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Summary for Policymakers
Climate Change 2001: Impacts, Adaptation and Vulnerability

Approved by IPCC Working Group II in Geneva, 13-16 February 2001

1. Introduction

The sensitivity, adaptive capacity, and vulnerability of natural and human systems to climate change, and the potential consequences of climate change, are assessed in the report of Working Group II of the Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2001: Impacts, Adaptation, and Vulnerability*.[1] This report builds upon the past assessment reports of the IPCC, reexamining key conclusions of the earlier assessments and incorporating results from more recent research.[2,3]

[FOOTNOTE 1: *Climate change* in IPCC usage refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the Framework Convention on Climate Change, where *climate change* refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods. Attribution of climate change to natural forcing and human activities has been addressed by Working Group I.]

[FOOTNOTE 2: The report has been written by 183 Coordinating Lead Authors and Lead Authors, and 243 Contributing Authors. It was reviewed by 440 government and expert reviewers, and 33 Review Editors oversaw the review process.]

[FOOTNOTE 3: Delegations from 100 IPCC member countries participated in the Sixth Session of Working Group II in Geneva on 13-16 February 2001.]

Observed changes in climate, their causes, and potential future changes are assessed in the report of Working Group I of the IPCC, *Climate Change 2001: The Scientific Basis*. The Working Group I report concludes, *inter alia*, that the globally averaged surface temperatures have increased by $0.6 \pm 0.2^{o}C$ over the 20^{th} century; and that, for the range of scenarios developed in the IPCC *Special Report on Emission Scenarios* (SRES), the globally averaged surface air temperature is projected by models to warm 1.4 to $5.8^{o}C$ by 2100 relative to 1990, and globally averaged sea level is projected by models to rise 0.09 to 0.88 meters by 2100. These projections indicate that the warming would vary by region, and be accompanied by increases and decreases in precipitation. In addition there would be changes in the variability of climate, and changes in the frequency and intensity of some extreme climate phenomena. These general features of climate change act on natural and human systems and they set the context for the Working Group II assessment. The available literature has not yet investigated climate change impacts, adaptation, and vulnerability associated with the upper end of the projected range of warming.

This Summary for Policymakers, which was approved by IPCC member governments in Geneva in February 2001, describes the current state of understanding of the impacts, adaptation, and vulnerability to climate change and their uncertainties. Further details can be found in the underlying report.[4] Section 2 of the Summary presents a number of general findings that emerge from integration of information across the full report. Each of these findings addresses a different dimension of climate change impacts, adaptation, and vulnerability, and no one dimension is paramount. Section 3 presents findings regarding individual natural and human systems, and Section 4 highlights some of the issues of concern for different regions of the world. Section 5 identifies priority research areas to further advance understanding of the potential consequences of and adaptation to climate change.

[FOOTNOTE 4: A more comprehensive summary of the report is provided in the Technical Summary, and relevant sections of that volume are referenced in brackets at the end of paragraphs of the Summary for Policymakers for readers who need more information.]

2. Emergent Findings

2.1. Recent Regional Climate Changes, Particularly Temperature Increases, have Already Affected Many Physical and Biological Systems

Available observational evidence indicates that regional changes in climate, particularly increases in temperature, have already affected a diverse set of physical and biological systems in many parts of the world. Examples of observed changes include shrinkage of glaciers, thawing of permafrost, later freezing and earlier break-up of ice on rivers and lakes, lengthening of mid- to high-latitude growing seasons, poleward and altitudinal shifts of plant and animal ranges, declines of some plant and animal populations, and earlier flowering of trees, emergence of insects, and egg-laying in birds (see Figure SPM-1). Associations between changes in regional temperatures and observed changes in physical and biological systems have been documented in many aquatic, terrestrial, and marine environments. [2.1, 4.3, 4.4, 5.7, and 7.1]

[Insert Figure SPM-1 here]

The studies mentioned above and illustrated in Figure SPM-1 were drawn from a literature survey, which identified long-term studies, typically 20 years or more, of changes in biological and physical systems that could be correlated with regional changes in temperature[5]. In most cases where changes in biological and physical systems were detected, the direction of change was that expected on the basis of known mechanisms. The probability that the observed changes in the expected direction (with no reference to magnitude) could occur by chance alone is negligible. In many parts of the world, precipitation-related impacts may be important. At present, there is a lack of systematic concurrent climatic and biophysical data of sufficient length (2 or more decades) that are considered necessary for assessment of precipitation impacts.

[FOOTNOTE 5: There are 44 regional studies of over 400 plants and animals, which varied in length from about 20-50 years, mainly from North America, Europe, and the southern polar region. There are 16 regional studies covering about 100 physical processes over most regions of the world, which varied in length from about 20-150 years. See Section 7.1 of the Technical Summary for more details.]

