observed and projected changes in annual average temperature (A) and precipitation (B). (A, top panel) Observed temperature trends from 1901-2012 determined by linear regression. [WGI AR5 Figures SPM.1 and 2.21] (B, top panel) Observed precipitation change from 1951-2010 determined by linear regression. [WGI AR5 Figure SPM.2] For observed temperature and precipitation, 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. (A, middle panel) 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] (A and B, bottom panel) CMIP5 multi-model mean projections of annual average temperature changes (A) and average percent change in annual mean precipitation (B) 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 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 projects, may differentially affect stakeholders. Awareness that climate change may exceed the adaptive capacity of some people and ecosystems may have ethical implications for mitigation decisions and investments. Recognition of diverse interests, values, and expectations, including local and indigenous knowledge, can benefit decision-making processes. Economic analysis of adaptation is moving away from a unique emphasis on efficiency, market solutions, and benefit/cost analysis to include consideration of non-monetary and non-market measures, risks, inequities, behavioral biases, barriers and limits, and consideration of ancillary benefits and costs. [2.2-4, 12.3, 15.2, 16.2-4, 16.6-7, 17.2-3, 21.3, 22.4, 25.4, 25.8, 26.7, 26.9, Table 15-1, Boxes 16-1, 16-4, and 25-7]

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*). [2.1-4, 8.4, 14.4, 16.2-3, 16.5, 21.2-3, 21.5, 22.4, Box 9-4]

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. [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]

Scenarios can be divided into those that explore how futures may unfold under various drivers (problem exploration) and those that test how various interventions may play out (solution exploration) (*robust evidence, high agreement*). Adaptation approaches address uncertainties associated with future climate and socioeconomic conditions and with the diversity of specific contexts (*medium evidence, high agreement*). Although many national studies identify a variety of strategies and approaches for adaptation, they can be classified into two broad categories: 'top-down' and 'bottom-up' approaches. The top-down approach is a scenario-impact approach, consisting of downscaled climate projections, impact assessments, and formulation of strategies and options. The bottom-up approach is a vulnerability-threshold approach, starting with identification of vulnerabilities, sensitivities, and thresholds for specific sectors or communities. Iterative assessments of impacts and adaptation in the top-down approach and building adaptive capacity of local communities are typical strategies for responding to uncertainties. [2.2-3, 15.3]

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. [11.3, 21.3-5, 25.3-4, 25.11, 26.2]

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 examines the distribution of risks across populations with contrasting vulnerability and adaptive capacity, across sectors where metrics for quantifying impacts may be quite different, and across regions with varying traditions and resources. The assessment features interactions across sectors and regions and among climate change and other stressors. The section describes risks and potential benefits over the next few decades, the near-term era of committed climate change. Over this timeframe, magnitude of projected climate change is similar across high and low emission scenarios. The section also provides information on risks and potential benefits in the second half of the 21st century and beyond, the longer-term era of climate options. Over this longer term, magnitude of climate change diverges across high and low emission scenarios, and the assessment distinguishes potential outcomes for 2°C and 4°C global mean temperature increase above preindustrial levels. The section elucidates how and when choices matter in reducing future risks, highlighting the differing timeframes for mitigation and adaptation benefits.

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 TS.5.

Key risks that span sectors and regions (*high confidence*) include the following, each of which contributes to one or more RFC. Roman numerals correspond to entries in Table TS.3, which further illustrates relevant examples and interactions. [19.2-4, 19.6, Table 19-4, Boxes 19-2 and CC-KR]

i. Risk of death, injury, and disruption to livelihoods, food supplies, and drinking water, in addition to loss of common-pool resources, sense of place, and identity, due to sea-level rise, coastal flooding, and storm surges affecting high concentrations of people, economic activity, biodiversity, and critical infrastructure in low-lying coastal zones and small island developing states. See RFC 1-5. [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, Figure 26-2, Boxes 25-1, 25-7, and CC-KR]
ii. Risk of food insecurity and breakdown of food systems linked to warming, drought, and precipitation variability, particularly in regions with poorer populations. See RFC 2-4. [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, Figure 7-4, Boxes CC-KR and CC-VW]
iii. Risk of severe harm due to inland flooding and limited coping and adaptive capacities of large urban populations. See RFC 2 and 3. [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]
iv. Risk of loss of rural livelihoods and income of rural residents due to insufficient access to drinking and irrigation water and reduced agricultural productivity, as well as risk of food insecurity, particularly for farmers and pastoralists with minimal capital in semi-arid regions. See RFC 2 and 3. [3.2, 3.4-5, 8.2, 9.3, 12.3, 13.2, 19.3, 19.6, 24.4, 25.7, 26.8, Table 19-4, Boxes 25-5 and CC-KR]
v. Systemic risks due to multiple interacting hazards affecting infrastructure networks in combination with a high dependency of people on critical services (e.g., electricity, water supply, and health and emergency services) that may break down during extreme events. See RFC 2-4. [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]
vi. Risk of loss of marine ecosystems and the services they provide for coastal livelihoods. Biodiversity and coastal ecosystem services important for fishing communities in the tropics and the Arctic are especially at risk due to rising water temperature, increased stratification, and ocean acidification. See RFC 1-5. [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]
vii. Risk of loss of terrestrial ecosystems and the services they provide for terrestrial livelihoods. These services are at risk due to rising temperatures, changes in precipitation patterns, and extreme weather events. Risks are high for communities whose livelihoods depend on provisioning services. See RFC 1, 3, and 4. [4.3, 19.3-6, 22.3-4, 25.6, 27.3, 28.2-3, Tables 19-4 and 23-2, Boxes CC-KR and CC-WE]

viii. Risk of mortality, morbidity, and other harms during periods of extreme heat, particularly for urban populations of the elderly, infants, people with chronic ill-health, and expectant mothers. Increasing frequency and intensity of extreme heat (including exposure to the urban heat island effect and air pollution) interacts with an inability of some local organizations that provide health, emergency, and social services to adapt to new risk levels for vulnerable groups. See RFC 2 and 3. [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]

[INSERT TABLE TS.3 HERE
Table TS.3: A selection of the hazards, key vulnerabilities, key risks, and emergent risks identified in chapters of this report. The examples underscore the complexity of risks determined by various interacting climate-related hazards, non-climatic stressors, and multifaceted vulnerabilities (see also Figure TS.1). Vulnerabilities identified as key arise when exposure to hazards combines with social, institutional, economic, or environmental vulnerability, as indicated by icons in the table. Emergent risks arise from complex-system interactions. Roman numerals correspond with key risks listed in section B-1. [19.6, Table 19-4]]

Mitigation of greenhouse gas emissions 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*). Since mitigation reduces the rate as well as the magnitude of warming, it also increases the time available for adaptation to a particular level of climate change, potentially by several decades, but adaptation cannot generally overcome all climate change effects. In addition to biophysical limits to adaptation for example under high temperatures, some adaptation options will be too costly or resource intensive or will be cost ineffective until climate change effects grow to merit investment costs (*high confidence*). Some mitigation or adaptation options also pose risks. [3.4-5, 4.2, 4.4, 16.3, 16.6, 17.2, 19.7, 20.3, 22.4-5, 25.10, Tables 3-2, 8-3, and 8-5, Boxes 13-2, 16-3, and 25-1]

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*). [4.2-3, 11.8, 19.5, 19.7, 26.5, Box CC-HS]

_____ START BOX TS.5 HERE _____

Box TS.5. 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. Scientific assessment can characterize risks based on the likelihood, magnitude, and scope of potential consequences of climate change. Science can also evaluate risks varying spatially and temporally across alternative development pathways, which affect vulnerability, exposure, and level of climate change. Interpreting the potential danger of risks, however, also requires value judgments by people with differing goals and worldviews. Judgments about the risks of climate change depend on the relative importance ascribed to economic vs. ecosystem assets, to the present vs. the future, and to the distribution vs. aggregation of impacts. From some perspectives, isolated or infrequent impacts from climate change may not rise to the level of dangerous anthropogenic interference, but accumulation of the same kinds of impacts could, as they become more widespread, more frequent, or more severe. The rate of climate change can also influence risks. 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 TS.5 Figure 1. All temperature changes are given relative to 1986-2005 ("recent"). [18.6, 19.6]

(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*).
(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*).

[INSERT BOX TS.5 FIGURE 1 HERE
Box TS.5 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 TS.5. [Figure RC-1, Box CC-RC; WGI AR5 Figures SPM.1 and SPM.7]]

_____ END BOX TS.5 HERE _____

_____ START BOX TS.6 HERE _____

Box TS.6. Consequences of Large Temperature Increase

This box provides a selection of salient climate change impacts projected for large temperature rise. Warming levels described here (e.g., 4°C warming) refer to global mean temperature increase above preindustrial levels.

With 4°C warming, climate change is projected to become the dominant driver of impacts on ecosystems, superseding drivers such as land-use change. [4.2.4, 19.5.1, 26.3] A number of studies project large increases in water stress, groundwater supplies, and drought in a number of regions with >4°C warming, and decreases in others, generally placing already arid regions at greater water stress. [19.5.1, Box 26-1]

Risks of large-scale singular events such as ice sheet disintegration, methane release from clathrates, and onset of long-term droughts in areas such as southwest North America [Box 26-1; WGI AR5 12.4.5, 12.5.5, 13.4], as well as regime shifts in ecosystems and substantial species loss [4.3.2, 19.6.3], are higher with increased warming. Sustained warming greater than some threshold would lead to the near-complete loss of the Greenland ice sheet over a millennium or more, causing a global mean sea-level rise of up to 7 m (*high confidence*); current estimates indicate that the threshold is greater than about 1°C (*low confidence*) but less than about 4°C (*medium confidence*) global mean warming. [WGI AR5 5.8, 13.4-5] Abrupt and irreversible ice loss from a potential instability of marine-based areas of the Antarctic ice sheet in response to climate forcing is possible, but current evidence and understanding is insufficient to make a quantitative assessment. [19.6.3; WGI AR5 5.8, 13.4-5] Sea-level rise of 0.45-0.82 m (mean 0.63m) is *likely* by 2081-2100 under RCP8.5 (*medium confidence*) [WGI AR5 Table 13.5], with sea level continuing to rise beyond 2100.

The Atlantic Meridional Overturning Circulation (AMOC) is considered *very likely* to weaken over the 21st century, with a best estimate of 34% loss (range 12-54%) under RCP8.5. [WGI AR5 12.4] The release of CO_2 or CH_4 to the atmosphere from thawing permafrost carbon stocks over the 21st century is assessed to be in the range of 180 to 910 $GtCO_2$ for RCP8.5 (*low confidence*). [WGI AR5 6.4] A nearly ice-free Arctic Ocean in September before mid-century is *likely* under RCP8.5 (*medium confidence*). [WGI AR5 11.3, 12.4-5]

For RCP8.5 by 2100, the combination of high temperatures and high humidity in some areas for parts of the year will compromise normal human activities, including growing food or working outdoors (*high confidence*). [11.8.1] Above 4°C local warming, risks for food security become very significant (*high confidence*). [7.5, Table 7-3, Figure 7-7]

Under 4°C warming, some models project large increases in fire risk in parts of the world. [4.3.3, Figure 4-6] 4°C warming implies a substantial increase in extinction risk for terrestrial and freshwater species, although there is *low agreement* concerning the fraction of species at risk. [4.3.2] Widespread coral reef mortality is expected with significant impacts on coral reef ecosystems (*high confidence*). [5.4.2, Box CC-CR] Assessments of potential ecological impacts at and above 4°C warming imply a high risk of extensive loss of biodiversity with concomitant loss of ecosystem services (*high confidence*). [4.3.2, 4.3.4, 19.3.2, Box 25-6]

Projected large increases in exposure to water stress, fluvial and coastal flooding, negative impacts on crop yields, and disruption of ecosystem function and services would represent large, potentially compounding impacts of climate change on society generally and on the global economy. [19.4.3, 19.5.1, 19.6.3, 26.3, 26.7, 26.8, Figure 7-4]

_____ END BOX TS.6 HERE _____

B-2. Sectoral Risks and Potential for Adaptation

For the near-term era of committed climate change (the next few decades) and the longer-term era of climate options (the second half of the 21st century), climate change will amplify climate-related risks to natural and human systems, dependent on the magnitude and rate of climate change and on the vulnerability and exposure of interlinked human and natural 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. Key sectoral risks identified with *medium* to *high confidence* are presented in Table TS.4. For extended summary of sectoral risks and the more limited potential benefits, see introductory overviews for each sector below and also Chapters 3-13.

[INSERT TABLE TS.4 HERE
Table TS.4: Key sectoral risks from climate change and the potential for reducing risks through mitigation and adaptation. Risks have been identified based on assessment of the relevant scientific, technical, and socioeconomic literature, as detailed in supporting chapter sections. Each key risk is characterized as very low to very high for three timeframes: the present, near-term (here, assessed over 2030-2040), and longer-term (here, assessed over 2080-2100). Assessed risk levels integrate probability and consequence over the full range of possible outcomes, acknowledging the importance of differences in values and objectives in interpretation of the assessed risk levels. 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 across sectors because the assessment considers potential impacts and adaptation across diverse physical, biological, and human systems.]

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. See Figure TS.6. In presently dry regions, drought frequency will *likely* increase by the end of this century under RCP8.5 (*medium confidence*). [3.4-5, 26.3, Tables 3-2 and 25-1, Box 25-8; WGI AR5 12.4.5]

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*). [3.2, 3.4-5, 22.3, 25.5, 26.3, Table 3-2, Boxes 25-10 and CC-WE]

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*). Barriers to progress include lack of human and institutional capacity, financial resources, awareness, and communication. [3.6, Box 25-2]

[INSERT FIGURE TS.6 HERE
Figure TS.6: Projected change in river flood return period and exposure, based on one hydrological model driven by 11 CMIP5 GCMs and on global population in 2005. (A) In the 2080s under RCP8.5, multi-model median return period (years) for the 20th-century 100-year flood. (B) Global exposure to the 20th-century 100-year flood in millions of people. Left: ensemble means of historical (black line) and future simulations (colored lines) for each scenario. Shading denotes ±1 standard deviation. Right: maximum and minimum (whiskers), mean (horizontal lines within each bar), ±1 standard deviation (box), and projections of each GCM (colored symbols) averaged over the 21st century. [Figure 3-6]]

Terrestrial and freshwater ecosystems

Climate change is projected to be a powerful stressor on terrestrial and freshwater ecosystems in the second half of the 21st century, especially under high-warming scenarios such as RCP6.0 and 8.5 (*high confidence*). Through to 2040 globally, direct human impacts such as land-use change, pollution, and water resource development will continue to dominate threats to most freshwater ecosystems (*high confidence*) and most terrestrial ecosystems (*medium confidence*). Many species will be unable to move fast enough during the 21st century to track suitable climates under mid- and high-range rates of climate change (i.e., RCP4.5, 6.0, and 8.5) (*medium confidence*). See Figure TS.7. 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. 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*). [4.3-4, 25.6, 26.4, Boxes 4-2, 4-3, and CC-RF]

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. Models project that the risk of species extinctions will increase in the future due to climate change, but there is *low agreement* concerning the fraction of species at increased risk, the regional and taxonomic distribution of such extinctions, and the timeframe over which extinctions could occur. Some aspects leading to uncertainty in the quantitative projections of extinction risks were not taken into account in previous models; as more realistic details are included, it has been shown that the extinction risks may be either underestimated or overestimated when based on simpler models. [4.3, 25.6]

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*). For the boreal-tundra system, continued climate change will transform the species composition, land cover, drainage, and permafrost extent of the boreal-tundra system, leading to decreased albedo and the release of greenhouse gases (*medium confidence*), with adaptation measures unable to prevent substantial change (*high confidence*). Increased severe drought together with land-use change and forest fire would cause much of the Amazon forest to transform to less-dense drought- and fire-adapted ecosystems, increasing risk for biodiversity while decreasing net carbon uptake from the atmosphere (*medium confidence*). Large reductions in deforestation, as well as wider application of effective wildfire management, will lower the risk of abrupt change in the Amazon, as well as potential negative impacts of that change (*medium confidence*). [4.2-3, Figure 4-8, Boxes 4-3 and 4-4]

The natural carbon sink provided by terrestrial ecosystems is partially offset at the decadal timescale by carbon released through the conversion of natural ecosystems (principally forests) to farm and grazing land and through ecosystem degradation (*high confidence*). Carbon stored in the terrestrial biosphere is vulnerable to loss to the atmosphere as a result of climate change, deforestation, and ecosystem degradation. [4.2-3, Box 4-3]

[INSERT FIGURE TS.7 HERE
Figure TS.7: Rates of climate change (A), corresponding climate velocities (B), and rates of displacement of several terrestrial and freshwater species groups in the absence of human intervention (C). Horizontal and vertical pink bands provide a guide to interpretation of the figure. Species groups with displacement rates left of each band (in C) are projected to be unable to track climate in the absence of human intervention. Extended introduction of each panel follows: (A) Observed rates of climate change for global land areas are derived from CRUTEM4 climate data reanalysis; all other rates are calculated based on the average of CMIP5 climate model ensembles for the historical period (grey shading indicates model uncertainty) and for the future based on the four RCPs. Data were smoothed using a 20-year sliding window, and rates are means of between 17 and 30 models using one member per model. (B) Estimates of climate velocity for temperature were synthesized from historical and projected future relationships between rates of temperature change and climate velocity. The three scalars are climate velocities representative of mountainous areas (left), the global-land-area average (center), and large flat regions (right). (C) Rates of displacement for trees, plants, mammals, birds, plant-feeding insects, and freshwater mollusks. [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*). [5.3-5, 22.3, 24.4, 25.6, 26.3, 26.8, Table 26-1, Box 25-1]

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. [5.3-5, 24.4, 25.6, Box 25-1]

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*). Species displacements are projected to lead to high-latitude invasions and high local-extinction rates in the tropics and semi-enclosed seas. Animal displacements will cause a 30-70% increase in the fisheries yield of some high-latitude regions by 2055 (relative to 2005), a redistribution at mid latitudes, and a drop of 40-60% in some of the tropics and the Antarctic, for 2°C warming above preindustrial levels (*medium confidence* for direction of fisheries' yield trends, *low confidence* for the precise magnitudes of yield change). See Figure TS.8A. Open-ocean net primary production is projected to redistribute and to fall globally by 2100 under RCP8.5 (*medium confidence*). [6.3-5, 25.6, 28.3, 30.4-6, Boxes CC-MB and CC-PP]

The progressive redistribution of species and the reduction in marine biodiversity in sensitive regions and habitats puts the sustained provision of fisheries productivity and other ecosystem services at risk, which will increase due to warming by 1°C or more by 2100 compared to the present, with limited adaptive capacity of human societies (*high confidence*). Socioeconomic vulnerability is highest in developing tropical countries, leading to risks from reduced supplies, income, and employment from marine fisheries. [6.4-5]

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*). See Box TS.7. 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 (Figure TS.8B). Ocean acidification occurs in combination with other environmental changes, both globally (e.g., 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. [5.3-4, 6.3, 6.5, 22.3, 25.6, 28.2-3, 30.4-5, Boxes CC-CR and CC-OA]

Climate change adds to the threats of over-fishing and other non-climatic stressors, thus complicating marine management regimes (*high confidence*). In the short term, strategies including climate forecasting and early warning systems can reduce risks from ocean warming and acidification for some fisheries and aquaculture industries. Fisheries and aquaculture industries with high-technology and/or large investments, as well as marine shipping and oil and gas industries, have high capacities for adaptation due to greater development of environmental monitoring, modeling, and resource assessments. For smaller-scale fisheries and developing nations, building social resilience, alternative livelihoods, and occupational flexibility represent important strategies for reducing the vulnerability of ocean-dependent human communities. [6.4, 7.3-4, 25.6, 29.4, 30.6-7]

[INSERT FIGURE TS.8 HERE
Figure TS.8: 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 TS.9 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. [7.4, 22.3, 24.4, 25.7, 26.5, Figures 7-4, 7-5, 7-6, and 7-7]

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. [7.5, 22.3, 25.7, 26.5, Table 7-2, Figures 7-4, 7-5, 7-7, and 7-8]

[INSERT FIGURE TS.9 HERE
Figure TS.9: 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

Rising sea levels and storm surges, heat stress, extreme precipitation, inland and coastal flooding, drought and water scarcity, and air pollution pose widespread negative risks for people, health, livelihoods, assets, local and national economies, and ecosystems (*very high confidence*). These risks are amplified for those who lack essential infrastructure and services or who live in exposed areas. [3.5, 8.2-3, 22.3, 24.4, 24.5, 26.8, Box CC-HS]

Reducing basic service deficits and building resilient infrastructure systems (e.g., for water supply, sanitation, storm and waste water drains, electricity, transportation and telecommunication, health care, education, and emergency response) could significantly reduce hazard exposure and vulnerability to climate change, especially for those who are most at risk or vulnerable (*very high confidence*). Urban adaptation provides opportunities for incremental and transformational adjustments towards resilience and sustainable development via effective multi-level urban risk governance, alignment of policies and incentives, strengthened local government and community adaptation capacity, synergies with the private sector, or appropriate financing and institutional development (*medium confidence*). Enabling the capacity of low-income groups and vulnerable communities and their partnerships with local governments can also be an effective urban adaptation strategy. [8.3-4, 24.4, 24.5, 26.8, Table 11-3, Box 25-9]

Rural areas

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. Climate change will increase international agricultural trade volumes in both physical and value terms (*limited evidence, medium agreement*). Importing food can help countries adjust to climate-change-induced domestic productivity shocks while short-term food deficits in low-income countries may have to be met through food aid. Valuation of non-marketed ecosystem services and limitations of economic valuation models that aggregate across contexts pose challenges for valuing rural impacts. [9.3, 26.8, Box 25-5]

Options exist for adaptations within international agricultural trade (*medium confidence*). Deepening agricultural markets and improving the predictability and the reliability of the world trading system through trade reform could result in reduced market volatility and manage food supply shortages caused by climate change. Investing in the production of small-scale farms in developing countries also provides benefits. [9.3, 25.9]

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. [3.5, 10.2, 10.7, 10.10, 25.7, 26.7, Box 25-7]

Climate change may influence the integrity and reliability of pipelines and electricity grids (*medium evidence, medium agreement*). Climate change may require changes in design standards for the construction and operation of pipelines and of power transmission and distribution lines. Adopting existing technology from other geographical and climatic conditions may reduce the cost of adapting new infrastructure as well as the cost of retrofitting existing pipelines and grids. Climate change may negatively affect transport infrastructure (*limited evidence, high agreement*). All infrastructure is vulnerable to freeze-thaw cycles; paved roads are particularly vulnerable to temperature extremes, unpaved roads and bridges to precipitation extremes. Transport infrastructure on ice or permafrost is especially vulnerable. [10.2, 10.4, 25.7, 26.7]

Climate change will affect tourism resorts, particularly ski resorts, beach resorts, and nature resorts (*robust evidence, high agreement*), and tourists may spend their holidays at higher altitudes and latitudes (*medium evidence, high agreement*). The economic implications of climate-change-induced changes in tourism demand and supply entail gains for countries closer to the poles and countries with higher elevations and losses for other countries. [10.6, 25.7]

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. [10.9]

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. Impacts on health will be reduced, but not eliminated, in populations that benefit from rapid social and economic development, particularly among the poorest and least healthy groups. Climate change will increase demands for health care services and facilities, including public health programs, disease prevention activities, health care personnel, infrastructure, and supplies for treatment (*medium evidence, high agreement*). 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*). 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*). See Figure TS.10. [8.2, 10.8, 11.3-8, 19.3, 22.3, 25.8, 26.6, Box CC-HS]

[INSERT FIGURE TS.10

Figure TS.10: Conceptual presentation of health risks from climate change and the potential for risk reduction through adaptation. Risks are identified in eight health-related categories based on assessment of the literature and expert judgments by authors of Chapter 11.The width of the slices indicates in a qualitative way relative importance in terms of burden of ill-health globally at present. Risk levels are assessed for the present and for the near-term era of committed climate change (here, for 2030-2040). For some categories, e.g., vector-borne diseases, heat/cold stress, and agricultural production and undernutrition, there may be benefits to health in some areas, but the net impact is expected to be negative. Risks levels are also presented for the longer-term era of climate options (here, for 2080-2100) for global mean temperature increase of 4°C above preindustrial levels. For each timeframe, risk levels are estimated for the current state of adaptation and for a hypothetical highly adapted state, indicated by different colors. [Figure 11-6]]

Human security

Human security will be progressively threatened as the climate changes (*robust evidence, high agreement*). Human insecurity almost never has single causes, but instead emerges from the interaction of multiple factors. Climate change is an important factor in threats to human security through (i) undermining livelihoods, (ii) compromising culture and identity, (iii) increasing migration that people would rather have avoided, and (iv) challenging the ability of states to provide the conditions necessary for human security. See Figure TS.11. [12.1-4, 12.6]