Factors such as land-use change and pollution also act on these physical and biological systems, making it difficult to attribute changes to particular causes in some specific cases. However, taken together, the observed changes in these systems are consistent in direction and coherent across diverse localities and/or regions (see Figure SPM-1) with the expected effects of regional changes in temperature. Thus, from the collective evidence, there is *high confidence*[6] that recent regional changes in temperature have had discernible impacts on many physical and biological systems.

[FOOTNOTE 6: In this Summary for Policymakers, the following words have been used where appropriate to indicate judgmental estimates of confidence (based upon the collective judgment of the authors using the observational evidence, modeling results, and theory that they have examined): *very high* (95% or greater), *high* (67-95%), *medium* (33-67%), *low* (5-33%), and *very low* (5% or less). In other instances, a qualitative scale to gauge the level of scientific understanding is used: *well established*, *established-but-incomplete*, *competing explanations*, and *speculative*. The approaches used to assess confidence levels and the level of scientific understanding, and the definitions of these terms, are presented in Section 1.4 of the Technical Summary. Each time these terms are used in the Summary for Policymakers, they are in *italics*.]

2.2. There are Preliminary Indications that Some Human Systems have been Affected by Recent Increases in Floods and Droughts

There is emerging evidence that some social and economic systems have been affected by the recent increasing frequency of floods and droughts in some areas. However, such systems are also affected by changes in socioeconomic factors such as demographic shifts and land-use changes. The relative impact of climatic and socioeconomic factors are generally difficult to quantify. [4.6 and 7.1]

2.3. Natural Systems are Vulnerable to Climate Change, and Some will be Irreversibly Damaged

Natural systems can be especially vulnerable to climate change because of limited adaptive capacity (see Box SPM-1), and some of these systems may undergo significant and irreversible damage. Natural systems at risk include glaciers, coral reefs and atolls, mangroves, boreal and tropical forests, polar and alpine ecosystems, prairie wetlands, and remnant native grasslands. While some species may increase in abundance or range, climate change will increase existing risks of extinction of some more vulnerable species and loss of biodiversity. It is *well-established*[6] that the geographical extent of the damage or loss, and the number of systems affected, will increase with the magnitude and rate of climate change (see Figure SPM-2). [4.3 and 7.2.1]

[Insert Figure SPM-2 here]

START BOX SPM-1 HERE__________

Box SPM-1. Climate Change Sensitivity, Adaptive Capacity, and Vulnerability

Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. Climate-related stimuli describe here all the elements of climate change, including mean climate characteristics, climate variability, and the frequency and magnitude of extremes. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea level rise).

Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

END BOX SPM-1 HERE__________

2.4. Many Human Systems are Sensitive to Climate Change, and Some are Vulnerable

Human systems that are sensitive to climate change include mainly water resources; agriculture (especially food security) and forestry; coastal zones and marine systems (fisheries); human settlements, energy, and industry; insurance and other financial services; and human health. The vulnerability of these systems varies with geographic location, time, and social, economic, and environmental conditions. [4.1, 4.2, 4.3, 4.4, 4.5, 4.6, and 4.7]

Projected adverse impacts based on models and other studies include:

- A general reduction in potential crop yields in most tropical and sub-tropical regions for most projected increases in temperature; [4.2]
- A general reduction, with some variation, in potential crop yields in most regions in mid-latitudes for increases in annual-average temperature of more than a few degrees C; [4.2]
- Decreased water availability for populations in many water scarce regions, particularly in the sub-tropics; [4.1]
- An increase in the number of people exposed to vector-borne diseases (e.g. malaria) and water-borne diseases (e.g. cholera) and an increase in heat stress mortality; [4.7]
- A widespread increase in the risk of flooding for many human settlements (tens of millions of inhabitants in settlements studied) from both increased heavy precipitation events and sea-level rise; [4.5]
- Increased energy demand for space cooling due to higher summer temperatures. [4.5]

Projected beneficial impacts based on models and other studies include:

- Increased potential crop yields in some regions at mid-latitudes for increases in temperature of less than a few degrees C; [4.2]
- A potential increase in global timber supply from appropriately managed forests; [4.3]
- Increased water availability for populations in some water scarce regions, for example in parts of South East Asia; [4.1]
- Reduced winter mortality in mid- and high-latitudes; [4.7]
- Reduced energy demand for space heating due to higher winter temperatures; [4.5]

2.5. Projected Changes in Climate Extremes could have Major Consequences

The vulnerability of human societies and natural systems to climate extremes is demonstrated by the damage, hardship, and death caused by events such as droughts, floods, heat waves, avalanches, and windstorms. While there are uncertainties attached to estimates of such changes, some extreme events are projected to increase in frequency and/or severity during the 21st century due to changes in the mean and/or variability of climate, so it can be expected that the severity of their impacts will also increase in concert with global warming (see Figure SPM-2). Conversely, the frequency and magnitude of extreme low temperature events, such as cold spells, is projected to decrease in the future, with both positive and negative impacts. The impacts of future changes in climate extremes are expected to fall disproportionately on the poor. Some representative examples of impacts of these projected changes in climate variability and climate extremes are presented in Table SPM-1. [3.5, 4.6, 6, and 7.2.4]