Climate change will compromise the cultural values that are important for community and individual well-being (*medium evidence, high agreement*). The effect of climate change on culture will vary across societies and over time, depending on cultural resilience and the mechanisms for maintaining and transferring knowledge. Changing weather and climatic conditions threaten cultural practices embedded in livelihoods and expressed in narratives, world views, identity, community cohesion, and sense of place. Loss of land and displacement, for example on small islands and coastal communities, have well documented negative cultural and well-being impacts. [12.3, 12.4]

Climate change over the 21st century will have significant impacts on forms of migration that compromise human security (*medium evidence, high agreement*). Coastal inundation and loss of permafrost can lead to migration and resettlement. Mobility is a widely used strategy to maintain livelihoods in response to social and environmental changes. Populations that lack the resources for mobility and 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. [9.3, 12.4, 19.4, 22.3, 22.6, 25.9]

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. [12.5, 13.2, 19.4]

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. [12.5-6, 23.9, 25.9]

[INSERT FIGURE TS.11 HERE
Figure TS.11: Schematic of climate change risks for human security and the interactions between livelihoods, conflict, culture, and migration. Interventions and policies are indicated by the difference between initial conditions (solid black circles) and the outcome of intervention (white circles). Some interventions (blue arrows) show net increase in human security while others (red arrows) lead to net decrease in human security. [Figure 12-3]]

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, including high mountain states, countries at risk from sea-level rise, and countries with indigenous peoples, and create new poverty pockets in upper-middle- to high-income countries in which inequality is increasing. 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 reduction may enhance long-term livelihood resilience among poor and marginalized people, if policies address multidimensional poverty. [8.1, 8.4, 9.3, 10.9, 13.2-4, 22.3, 26.8]

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Box TS.7. Ocean Acidification

Anthropogenic ocean acidification and global warming share the same primary cause, which is the increase of atmospheric CO_2 (Box TS.7 Figure 1A). [WGI AR5 2.2] Eutrophication, upwelling, and deposition of atmospheric nitrogen and sulfur contribute to ocean acidification locally. [5.3, 6.1, 30.3] The fundamental chemistry of ocean acidification is well understood (*robust evidence, high agreement*). [30.3; WGI AR5 3.8, 6.4] It has been more difficult to understand and project changes within the more complex coastal systems. [5.3, 30.3]

Ocean acidification occurs on a backdrop of other environmental changes, both globally (e.g., warming, decreasing oxygen levels) and locally (e.g., pollution, eutrophication), yet their combined impacts remain poorly understood. A pattern of positive and negative impacts of ocean acidification emerges for processes and organisms (*high confidence*; Box TS.7 Figure 1B), but key uncertainties remain from organismal to ecosystem levels. A wide range of sensitivities exists within and across organisms, with higher sensitivity in early life stages. [6.3] Lower pH decreases the rate of calcification of most, but not all, sea-floor calcifiers, reducing their competitiveness with non-calcifiers (*robust evidence, medium agreement*). [5.4, 6.3] Ocean acidification stimulates dissolution of calcium carbonate (*very high confidence*). Growth and primary production are stimulated in seagrasses and some phytoplankton (*high confidence*), and harmful algal blooms could become more frequent (*limited evidence, medium agreement*). Serious behavioral disturbances have been reported in fishes (*high confidence*). [6.3] Natural analogues at CO_2 vents indicate decreased species diversity, biomass, and trophic complexity. Shifts in organisms' performance and distribution will change both predator-prey and competitive interactions, which could impact food webs and higher trophic levels (*limited evidence, high agreement*). [6.3]

A few studies provide *limited evidence* for adaptation in phytoplankton and mollusks. However, mass extinctions in Earth history occurred during much slower rates of change in ocean acidification, combined with other drivers, suggesting that evolutionary rates may be too slow for sensitive and long-lived species to adapt to the projected rates of future change (*medium confidence*). [6.1]

The biological, ecological, and biogeochemical changes driven by ocean acidification will affect key ecosystem services. The oceans will become less efficient at absorbing CO_2 and hence moderating climate (*very high confidence*). [WGI AR5 Figure 6.26] The impacts of ocean acidification on coral reefs, together with those of thermal stress (driving mass coral bleaching and mortality) and sea-level rise, will diminish their role in shoreline protection as well as their direct and indirect benefits to fishing and tourism industries (*limited evidence, high agreement*). [Box CC-CR] The global cost of production loss of mollusks could be over 100 billion US$ by 2100 (*low confidence*). The largest uncertainty is how the impacts on lower trophic levels will propagate through the food webs and to top predators. Models suggest that ocean acidification will generally reduce fish biomass and catch (*low confidence*) and complex additive, antagonistic, and/or synergistic interactions will occur with disruptive ramifications for ecosystems as well as for important ecosystem goods and services.

[INSERT BOX TS.7 FIGURE 1 HERE
Box TS.7 Figure 1: (A) Overview of the chemical, biological, and socioeconomic impacts of ocean acidification and of policy options. (B) Effect of near-future acidification (seawater pH reduction of 0.5 unit reduction or less) on

major response variables estimated using weighted random effects meta-analyses, with the exception of survival, which is not weighted. The log-transformed response ratio (LnRR) is the ratio of the mean effect in the acidification treatment to the mean effect in a control group. It indicates which process is most uniformly affected by ocean acidification, but large variability exists between species. Significance is determined when the 95% bootstrapped confidence interval does not cross zero. The number of experiments used in the analyses is shown in parentheses. '*' denotes a statistically significant effect. [Figure OA-1, Box CC-OA]]

_____ END BOX TS.7 HERE _____

B-3. Regional Risks and Potential for Adaptation

Climate change will amplify climate-related risks to natural and human systems in most parts of the world. Key regional risks identified with *medium* to *high confidence* are presented in Table TS.5. 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 introductory overviews for each region below and also Chapters 21-30.

[INSERT TABLE TS.5 HERE
Table TS.5: 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.]

Africa. **Climate change will amplify existing stress on water availability and on agricultural systems particularly in semi-arid environments (*high confidence*).** Increasing temperatures and changes in precipitation are *very likely* to reduce cereal crop productivity with strong adverse effects on food security (*high confidence*). Progress has been achieved on managing risks to food production from current climate variability and near-term climate change, but these will not be sufficient to address long-term impacts of climate change. Adaptive agricultural processes such as collaborative, participatory research that includes scientists and farmers, strengthened communication systems for anticipating and responding to climate risks, and increased flexibility in livelihood options provide potential pathways for strengthening adaptive capacities. Climate change is a multiplier of existing health vulnerabilities including insufficient access to safe water and improved sanitation, food insecurity, and limited access to health care and education. Strategies that integrate consideration of climate change risks with land and water management and disaster risk reduction bolster resilient development. [22.3-4, 22.6]

Europe. **Climate change will increase the likelihood of systemic failures across European countries caused by extreme climate events affecting multiple sectors (*medium confidence*).** Sea-level rise and increases in extreme rainfall are projected to further increase coastal and river flood risks and without adaptive measures will substantially increase flood damages (i.e., people affected and economic losses); adaptation can prevent most of the projected damages (*high confidence*). Heat-related deaths and injuries are *likely* to increase, particularly in southern Europe (*medium confidence*). Climate change is *likely* to increase cereal crop yields in northern Europe (*medium confidence*) but decrease yields in southern Europe (*high confidence*). Climate change will increase irrigation needs in Europe, and future irrigation will be constrained by reduced runoff, demand from other sectors, and economic costs, with integrated water management a strategy for addressing competing demands. Hydropower production is *likely* to decrease in all sub-regions except Scandinavia. Climate change is *very likely* to cause changes in habitats and species, with local extinctions (*high confidence*), continental-scale shifts in species distributions (*medium confidence*), and significantly reduced alpine-plant habitat (*high confidence*). Climate change is *likely* to entail the loss or displacement of coastal wetlands. The introduction and expansion of invasive species, especially those with high migration rates, from outside Europe is *likely* to increase with climate change (*medium confidence*). [23.2-9]

***Asia.* Climate change will cause declines in agricultural productivity in many subregions of Asia, for crops such as rice (*medium confidence*).** In Central Asia, cereal production in northern and eastern Kazakhstan could benefit from the longer growing season, warmer winters, and slight increase in winter precipitation, while droughts in western Turkmenistan and Uzbekistan could negatively affect cotton production, increase water demand for irrigation, and exacerbate desertification. The effectiveness of potential and practiced agricultural adaptation strategies is not well understood. Future projections of precipitation at subregional scales and thus of freshwater availability in most parts of Asia are uncertain (*low confidence* in projections), but increased water demand from population growth, increased water consumption per capita, and lack of good management will increase water scarcity challenges for most of the region (*medium confidence*). Adaptive responses include integrated water management strategies, such as development of water saving technologies, increased water productivity, and water reuse. Extreme climate events will have an increasing impact on human health, security, livelihoods, and poverty, with the type and magnitude of impact varying across Asia (*high confidence*). In many parts of Asia, observed terrestrial impacts, such as permafrost degradation and shifts in plant species' distributions, growth rates, and timing of seasonal activities, will increase due to climate change projected during the 21st century. Coastal and marine systems in Asia, such as mangroves, seagrass beds, salt marshes, and coral reefs, are under increasing stress from climatic and non-climatic drivers. In the Asian Arctic, sea-level rise interacting with projected changes in permafrost and the length of the ice-free season will increase rates of coastal erosion (*medium evidence, high agreement*). [24.4, 30.5]

***Australasia.* Without adaptation, further changes in climate, atmospheric CO_2, and ocean acidity are projected to have substantial impacts on water resources, coastal ecosystems, infrastructure, health, agriculture, and biodiversity (*high confidence*).** Freshwater resources are projected to decline in far south-west and far south-east mainland Australia (*high confidence*) and for some rivers in New Zealand (*medium confidence*). Rising sea levels and increasing heavy rainfall are projected to increase erosion and inundation, with consequent damages to many low-lying ecosystems, infrastructure, and housing (*high confidence*); increasing heat waves will increase risks to human health; rainfall changes and rising temperatures will shift agricultural production zones; and many native species will suffer from range contractions and some may face local or even global extinction. Uncertainty in projected rainfall changes remains large for many parts of Australia and New Zealand, which creates significant challenges for adaptation. Some sectors in some locations have the potential to benefit from projected changes in climate and increasing atmospheric CO_2, for example due to reduced energy demand for winter heating in New Zealand and southern parts of Australia, and due to forest growth in cooler regions except where soil nutrients or rainfall are limiting. Indigenous peoples in both Australia and New Zealand have higher than average exposure to climate change due to a heavy reliance on climate-sensitive primary industries and strong social connections to the natural environment, and face additional constraints to adaptation (*medium confidence*). [25.2-3, 25.5-8, Boxes 25-1, 25-2, 25-5, and 25-8]

***North America.* Many climate-related hazards that carry risk, particularly related to severe heat, heavy precipitation, and declining snowpack, will increase in frequency and/or severity in North America in the next decades (*very high confidence*).** Climate change will amplify risks to water resources already affected by non-climatic stressors, with potential impacts associated with decreased snowpack, decreased water quality, urban flooding, and decreased water supplies for urban areas and irrigation (*high confidence*). More adaptation options are available to address water supply deficits than flooding and water quality concerns (*medium confidence*). Ecosystems are under increasing stress from rising temperatures, CO_2 concentrations, and sea levels, with particular vulnerability to climate extremes (*very high confidence*). In many cases, climate stresses exacerbate other anthropogenic influences on ecosystems, including land-use changes, non-native species, and pollution. Projected increases in temperature, reductions in precipitation in some regions, and increased frequency of extreme events would result in net productivity declines in major North American crops by the end of the 21st century without adaptation, although some regions, particularly in the north, may benefit. Adaptation, often with mitigation co-benefits, could offset projected negative yield impacts for many crops at 2°C global mean temperature increase above preindustrial, with reduced effectiveness of adaptation at 4°C (*high confidence*). Although larger urban centers would have higher adaptive capacities, high population density, inadequate infrastructures, lack of institutional capacity, and degraded natural environments increase future climate risks from heat waves, droughts, storms, and sea-level rise (*medium evidence, high agreement*). Future risks from climate extremes can be reduced, for example through targeted and sustainable air conditioning, more effective warning and response systems, enhanced pollution controls, urban planning strategies, and resilient health infrastructure (*high confidence*). [26.3-6, 26.8]

Central and South America. **Despite improvements, high and persistent levels of poverty in most countries result in high vulnerability to climate variability and change (*high confidence*).** Climate change impacts on agricultural productivity are expected to exhibit large spatial variability, for example with sustained or increased productivity through mid-century in southeast South America and decreases in productivity in the near-term (by 2030) in Central America, threatening food security of the poorest populations (*medium confidence*). Reduced precipitation and increased evapotranspiration in semi-arid regions will increase risks from water-supply shortages, affecting cities, hydropower generation, and agriculture (*high confidence*). Ongoing adaptation strategies include reduced mismatch between water supply and demand, and water-management and coordination reforms (*medium confidence*). Conversion of natural ecosystems, a driver of anthropogenic climate change, is the main cause of biodiversity and ecosystem loss (*high confidence*). Climate change is expected to increase rates of species extinction (*medium confidence*). In coastal and marine systems, sea-level rise and human stressors increase risks for fish stocks, corals, mangroves, recreation and tourism, and control of diseases (*high confidence*). Climate change will exacerbate future health risks given regional population growth rates and vulnerabilities due to pollution, food insecurity in poor regions, and existing health, water, sanitation, and waste collection systems (*medium confidence*). [27.2-3]

Polar Regions. **In the Arctic, climate change and often-interconnected non-climate-related drivers, including environmental changes, demography, culture, and economic development, interact to determine physical, biological, and socioeconomic risks, with rates of change that may be faster than social systems can adapt (*high confidence*).** Thawing permafrost and changing precipitation patterns have the potential to affect infrastructure and related services, with particular risks for residential buildings, for example in Arctic cities and small rural settlements. Climate change will especially impact Arctic communities that have narrowly based economies limiting adaptive choices. Increased Arctic navigability and expanded land- and freshwater-based transportation networks will increase economic opportunities. Impacts on the informal, subsistence-based economy will include changing sea-ice conditions that increase the difficulty of hunting marine mammals. Polar bears have been and will be affected by loss of annual ice over continental shelves, decreased ice duration, and decreased ice thickness. Already, accelerated rates of change in permafrost thaw, loss of coastal sea ice, sea-level rise, and increased intensity of weather extremes are forcing relocation of some indigenous communities in Alaska (*high confidence*). In the Arctic and Antarctic, some marine species will shift their ranges in response to changing ocean and sea ice conditions (*medium confidence*). Climate change will increase the vulnerability of terrestrial ecosystems to invasions by non-indigenous species, the majority expected to arrive through direct human assistance (*high confidence*). [6.3, 6.5, 28.2-4]

Small Islands. **Small islands have high vulnerability to climatic and non-climatic stressors (*high confidence*).** Diverse physical and human attributes and their sensitivity to climate-related drivers lead to variable climate change risk profiles and adaptation from one island region to another and among countries in the same region. Risks can originate from transboundary interactions, for example associated with existing and future invasive species and human health challenges. Sea-level rise poses one of the most widely recognized climate change threats to low-lying coastal areas on islands and atolls. Projected sea-level rise at the end of the 21st century, superimposed on extreme sea-level events, presents severe coastal-flooding and erosion risks for low-lying coastal areas and atoll islands. Wave over-wash will degrade groundwater resources. Coral reef ecosystem degradation associated with increasing sea surface temperature and ocean acidification will negatively impact island communities and livelihoods, given the dependence of island communities on coral reef ecosystems for coastal protection, subsistence fisheries, and tourism. [29.3-5, 29.9, 30.5, Figure 29-1, Table 29-3, Box CC-CR]

The Ocean. **Warming will increase risks to ocean ecosystems (*high confidence*).** Coral reefs within coastal boundary systems, semi-enclosed seas, and sub-tropical gyres are rapidly declining as a result of local non-climatic stressors (i.e., coastal pollution, overexploitation) and climate change. Projected increases in mass coral bleaching and mortality will alter or eliminate ecosystems, increasing risks to coastal livelihoods and food security (*medium* to *high confidence*). An analysis of the CMIP5 ensemble projects loss of coral reefs from most sites globally to be *very likely* by 2050 under mid to high rates of ocean warming. Reducing non-climatic stressors represents an opportunity to strengthen ecological resilience. The highly productive high-latitude spring bloom systems in the Northeastern Atlantic are responding to warming (*medium evidence*, *high agreement*), with the greatest changes being observed since the late 1970s in the phenology, distribution, and abundance of plankton assemblages, and the reorganization of fish assemblages, with a range of consequences for fisheries (*high confidence*). Projected warming increases the likelihood of greater thermal stratification in some regions, which can lead to reduced O_2 ventilation and encourage the formation of hypoxic zones, especially in the Baltic and Black Seas (*medium confidence*). Changing surface winds and waves, sea level, and storm intensity will increase the vulnerability of ocean-based industries such as shipping, energy, and mineral extraction. New opportunities as well as international issues over access to resources and vulnerability may accompany warming waters particularly at high latitudes. [5.3-4, 6.4, 28.2-3, 30.3, 30.5-6, Table 30-1, Figures 30-4 and 30-10, Boxes 6-1, CC-CR, and CC-MB]

Understanding of extreme events and their interactions with climate change is particularly important for managing risks in a regional context. Table TS.6 provides a summary of observed and projected trends in some types of temperature and precipitation extremes.

[INSERT TABLE TS.6
Table TS.6: Observed and projected future changes in some types of temperature and precipitation extremes over 26 sub-continental regions as defined in SREX. Confidence levels are indicated by symbol color. Likelihood terms are given only for *high* or *very high confidence* statements. Observed trends in temperature and precipitation extremes, including dryness and drought, are generally calculated from 1950, using 1961-1990 as the reference period, unless otherwise indicated. Future changes are derived from global and regional climate model projections for 2071-2100 compared with 1961-1990 or for 2080-2100 compared with 1980-2000. Table entries are summaries of information in SREX Tables 3.2 and 3.3 supplemented with or superseded by material from WGI AR5 2.6, 14.4, and Table 2.13 and WGII AR5 Table 25-1. The source(s) of information for each entry are indicated by superscripts: (a) SREX Table 3.2; (b) SREX Table 3.3; (c) WGI AR5 2.6 and Table 2.13; (d) WGI AR5 14.4; (e) WGII AR5 Table 25-1. [Tables 21-7 and SM21-2, Figure 21-4]]

C) MANAGING FUTURE RISKS AND BUILDING RESILIENCE

Managing the risks of climate change involves decisions with implications for future societies, economies, environment, and climate. Figure TS.12 provides an overview of entry points, approaches, and core considerations in addressing climate change.

Starting with principles for effective adaptation, this section evaluates the ways that interlinked human and natural systems can build resilience through adaptation, mitigation, and sustainable development. It describes understanding of climate-resilient pathways, of incremental versus transformational changes, and of limits to adaptation, and it considers co-benefits, synergies, and tradeoffs among mitigation, adaptation, and development.

[INSERT FIGURE TS.12 HERE
Figure TS.12: 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

The report assesses a wide variety of approaches for managing risks and building resilience. Strategies and approaches to climate change adaptation include efforts to decrease vulnerability or exposure and/or increase resilience or adaptive capacity. Mitigation is assessed in the WGIII AR5. An overview of types of responses to climate change is presented in Table TS.7.

[INSERT TABLE TS.7 HERE
Table TS.7: 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.]

Adaptation is highly regionally and context specific, with no single approach for reducing risk 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*). [2.1, 8.3-4, 13.1, 13.3-4, 15.2-3, 15.5, 16.2-3, 16.5, 17.2, 17.5, 19.6, 21.3, 22.4, 25.4, 26.8-9, 29.6, 29.8]

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. [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, and 21-6, Boxes 16-1, 16-2, and 25-7]

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. Integration of adaptation into planning and decision-making can promote synergies with development. Adaptation strategies that also strengthen livelihoods, enhance development, and reduce poverty include improved social protection, improved water and land governance, enhanced water storage and services, greater involvement in planning, and elevated attention to urban and peri-urban areas heavily affected by migration of poor people. See Table TS.7. [3.6, 9.4, 11.2, 14.2, 15.2-3, 15.5, 17.2, 20.4, 20.6, 22.4, 24.4, 25.10, 27.3-5, Boxes 25-2, 25-6, 25-8, and 25-9]

Integration of adaptation into planning and decision-making can promote synergies with development and reduce the possibility of maladaptive actions (*robust evidence, high agreement*). Such mainstreaming embeds climate-sensitive thinking in existing and new institutions and organizations**.** Adaptation can generate larger benefits when connected with development activities and disaster risk reduction (*medium confidence*). [8.3, 9.3, 14.2, 14.6, 15.3-4, 17.2, 20.2-3, 22.4, 24.5, 29.6, Box CC-UR]

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. [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, 22.3-5, 23.6-7, 24.5, 25.4, 25.10, 26.8-9, 30.6, Table 25-2, Boxes 16-1, 16-3, and CC-EA]

Poor planning, overemphasizing short-term outcomes, or discounting or failing to consider all consequences can result in maladaptation (*medium evidence, high agreement*). Narrow focus on quantifiable costs and benefits can bias decisions against the poor, against ecosystems, and against those in the future whose values can be excluded or are understated. Maladaptation can increase the vulnerability or exposure of the target group in the future, or the vulnerability of other locations or sectors. [14.6, 15.5, 17.2-3, 22.4, 25.9]

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 contribute to increasing resilience to climate extremes and climate variability, but can also provide disincentives, cause market failure, and decrease equity. Mechanisms include insurance, reinsurance, micro insurance, and national, regional, and global risk pools. The public sector often plays a key role as regulator, provider, or insurer of last resort. [10.7, 10.9, 13.3, 17.4-5, 22.4, Box 25-7]

Indigenous, local, and traditional forms of knowledge are a major resource for adapting to climate change (*robust evidence, high agreement*). Natural resource dependent communities, including indigenous peoples, have a long history of adapting to highly variable and changing social and ecological conditions. But the salience of indigenous, local, and traditional knowledge will be challenged by climate change impacts. Such forms of knowledge are often neglected in policy and research, and their mutual recognition and integration with scientific knowledge will increase the effectiveness of adaptation. [9.4, 12.3, 15.2, 22.4, 24.4, 24.6, 25.8, Table 15-1]

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*). [17.4]

C-2. Climate-resilient Pathways and Transformation

Climate-resilient pathways are development trajectories that combine adaptation and mitigation to realize the goal of sustainable development. They can be seen as iterative, continually evolving processes for managing change within complex systems.

Climate-resilient pathways include strategies, choices, and actions that reduce climate change and its impacts. They also include actions to ensure that effective risk management and adaptation can be implemented and sustained (*high confidence*). Delaying actions may reduce options for climate-resilient pathways in the future. See Figure TS.13. Prospects for climate-resilient development pathways are related fundamentally to what the world accomplishes with climate change mitigation. Climate-resilient development pathways will have only marginal effects on poverty reduction, unless structural inequalities are addressed and needs for equity among poor and non-poor people are met (*medium confidence*). [1.1, 2.5, 13.4, 20.2-4, 20.6, Figure 1-5]

[INSERT FIGURE TS.13 HERE

Figure TS.13: Multiple stressors and climate-resilient pathways. The literature assessed in this report shows that climate change is just one of the many stressors that influence resilience. Climate-related risks interact with other biophysical stressors (such as biodiversity loss, soil erosion, and water contamination) and with social stressors (such as inequalities, poverty, gender discrimination, and lack of institutions). Rapid advances in knowledge about climate change and its risks along with experience and other factors provide policy relevant information for decision-making that can lead to climate-resilient development pathways. The decisions that societies make within this opportunity space can increase resilience and lower risks. Such decisions and choices are core elements of an iterative risk management process. [Figure 1-5]]

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*). See Box TS.8. Adaptation and greenhouse gas mitigation are complementary risk management strategies, but residual loss and damage will occur from climate change despite adaptive and mitigative action. 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. [1.1, 11.8, 16.2-7, 17.2, 20.2-4, 20.5-6, 25.10, 26.5, 26.9, Boxes 16-1, 16-3, and 16-4]

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. [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 and 16-4]

Examples of co-benefits, synergies, and tradeoffs among adaptation, mitigation, and sustainable development

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*). Illustrative examples include the following.

- 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 (*very high confidence*). See Box TS.9. Widespread transformation of terrestrial ecosystems in order to mitigate climate change, such as carbon sequestration through planting fast-growing tree species into ecosystems where they did not previously occur, or the conversion of previously uncultivated or non-degraded land to bioenergy plantations, will lead to negative impacts on ecosystems and biodiversity (*high confidence*). [3.7, 4.2-4, 22.6, 24.6, 25.7, 25.9, 27.3, Boxes 25-10 and CC-WE]
- Climate policies such as increasing energy supply from renewable resources, encouraging bioenergy crop cultivation, or facilitating payments under REDD+ will affect some rural areas both positively (e.g., increasing employment opportunities) and negatively (e.g., land use changes, increasing scarcity of natural capital) (*medium confidence*). These secondary impacts, and trade-offs between mitigation and adaptation in rural areas, have implications for governance, including benefits of promoting participation of rural stakeholders. Mitigation policies with social co-benefits expected in their design, such as CDM and REDD+, have had limited or no effect in terms of poverty alleviation and sustainable development (*medium confidence*). Mitigation efforts focused on land acquisition for biofuel production show preliminary negative impacts for the poor in many low and middle-income countries, and particularly for indigenous people and (women) smallholders. [9.3, 13.3, 22.6]
- Mangrove, sea grass, and salt marsh ecosystems offer important carbon storage and sequestration opportunities (*limited evidence*, *medium agreement*), in addition to ecosystem services such as protection against coastal erosion and storm damage and maintenance of habitats for fisheries species. For ocean-related mitigation and adaptation in the context of anthropogenic ocean warming and acidification, international frameworks offer opportunities to solve problems collectively, for example managing fisheries across national borders and responding to extreme events. [5.4, 25.6, 30.6-7]

- Geoengineering approaches involving manipulation of the ocean to ameliorate climate change (such as nutrient fertilization, binding of CO_2 by enhanced alkalinity, or direct CO_2 injection into the deep ocean) have very large environmental and associated socioeconomic consequences (*high confidence*). Alternative methods focusing on solar radiation management (SRM) leave ocean acidification unabated as they cannot mitigate rising atmospheric CO_2 emissions. [6.4]
- Some agricultural practices can reduce emissions and also increase resilience of crops to temperature and rainfall variability (*high confidence*). [23.8, Table 25-7]
- Many solutions for reducing energy and water consumption in urban areas with co-benefits for climate change adaptation (e.g., greening cities and recycling water) are already being implemented (*high confidence*). Transport systems promoting active transport and reduced motorized-vehicle use can improve air quality and increase physical activity (*medium confidence*). [11.9, 23.8, 24.4, 26.3, 26.8, Boxes 25-2 and 25-9]
- Improved energy efficiency and a shift to cleaner energy sources can reduce local emissions of health-damaging climate-altering air pollutants (*very high confidence*). [11.9, 23.8]
- In Africa, experience in implementing integrated adaptation–mitigation responses that leverage developmental benefits encompasses some participation of farmers and local communities in carbon offset systems and increased use of agroforestry and farmer-assisted tree regeneration (*high confidence*). [22.4, 22.6]
- In Asia, development of sustainable cities with fewer fossil-fuel-driven vehicles and with more trees and greenery would have a number of co-benefits, including improved public health (*high confidence*). [24.4-7]
- In Australasia, transboundary effects from climate change impacts and responses outside Australasia have the potential to outweigh some of the direct impacts within the region, particularly economic impacts on trade-intensive sectors such as agriculture (*medium confidence*) and tourism (*limited evidence, high agreement*), but they remain among the least-explored issues. [25.7, 25.9, Box 25-10]
- In North America, policies addressing local concerns (e.g., air pollution, housing for the poor, declines in agricultural production) can be adapted at low or no cost to fulfill adaptation, mitigation, and sustainability goals (*medium confidence*). [26.9]
- In Central and South America, biomass-based renewable energy can impact land use change and deforestation, and could be affected by climate change (*medium confidence*). The expansion of sugarcane, soy, and oil palm may have some effect on land use, leading to deforestation in parts of the Amazon and Central America, among other subregions, and to loss of employment in some countries. [27.3]
- For small islands, energy supply and use, tourism infrastructure and activities, and coastal wetlands offer opportunities for adaptation-mitigation synergies (*medium confidence*). [29.6-8]

Table TS.8 provides further specific examples of interactions among adaptation, mitigation, and sustainable development to complement the assessment findings above.

[INSERT TABLE TS.8 HERE
Table TS.8: Illustrative examples of intra-regional interactions among adaptation, mitigation, and sustainable development.]

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Box TS.8. Adaptation Limits and Transformation

Adaptation can expand the capacity of natural and human systems to cope with a changing climate. Risk-based decision-making can be used to assess potential limits to adaptation. Such limits to adaptation may be signaled by the inability to prevent intolerable risks to an actor's objectives and/or to the needs of an ecosystem. Limits to adaptation are context-specific and closely linked to cultural norms and societal values. Judgments of what constitutes an intolerable risk may differ among actors, but understandings of limits to adaptation can be informed by historical experiences, or by anticipation of impacts, vulnerability, and adaptation associated with different scenarios of climate change. The greater the magnitude of climate change, the greater the likelihood that adaptation will encounter limits. [16.2-4, 20.5, 20.6, 22.4, 25.4, 25.10, Box 16-2]

Limits to adaptation may be influenced by the subjective values of societal actors, which can affect both the perceived need for adaptation and the perceived appropriateness of specific policies and measures. While limits imply that intolerable risks and the increased potential for losses and damages can no longer be avoided, the dynamics of social and ecological systems mean that there are both "soft" and "hard" limits to adaptation. For "soft" limits, there are opportunities in the future to alter limits and reduce risks, for example through the emergence of new technologies or changes in laws, institutions, or values. In contrast, "hard" limits are those where there are no reasonable prospects for avoiding intolerable risks. Recent studies on tipping points, key vulnerabilities, and planetary boundaries provide some insights on the behavior of complex systems. [16.2-7, 25.10]

In cases where the limits to adaptation have been surpassed, losses and damage may increase and the objectives of some actors may no longer be achievable. There may be a need for transformational adaptation to change fundamental attributes of a system in response to actual or expected impacts of climate change. It may involve adaptations at a greater scale or intensity than previously experienced, adaptations that are new to a region or system, or adaptations that transform places or lead to a shift in the location of activities. [16.2-4, 20.3, 20.5, 22.4, 25.10, Boxes 25-1 and 25-9]

The existence of limits to adaptation suggests transformational change may be a requirement for sustainable development in a changing climate; i.e., not only for adapting to the impacts of climate change, but for altering the systems and structures, economic and social relations, and beliefs and behaviors that contribute to climate change and social vulnerability. However, just as there are ethical implications associated with some adaptation options, there are also legitimate concerns about the equity and ethical dimensions of transformation. 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 at multiple levels to reconcile conflicting goals and visions for the future. [1.1, 16.2-7, 20.5, 25.10]

_____ END BOX TS.8 HERE _____

_____ START BOX TS.9 HERE _____

Box TS.9. The Water-Energy-Food Nexus

Water, energy, and food/feed/fiber are linked through numerous interactive pathways affected by a changing climate (Box TS.9 Figure 1). [Box CC-WE] The depth and intensity of those linkages vary enormously among countries, regions, and production systems. Many energy sources require significant amounts of water and produce a large quantity of waste water that requires energy for treatment. [3.7, 7.3, 10.2-3, 22.3, 25.7, Box CC-WE] Food production, refrigeration, transport, and processing also require both energy and water. A major link between food and energy as related to climate change is the competition of bioenergy and food production for land and water, and the sensitivity of precipitation, temperature, and crop yields to climate change (*robust evidence, high agreement*). [7.3, Boxes 25-10 and CC-WE]

Most energy production methods require significant amounts of water, either directly (e.g., crop-based energy sources and hydropower) or indirectly (e.g., cooling for thermal energy sources or other operations) (*robust evidence, high agreement*). [10.2-3, 25.7, Box CC-WE] Water is required for mining, processing, and residue disposal of fossil fuels or their byproducts. [25.7] Water for energy currently ranges from a few percent in most developing countries to more than 50% of freshwater withdrawals in some developed countries, depending on the country. [Box CC-WE] Future water requirements will depend on electric demand growth, the portfolio of generation technologies, and water management options. Future water availability for energy production will change due to climate change (*robust evidence, high agreement*). [3.4-5]

Energy is also required to supply and treat water. Water may require significant amounts of energy for lifting (especially as aquifers continue to be depleted), transport, and distribution and for its treatment either to use it or to depollute it. Wastewater and even excess rainfall in cities requires energy to be treated or disposed. Some non-conventional water sources (wastewater or seawater) are often highly energy intensive. [Table 25-7, Box 25-2] Energy intensities per m^3 of water vary by about a factor of 10 among different sources, e.g., locally produced potable water from ground/surface water sources vs. desalinated seawater. [Boxes 25-2 and CC-WE] Groundwater is generally more energy intensive than surface water. [Box CC-WE]

Linkages among water, energy, food/feed/fiber, and climate are strongly related to land use and management, such as afforestation, which can affect water as well as other ecosystem services, climate, and water cycles (*robust* *evidence, high agreement*). [4.4, Box 25-10] Land degradation often reduces efficiency of water and energy use (e.g., resulting in higher fertilizer demand and surface runoff), and many of these interactions can compromise food security. [3.7, 4.4] On the other hand, afforestation activities to sequester carbon have important co-benefits of reducing soil erosion and providing additional (even if only temporary) habitat, but may reduce renewable water resources. [Box 25-10]

Consideration of the interlinkages of energy, food/feed/fiber, water, land use, and climate change has implications for security of supplies of energy, food, and water; adaptation and mitigation pathways; air pollution reduction; and health and economic impacts. This nexus is increasingly recognized as critical to effective climate-resilient-pathway decision-making (*medium evidence, high agreement*), although tools to support local- and regional-scale assessments and decision-support remain very limited.

[INSERT BOX TS.9 FIGURE 1 HERE
Box TS.9 Figure 1: The water-energy-food nexus as related to climate change, with implications for both adaptation and mitigation strategies. [Figure WE-1, Box CC-WE]]

_____ END BOX TS.9 HERE _____

Table TS.1.

REGION	Snow & Ice, Rivers & Lakes, Floods & Drought	Terrestrial Ecosystems	Coastal Erosion & Marine Ecosystems	Food Production & Livelihoods
Africa	Retreat of tropical highland glaciers in East Africa (H,C) Lake surface warming and water column stratification increases in the Great Lakes and Lake Kariba (H,C) Increased soil moisture drought in the Sahel since 1970, partially wetter conditions since 1990 (M,C) [22.2.2-3, 22.3.2, Tables 18-5, 18-6, and 22-3]	Tree density decreases in Sahel & semi-arid Morocco, beyond changes due to land use (M,C) Range shifts of several southern plants & animals, beyond changes due to land use (M,C) [22.3.2, Tables 18-7 and 22-3]		
Europe	Retreat of Alpine, Scandinavian, and Icelandic glaciers (H,C) Increase in rock slope failures in Western Alps (M,C) [18.3.1, 23.3.1, Table 18-5; WGI AR5 4.3.3]	Earlier greening, leaf emergence, & fruiting in temperate & boreal trees (H,C) Increased colonization of alien plant species in Europe, beyond a baseline of some invasion (M,C) Earlier arrival of migratory birds in Europe since 1970 (M,C) Increasing burnt forest areas during recent decades in Portugal and Greece, beyond some increase due to land use (H,C) [4.3.2-3, Tables 18-7 and 23-6]	Northward distributional shifts of zooplankton, fishes, seabirds, & benthic invertebrates in Northeast Atlantic (H,C) Northward and depth shift in distribution of many fish species across European seas (M,C) Plankton phenology changes in Northeast Atlantic (M,C) Spread of warm water species into the Mediterranean, beyond changes due to invasive species and human impacts (M,C) [6.3.1, 23.6.4-5, 30.5.1, 30.5.3, Tables 6-2 and 18-8, Boxes 6-1 and CC-MB]	Impacts on livelihoods of Sámi people in northern Europe, beyond effects of economic and sociopolitical changes (M,C) Stagnation of wheat yields in some countries in recent decades, despite improved technology (M,c) Positive yield impacts for some crops mainly in northern Europe, beyond increase due to improved technology (M,c) Spread of bluetongue virus in sheep, and of ticks across parts of Europe (M,c) [23.4.1, 23.4.2, Table 18-9, Figure 7-2]
Asia	Permafrost degradation in Siberia, Central Asia, & Tibetan Plateau (H,C) Shrinking mountain glaciers across Asia (M,C) Increased flow in many rivers due to shrinking glaciers in the Himalayas & Central Asia (H,C) Earlier timing of maximum spring flood in Russian rivers (M,C) Reduced soil moisture in North Central and Northeast China (1950-2006) (M,C) Surface water degradation in parts of Asia beyond changes due to land use (M,c) [24.4.1-2, 28.2.1, Tables 18-5 and 18-6, Boxes 3-1 and 3-2; WGI AR5 4.3.2-3, 10.5.3]	Changes in plant phenology & growth in many parts of Asia (earlier greening), particularly in the north & east (M,C) Distribution shifts of many plant & animal species upwards in elevation or polewards, particularly in the north of Asia (M,C) Advance of shrubs into the Siberian tundra (H,C) [4.3.2-3, 24.4.2, 28.2.3, Table 18-7, Figure 4-4]	Decline in coral reefs & large seaweeds in tropical Asian waters & coastal waters of western Japan, beyond decline due to human impacts (H,C) Northward range extension of coral reefs and predatory fish in Sea of Japan (M,C) [24.4.3, 30.5.1, Table 18-8]	Negative impacts on aggregate wheat yields in South Asia, against a baseline of increase due to improved technology (M,c) [7.2.1, Table 18-9, Figure 7-2]
Australasia	Significant decline in late-season snow depth at 3 of 4 alpine sites in Australia (1957-2002) (M,C) Substantial reduction in ice and glacier ice volume in New Zealand (M,C) Reduced inflow in river systems in southwestern Australia (since the mid-1970s) (H,C) [25.5.1, Tables 18-5, 18-6, and 25-1; WGI AR5 4.3.3]	Changes in genetics, growth, distribution, & phenology of many species, in particular birds, butterflies, & plants in Australia, beyond fluctuations due to variable local climates, land use, pollution, & invasive species (H,C) Expansion of monsoon rainforest at expense of savannah and grasslands in northern Australia (M,C) [Tables 18-7 and 25-3]	Southward shifts in the distribution of marine species near Australia, beyond changes due to short-term environmental fluctuations, fishing, and pollution (M,C) Increased coral bleaching in Great Barrier Reef and Western Australian Reefs, beyond effects from pollution & physical disturbance (H,C) Changed coral disease patterns at Great Barrier Reef, beyond effects from pollution (M,C) [6.3.1, 25.6.2, Tables 18-8 and 25-3]	Advanced timing of wine-grape maturation in recent decades, beyond advance due to improved management (M,C) [Tables 18-9 and 25-3]

REGION	Snow & Ice, Rivers & Lakes, Floods & Drought	Terrestrial Ecosystems	Coastal Erosion & Marine Ecosystems	Food Production & Livelihoods
North America	Shrinkage of glaciers across western and northern North America (H,C) Decreasing amount of water in spring snowpack in western North America (1960-2002) (H,C) Shift to earlier peak flow in snow dominated rivers in western North America (H,C) [Tables 18-5 and 18-6; WGI AR5 2.6.2, 4.3.3]	Phenology changes & species distribution shifts upward in elevation & northward across multiple taxa (M,C) Increased wildfire frequency in subarctic conifer forests and tundra (M,C) Increase in wildfire activity, fire frequency & duration, & burnt area in boreal forest of North America, beyond changes due to land use & fire management (M,c) [26.4.1, 28.2.3, Table 18-7, Box 26-2]	Northward distributional shifts of Northwest Atlantic fish species (H,C) Changes in musselbeds along the west coast of US (H,C) Changed migration and survival of salmon in northeast Pacific (H,C) Increased coastal erosion in Alaska and Canada (M,C) [18.3.1, 18.3.3, 30.5.1, Tables 6-2 and 18-8]	Impacts on livelihoods of indigenous groups in the Canadian Arctic, beyond effects of economic and sociopolitical changes (M,C) [18.4.6, Tables 18-4 and 18-9, 28.2.4]
Central & South America	Shrinkage of Andean glaciers (H,C) Changes in extreme flows in Amazon River (M,C) Changing discharge patterns in rivers in the Western Andes (M,c) Increased streamflow in sub-basins of the La Plata River, beyond increase due to land use change (H,C) [27.3.1, Tables 18-5, 18-6, and 27-3; WGI AR5 4.3.3]		Increased coral bleaching in western Caribbean, beyond effects from pollution & physical disturbance (H,C) [27.3.3, Table 18-8]	More vulnerable livelihood trajectories for indigenous Aymara farmers in Bolivia due to water shortage, beyond effects of increasing social and economic stress (M,C) Increase in agricultural yields and expansion of agricultural areas in southeastern South America, beyond increase due to improved technology (M,C) [13.1.4, 27.3.4, Table 18-9]
Polar Regions	Decreasing Arctic sea ice cover in summer (H,C) Reduction in ice volume in Arctic glaciers (H,C) Decreasing snow cover extent across the Arctic (M,C) Widespread permafrost degradation, especially in the southern Arctic (H,C) Ice mass loss along coastal Antarctica (M,C) Increased winter minimum river flow in most sectors of the Arctic (M,C) Increased lake water temperatures 1985–2009 and prolonged ice-free seasons (M,C) Disappearance of thermokarst lakes due to permafrost degradation in the low Arctic. New lakes created in areas of formerly frozen peat (H,C) [28.2.1, 28.2.3, Tables 18-5 and 18-6; WGI AR5 4.2.2-3, 4.3.3, 4.4, 4.6, 10.5.2-3]	Increased shrub cover in tundra in North America & Eurasia (H,C). Advance of Arctic tree-line in latitude & altitude (M,C). Changed breeding area & population size of subarctic birds, due to snowbed reduction &/or tundra shrub encroachment (M,C) Loss of snow-bed ecosystems & tussock tundra (H,C). Impacts on tundra animals from increased ice layers in snow pack, following rain-on-snow events (M,C) Increased plant species ranges in the West Antarctic Peninsula & nearby islands over the past 50 years (H,C) [28.2.3, Table 18-7]	Increased coastal erosion across Arctic (M,C) Negative effects on non-migratory Arctic species (H,C) Decreased reproductive success in Arctic seabirds (M,C) Decline in Southern Ocean seals & seabirds (M,C) Reduced thickness of foraminiferal shells in southern oceans (M,C) Reduced krill density in Scotia Sea (M,C) [6.3.2, 18.3.1, 18.3.3, 24.4.3, 28.2.2, 28.2.4, 28.3.4, Table 18-8]	Impact on livelihoods of Arctic indigenous peoples, beyond effects of economic and sociopolitical changes (M,C) Increased shipping traffic across the Bering Strait (M,C) [18.4.6, 28.2.4, 28.2.6, Tables 18-4 and 18-9, Figure 28-4]
Small Islands		Tropical bird population changes in Mauritius (M,C) Decline of an endemic plant in Hawai'i (M,C) [29.3.2, Table 18-7]	Increased coral bleaching near many tropical small islands, beyond effects of degradation due to fishing and pollution (H,C) [29.3.1, Table 18-8]	

Table TS.2.

Early warning systems for heat
EXPOSURE AND VULNERABILITY : Factors affecting exposure and vulnerability include age, pre-existing health status, level of outdoor activity, socioeconomic factors including poverty and social isolation, access to and use of cooling, physiological and behavioral adaptation of the population, urban heat island effects, and urban infrastructure. [8.2.3-4, 11.3.3-4, 11.4.1, 11.7, 13.2.1, 19.3.2, 23.5.1, 25.3, 25.8.1, SREX Table SPM.1]
CLIMATE INFORMATION AT THE GLOBAL SCALE: **Observed:** *Very likely* decrease in the number of cold days and nights and increase in the number of warm days and nights, on the global scale between 1951 and 2010. [WGI AR5 2.6.1] *Medium confidence* that the length and frequency of warm spells, including heat waves, has increased globally since 1950. [WGI AR5 2.6.1] **Projected:** *Virtually certain* that, in most places, there will be more hot and fewer cold temperature extremes as global mean temperatures increase, for events defined as extremes on both daily and seasonal timescales. [WGI AR5 12.4.3]
CLIMATE INFORMATION AT THE REGIONAL SCALE: **Observed:** *Likely* that heat wave frequency has increased since 1950 in large parts of Europe, Asia, and Australia. [WGI AR5 2.6.1] *Medium confidence* in overall increase in heat waves and warm spells in North America since 1960. Insufficient evidence for assessment or spatially varying trends in heat waves or warm spells for South America and most of Africa. [SREX Table 3-2; WGI AR5 2.6.1] **Projected:** *Likely* that, by the end of the 21st century under RCP8.5 in most land regions, a current 20-year high temperature event will at least double its frequency and in many regions occur every two years or annually, while a current 20-year low temperature event will become exceedingly rare. [WGI AR5 12.4.3] *Very likely* more frequent and/or longer heat waves or warm spells over most land areas. [WGI AR5 12.4.3]
DESCRIPTION: Heat-health early warning systems are instruments to prevent negative health impacts during heat waves. Weather forecasts are used to predict situations associated with increased mortality or morbidity. Components of effective heatwave and health warning systems include identifying weather situations that adversely affect human health, monitoring weather forecasts, communicating heatwave and prevention responses, targeting notifications to vulnerable populations, and evaluating and revising the system to increase effectiveness in a changing climate. Warning systems for heat waves have been planned and implemented broadly, for example in Europe, the United States, Asia, and Australia. [11.7.3, 24.4.6, 25.8.1, 26.6, Box 25-6]
BROADER CONTEXT: •Heat health warning systems can be combined with other elements of a health protection plan, for example building capacity to support communities most at risk, supporting and funding health services, and distributing public health information. •In Africa, Asia, and elsewhere, early warning systems have been used to provide warning of and reduce a variety of risks, related to famine and food insecurity; flooding and other weather-related hazards; exposure to air pollution from fire; and vector-borne and food-borne disease outbreaks. [7.5.1, 11.7,15.4.2, 22.4.5, 24.4.6, 25.8.1, 26.6.3, Box 25-6]
Mangrove restoration to reduce flood risks and protect shorelines from storm surge
EXPOSURE AND VULNERABILITY : Loss of mangroves increases exposure of coastlines to storm surge, coastal erosion, saline intrusion, and tropical cyclones. Exposed infrastructure, livelihoods, and people are vulnerable to associated damage. Areas with development in the coastal zone, such as on small islands, can be particularly vulnerable. [5.4.3, 5.5.6, 29.7.2, Box CC-EA]
CLIMATE INFORMATION AT THE GLOBAL SCALE: **Observed:** *Likely* increase in the magnitude of extreme high sea level events since 1970, mostly explained by rising mean sea level. [WGI AR5 3.7.5] *Low confidence* in long-term (centennial) changes in tropical cyclone activity, after accounting for past changes in observing capabilities. [WGI AR5 2.6.3] **Projected:** *Very likely* significant increase in the occurrence of future sea level extremes by 2050 and 2100. [WGI AR5 13.7.2] In the 21st century, *likely* that the global frequency of tropical cyclones will either decrease or remain essentially unchanged. *Likely* increase in both global mean tropical cyclone maximum wind speed and rainfall rates. [WGI AR5 14.6]
CLIMATE INFORMATION AT THE REGIONAL SCALE: **Observed:** Change in sea level relative to the land (relative sea level) can be significantly different from the global mean sea level change because of changes in the distribution of water in the ocean and vertical movement of the land. [WGI AR5 3.7.3] **Projected:** *Low confidence* in region-specific projections of storminess and associated storm surges. [WGI AR5 13.7.2] Projections of regional changes in sea level reach values of up to 30% above the global mean value in the Southern Ocean and around North America, and between 10% to 20% above the global mean value in equatorial regions. [WGI AR5 13.6.5] *More likely than not* substantial increase in the frequency of the most intense tropical cyclones in the western North Pacific and North Atlantic. [WGI AR5 14.6]
DESCRIPTION: Mangrove restoration and rehabilitation has occurred in a number of locations (e.g., Vietnam, Djibouti, and Brazil) to reduce coastal flooding risks and protect shorelines from storm surge. Restored mangroves have been shown to attenuate wave height and thus reduce wave damage and erosion. They protect aquaculture industry from storm damage and reduce saltwater intrusion. [2.4.3, 5.5.4, 8.3.3, 22.4.5, 27.3.3]

BROADER CONTEXT:
•Considered a low-regrets option benefiting sustainable development, livelihood improvement, and human well-being through improvements for food security and reduced risks from flooding, saline intrusion, wave damage, and erosion. Restoration and rehabilitation of mangroves, as well as of wetlands or deltas, is ecosystem-based adaptation that enhances ecosystem services.
•Synergies with mitigation given that mangrove forests represent large stores of carbon.
•Well-integrated ecosystem-based adaptation can be more cost effective and sustainable than non-integrated physical engineering approaches.
[5.5, 8.4.2, 14.3.1, 24.6, 29.3.1, 29.7.2, 30.6.1-2, Table 5-4, Box CC-EA]