[Insert Table SPM-1 here]

2.6. The Potential for Large-Scale and Possibly Irreversible Impacts Poses Risks that have yet to be Reliably Quantified

Projected climate changes[7] during the 21st century have the potential to lead to future large-scale and possibly irreversible changes in Earth systems resulting in impacts at continental and global scales. These possibilities are very climate scenario-dependent and a full range of plausible scenarios has not yet been evaluated. Examples include significant slowing of the ocean circulation that transports warm water to the North Atlantic, large reductions in the Greenland and West Antarctic Ice Sheets, accelerated global warming due to carbon cycle feedbacks in the terrestrial biosphere, and releases of terrestrial carbon from permafrost regions and methane from hydrates in the coastal sediments. The likelihood of many of these changes in Earth systems is not well-known but is probably very low; however, their likelihood is expected to increase with the rate, magnitude, and duration of climate change (see Figure SPM-2). [3.5, 5.7, and 7.2.5]

[FOOTNOTE 7: Details of the projected changes in climate, illustrated in Figure SPM-2, are provided in the Working Group I Summary for Policymakers.]

If these changes in Earth systems were to occur, their impacts would be widespread and sustained. For example, significant slowing of the oceanic thermohaline circulation would impact deep-water oxygen levels, carbon uptake by oceans and marine ecosystems, and would reduce warming over parts of Europe. Disintegration of the West Antarctic Ice Sheet or melting of the Greenland Ice Sheet could raise global sea level up to 3 meters each over the next 1,000 years[8], submerge many islands, and inundate extensive coastal areas. Depending on the rate of ice loss, the rate and magnitude of sea-level rise could greatly exceed the capacity of human and natural systems to adapt without substantial impacts. Releases of terrestrial carbon from permafrost regions and methane from hydrates in the coastal sediments, induced by warming, would further increase greenhouse gas concentrations in the atmosphere and amplify climate change. [3.5, 5.7, and 7.2.5]

FOOTNOTE 8: Details of projected contributions to sea level rise from the West Anarctic Ice Sheet and Greenland Ice Sheet are provided in the Working Group I Summary for Policymakers.]

2.7. Adaptation is a Necessary Strategy at All Scales to Complement Climate Change Mitigation Efforts

Adaptation has the potential to reduce adverse impacts of climate change and to enhance beneficial impacts, but will incur costs and will not prevent all damages. Extremes, variability, and rates of change are all key features in addressing vulnerability and adaptation to climate change, not simply changes in average climate conditions. Human and natural systems will to some degree adapt autonomously to climate change. Planned adaptation can supplement autonomous adaptation, though options and incentives are greater for adaptation of human systems than for adaptation to protect natural systems. Adaptation is a necessary strategy at all scales to complement climate change mitigation efforts. [6]

Experience with adaptation to climate variability and extremes can be drawn upon to develop appropriate strategies for adapting to anticipated climate change. Adaptation to current climate variability and extremes often produces benefits as well as forming a basis for coping with future climate change. However, experience also demonstrates that there are constraints to achieving the full measure of potential adaptation. In addition, maladaptation, such as promoting development in risk-prone locations, can occur due to decisions based on short-term considerations, neglect of known climatic variability, imperfect foresight, insufficient information, and over-reliance on insurance mechanisms. [6]

2.8 Those with the Least Resources have the Least Capacity to Adapt and are the Most Vulnerable

The ability of human systems to adapt to and cope with climate change depends on such factors as wealth, technology, education, information, skills, infrastructure, access to resources, and management capabilities. There is potential for developed and developing countries to enhance and/or acquire adaptive capabilities. Populations and communities are highly variable in their endowments with these attributes, and the developing countries, particularly the least developed countries, are generally poorest in this regard. As a result, they have lesser capacity to adapt and are more vulnerable to climate change damages, just as they are more vulnerable to other stresses. This condition is most extreme among the poorest people. [6.1; see also 5.1.7, 5.2.7, 5.3.5, 5.4.6, 5.6.1, 5.6.2, 5.7, and 5.8.1 for regional-scale information]

Benefits and costs of climate change effects have been estimated in monetary units and aggregated to national, regional, and global scales. These estimates generally exclude the effects of changes in climate variability and extremes, do not account for the effects of different rates of change, and only partially account for impacts on goods and services that are not traded in markets. These omissions are likely to result in underestimates of economic losses and overestimates of economic gains. Estimates of aggregate impacts are controversial because they treat gains for some as canceling out losses for others and because the weights that are used to aggregate across individuals are necessarily subjective. [7.2.2 and 7.2.3]

Notwithstanding the limitations expressed above, based on a few published estimates, increases in global mean temperature[9] would produce net economic losses in many developing countries for all magnitudes of warming studied (*low confidence*[6]), and losses would be greater in magnitude the higher the level of warming (*medium confidence*[6]). In contrast, an increase in global mean temperature of up to a few degrees C would produce a mixture of economic gains and losses in developed countries (*low confidence*[6]), with economic losses for larger temperature increases (*medium confidence*[6]). The projected distribution of economic impacts is such that it would increase the disparity in well-being between developed countries and developing countries, with disparity growing for higher projected temperature increases (*medium confidence*[6]). The more damaging impacts estimated for developing countries reflects, in part, their lesser adaptive capacity relative to developed countries. [7.2.3]

[FOOTNOTE 9: Global mean temperature change is used as an indicator of the magnitude of climate change. Scenario-dependent exposures taken into account in these studies include regionally differentiated changes in temperature, precipitation, and other climatic variables.]

Further, when aggregated to a global scale, world GDP would change by ± a few percent for global mean temperature increases of up to a few degrees C (*low confidence*[6]), and increasing net losses would result for larger increases in temperature (*medium confidence*[6]) (see Figure SPM-2). More people are projected to be harmed than benefited by climate change, even for global mean temperature increases of less than a few degrees C (*low confidence*[6]). These results are sensitive to assumptions about changes in regional climate, level of development, adaptive capacity, rate of change, the valuation of impacts, and the methods used for aggregating monetary losses and gains, including the choice of discount rate. [7.2.2]

The effects of climate change are expected to be greatest in developing countries in terms of loss of life and relative effects on investment and the economy. For example, the relative percentage damages to GDP from climate extremes have been substantially greater in developing countries than in developed countries. [4.6]

2.9. Adaptation, Sustainable Development, and Enhancement of Equity can be Mutually Reinforcing

Many communities and regions that are vulnerable to climate change are also under pressure from forces such as population growth, resource depletion, and poverty. Policies that lessen pressures on resources, improve management of environmental risks, and increase the welfare of the poorest members of society can simultaneously advance sustainable development and equity, enhance adaptive capacity, and reduce vulnerability to climate and other stresses. Inclusion of climatic risks in the design and implementation of national and international development initiatives can promote equity and development that is more sustainable and that reduces vulnerability to climate change. [6.2]

3. Effects on and Vulnerability of Natural and Human Systems

3.1. Hydrology and Water Resources

The effect of climate change on streamflow and groundwater recharge varies regionally and between scenarios, largely following projected changes in precipitation. A consistent projection across most climate change scenarios, in which we have *medium confidence*[6], is for increases in annual mean streamflow in high latitudes and southeast Asia, and decreases in central Asia, the area around the Mediterranean, southern Africa, and Australia (see Figure SPM-3). The amount of change, however, varies between scenarios. For other areas, including mid-latitudes, there is no strong consistency in projections of streamflow, partly because of differences in projected rainfall and partly because of differences in projected evaporation, which can offset rainfall increases. In general, the projected changes in average annual runoff based on different climate model projections are less robust than impacts based on temperature change, due to the smaller signal-to-noise ratio for precipitation than temperature. At the catchment scale, the effect of a given change in climate varies with catchment physical properties and vegetation, and may be in addition to land cover changes. [4.1]

[Insert Figure SPM-3 here]

One third of the world's population, approximately 1.7 billion people, presently lives in countries that are water stressed (*i.e.* use more than 20% of their renewable water supply, a commonly-used indicator of water stress). Population growth and increased water withdrawals are projected to increase this number to around 5 billion by 2025, depending on the rate of population growth. Projected climate change would further decrease the available water in many of these water-stressed countries, for example in central Asia, southern Africa, and countries around the Mediterranean Sea , but may increase it in some others. [4.1. See also 5.1.1, 5.2.3, 5.3.1, 5.4.1, 5.5.1, 5.6.2, and 5.8.4 for regional scale information.]

Flood magnitude and frequency could increase in most regions as a consequence of increased frequency of heavy precipitation events. Streamflow during seasonal low flow periods would decrease in many areas due to greater evaporation; changes in precipitation may exacerbate or offset the effects of increased evaporation. Projected climate change will tend to degrade water quality through higher water temperatures and increased pollutant load from runoff and overflows of waste facilities. Quality would be degraded further where flows decrease, but increases in flows may mitigate to a certain extent some degradations in water quality by increasing dilution. Where snowfall is currently an important component of the water balance, a greater proportion of winter precipitation may fall as rain, and move peak streamflow from spring toward winter. [4.1]

Demand for water is generally increasing due to population growth and economic development, but is falling in some countries because of increased efficiency of use. Climate change is unlikely to have a big effect on municipal and industrial demands in general, but may substantially affect irrigation withdrawals, which depend on how increases in evaporation are offset or exaggerated by changes in precipitation. Higher temperatures, and hence higher crop evaporative demand, mean that the general tendency would be towards an increase in irrigation demands. [4.1]