Community-based adaptation and traditional practices in small island contexts

EXPOSURE AND VULNERABILITY:
With small land area, often low elevation coasts, and concentration of human communities and infrastructure in coastal zones, small islands are particularly vulnerable to rising sea levels and impacts such as inundation, saltwater intrusion, and shoreline change. [29.3.1, 29.3.3, 29.6.1-2, 29.7.2]

CLIMATE INFORMATION AT THE GLOBAL SCALE:
Observed: *Likely* increase in the magnitude of extreme high sea level events since 1970, mostly explained by rising mean sea level. [WGI AR5 3.7.5]
Low confidence in long-term (centennial) changes in tropical cyclone activity, after accounting for past changes in observing capabilities. [WGI AR5 2.6.3]
Since 1950 the number of heavy precipitation events over land has *likely* increased in more regions than it has decreased. [WGI AR5 2.6.2]
Projected: *Very likely* significant increase in the occurrence of future sea level extremes by 2050 and 2100. [WGI AR5 13.7.2]
In the 21st century, *likely* that the global frequency of tropical cyclones will either decrease or remain essentially unchanged. *Likely* increase in both global mean tropical cyclone maximum wind speed and rainfall rates. [WGI AR5 14.6]
Globally, for short-duration precipitation events, *likely* shift to more intense individual storms and fewer weak storms. [WGI AR5 12.4.5]

CLIMATE INFORMATION AT THE REGIONAL SCALE:
Observed: Change in sea level relative to the land (relative sea level) can be significantly different from the global mean sea level change because of changes in the distribution of water in the ocean and vertical movement of the land. [WGI AR5 3.7.3]
Projected: *Low confidence* in region-specific projections of storminess and associated storm surges. [WGI AR5 13.7.2]
Projections of regional changes in sea level reach values of up to 30% above the global mean value in the Southern Ocean and around North America, and between 10% to 20% above the global mean value in equatorial regions. [WGI AR5 13.6.5]
More likely than not substantial increase in the frequency of the most intense tropical cyclones in the western North Pacific and North Atlantic. [WGI AR5 14.6]

DESCRIPTION:
Traditional technologies and skills can be relevant for climate adaptation in small island contexts. In the Solomon Islands, relevant traditional practices include elevating concrete floors to keep them dry during heavy precipitation events and building low aerodynamic houses with palm leaves as roofing to avoid hazards from flying debris during cyclones, supported by perceptions that traditional construction methods are more resilient to extreme weather. In Fiji after cyclone Ami in 2003, mutual support and risk sharing formed a central pillar for community-based adaptation, with unaffected households fishing to support those with damaged homes. Participatory consultations across stakeholders and sectors within communities and capacity building taking into account traditional practices can be vital to the success of adaptation initiatives in island communities, such as in Fiji or Samoa. [29.6.2]

BROADER CONTEXT:
• Perceptions of self-efficacy and adaptive capacity in addressing climate stress can be important in determining resilience and identifying useful solutions.
•The relevance of community-based adaptation principles to island communities, as a facilitating factor in adaptation planning and implementation, has been highlighted, for example with focus on empowerment and learning-by-doing, while addressing local priorities and building on local knowledge and capacity. Community-based adaptation can include measures that cut across sectors and technological, social, and institutional processes, recognizing that technology by itself is only one component of successful adaptation.
[5.5.4, 29.6.2]

Adaptive approaches to flood defense in Europe

EXPOSURE AND VULNERABILITY :
Increased exposure of persons and property in flood risk areas has contributed to increased damages from flood events over recent decades. [5.4.3-4, 5.5.5, 23.3.1, Box 5-1]

CLIMATE INFORMATION AT THE GLOBAL SCALE:
Observed: *Likely* increase in the magnitude of extreme high sea level events since 1970, mostly explained by rising mean sea level. [WGI AR5 3.7.5]
Since 1950 the number of heavy precipitation events over land has *likely* increased in more regions than it has decreased. [WGI AR5 2.6.2]
Projected: *Very likely* that the time-mean rate of global mean sea level rise during the 21st century will exceed the rate observed during 1971-2010 for all RCP scenarios. [WGI AR5 13.5.1]
Globally, for short-duration precipitation events, *likely* shift to more intense individual storms and fewer weak storms. [WGI AR5 12.4.5]

CLIMATE INFORMATION AT THE REGIONAL SCALE:
Observed: *Likely* increase in the frequency or intensity of heavy precipitation in Europe, with some seasonal and/or regional variations. [WGI AR5 2.6.2] Increase in heavy precipitation in winter since the 1950s in some areas of northern Europe (*medium confidence*). Increase in heavy

precipitation since the 1950s in some parts of west-central Europe and European Russia, especially in winter (*medium confidence*). [SREX Table 3-2]
Increasing mean sea level with regional variations, except in the Baltic sea where the relative sea level is decreasing due to vertical crustal motion. [5.3.2, 23.2.2]
Projected: Over most of the mid-latitude land-masses, extreme precipitation events will *very likely* be more intense and more frequent in a warmer world. [WGI AR5 12.4.5]
Overall precipitation increase in northern Europe and decrease in southern Europe (*medium confidence*). [23.2.2]
Increased extreme precipitation in northern Europe during all seasons, particularly winter, and in central Europe except in summer (*high confidence*). [23.2.2; SREX Table 3.3]

DESCRIPTION:
Several governments have made ambitious efforts to address flood risk and sea level rise over the coming century. In the Netherlands, government recommendations include "soft" measures preserving land from development to accommodate increased river inundation, maintaining coastal protection through beach nourishment, and ensuring necessary political-administrative, legal, and financial resources. Through a multi-stage process, the British government has also developed extensive adaptation plans to adjust and improve flood defenses in order to protect London from future storm surges and river flooding. Pathways have been analyzed for different adaptation options and decisions, depending on eventual sea level rise, with ongoing monitoring of the drivers of risk informing decisions. [5.5.4, 23.7.1, Box 5-1]

BROADER CONTEXT:
•The Dutch plan is considered a paradigm shift, addressing coastal protection by "working with nature" and providing "room for river."
•The British plan incorporates iterative, adaptive decisions depending on the eventual sea level rise with numerous and diverse measures possible over the next 50-100 years to reduce risk to acceptable levels.
• In cities in Europe and elsewhere, the importance of strong political leadership or government champions in driving successful adaptation action has been noted.
[5.5.3-4, 8.4.3, 23.7.1-2, 23.7.4, Boxes 5-1 and 26-3]

Index-based insurance for agriculture in Africa

EXPOSURE AND VULNERABILITY:
Susceptibility to food insecurity and depletion of farmers' productive assets following crop failure. Low prevalence of insurance due to absent or poorly developed insurance markets or to amount of premium payments. The most marginalized and resource-poor especially may have limited ability to afford insurance premiums. [10.7.6, 13.3.2, Box 22-1]

CLIMATE INFORMATION AT THE GLOBAL SCALE:
Observed: *Very likely* decrease in the number of cold days and nights and increase in the number of warm days and nights, on the global scale between 1951 and 2010. [WGI AR5 2.6.1]
Medium confidence that the length and frequency of warm spells, including heat waves, has increased globally since 1950. [WGI AR5 2.6.1]
Since 1950 the number of heavy precipitation events over land has *likely* increased in more regions than it has decreased. [WGI AR5 2.6.2]
Low confidence in a global-scale observed trend in drought or dryness (lack of rainfall). [WGI AR5 2.6.2]
Projected: *Virtually certain* that, in most places, there will be more hot and fewer cold temperature extremes as global mean temperatures increase, for events defined as extremes on both daily and seasonal timescales. [WGI AR5 12.4.3]
Regional to global-scale projected decreases in soil moisture and increased risk of agricultural drought are *likely* in presently dry regions, and are projected with *medium confidence* by the end of this century under the RCP8.5 scenario. [WGI AR5 12.4.5]
Globally, for short-duration precipitation events, *likely* shift to more intense individual storms and fewer weak storms. [WGI AR5 12.4.5]

CLIMATE INFORMATION AT THE REGIONAL SCALE:
Observed: *Medium confidence* in increase in frequency of warm days and decrease in frequency of cold days and nights in southern Africa. [SREX Table 3-2]
Medium confidence in increase in frequency of warm nights in northern and southern Africa. [SREX Table 3-2]
Projected: *Likely* surface drying in southern Africa by the end of this century under RCP8.5 (*high confidence*). [WGI AR5 12.4.5]
Likely increase in warm days and nights and decrease in cold days and nights in all regions of Africa (*high confidence*). Increase in warm days largest in summer and fall (*medium confidence*). [Table SREX 3-3]
Likely more frequent and/or longer heat waves and warm spells in Africa (*high confidence*). [Table SREX 3-3]

DESCRIPTION:
A recently introduced mechanism that has been piloted in a number of rural locations, including in Malawi, Sudan, and Ethiopia, as well as in India. When physical conditions reach a particular predetermined threshold where significant losses are expected to occur--weather conditions such as excessively high or low cumulative rainfall or temperature peaks--the insurance pays out. [9.4.2, 13.3.2, 15.4.4, Box 22-1]

BROADER CONTEXT:
•Index-based weather insurance is considered well-suited to the agricultural sector in developing countries.
•The mechanism allows risk to be shared across communities, with costs spread over time, while overcoming obstacles to traditional agricultural and disaster insurance markets. It can be integrated with other strategies such as micro-finance and social protection programs.
•Risk-based premiums can help encourage adaptive responses and foster risk awareness and risk reduction by providing financial incentives to policyholders to reduce their risk profile.
•Challenges can be associated with limited availability of accurate weather data and difficulties in establishing which weather conditions cause losses. Basis risk (i.e., farmers suffer losses but no payout is triggered based on weather data) can promote distrust. There can also be difficulty in scaling up pilot schemes.

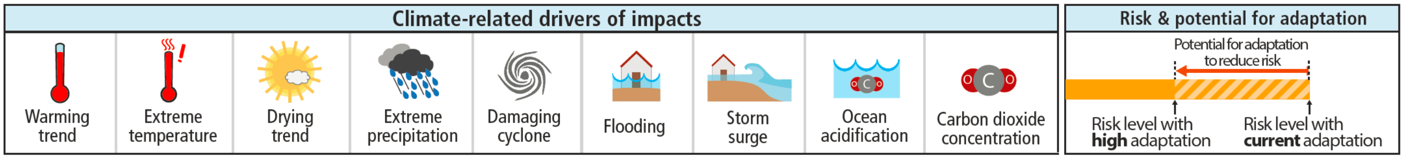
•Insurance for work programs can enable cash-poor farmers to work for insurance premiums by engaging in community-identified disaster risk reduction projects. [10.7.4-6, 13.3.2, 15.4.4, Table 10-7, Box 22-1, Box 25-7]
Relocation of agricultural industries in Australia
EXPOSURE AND VULNERABILITY : Crops sensitive to changing patterns of temperature, rainfall, and water availability. [7.3, 7.5.2]
CLIMATE INFORMATION AT THE GLOBAL SCALE: **Observed:** *Very likely* decrease in the number of cold days and nights and increase in the number of warm days and nights, on the global scale between 1951 and 2010. [WGI AR5 2.6.1] *Medium confidence* that the length and frequency of warm spells, including heat waves, has increased globally since 1950. [WGI AR5 2.6.1] *Medium confidence* in precipitation change over global land areas since 1950. [WGI AR5 2.5.1] Since 1950 the number of heavy precipitation events over land has *likely* increased in more regions than it has decreased. [WGI AR5 2.6.2] *Low confidence* in a global-scale observed trend in drought or dryness (lack of rainfall). [WGI AR5 2.6.2] **Projected:** *Virtually certain* that, in most places, there will be more hot and fewer cold temperature extremes as global mean temperatures increase, for events defined as extremes on both daily and seasonal timescales. [WGI AR5 12.4.3] *Virtually certain* increase in global precipitation as global mean surface temperature increases. [WGI AR5 12.4.1] Regional to global-scale projected decreases in soil moisture and increased risk of agricultural drought are *likely* in presently dry regions, and are projected with *medium confidence* by the end of this century under the RCP8.5 scenario. [WGI AR5 12.4.5] Globally, for short-duration precipitation events, *likely* shift to more intense individual storms and fewer weak storms. [WGI AR5 12.4.5]
CLIMATE INFORMATION AT THE REGIONAL SCALE: **Observed:** Cool extremes rarer and hot extremes more frequent and intense over Australia and New Zealand, since 1950 (*high confidence*). [Table 25-1] *Likely* increase in heat wave frequency since 1950 in large parts of Australia. [WGI AR5 2.6.1] Late autumn/winter decreases in precipitation in Southwestern Australia since the 1970s and Southeastern Australia since the mid-1990s, and annual increases in precipitation in Northwestern Australia since the 1950s (*very high confidence*). [Table 25-1] Mixed or insignificant trends in annual daily precipitation extremes, but a tendency to significant increase in annual intensity of heavy precipitation in recent decades for sub-daily events in Australia (*high confidence*). [Table 25-1] **Projected:** Hot days and nights more frequent and cold days and nights less frequent during the 21st century in Australia and New Zealand (*high confidence*). [Table 25-1] Annual decline in precipitation over southwestern Australia (*high confidence*) and elsewhere in southern Australia (*medium confidence*). Reductions strongest in the winter half-year (*high confidence*). [Table 25-1] Increase in most regions in the intensity of rare daily rainfall extremes and in sub-daily extremes (*medium confidence*) in Australia and New Zealand. [Table 25-1] Drought occurrence to increase in Southern Australia (*medium confidence*). [Table 25-1] Snow depth and snow area to decline in Australia (*very high confidence*). [Table 25-1] Freshwater resources projected to decline in far southeastern and far southwest Australia (*high confidence*). [25.5.2]
DESCRIPTION: Industries and individual farmers are relocating parts of their operations, for example for rice, wine, or peanuts in Australia, or are changing land use in situ in response to recent climate change or expectations of future change. For example, there has been some switching from grazing to cropping in South Australia. Adaptive movement of crops has also occurred elsewhere. [7.5.1, 25.7.2, Table 9-7, Box 25-5]
BROADER CONTEXT: •Considered transformational adaptation in response to impacts of climate change. •Positive or negative implications for the wider communities in origin and destination regions. [25.7.2, Box 25-5]

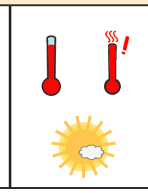
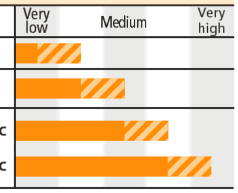
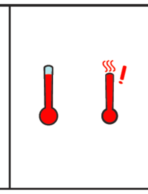
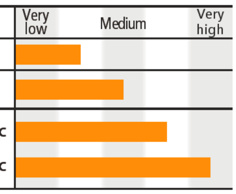
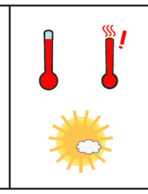
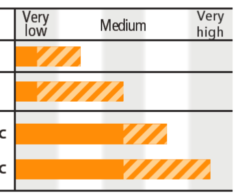
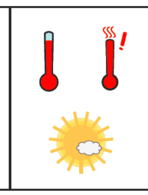
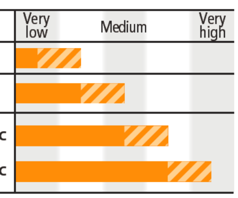
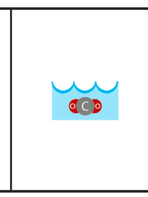
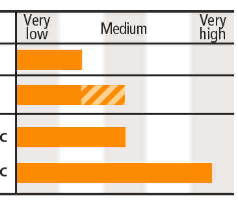
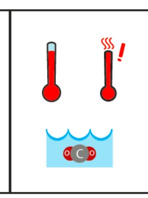
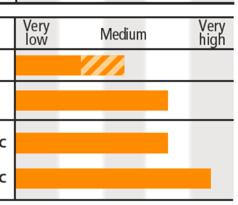
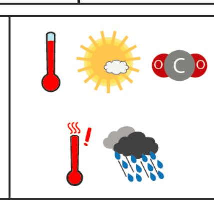
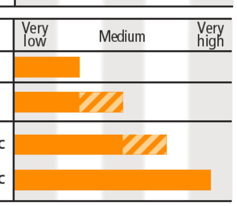
Table TS.3.

#	Hazard	Key vulnerabilities		Key risks	Emergent risks
i	Sea level rise and coastal flooding including storm surges. [5.4.3, 8.1.4, 8.2.3-4, 13.1.4, 13.2.2, 24.4-5, 26.7-8, 29.3, 30.3.1, Figure 26-2, Boxes 25-1 and 25-7; WGI AR5 3.7, 13.5, Table 13-5]	High exposure of people, economic activity, and infrastructure in low-lying coastal zones and Small Island Developing States (SIDS). Urban population unprotected due to substandard housing and inadequate insurance. Marginalized rural population with multidimensional poverty and limited alternative livelihoods. Inadequate local governmental attention to disaster risk reduction.	exposure social vulnerability institutional vulnerability	Death, injury, and disruption to livelihoods, food supplies, and drinking water. Loss of common-pool resources, sense of place, and identity, especially among indigenous populations in rural coastal zones.	Interaction of rapid urbanization, sea level rise, increasing economic activity, disappearance of natural resources, and limits of insurance; burden of risk management shifted from the state to those at risk leading to greater inequality.
ii	Warming, drought, and precipitation variability. [7.4-5, 11.3, 11.6.1, 13.2, 19.3.2, 19.4.1, 22.3.4, 24.4.4, 26.8, 27.3.4; WGI AR5 11.3.2]	Poorer populations in urban and rural settings are susceptible to resulting food insecurity; includes particularly farmers who are net food buyers and people in low-income, agriculturally dependent economies that are net food importers. Limited ability to cope among the elderly and female-headed households.	social vulnerability institutional vulnerability	Risk of harm and loss of life due to reversal of progress in reducing malnutrition.	Interactions of climate changes, population growth, reduced productivity, biofuel crop cultivation, and food prices with persistent inequality, and ongoing food insecurity for the poor increases malnutrition, giving rise to larger burden of disease. Exhaustion of social networks reduces coping capacity.
iii	Extreme precipitation and inland flooding. [3.2.7, 3.4.8, 8.2.3-4, 13.2.1, 25.10, 26.3, 26.7-8, 27.3.5, Box 25-8; WGI AR5 11.3.2]	Large numbers of people exposed in urban areas to flood events, particularly in low-income informal settlements. Overwhelmed, aging, poorly maintained, and inadequate urban drainage infrastructure and limited ability to cope and adapt due to marginalization, high poverty, and culturally imposed gender roles. Inadequate governmental attention to disaster risk reduction.	exposure social vulnerability institutional vulnerability	Death, injury, and disruption of human security, especially among children, elderly, and disabled.	Interaction of increasing frequency of intense precipitation, urbanization, and limits of insurance; burden of risk management shifted from the state to those at risk leading to greater inequality, eroded assets due to infrastructure damage, abandonment of urban districts, and the creation of high risk/high poverty spatial traps.
iv	Drought. [3.2.7, 3.4.8, 3.5.1, 8.2.3-4, 9.3.3, 9.3.5, 13.2.1, 19.3.2, 24.4; WGI AR5 12.4.1, 12.4.5]	Urban populations with inadequate water services. Existing water shortages (and irregular supplies), and constraints on increasing supplies. Lack of capacity and resilience in water management regimes including rural-urban linkages.	social vulnerability institutional vulnerability	Insufficient water supply for people and industry yielding severe harm and economic impacts.	Interaction of urbanization, infrastructure insufficiency, groundwater depletion.
		Poorly endowed farmers in drylands or pastoralists with insufficient access to drinking and irrigation water. Limited ability to compensate for losses in water-dependent farming and pastoral systems, and conflict over natural resources.	exposure	Loss of agricultural productivity and/or income of rural people. Destruction of livelihoods particularly for those depending on water-intensive agriculture. Risk of food insecurity.	Interactions across human vulnerabilities: deteriorating livelihoods, poverty traps, heightened food insecurity, decreased land productivity, rural outmigration, and increase in new urban poor in low- and middle-income countries. Potential tipping point in rain-

		Lack of capacity and resilience in water management regimes, inappropriate land policy, and misperception and undermining of pastoral livelihoods.	social vulnerability institutional vulnerability		fed farming system and/or pastoralism.
v	Novel hazards yielding systemic risks. [8.1.4, 8.2.4, 10.2-3, 12.6, 23.9, 25.10, 26.7-8; WGI AR5 11.3.2]	Populations and infrastructure exposed and lacking historical experience with these hazards. Overly hazard-specific management planning and infrastructure design, and/or low forecasting capability.	exposure institutional vulnerability	Failure of systems coupled to electric power system, e.g., drainage systems reliant on electric pumps or emergency services reliant on telecommunications. Collapse of health and emergency services in extreme events.	Interactions due to dependence on coupled systems lead to magnification of impacts of extreme events. Reduced social cohesion due to loss of faith in management institutions undermines preparation and capacity for response.
vi	Rising ocean temperature, stratification, ocean acidification, and loss of Arctic sea ice. [5.4.2, 6.3.1-2, 7.4.2, 9.3.5, 22.3.2, 25.6, 27.3.3, 28.2-3, 29.3.1, 30.5-6, Boxes CC-OA and CC-CR; WGI AR5 11.3.3]	High susceptibility of warm-water coral reefs and respective ecosystem services for coastal communities; high susceptibility of polar systems, e.g., to invasive species. Susceptibility of coastal and SIDS fishing communities depending on these ecosystem services; and of Arctic settlements and culture.	environmental vulnerability economic vulnerability environmental vulnerability	Loss of coral cover, Arctic species, and associated ecosystems with reduction of biodiversity and potential losses of important ecosystem services. Risk of loss of endemic species, mixing of ecosystem types, and increased dominance of invasive organisms.	Interactions of stressors such as acidification and warming on calcareous organisms enhancing risk.
vii	Rising land temperatures, and changes in precipitation patterns and in frequency and intensity of extreme heat. [4.3.4, 19.3.2, 22.4.5, 27.3, Table 23-2, Box CC-WE; WGI AR5 11.3.2]	Susceptibility of human systems, agro-ecosystems and natural ecosystems to (i) loss of regulation of pests and diseases, fire, landslide, erosion, flooding, avalanche, water quality, and local climate (ii) loss of provision of food, livestock, fiber, bioenergy (iii) loss of recreation, tourism, aesthetic and heritage values, and biodiversity.	economic vulnerability environmental vulnerability	Reduction of biodiversity and potential losses of important ecosystem services. Risk of loss of endemic species, mixing of ecosystem types, and increased dominance of invasive organisms.	Interaction of social-ecological systems with loss of ecosystem services upon which they depend.
viii	Increasing frequency and intensity of extreme heat, including urban heat island effect. [8.2.3, 11.3, 11.4.1, 13.2, 23.5.1, 24.4.6, 25.8.1, 26.6, 26.8, Box CC-HS; WGI AR5 11.3.2]	Increasing urban population of the elderly, the very young, expectant mothers, and people with chronic health problems in settlements subject to higher temperatures. Inability of local organizations that provide health, emergency, and social services to adapt to new risk levels for vulnerable groups.	social vulnerability institutional vulnerability	Increased mortality and morbidity during periods of extreme heat.	Interaction of demographic shifts with changes in regional temperature extremes, local heat island, and air pollution. Overloading of health and emergency services. Mortality, morbidity, and productivity loss among manual workers in hot climates.

Table TS.4.



Key risk	Adaptation issues and prospects	Climatic drivers	Supporting ch. sections	Timeframe	Risk for current and high adaptation
Global Risks					
Reduction in terrestrial carbon sink: Carbon stored in terrestrial ecosystems is vulnerable to loss back into the atmosphere, resulting from increased fire frequency due to climate change and the sensitivity of ecosystem respiration to rising temperatures (*medium confidence*)	• Adaptation options include managing land use (including deforestation), fire and other disturbances, and non-climatic stressors.		4.2-3	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Boreal tipping point: Arctic ecosystems are vulnerable to abrupt change related to the thawing of permafrost, spread of shrubs in tundra, and increase in pests and fires in boreal forests (*medium confidence*)	• There are few adaptation options in the Arctic.		4.3, Box 4-4	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Amazon tipping point: Moist Amazon forests could change abruptly to less-carbon-dense, drought- and fire-adapted ecosystems (*medium confidence*)	• Policy and market measures can reduce deforestation and fire.		4.3, Box 4-3	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Increased risk of species extinction: A large fraction of the species assessed is vulnerable to extinction due to climate change, often in interaction with other threats. Species with an intrinsically low dispersal rate, especially when occupying flat landscapes where the projected climate velocity is high, and species in isolated habitats such as mountaintops, islands, or small protected areas are especially at risk. Cascading effects through organism interactions, especially those vulnerable to phenological changes, amplify risk (*high confidence*)	• Adaptation options include reduction of habitat modification and fragmentation, pollution, over-exploitation, and invasive species; protected area expansion; assisted dispersal; and *ex situ* conservation.		4.3-4	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Reduced growth and survival of commercially valuable shellfish and other calcifiers (e.g., reef building corals, calcareous red algae) due to ocean acidification (*high confidence*)	• Evidence for differential resistance and evolutionary adaptation of some species exists but is *likely* to be limited at higher CO_2 concentrations and temperatures. • Adaptation options include exploiting more resilient species or protecting habitats with low natural CO_2 levels, as well as reducing other stresses, mainly pollution, and limiting pressures from tourism and fishing.		5.3, 6.1, 6.3-4, 30.3, Box CC-OA	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Marine biodiversity loss with high rate of climate change (*medium confidence*)	• Adaptation options are limited to reducing other stresses, mainly pollution, and limiting pressures from coastal human activities such as tourism and fishing.		6.3-4, Table 30-4, Box CC-MB	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	
Negative impacts on average crop yields and increases in yield variability due to climate change (*high confidence*)	• With or without adaptation, negative impacts on average yields become *likely* from the 2030s with median yield impacts of 0 to -2% per decade projected for the rest of the century, and after 2050 the risk of more severe impacts increases.		7.2-5, Box 7-1	Present Near-term (2030-2040) Long-term (2080-2100) 2°C 4°C	

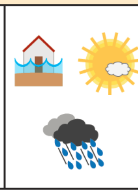
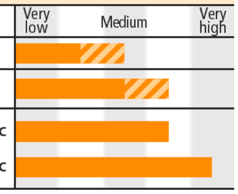
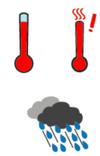
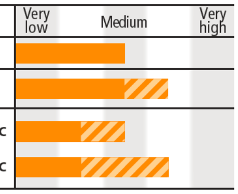
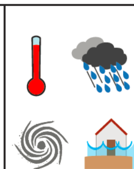
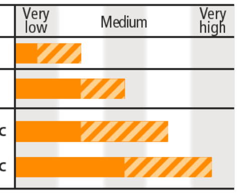
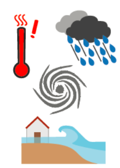
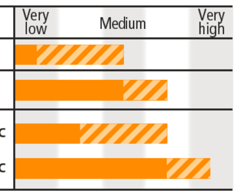
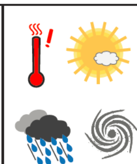
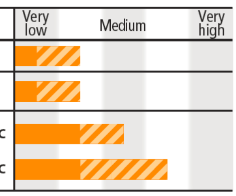
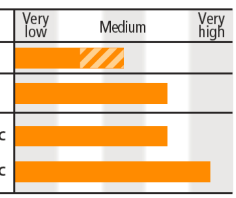
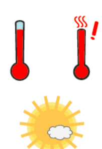
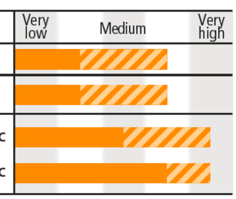
Key risk	Adaptation issues and prospects	Climatic drivers	Supporting ch. sections	Timeframe	Risk for current and high adaptation
Global Risks					
Urban risks associated with water supply systems (*high confidence*)	• Adaptation options include changes to network infrastructure as well as demand-side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

Table TS.5.

Climate-related drivers of impacts										Risk & potential for adaptation
Warming trend	Extreme temperature	Drying trend	Extreme precipitation	Precipitation	Snow cover	Damaging cyclone	Sea level	Ocean acidification	Carbon dioxide concentration	Potential for adaptation to reduce risk Risk level with **high** adaptation Risk level with **current** adaptation

Key risk	Adaptation issues and prospects	Climatic drivers	Supporting ch. sections	Timeframe	Risk for current and high adaptation
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	Very low / Medium / Very high
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	Very low / Medium / Very high
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	Very low / Medium / Very high

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	Very low / Medium / Very high
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	Very low / Medium / Very high
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	Very low / Medium / Very high

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	Very low / Medium / Very high

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	Very low – Medium – Very high
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	Very low – Medium – Very high

Key risk	Adaptation issues and prospects	Climatic drivers	Supporting ch. sections	Timeframe	Risk for current and high adaptation
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	Very low – Medium – Very high
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	Very low – Medium – Very high
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	Very low – Medium – Very high

Key risk	Adaptation issues and prospects	Climatic drivers	Supporting ch. sections	Timeframe	Risk for current and high adaptation
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	Very low – Medium – Very high
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	Very low – Medium – Very high
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	Very low – Medium – Very high

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 TS.6.

Key

Symbols

- Increasing trend or signal
- Decreasing trend or signal
- Both increasing and decreasing trends or signals
- Inconsistent trend or signal or insufficient evidence
- No or only slight change

Level of confidence in findings

- Low confidence
- Medium confidence
- High confidence

Region/ region code	Trends in daytime temperature extremes (frequency of hot and cool days)		Trends in heavy precipitation (rain, snow)		Trends in dryness and drought	
	Observed	Projected	Observed	Projected	Observed	Projected
West North America WNA, 3	*Very likely* large increases in hot days (large decreases in cool days)[a]	*Very likely* increase in hot days (decrease in cool days)[b]	Spatially varying trends. General increase, decrease in some areas[a]	Increase in 20-year return value of annual maximum daily precipitation and other metrics over northern part of the region (Canada)[b] Less confidence in Southern part of the region, due to inconsistent signal in these other metrics[b]	No or overall slight decrease in dryness[a]	Inconsistent signal[b]
Central North America CNA, 4	Spatially varying trends: small increases in hot days in the north, decreases in the south[a]	*Very likely* increase in hot days (decrease in cool days)[b]	*Very likely* increase since 1950[a]	Increase in 20-year return value of annual maximum daily precipitation[b] Inconsistent signal in other heavy precipitation days metrics[b]	*Likely* decrease[a, c]	Increase in consecutive dry days and soil moisture in southern part of Central North America[b] Inconsistent signal in the rest of the region[b]
East North America ENA, 5	Spatially varying trends. Overall increases in hot days (decreases in cool days), opposite or insignificant signal in a few areas[a]	*Very likely* increase in hot days (decrease in cool days)[b]	*Very likely* increase since 1950[a]	Increase in 20-year return value of annual maximum daily precipitation. Additional metrics support an increase in heavy precipitation over northern part of the region[b] No signal or inconsistent signal in these other metrics in the southern part of the region[b]	Slight decrease in dryness since 1950[a]	Inconsistent signal in consecutive dry days, some consistent decrease in soil moisture[b]
Alaska/ Northwest Canada ALA, 1	*Very likely* large increases in warm days (decreases in cold days)[a]	*Very likely* increase in hot days (decrease in cool days)[b]	Slight tendency for increase[a] No significant trend in southern Alaska[a]	*Likely* increase in heavy precipitation[b]	Inconsistent trends[a] Increases in dryness in part of the region[a]	Inconsistent signal[b]
East Canada, Greenland, Iceland CGI, 2	*Likely* increases in hot days (decreases in cool days) in some areas, decrease in hot days (increase in cool days) in others[a]	*Very likely* increase in warm days (decrease in cold days)[b]	Increase in a few areas[a]	*Likely* increase in heavy precipitation[b]	Insufficent evidence[a]	Inconsistent signal[b]
Northern Europe NEU, 11	Increase in hot days (decrease in cool days), but generally not significant at the local scale[a]	*Very likely* increase in hot days (decrease in cool days) [but smaller trends than in central and southern Europe][b]	Increase in winter in some areas, but often insignificant or inconsistent trends at subregional scale, particularly in summer[a]	*Likely* increase in 20-year return value of annual maximum daily precipitation. *Very likely* increases in heavy preciptation intensity and frequency in winter in the north[b]	Spatially varying trends. Overall only slight or no increase in dryness, slight decrease in dryness in part of the region[a]	No major changes in dryness[b]

Region/ region code	Trends in daytime temperature extremes (frequency of hot and cool days)		Trends in heavy precipitation (rain, snow)		Trends in dryness and drought	
	Observed	Projected	Observed	Projected	Observed	Projected
Central Europe CEU, 12	*Likely* overall increase in hot days (decrease in cool days) since 1950 in most regions. *Very likely* increase in hot days (likely decrease in cool days) in west Central Europe[a] Lower confidence in trends in east Central Europe (due to lack of literature, partial lack of access to observations, overall weaker signals, and change point in trends)[a]	*Very likely* increase in hot days (decrease in cool days)[b]	Increase in part of the region, in particular central Western Europe and European Russia, especially in winter[a] Insignificant or inconsistent trends elsewhere, in particular in summer[a]	*Likely* increase in 20-year return value of annual maximum daily precipitation. Additional metrics support an increase in heavy precipitation in large part of the region over winter[b] Less confidence in summer, due to inconsistent evidence[b]	Spatially varying trends. Increase in dryness in part of the region but some regional variation in dryness trends and dependence of trends on studies considered (index, time period)[a]	Increase in dryness in central Europe and increase in short-term droughts[b]
Southern Europe and Mediterra-nean MED, 13	*Likely* increase in hot days (decrease in cool days) in most of the region. Some regional and temporal variations in the significance of the trends. Likely strongest and most significant trends in Iberian peninsula and southern France[a] Smaller or less significant trends in southeastern Europe and Italy due to change point in trends, strongest increase in hot days since 1976[a]	*Very likely* increase in hot days (decrease in cool days)[b]	Inconsistent trends across the region and across studies[a]	Inconsistent changes and/or regional variations[b]	Overall increase in dryness, *likely* increase in the Mediterranean[a, c]	Increase in dryness. Consistent increase in area of drought[b, d]
West Africa WAF, 15	Significant increase in temperature of hottest day and coolest day in some parts[a] Insufficient evidence in other parts[a]	*Likely* increase in hot days (decrease in cool days)[b]	Rainfall intensity increased[a]	Slight or no change in heavy precipitation indicators in most areas[b] Low model agreement in northern areas[b]	*Likely* increase but 1970s Sahel drought dominates the trend; greater inter- annual variation in recent years[a, c]	Inconsistent signal[b]
East Africa EAF, 16	Lack of evidence due to lack of literature and spatially non-uniform trends[a] Increases in hot days in Southern tip (decrease in cool days)[a]	*Likely* increase in hot days (decrease in cool days)[b]	Insufficient evidence[a]	*Likely* increase in heavy precipitation[b]	Spatially varying trends in dryness[a]	Decreasing dryness in large areas[b]
Southern Africa SAF, 17	*Likely* increase in hot days (decrease in cool days)[a, c]	*Likely* increase in hot days (decrease in cool days)[b]	Increases in more regions than decreases but spatially varying trends[a]	Lack of agreement in signal for region as a whole[b] Some evidence of increase in heavy precipitation in southeast regions[b]	General increase in dryness[a]	Increase in dryness, except eastern part[b, d] Consistent increase in area of drought[b]
Sahara SAH, 14	Lack of literature[a]	*Likely* increase in hot days (decrease in cool days)[b]	Insufficient evidence[a]	Low agreement[b]	Limited data, spatial variation of the trends[a]	Inconsistent signal of change[b]
Central America and Mexico CAM, 6	Increases in the number of hot days, decreases in the number of cool days[a]	*Likely* increase in hot days (decrease in cool days)[b]	Spatially varying trends. Increase in many areas, decrease in a few others[a]	Inconsistent trends[b]	Varying and inconsistent trends[a]	Increase in dryness in Central America and Mexico, with less confidence in trend in extreme South of region[b]

Region/ region code	Trends in daytime temperature extremes (frequency of hot and cool days)		Trends in heavy precipitation (rain, snow)		Trends in dryness and drought	
	Observed	Projected	Observed	Projected	Observed	Projected
Amazon AMZ, 7	Insufficient evidence to identify trends[a]	Hot days *likely* to increase (cool days *likely* to decrease)[b]	Increases in many areas, decreases in a few[a]	Tendency for increases in heavy precipitation events in some metrics[b]	Decrease in dryness for much of the region. Some opposite trends and inconsistencies[a]	Inconsistent signals[b]
Northeastern Brazil NEB, 8	Increases in the number of hot days[a]	Hot days *likely* to increase (cool days *likely* to decrease)[b]	Increases in many areas, decreases in a few[a]	Slight or no change[b]	Varying and inconsistent trends[a]	Increase in dryness[b]
Southeast-ern South America SSA, 10	Spatially varying trends (increases in some areas decreases in others)[a]	Hot days *likely* to increase (cool days *likely* decrease)[b]	Increases in northern areas[a] Insufficient evidence in southern areas[a]	Increases in northern areas[b] Insufficient evidence in southern areas[b]	Varying and inconsistent trends[a]	Inconsistent signals[b]
West Coast South America WSA, 9	Spatially varying trends (increases in some areas decreases in others)[a]	Hot days *likely* to increase (cool days *likely* decrease)[b]	Increases in many areas, decrease in a few areas[a]	Increases in tropics[b] Low confidence in extratropics[b]	Varying and inconsistent trends[a]	Decrease in consecutive dry days in the tropics, and increase in the extratropics[b] Increase in consecutive dry days and soil moisture in southwest South America[b]
North Asia NAS, 18	*Likely* increase in hot days (decrease cool days)[a]	*Likely* increase in hot days (decrease in cool days)[b]	Increase in some regions, but spatial variation[a]	*Likely* increase in heavy precipitation for most regions[b]	Spatially varying trends[a]	Inconsistent signal of change[b]
Central Asia CAS, 20	*Likely* increase in hot days (decrease cool days)[a]	*Likely* increase in hot days (decrease in cool days)[b]	Spatially varying trends[a]	Inconsistent signal in models[b]	Spatially varying trends[a]	Inconsistent signal of change[b]
East Asia EAS, 22	*Likely* increase in hot days (decrease cool days)[a]	*Likely* increase in hot days (decrease in cool days)[b]	Spatially varying trends[a]	Increase in heavy precipitation across the region[b]	Tendency for increased dryness[a]	Inconsistent signal of change[b]
Southeast Asia SEA, 24	Increase in hot days (decrease cool days) for northern areas[a] Insufficient evidence for Malay Archipelago[a]	*Likely* increase in hot days (decrease in cool days)[b]	Spatially varying trends, partial lack of evidence[a]	Increases in most metrics over most (especially non-continental) regions. One metric shows inconsistent signals of change[b]	Spatially varying trends[a]	Inconsistent signal of change[b]
South Asia SAS, 23	Increase in hot days (decrease cool days)[a]	*Likely* increase in hot days (decrease in cool days)[b]	Mixed signal in India[a]	More frequent and intense heavy precipitation days over parts of S. Asia. Either no change or some consistent increases in other metrics[b]	Inconsistent signal for different studies and indices[a]	Inconsistent signal of change[b]
West Asia WAS, 19	*Very likely* increase in hot days (decrease in cool days *more likely than not*)[a]	*Likely* increase in hot days (decrease in cool days)[b]	Decrease in heavy precipitation events[a]	Inconsistent signal of change[b]	Lack of studies, mixed results[a]	Inconsistent signal of change[b]
Tibetan Plateau TIB, 21	*Likely* increase in hot days (decrease cool days)[a]	*Likely* increase in hot days (decrease in cool days)[b]	Insufficient evidence[a]	Increase in heavy precipitation[b]	Insufficient evidence. Tendency to decreased dryness[a]	Inconsistent signal of change[b]
North Australia NAU, 25	*Likely* increase in hot days (decrease in cool days). Weaker trends in northwest[a]	*Very likely* increase in hot days (decrease in cool days)[b]	Spatially varying trends, which mostly reflect changes in mean rainfall[e]	Increase in most regions in the intensity of extreme (i.e. current 20 year return period) heavy rainfall events[e]	No significant change in drought occurrence over Australia (defined using rainfall anomalies)[e]	Inconsistent signal[b]

Region/ region code	Trends in daytime temperature extremes (frequency of hot and cool days)		Trends in heavy precipitation (rain, snow)		Trends in dryness and drought	
	Observed	Projected	Observed	Projected	Observed	Projected
South Australia/ New Zealand SAU, 26	*Very likely* increase in hot days (decrease in cool days)[a]	*Very likely* increase in hot days (decrease in cool days)[b]	Spatially varying trends in S Australia, which mostly reflect changes in mean rainfall[e] Spatially varying trends in NZ, which mostly reflect changes in mean rainfall[e]	Increase in most regions in the intensity of extreme (i.e. current 20 year return period) heavy rainfall events[e]	No significant change in drought occurrence over Australia (defined using rainfall anomalies)[e] No trend in drought occurrence over New Zealand (defined using a soil water balance model) since 1972[e]	Increase in drought frequency in southern Australia, and in many regions of New Zealand[e]

Table TS.7.

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.		

Table TS.8.

Green infrastructure and green roofs
Objectives: Storm water management, adaptation to increasing temperatures, reduced energy use, urban regeneration
Relevant Sectors: Infrastructure, energy use, water management
Overview: Benefits of green infrastructure and roofs can include reduction of storm water runoff and the urban heat island effect, improved energy performance of buildings, reduced noise and air pollution, health improvements, better amenity value, increased property values, improved biodiversity, and inward investment. Trade-offs can result between higher urban density to improve energy efficiency and open space for green infrastructure. [8.3.3, 11.7.4, 23.7.4, 24.6, Tables 11-3 and 25-5]
EXAMPLES WITH INTERACTIONS: **London:** The Green Grid for East London seeks to create interlinked and multi-purpose open spaces to support regeneration of the area. It aims to connect people and places, to absorb and store water, to cool the vicinity, and to provide a diverse mosaic of habitats for wildlife. [8.3.3] **New York**: In preparation for more intense storms, New York is using green infrastructure to capture rainwater before it can flood the combined sewer system, implementing green roofs, and elevating boilers and other equipment above ground. [8.3.3, 26.3.3, 26.8.4] **Singapore**: Singapore has used several anticipatory plans and projects to enhance green infrastructure, including its Streetscape Greenery Master Plan, constructed wetlands or drains, and community gardens. Under its Skyrise Greenery project, Singapore has provided subsidies and handbooks for rooftop and wall greening initiatives. [8.3.3] **Durban**: Ecosystem-based adaptation is part of Durban's climate change adaptation strategy. The approach seeks a more detailed understanding of the ecology of indigenous ecosystems and ways in which biodiversity and ecosystem services can reduce vulnerability of ecosystems and people. Examples include the Community Reforestation Programme, in which communities produce indigenous seedlings used in the planting and managing of restored forest areas. Development of ecosystem-based adaptation in Durban has demonstrated needs for local knowledge and data and the benefits of enhancing existing protected areas, land-use practices, and local initiatives contributing to jobs, business, and skill development. [8.3.3, Box 8-2]
Water management
Primary Objective: Water resource management given multiple stressors in a changing climate
Relevant Sectors: Water use, energy production and use, biodiversity, carbon sequestration, biofuel production, food production
Overview: Water management in the context of climate change can encompass ecosystem-based approaches (e.g., watershed management or restoration, flood regulation services, and reduction of erosion or siltation), supply-side approaches (e.g., dams, reservoirs, groundwater pumping and recharge, and water capture), and demand-side approaches (e.g., increased use efficiency through water recycling, infrastructure upgrades, water-sensitive design, or more efficient allocation). Water may require significant amounts of energy for lifting, transport, distribution, and treatment. [3.7.2, 26.3, Tables 9-8 and 25-5, Boxes CC-EA and CC-WE]
EXAMPLES WITH INTERACTIONS: **New York**: New York has a well-established program to protect and enhance its water supply through watershed protection. The Watershed Protection Program includes city ownership of land that remains undeveloped and coordination with landowners and communities to balance water-quality protection, local economic development, and improved wastewater treatment. The city government indicates it is the most cost-effective choice for New York given the costs and environmental impacts of a filtration plant. [8.3.3, Box 26-3] **Cape Town:** Facing challenges in ensuring future supplies, Cape Town responded by commissioning water management studies, which identified the need to incorporate climate change, as well as population and economic growth, in planning. During the 2005 drought, local authorities increased water tariffs to promote efficient water usage. Additional measures may include water restrictions, reuse of grey water, consumer education, or technological solutions such as low-flow systems or dual flush toilets. [8.3.3] **Capital cities in Australia:** Many Australian capital cities are reducing reliance on catchment runoff and groundwater—water resources most sensitive to climate change and drought—and are diversifying supplies through desalination plants, water reuse including sewage and storm water recycling, and integrated water cycle management that considers climate change impacts. Demand is being reduced through water conservation and water-sensitive urban design and, during severe shortfalls, through implementation of restrictions. The water augmentation program in Melbourne includes a desalination plant. Trade-offs beyond energy intensiveness have been noted, such as damage to sites significant to aboriginal communities and higher water costs that will disproportionately affect poorer households. [14.6.2, Table 25-7, Box 25-2]
Payment for environmental services and green fiscal policies
Primary Objective: Management incorporating the costs of environmental externalities and the benefits of ecosystem services
Relevant Sectors: Biodiversity, ecosystem services
Overview: Payment for environmental services (PES) is a market-based approach that aims to protect natural areas, and associated livelihoods and environmental services, by developing financial incentives for preservation. Mitigation-focused PES schemes are common, and there is emerging evidence of adaptation-focused PES schemes. Successful PES approaches can be difficult to design for services that are hard to define or quantify. [17.5.2, 27.6.2]
EXAMPLES WITH INTERACTIONS: **Central and South America**: A variety of PES schemes have been implemented in Central and South America. For example, national-level

programs have operated in Costa Rica and Guatemala since 1997 and in Ecuador since 2008. Examples to date have shown that PES can finance conservation, ecosystem restoration and reforestation, better land-use practices, mitigation, and more recently adaptation. Uniform payments for beneficiaries can be inefficient if, for example, recipients that promote greater environmental gains receive only the prevailing payment. [17.5.2, 27.3.2, 27.6.2, Table 27-8]

Brazil: Municipal funding in Brazil tied to ecosystem-management quality is a form of revenue transfer important to funding local adaptation actions. State governments collect a value-added tax redistributed among municipalities, and some states allocate revenues in part based on municipality area set aside for protection. This mechanism has helped improve environmental management and increased creation of protected areas. It benefits relations between protected areas and surrounding inhabitants, as the areas can be perceived as opportunities for revenue generation rather than as obstacles to development. The approach builds on existing institutions and administrative procedures and thus has low transaction costs. [8.4.3, Box 8-4]

Renewable Energy
Primary Objective: Renewable energy production and reduction of emissions
Relevant Sectors: Biodiversity, agriculture, food security
Overview: Renewable energy production can require significant land areas and water resources, creating the potential for both positive and negative interactions between mitigation policies and land management. [4.4.4, 13.3.1, 19.3.2, 19.4.1, Box CC-WE]
EXAMPLES WITH INTERACTIONS: **Central and South America**: Renewable resources, especially hydroelectric power and biofuels, account for substantial fractions of energy production in countries such as Brazil. Where bioenergy crops compete for land with food crops, substantial trade-offs can exist. Land-use change to produce bioenergy can affect food crops, biodiversity, and ecosystem services. Lignocellulosic feedstocks, such as sugarcane second-generation technologies, do not compete with food. [19.3.2, 27.3.6, 27.6.1, Table 27-6] **Australia & New Zealand**: Mandatory renewable energy targets and incentives to increase carbon storage support increased biofuel production and increased biological carbon sequestration, with impacts on biodiversity depending on implementation. Benefits can include reduced erosion, additional habitat, and enhanced connectivity, with risks or lost opportunities associated with large-scale monocultures especially if replacing more diverse landscapes. Large-scale land-cover changes can affect catchment yields and regional climate in complex ways. New crops such as oil mallees or other eucalypts may provide multiple benefits, especially in marginal areas, displacing fossil fuels or sequestering carbon, generating income for landholders (essential oils, charcoal, bio-char, biofuels), and providing ecosystem services. [Table 25-7, Box 25-10]

Disaster risk reduction and adaptation to climate extremes
Primary Objective: Increasing resilience to extreme weather events in a changing climate
Relevant Sectors: Infrastructure, energy use, spatial planning
Overview: Synergies and tradeoffs among sustainable development, adaptation, and mitigation occur in preparing for and responding to climate extremes and disasters. [13.2-4, 20.3-4]
EXAMPLES WITH INTERACTIONS: **Philippines:** The Homeless People's Federation of the Philippines developed responses following disasters, including: community-rooted data gathering (e.g., assessing destruction and victims' immediate needs); trust and contact building; savings support; community-organization registration; and identification of needed interventions (e.g., building-materials loans). Community surveys mapped inhabitants especially at risk in informal settlements, raising risk-awareness among the inhabitants and increasing community engagement in planning risk reduction and early warning systems. [8.3.2, 8.4.2] **London:** Within London, built form and other dwelling characteristics can have a stronger influence on indoor temperatures during heat waves than the urban heat island effect, and utilizing shade, thermal mass, ventilation control, and other passive-design features are effective adaptation options. Passive housing designs enhance natural ventilation and improve insulation, while also reducing household emissions. For example, in London the Beddington Zero Energy Development was designed to reduce or eliminate energy demand for heating, cooling, and ventilation for much of the year. [8.3.3, 11.7.4] **United States:** In the United States, post-disaster funds for loss reduction are added to funds provided for disaster recovery. They can be used, for instance, to buy out properties that have experienced repetitive flood losses and relocate residents to safer locations, to elevate structures, to assist communities with purchasing property and altering land-use patterns in flood-prone areas, and to undertake other activities designed to lessen the impacts of future disasters. [14.3.3]