The greatest vulnerabilities are likely to be in unmanaged water systems and systems that are currently stressed or poorly and unsustainably managed due to pricing and other policies that discourage efficient water use and protection of water quality, failure to manage variable water supply and demand, use of inappropriate technology, or lack of sound professional guidance. In unmanaged systems there are few or no structures in place to buffer the effects of hydrologic variability on water quality and supply. In unsustainably managed systems, water and land uses can add stresses that heighten vulnerability to climate change. Water resource management techniques, particularly those of integrated water resource management, can be applied to adapt to hydrologic effects of climate change, and to additional uncertainty, so as to lessen vulnerabilities. Currently, supply-side approaches (changes in water supply) are more widely used than demand-side approaches (which alter the exposure to stress); the latter—based on a range of measures including differential pricing, public awareness campaigns, or statutory requirements—are the focus of increasing attention. However, the capacity to implement effective management responses is unevenly distributed around the world and is low in many developing and transition countries. [4.1]

3.2. Agriculture and Food Security

Based on experimental research, crop yield responses to climate change vary widely, depending upon species and cultivar; soil properties; pests and pathogens; the direct effects of CO_2 on plants; and interactions between CO_2, air temperature, water stress, mineral nutrition, air quality, and adaptive responses. Even though increased CO_2 concentration can stimulate crop growth and yield, that benefit may not always overcome the adverse effects of excessive heat and drought (*medium confidence*[6]). These advances, along with advances in research on agricultural adaptation, have been incorporated since the SAR into models used to assess the effects of climate change on crop yields, food supply, farm incomes, and prices. [4.2]

Costs will be involved in coping with climate-induced yield losses and adaptation of livestock production systems. These agronomic and husbandry adaptation options could include, for example, adjustments to planting dates, fertilization rates, irrigation applications, cultivar traits, and selection of animal species. [4.2]

When autonomous agronomic adaptation is included, crop modeling assessments indicate with *medium* to *low confidence*[6] that climate change will lead to generally positive responses at less than a few degrees C warming and generally negative responses for more than a few degrees C in mid-latitude crop yields. Similar assessments indicate that yields of some crops in tropical locations would decrease generally with even minimal increases in temperature because such crops are near their maximum temperature tolerance and dryland/rainfed agriculture predominates. Where there is also a large decrease in rainfall, tropical crop yields would be even more adversely affected. With autonomous agronomic adaptation, crop yields in the tropics tend to be less adversely affected by climate change than without adaptation, but they still tend to remain below levels estimated with current climate. [4.2]

Most global and regional economic studies not incorporating climate change indicate that the downward trend in global real commodity prices in the 20th century is likely to continue into the 21st, although confidence in these predictions decreases farther into the future. Economic modeling assessments indicate with *low confidence*[6] that impacts of climate change on agricultural production and prices are estimated to result in small percentage changes in global income, with larger increases in more developed regions and smaller increases or declines in developing regions. Improved confidence in this finding depends on further research into the sensitivity of economic modeling assessments to their base assumptions. [4.2 and Box 5-5]

Most studies indicate (*established, but incomplete*[6]) that global mean annual temperature increases of a few degrees C or greater would prompt food prices to increase due to a slowing in the expansion of global food supply relative to growth in global food demand. At lesser amounts of warming than a few degrees C, economic models do not clearly distinguish the climate change signal from other sources of change based on those studies included in this assessment. Some recent aggregated studies have estimated economic impacts on vulnerable populations such as smallholder producers and poor urban consumers. These studies find that climate change would lower incomes of the vulnerable populations and increase the absolute number of people at risk of hunger, though this is uncertain and requires further research. It is established, though incompletely, that climate change, mainly through increased extremes and temporal/spatial shifts, will worsen food security in Africa. [4.2]

3.3. Terrestrial and Freshwater Ecosystems

Vegetation modeling studies continue to show the potential for significant disruption of ecosystems under climate change (*high confidence*[6]). Migration of ecosystems or biomes as discrete units is unlikely to occur; instead at a given site, species composition and dominance will change. The results of these changes will lag behind the changes in climate by years to decades to centuries (*high confidence*[6]). [4.3]

Distributions, population sizes, population density and behavior of wildlife have been, and will continue to be, affected directly by changes in global or regional climate and indirectly through changes in vegetation. Climate change will lead to poleward movement of the boundaries of freshwater fish distributions along with loss of habitat for cold and cool water fishes and gain in habitat for warm water fishes (*high confidence*[6]). Many species and populations are already at high risk, and are expected to be placed at greater risk by the synergy between climate change rendering portions of current habitat unsuitable for many species, and land-use change fragmenting habitats and raising obstacles to species migration. Without appropriate management, these pressures will cause some species currently classified as "critically endangered" to become extinct and the majority of those labeled "endangered or vulnerable" to become rarer, and thereby closer to extinction, in the 21st century (*high confidence*[6]). [4.3]

Possible adaptation methods to reduce risks to species could include: 1) establishment of refuges, parks, and reserves with corridors to allow migration of species, and 2) use of captive breeding and translocation. However, these options may have limitations due to costs. [4.3]