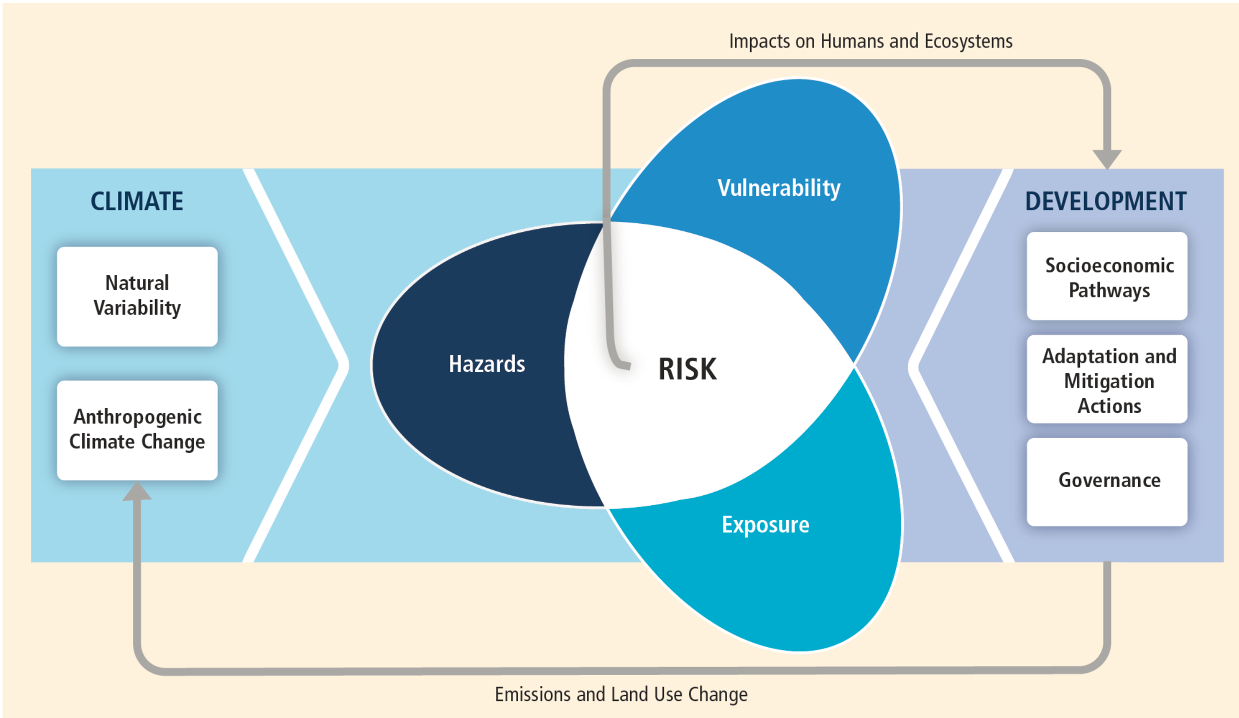
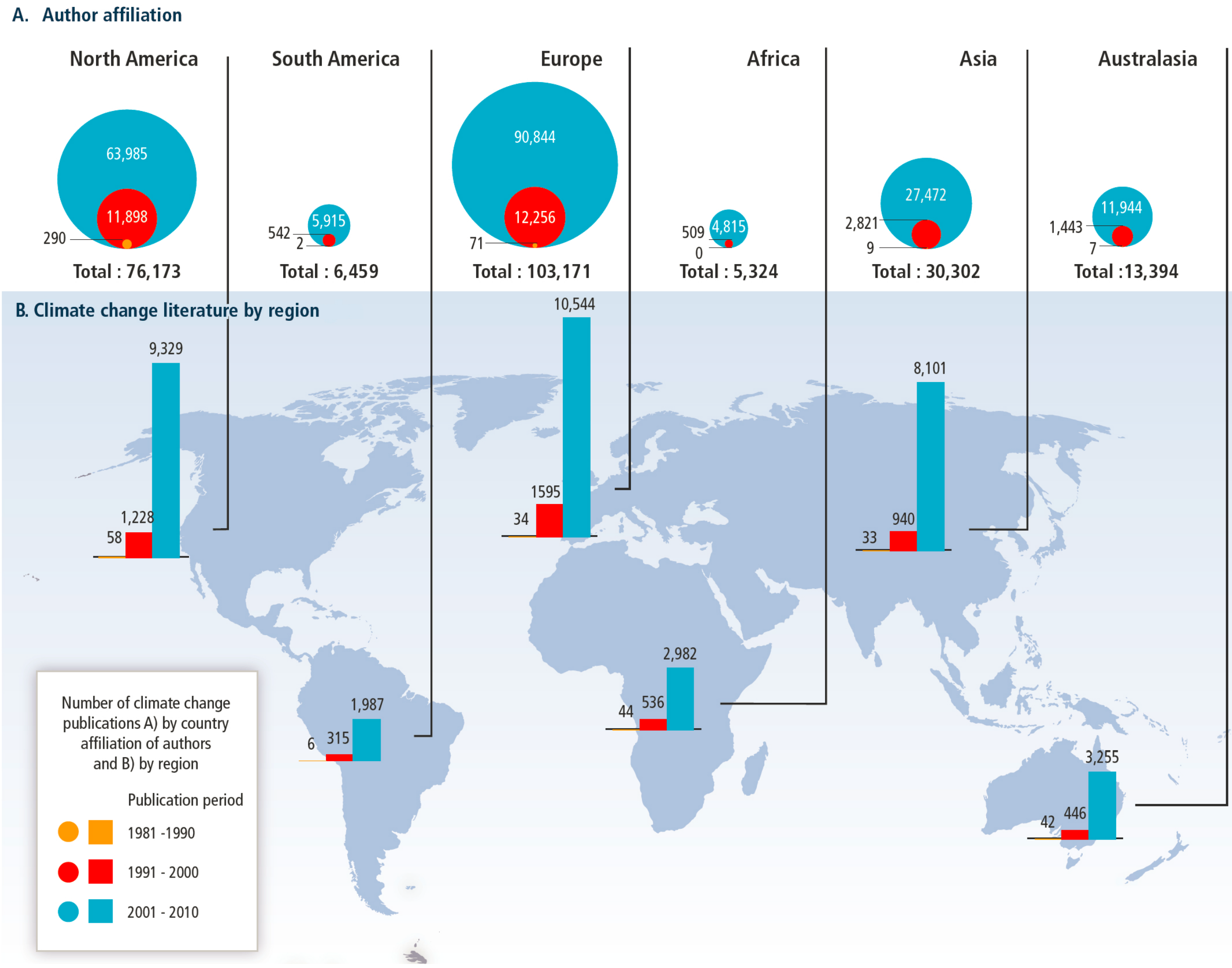
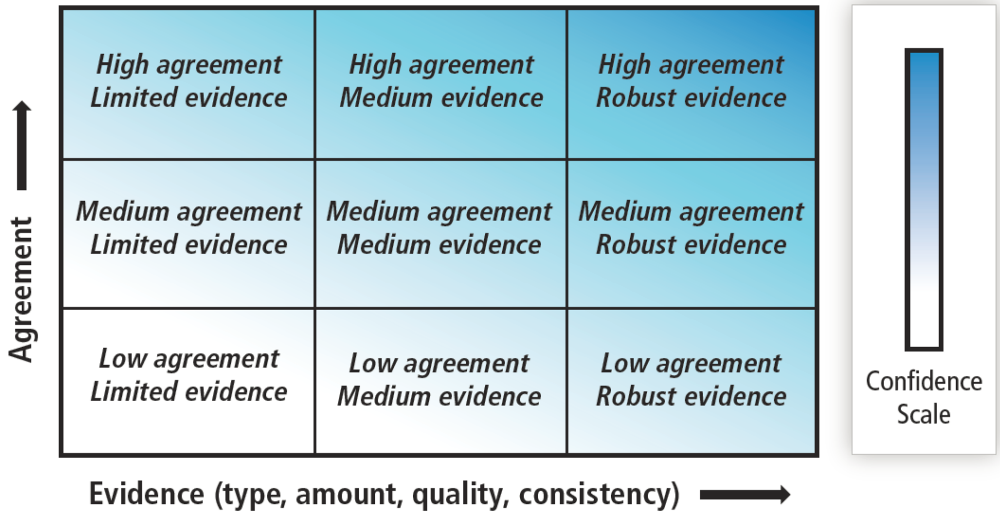

Impacts on Humans and Ecosystems
CLIMATE
Natural Variability
Anthropogenic Climate Change
Vulnerability
Hazards
RISK
Exposure
DEVELOPMENT
Socioeconomic Pathways
Adaptation and Mitigation Actions
Governance
Emissions and Land Use Change

Figure TS.1.



Box TS.1 Figure 1.



Box TS.3 Figure 1.

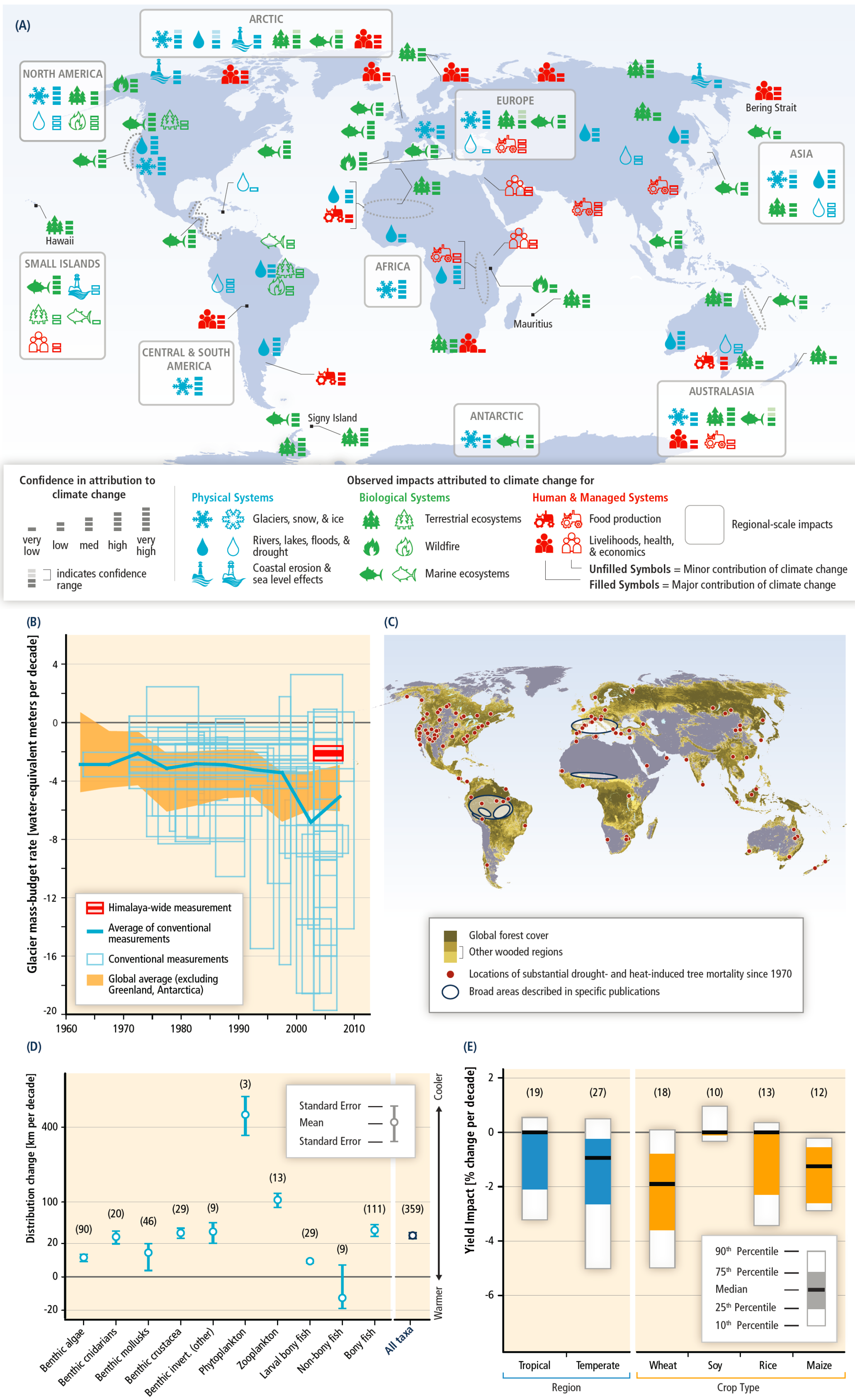
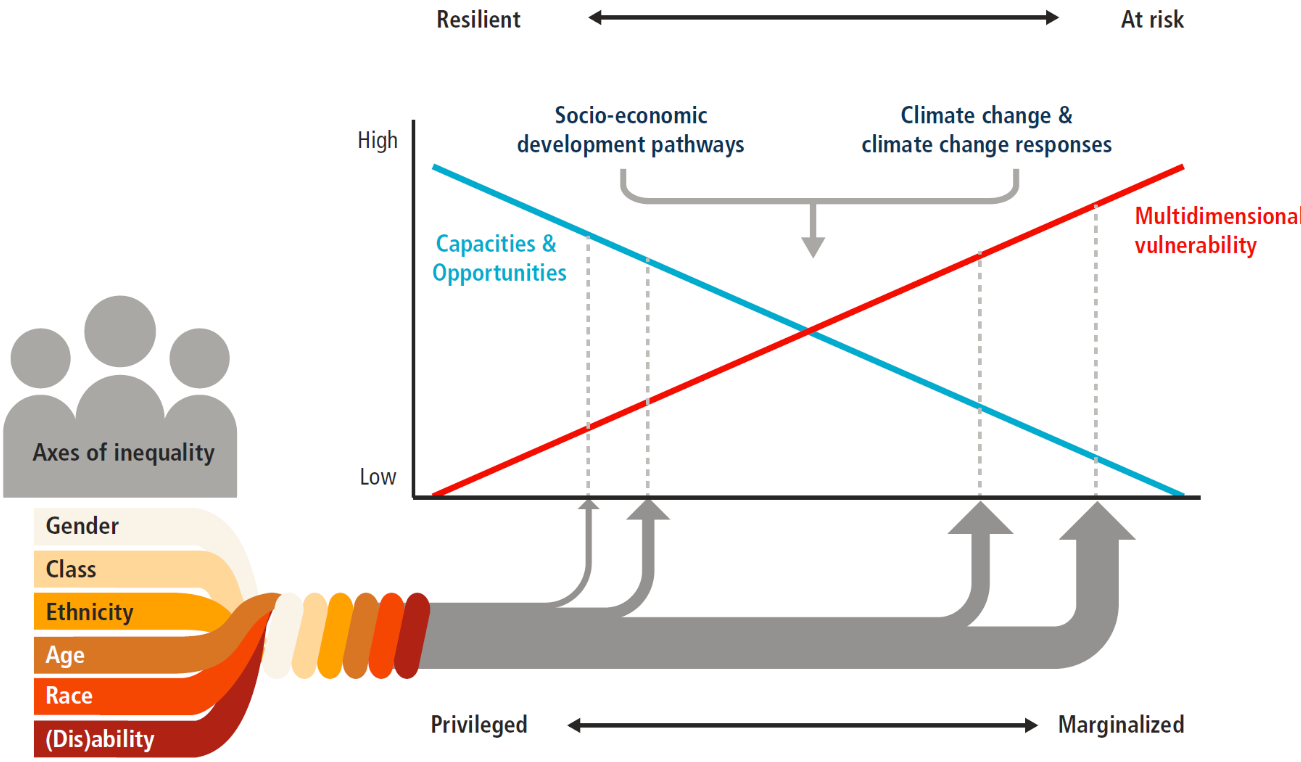

(A)
ARCTIC
NORTH AMERICA
EUROPE
ASIA
Bering Strait
Hawaii
SMALL ISLANDS
AFRICA
CENTRAL & SOUTH AMERICA
Mauritius
AUSTRALASIA
ANTARCTIC
Signy Island
Confidence in attribution to climate change
very low
low
med
high
very high
indicates confidence range
Observed impacts attributed to climate change for
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 mollucks
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 TS.2.



Box TS.4 Figure 1.

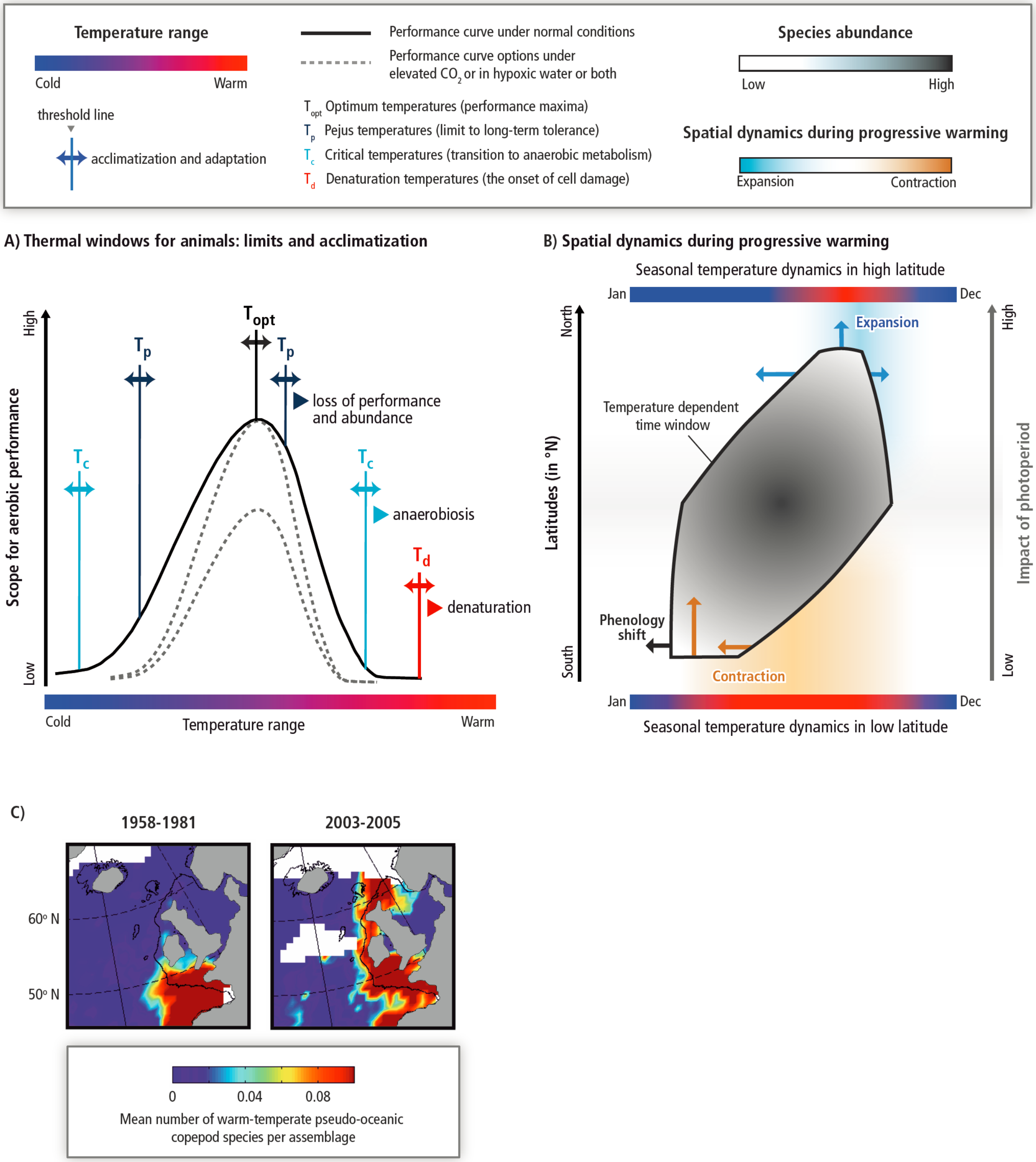

Temperature range
Cold
Warm
threshold line
acclimatization and adaptation
Performance curve under normal conditions
Performance curve options under elevated CO2 or in hypoxic water or both
Topt Optimum temperatures (performance maxima)
Tp Pejus temperatures (limit to long-term tolerance)
Tc Critical temperatures (transition to anaerobic metabolism)
Td Denaturation temperatures (the onset of cell damage)
Species abundance
Low
High
Spatial dynamics during progressive warming
Expansion
Contraction
A) Thermal windows for animals: limits and acclimatization
Scope for aerobic performance
High
Low
Topt
Tp
Tc
Td
loss of performance and abundance
anaerobiosis
denaturation
Cold
Temperature range
Warm
B) Spatial dynamics during progressive warming
Seasonal temperature dynamics in high latitude
Jan
Dec
North
South
Latitudes (in °N)
Expansion
Temperature dependent time window
Phenology shift
Contraction
Impact of photoperiod
High
Low
Seasonal temperature dynamics in low latitude
C)
1958-1981
2003-2005
60° N
50° N
0
0.04
0.08
Mean number of warm-temperate pseudo-oceanic copepod species per assemblage

Figure TS.3.

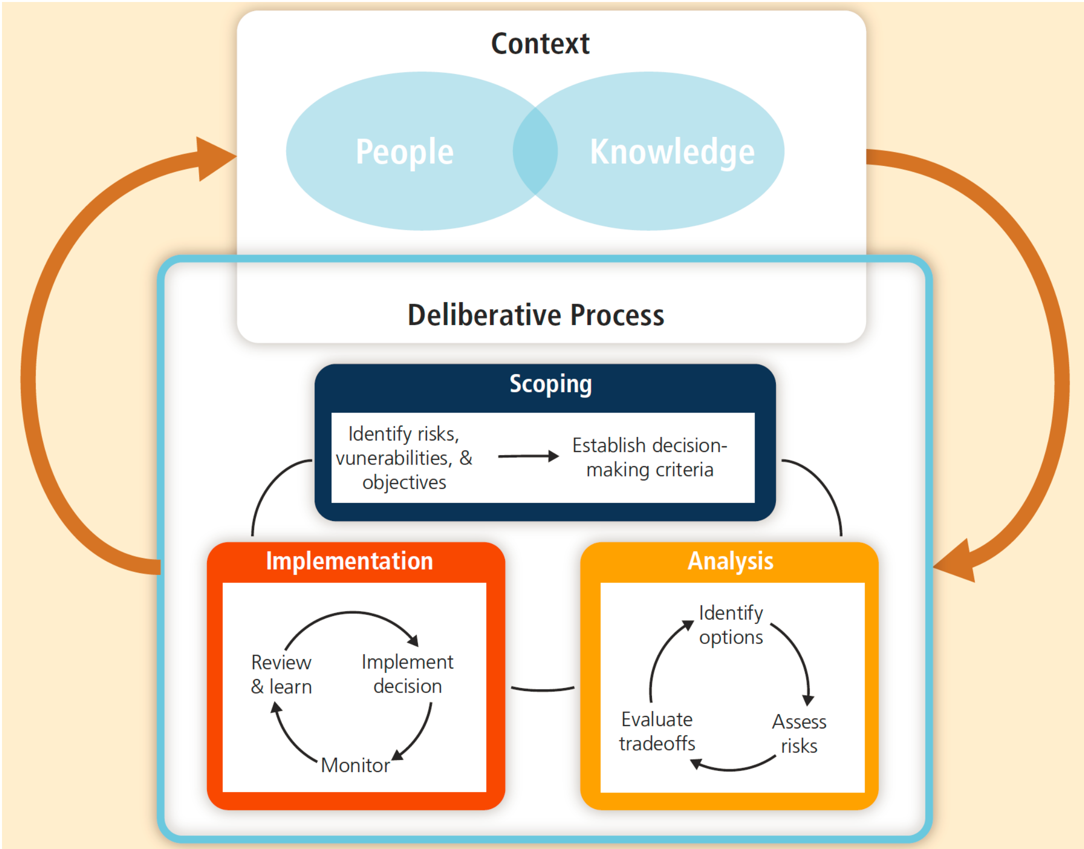

Context
People
Knowledge
Deliberative Process
Scoping
Identify risks, vunerabilities, & objectives
Establish decision-making criteria
Implementation
Review & learn
Implement decision
Monitor
Analysis
Identify options
Assess risks
Evaluate tradeoffs

Figure TS.4.