Terrestrial ecosystems appear to be storing increasing amounts of carbon. At the time of the SAR, this was largely attributed to increasing plant productivity because of the interaction between elevated CO_2 concentration, increasing temperatures, and soil moisture changes. Recent results confirm that productivity gains are occurring but suggest that they are smaller under field conditions than indicated by plant-pot experiments (*medium confidence*[6]). Hence the terrestrial uptake may be due more to change in uses and management of land than to the direct effects of elevated CO_2 and climate. The degree to which terrestrial ecosystems continue to be net sinks for carbon is uncertain due to the complex interactions between the factors mentioned above (e.g., arctic terrestrial ecosystems and wetlands may act as both sources and sinks) (*medium confidence*[6]). [4.3]

Contrary to the SAR, global timber market studies that include adaptations through land and product management, even without forestry projects that increase the capture and storage of carbon, suggest that a small amount of climate change would increase global timber supply and enhance existing market trends towards rising market share in developing countries (*medium confidence*[6]). Consumers may benefit from lower timber prices while producers may gain or lose depending on regional changes in timber productivity and potential dieback effects. [4.3]

3.4. Coastal Zones and Marine Ecosystems

Large-scale impacts of climate change on oceans are expected to include increases in sea surface temperature and mean global sea level, decreases in sea ice cover, and changes in salinity, wave conditions, and ocean circulation. The oceans are an integral and responsive component of the climate system with important physical and biogeochemical feedbacks to climate. Many marine ecosystems are sensitive to climate change. Climate trends and variability as reflected in multiyear climate-ocean regimes (e.g., Pacific Decadal Oscillation) and switches from one regime to another are now recognized to strongly affect fish abundance and population dynamics, with significant impacts on fish-dependent human societies. [4.4]

Many coastal areas will experience increased levels of flooding, accelerated erosion, loss of wetlands and mangroves, and seawater intrusion into fresh water sources as a result of climate change. The extent and severity of storm impacts, including storm-surge floods and shore erosion, will increase as a result of climate change including sea-level rise. High latitude coasts will experience added impacts related to higher wave energy and permafrost degradation. Changes in relative sea level will vary locally due to uplift and subsidence caused by other factors. [4.4]

Impacts on highly diverse and productive coastal ecosystems such as coral reefs, atolls and reef islands, salt marshes and mangrove forests will depend upon the rate of sea level rise relative to growth rates and sediment supply, space for and obstacles to horizontal migration, changes in the climate-ocean environment such as sea surface temperatures and storminess, and pressures from human activities in coastal zones. Episodes of coral bleaching over the past 20 years have been associated with several causes, including increased ocean temperatures. Future sea surface warming would increase stress on coral reefs and result in increased frequency of marine diseases (*high confidence*[6]). Assessments of adaptation strategies for coastal zones have shifted emphasis away from hard protection structures of shorelines (e.g., seawalls, groins) toward soft protection measures (e.g., beach nourishment), managed retreat, and enhanced resilience of biophysical and socioeconomic systems in coastal regions. [4.4.]

Adaptation options for coastal and marine management are most effective when incorporated with policies in other areas, such as disaster mitigation plans and land-use plans. [4.4]

3.5. Human Health

The impacts of short-term weather events on human health have been further elucidated since the Second Assessment Report, particularly in relation to periods of thermal stress, the modulation of air pollution impacts, the impacts of storms and floods, and the influences of seasonal and interannual climatic variability on infectious diseases. There has been increased understanding of the determinants of population vulnerability to adverse health impacts and the possibilities for adaptive responses. [4.7]

Many vector-borne, food-borne and water-borne infectious diseases are known to be sensitive to changes in climatic conditions. From results of most predictive model studies[10], there is *medium*-to-*high confidence*[6] that, under climate change scenarios, there would be a net increase in the geographic range of potential transmission of malaria and dengue–two vector-borne infections each of which currently impinge on 40-50% of the world population. Within their present ranges, these and many other infectious diseases would tend to increase in incidence and seasonality–although regional decreases would occur in some infectious diseases. In all cases, however, actual disease occurrence is strongly influenced by local environmental conditions, socioeconomic circumstances, and public health infrastructure. [4.7]
FOOTNOTE 10: Eight studies have modeled the effects of climate change on malaria (5) and dengue (3). Seven use a biological, or process-based approach, and one uses an empirical, statistical approach.]