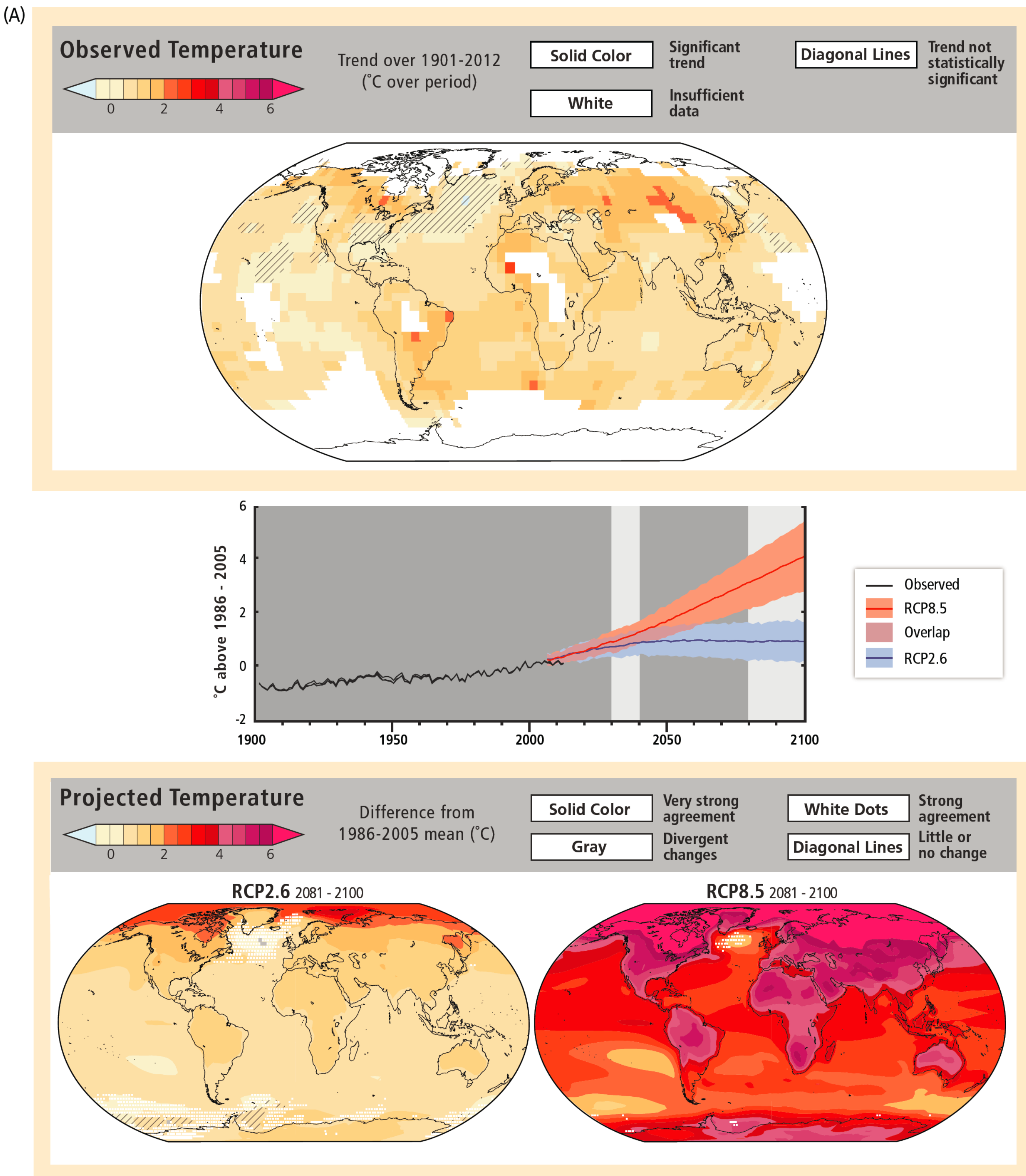

(A)
Observed Temperature
0 2 4 6
Trend over 1901-2012
(˚C over period)
Solid Color
Significant trend
White
Insufficient data
Diagonal Lines
Trend not statistically significant
°C above 1986 - 2005
6
4
2
0
-2
1900
1950
2000
2050
2100
Observed
RCP8.5
Overlap
RCP2.6
Projected Temperature
0 2 4 6
Difference 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 TS.5.

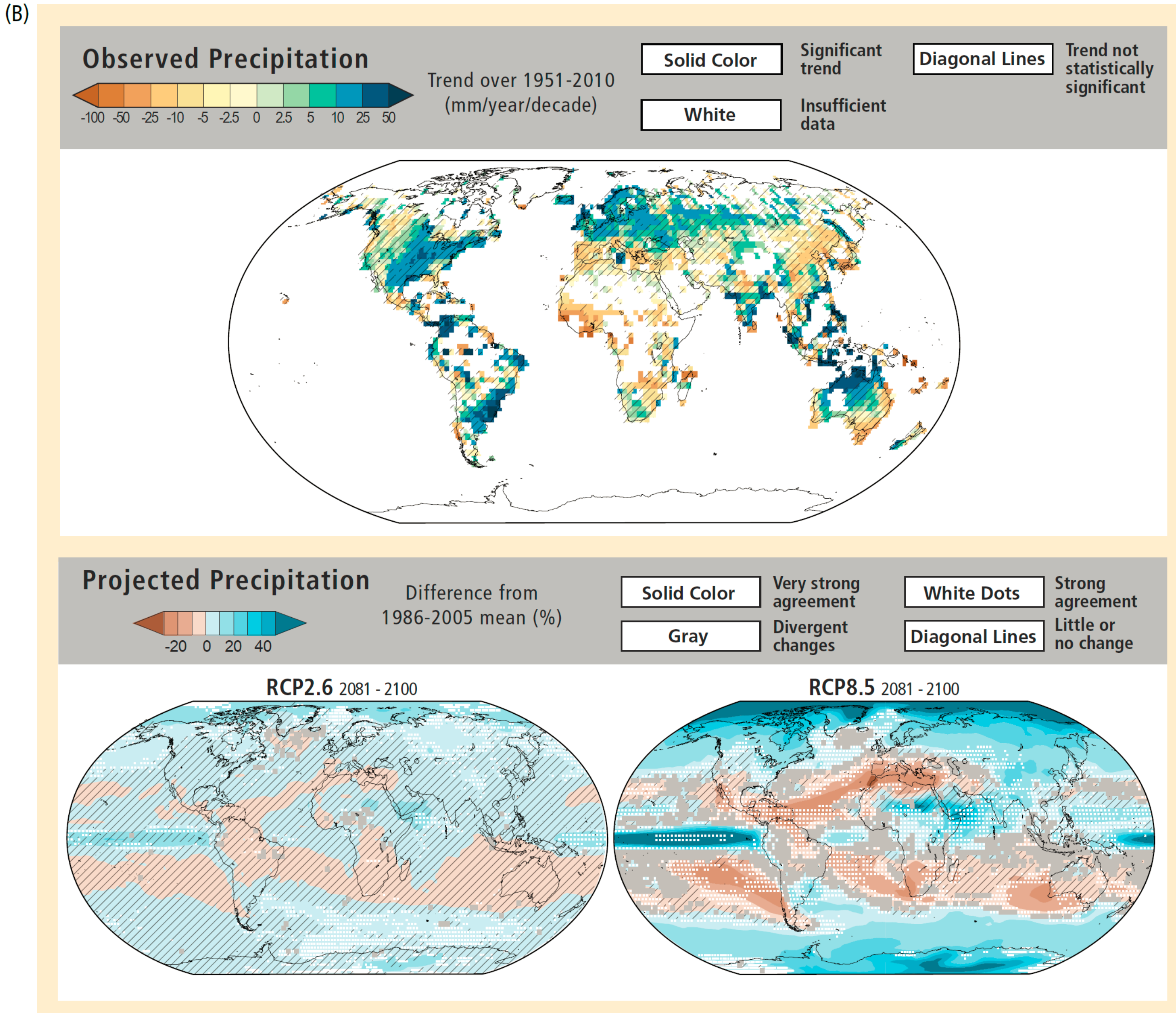
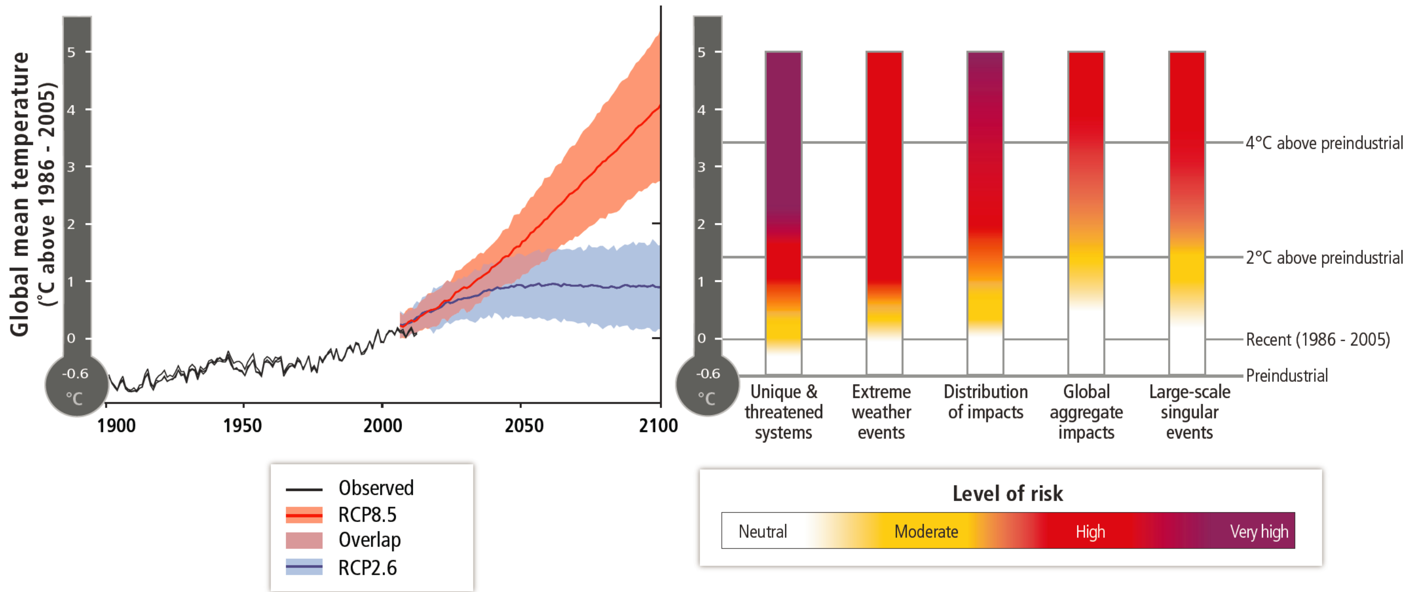

(B)
Observed Precipitation
-100 -50 -25 -10 -5 -2.5 0 2.5 5 10 25 50
Trend over 1951-2010 (mm/year/decade)
Solid Color
Significant trend
White
Insufficient data
Diagonal Lines
Trend not statistically significant
Projected Precipitation
-20 0 20 40
Difference from 1986-2005 mean (%)
Solid Color
Very strong agreement
Gray
Divergent changes
White Dots
Strong agreement
Diagonal Lines
Little or no change
RCP2.6 2081 - 2100
RCP8.5 2081 - 2100

Figure TS.5.



Box TS.5 Figure 1.

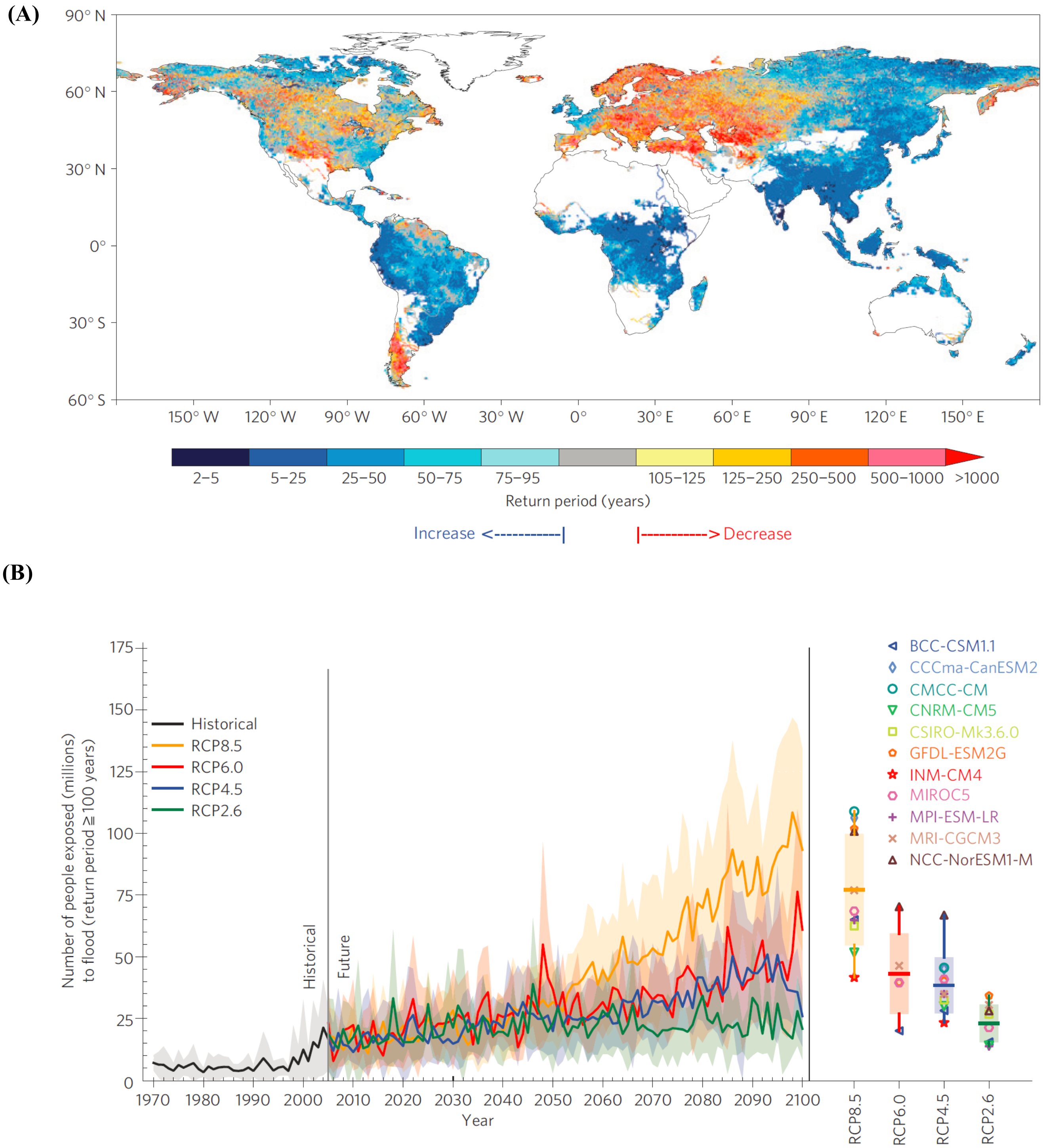

(A)
90° N
60° N
30° N
0°
30° S
60° S
150° W
120° W
90° W
60° W
30° W
0°
30° E
60° E
90° E
120° E
150° E
2–5
5–25
25–50
50–75
75–95
105–125
125–250
250–500
500–1000
>1000
Return period (years)
Increase
Decrease
(B)
Number of people exposed (millions) to flood (return period ≥ 100 years)
175
150
125
100
75
50
25
0
Historical
RCP8.5
RCP6.0
RCP4.5
RCP2.6
Historical
Future
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
BCC-CSM1.1
CCCma-CanESM2
CMCC-CM
CNRM-CM5
CSIRO-Mk3.6.0
GFDL-ESM2G
INM-CM4
MIROC5
MPI-ESM-LR
MRI-CGCM3
NCC-NorESM1-M
RCP8.5
RCP6.0
RCP4.5
RCP2.6

Figure TS.6.

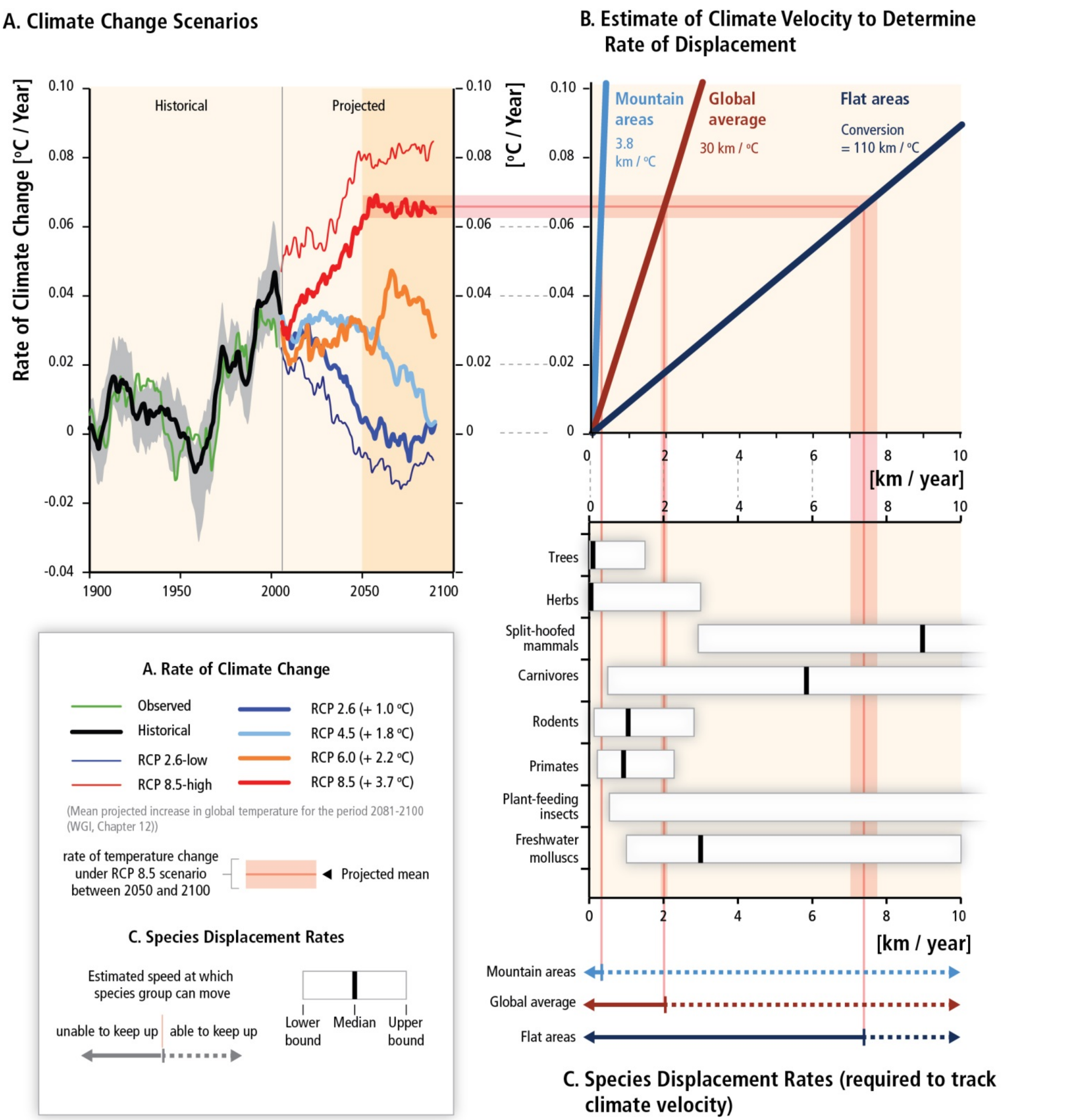

A. Climate Change Scenarios
Rate of Climate Change [°C / Year]
Historical
Projected
[°C / Year]
0.10
0.08
0.06
0.04
0.02
0
-0.02
-0.04
1900
1950
2000
2050
2100
B. Estimate of Climate Velocity to Determine Rate of Displacement
Mountain areas
3.8 km / °C
Global average
30 km / °C
Flat areas
Conversion = 110 km / °C
[km / year]
Trees
Herbs
Split-hoofed mammals
Carnivores
Rodents
Primates
Plant-feeding insects
Freshwater molluscs
[km / year]
Mountain areas
Global average
Flat areas
C. Species Displacement Rates (required to track climate velocity)
A. Rate of Climate Change
Observed
Historical
RCP 2.6-low
RCP 8.5-high
RCP 2.6 (+ 1.0 °C)
RCP 4.5 (+ 1.8 °C)
RCP 6.0 (+ 2.2 °C)
RCP 8.5 (+ 3.7 °C)
(Mean projected increase in global temperature for the period 2081-2100 (WGI, Chapter 12))
rate of temperature change under RCP 8.5 scenario between 2050 and 2100
Projected mean
C. Species Displacement Rates
Estimated speed at which species group can move
unable to keep up
able to keep up
Lower bound
Median
Upper bound

Figure TS.7.

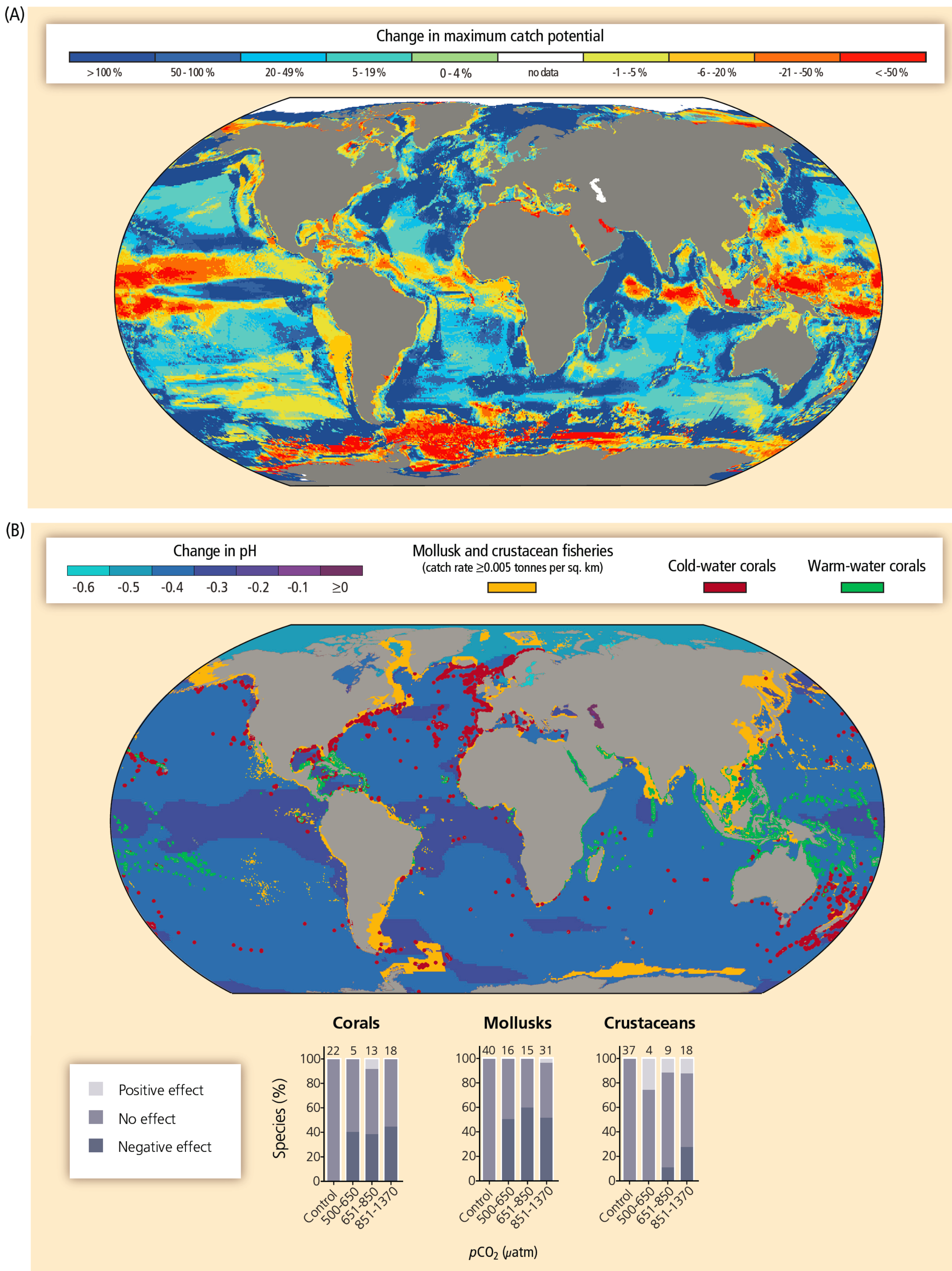

(A)
Change in maximum catch potential
> 100 %
50 - 100 %
20 - 49 %
5 - 19 %
0 - 4 %
no data
-1 - -5 %
-6 - -20 %
-21 - -50 %
< -50 %
(B)
Change in pH
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
≥0
Mollusk and crustacean fisheries
(catch rate ≥0.005 tonnes per sq. km)
Cold-water corals
Warm-water corals
Corals
Mollusks
Crustaceans
Positive effect
No effect
Negative effect
Species (%)
22 5 13 18
40 16 15 31
37 4 9 18
Control
500-650
651-850
851-1370
$p\mathrm{CO_2}$ (µatm)

Figure TS.8.