Projected climate change will be accompanied by an increase in heatwaves, often exacerbated by increased humidity and urban air pollution, which would cause an increase in heat-related deaths and illness episodes. The evidence indicates that, with *high confidence*[6], the impact would be greatest in urban populations, affecting particularly the elderly, sick and those without access to air-conditioning . Limited evidence indicates that in some temperate countries reduced winter deaths would outnumber increased summer deaths (medium *confidence*[6]). However, published research has been largely confined to populations in developed countries, thus precluding a generalized comparison of changes in summer and winter mortality. [3.5 and 4.7]

Extensive experience makes clear, with *high confidence*[6], that any increase in flooding will increase the risk of drowning, diarrhoeal and respiratory diseases and, in developing countries, hunger and malnutrition. If cyclones were to increase regionally, devastating impacts would often occur, particularly in densely settled populations with inadequate resources. A reduction in crop yields and food production because of climate change in some regions, particularly in the tropics, will predispose food-insecure populations to malnutrition, leading to impaired child development and decreased adult activity. Socioeconomic disruptions could occur in some regions, impairing both livelihoods and health. [3.5, 4.1, 4.2, 4.5, and 4.7]

For each anticipated adverse health impact there is a range of social, institutional, technological, and behavioral adaptation options to lessen that impact. Adaptations could, for example, encompass strengthening of the public health infrastructure, health-oriented management of the environment (including air and water quality, food safety, urban and housing design, and surface water management) and the provision of appropriate medical care facilities. [TS 4.7]

Overall, the adverse health impacts of climate change will be greatest in vulnerable lower-income populations, predominantly within tropical/subtropical countries. Adaptive policies would, in general, reduce these impacts. [4.7]

3.6. Human Settlements, Energy, and Industry

A growing and increasingly quantitative literature shows that human settlements are affected by climate change in one of the three major ways.

1) The economic sectors that support the settlement are affected because of changes in resource productivity or changes in market demand for the goods and services produced there. [4.5]
2) Some aspects of physical infrastructure (including energy transmission and distribution systems), buildings, urban services (including transportation systems) and specific industries (such as agroindustry, tourism, and construction) may be directly affected. [4.5]
3) Populations may be directly affected through extreme weather, changes in health status, or migration. The problems are somewhat different in the largest population centers (e.g. those over 1 million) and mid-sized to small-sized populations. [4.5]

The most widespread direct risk to human settlements from climate change is flooding and landslides, driven by projected increases in rainfall intensity and, in coastal areas, sea level rise. There is *high confidence*[6] that riverine and coastal settlements are particularly at risk, but urban flooding could be a problem anywhere that storm drains, water supply, and waste management systems have inadequate capacity. In such areas, squatter and other informal urban settlements with high population density, poor shelter, little or no access to resources such as safe water and public health services, and low adaptive capacity are highly vulnerable. Human settlements currently experience other significant environmental problems which could be exacerbated under higher temperature/increased precipitation regimes, including water and energy resources and infrastructure, waste treatment, and transportation [4.5]

Rapid urbanization in low lying coastal areas of both the developing and developed world is greatly increasing population densities and the value of human-made assets exposed to coastal climatic extremes such as tropical cyclones. Model-based projections of the mean annual number of people who would be flooded by coastal storm surges increase several fold (by 75 million to 200 million people depending on adaptive responses) for mid-range scenarios of 40 cm sea level rise by 2080s relative to scenarios with no sea level rise. Potential damages to infrastructure in coastal areas from sea level rise have been projected to be tens of billions of dollars for individual countries, for example Egypt, Poland, and Vietnam. [4.5]

There is *high confidence*[6] that settlements with little economic diversification and where a high percentage of incomes derive from climate-sensitive primary resource industries (agriculture, forestry, and fisheries) are more vulnerable than more diversified settlements. In developed areas of the Arctic, and where the permafrost is ice-rich, special attention will be required to mitigate the detrimental impacts of thawing, such as severe damage to buildings and transport infrastructure (*very high confidence*[6]). Industrial, transportation, and commercial infrastructure is generally vulnerable to the same hazards as settlement infrastructure. Energy demand is expected to increase for space cooling and decrease for space heating, but the net effect is scenario- and location-dependent. Some energy production and distribution systems may experience adverse impacts that would reduce supplies or system reliability while other energy systems may benefit. [4.5 and 5.7]

Possible adaptation options involve the planning of settlements and their infrastructure, placement of industrial facilities, and making similar long-lived decisions in a manner to reduce the adverse effects of events that are of low (but increasing) probability and high (and perhaps rising) consequences. [4.5]

3.7. Insurance and Other Financial Services

The costs of ordinary and extreme weather events have increased rapidly in recent decades. Global economic losses from catastrophic events increased 10.3-fold from 3.9 billion US$ per year in the 1950s to 40 billion US$ per year in the 1990s (all in 1999 US$, unadjusted for purchasing power parity), with approximately one-quarter of the losses occurring in developing countries. The insured portion of these losses rose from a negligible level to 9.2 billion US$ per year during the same period. Total costs are a factor of two larger when losses from smaller, non-catastrophic weather-related events are included. As a measure of increasing insurance industry vulnerability, the ratio of global property/casual insurance premiums to weather related losses fell by a factor of three between 1985 and 1999. [4.6]