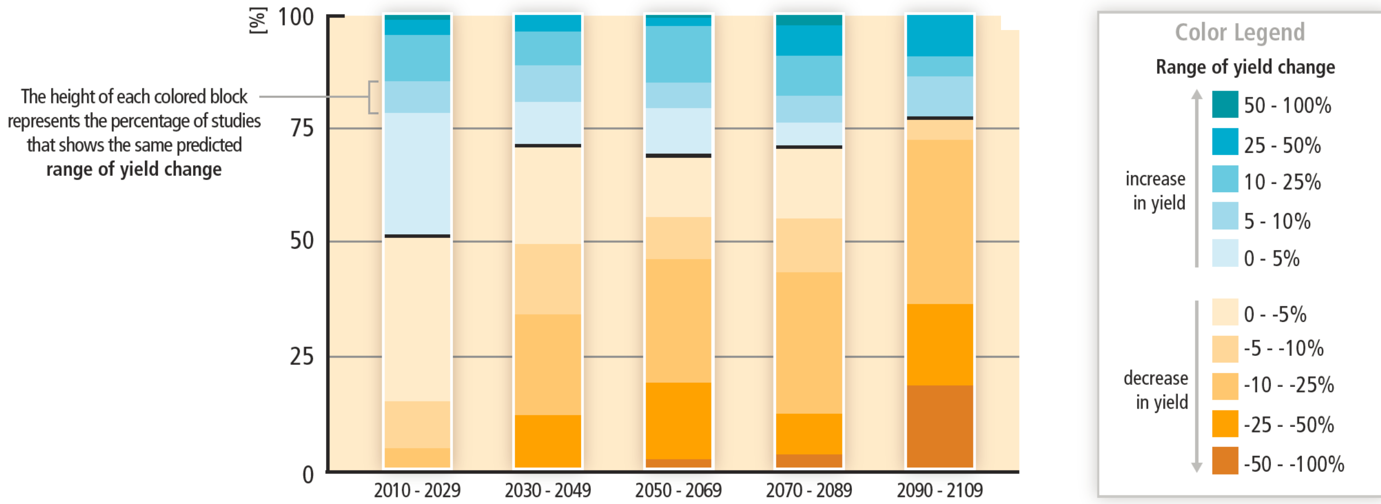

The height of each colored block represents the percentage of studies that shows the same predicted range of yield change
[%]
100
75
50
25
0
2010 - 2029
2030 - 2049
2050 - 2069
2070 - 2089
2090 - 2109
Color Legend
Range of yield change
increase in yield
50 - 100%
25 - 50%
10 - 25%
5 - 10%
0 - 5%
decrease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

Figure TS.9.

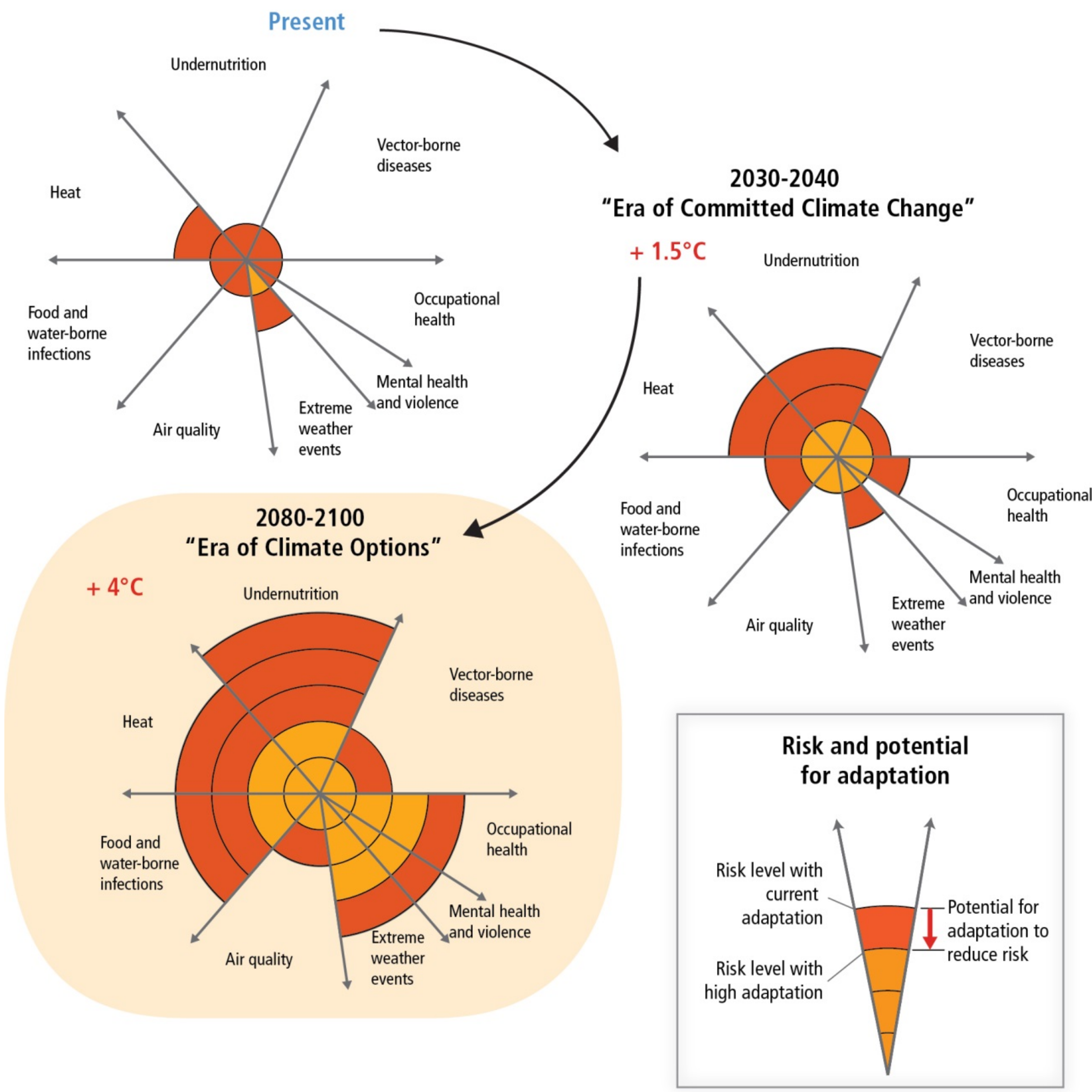

Present
Undernutrition
Vector-borne diseases
Heat
Food and water-borne infections
Occupational health
Mental health and violence
Air quality
Extreme weather events
2030-2040
“Era of Committed Climate Change”
+ 1.5°C
2080-2100
“Era of Climate Options”
+ 4°C
Risk and potential for adaptation
Risk level with current adaptation
Risk level with high adaptation
Potential for adaptation to reduce risk

Figure TS.10.

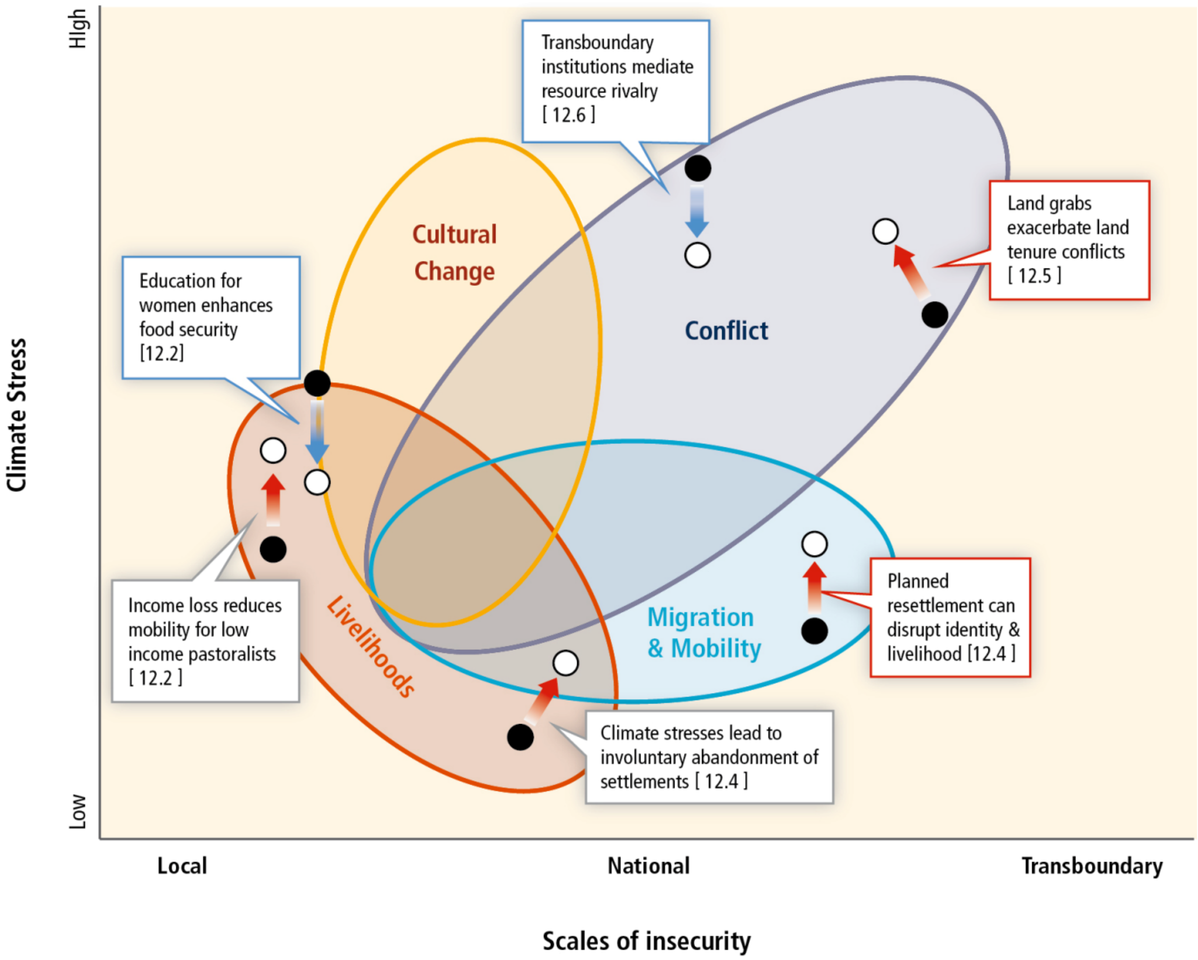
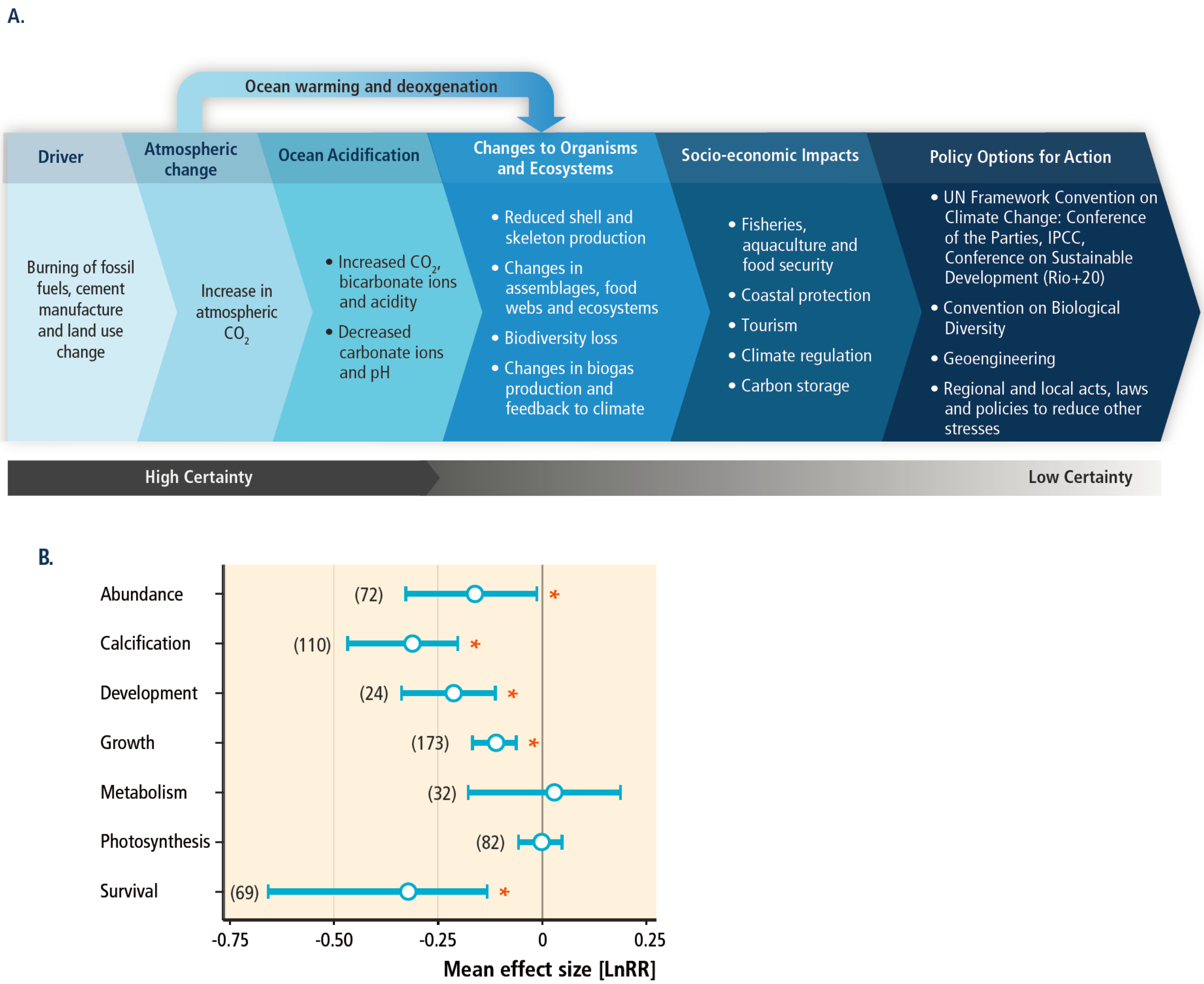

High
Low
Climate Stress
Transboundary institutions mediate resource rivalry [12.6]
Land grabs exacerbate land tenure conflicts [12.5]
Education for women enhances food security [12.2]
Cultural Change
Conflict
Income loss reduces mobility for low income pastoralists [12.2]
Livelihoods
Migration & Mobility
Planned resettlement can disrupt identity & livelihood [12.4]
Climate stresses lead to involuntary abandonment of settlements [12.4]
Local
National
Transboundary
Scales of insecurity

Figure TS.11.



Box TS.7 Figure 1.

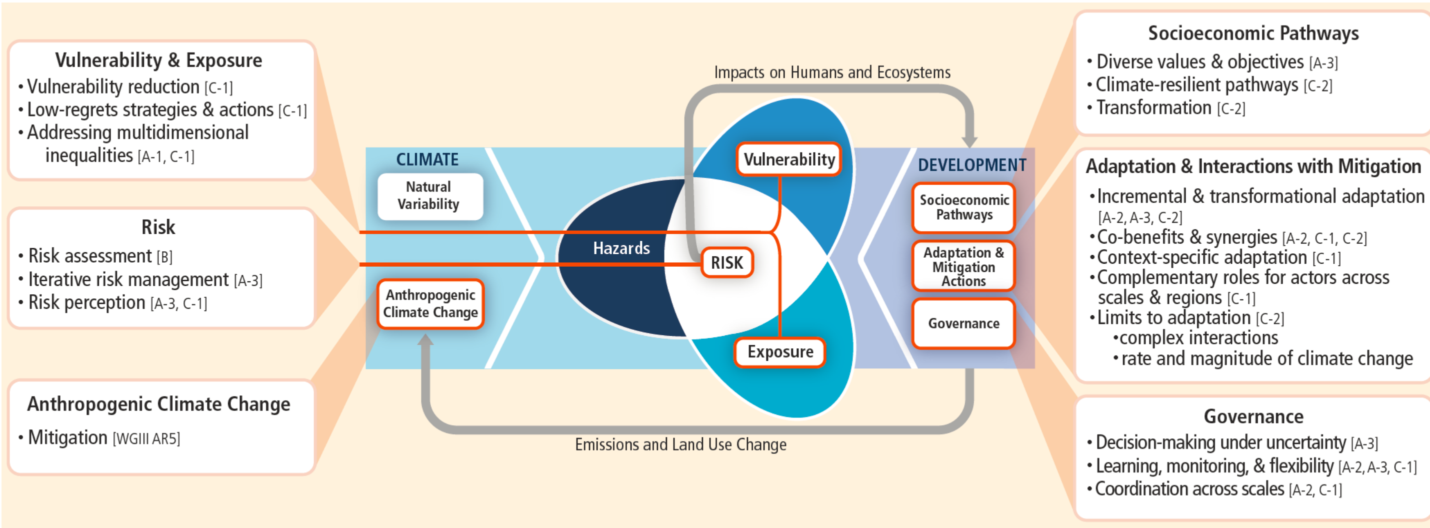

Vulnerability & Exposure
• Vulnerability reduction [C-1]
• Low-regrets strategies & actions [C-1]
• Addressing multidimensional inequalities [A-1, C-1]
Risk
• Risk assessment [B]
• Iterative risk management [A-3]
• Risk perception [A-3, C-1]
Anthropogenic Climate Change
• Mitigation [WGIII AR5]
CLIMATE
Natural Variability
Anthropogenic Climate Change
Hazards
RISK
Vulnerability
Exposure
Impacts on Humans and Ecosystems
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 TS.12.

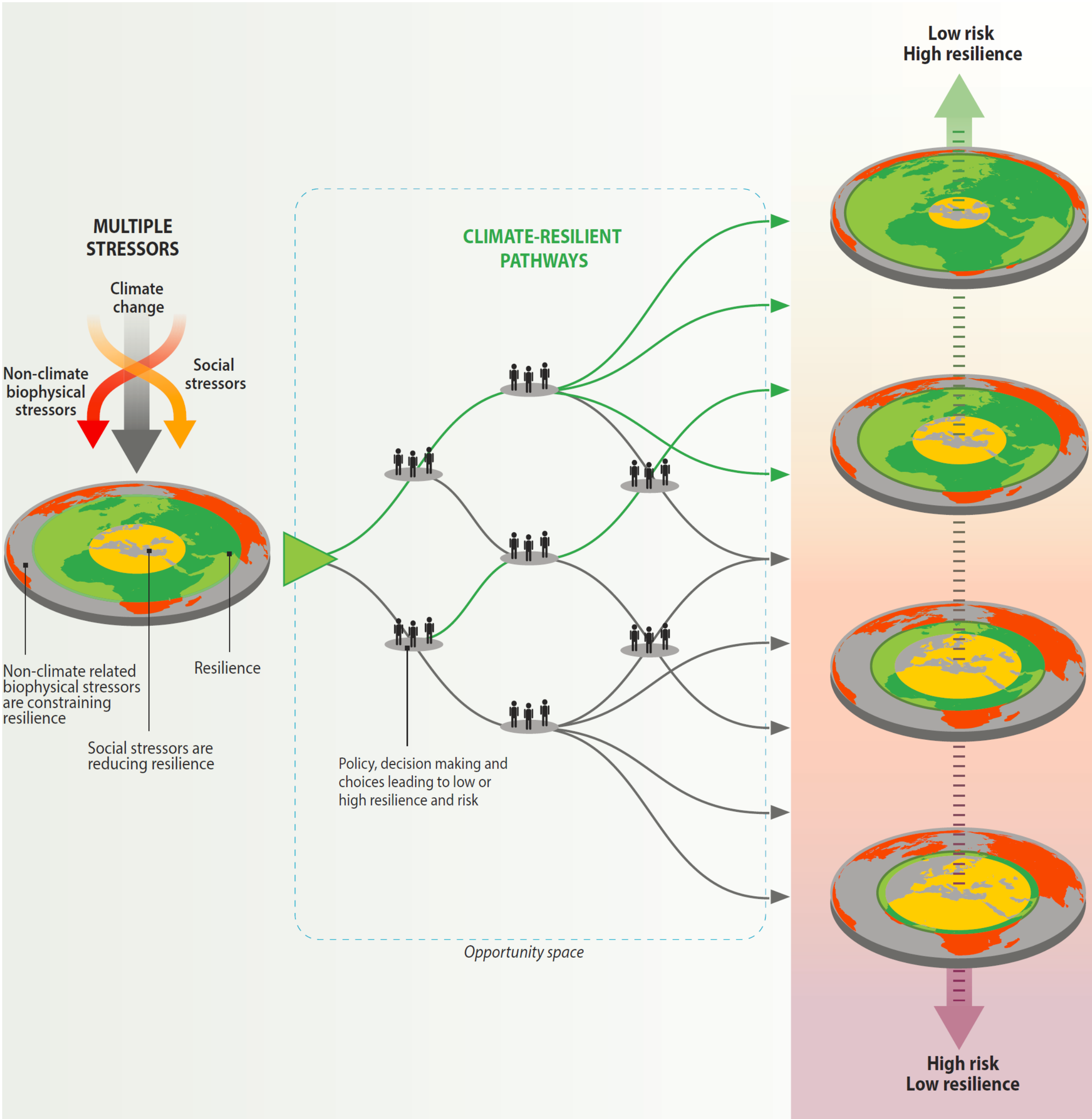
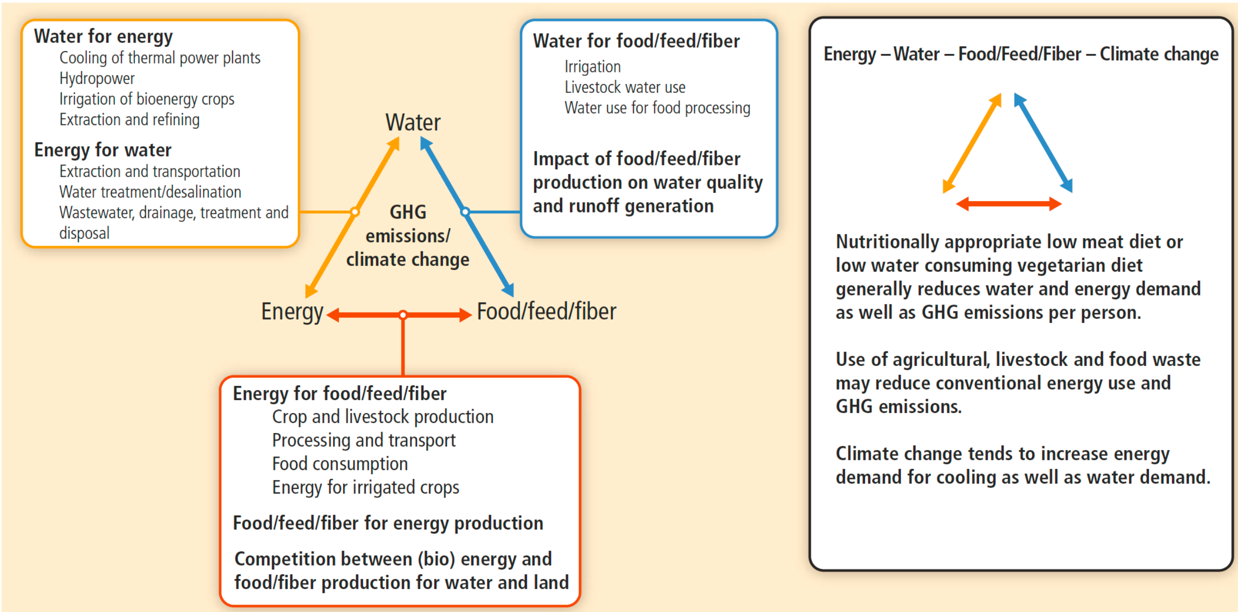

Low risk
High resilience
MULTIPLE STRESSORS
Climate change
Non-climate biophysical stressors
Social stressors
CLIMATE-RESILIENT PATHWAYS
Non-climate related biophysical stressors are constraining resilience
Resilience
Social stressors are reducing resilience
Policy, decision making and choices leading to low or high resilience and risk
Opportunity space
High risk
Low resilience

Figure TS.13.



Box TS.9 Figure 1.