The costs of weather events have risen rapidly despite significant and increasing efforts at fortifying infrastructure and enhancing disaster preparedness. Part of the observed upward trend in disaster losses over the past 50 years is linked to socioeconomic factors, such as population growth, increased wealth, and urbanization in vulnerable areas, and part is linked to climatic factors such as the observed changes in precipitation and flooding events. Precise attribution is complex and there are differences in the balance of these two causes by region and type of event. [4.6]

There is *high confidence*[6] that climate change and anticipated changes in weather-related events perceived to be linked to climate change would increase actuarial uncertainty in risk assessment. Such developments would place upward pressure on insurance premiums and/or could lead to certain risks being reclassified as uninsurable with subsequent withdrawal of coverage. Such changes would trigger increased insurance costs, slow the expansion of financial services into developing countries, reduce the availability of insurance for spreading risk, and increase the demand for government-funded compensation following natural disasters. In the event of such changes, the relative roles of public and private entities in providing insurance and risk management resources can be expected to change. [4.6]

The financial services sector as a whole is expected to be able to cope with the impacts of climate change, although the historic record demonstrates that low-probability high-impact events or multiple closely spaced events severely affect parts of the sector, especially if adaptive capacity happens to be simultaneously depleted by non-climate factors (e.g., adverse financial market conditions). The property/casualty insurance and reinsurance segments and small specialized or undiversified companies have exhibited greater sensitivity, including reduced profitability and bankruptcy triggered by weather-related events. [4.6]

Adaptation to climate change presents complex challenges, but also opportunities, to the sector. Regulatory involvement in pricing, tax treatment of reserves, and the (in)ability of firms to withdraw from at-risk markets are examples of factors that influence the resilience of the sector. Public- and private-sector actors also support adaptation by promoting disaster preparedness, loss-prevention programs, building codes, and improved land-use planning. However, in some cases public insurance and relief programs have inadvertently fostered complacency and mal-adaptation by inducing development in at-risk areas such as U.S. flood plains and coastal zones. [4.6]

The effects of climate change are expected to be greatest in the developing world, especially in countries reliant on primary production as a major source of income. Some countries experience impacts on their GDP as a consequence of natural disasters, with damages as high as half of GDP in one case. Equity issues and development constraints would arise if weather-related risks become uninsurable, prices increase, or availability becomes limited. Conversely, more extensive access to insurance and more widespread introduction of micro-financing schemes and development banking would increase the ability of developing countries to adapt to climate change. [4.6]

4. Vulnerability Varies Across Regions

The vulnerability of human populations and natural systems to climate change differs substantially across regions and across populations within regions. Regional differences in baseline climate and expected climate change give rise to different exposures to climate stimuli across regions. The natural and social systems of different regions have varied characteristics, resources, and institutions, and are subject to varied pressures that give rise to differences in sensitivity and adaptive capacity. From these differences emerge different key concerns for each of the major regions of the world. Even within regions however, impacts, adaptive capacity, and vulnerability will vary. [5]

In light of the above, all regions are likely to experience some adverse effects of climate change. Table SPM-2 presents in a highly summarized fashion some of the key concerns for the different regions. Some regions are particularly vulnerable because of their physical exposure to climate change hazards and/or their limited adaptive capacity. Most less-developed regions are especially vulnerable because a larger share of their economies are in climate-sensitive sectors and their adaptive capacity is low due to low levels of human, financial, and natural resources, as well as limited institutional and technological capability. For example, small island states and low-lying coastal areas are particularly vulnerable to increases in sea level and storms, and most of them have limited capabilities for adaptation. Climate change impacts in polar regions are expected to be large and rapid, including reduction in sea-ice extent and thickness and degradation of permafrost. Adverse changes in seasonal river flows, floods and droughts, food security, fisheries, health effects, and loss of biodiversity are among the major regional vulnerabilities and concerns of Africa, Latin America, and Asia where adaptation opportunities are generally low. Even in regions with higher adaptive capacity, such as North America and Australia and New Zealand, there are vulnerable communities, such as indigenous peoples, and the possibility of adaptation of ecosystems is very limited. In Europe, vulnerability is significantly greater in the south and in the Arctic than elsewhere in the region. [5]

[Insert Table SPM-2 here]

5. Improving Assessments of Impacts, Vulnerabilities, and Adaptation

Advances have been made since previous IPCC assessments in the detection of change in biotic and physical systems, and steps have been taken to improve the understanding of adaptive capacity, vulnerability to climate extremes, and other critical impact-related issues. These advances indicate a need for initiatives to begin designing adaptation strategies and building adaptive capacities. Further research is required, however, to strengthen future assessments and to reduce uncertainties in order to assure that sufficient information is available for policymaking about responses to possible consequences of climate change, including research in and by developing countries. [8]

The following are high priorities for narrowing gaps between current knowledge and policymaking needs:

- Quantitative assessment of the sensitivity, adaptive capacity, and vulnerability of natural and human systems to climate change, with particular emphasis on changes in the range of climatic variation and the frequency and severity of extreme climate events
- Assessment of possible thresholds at which strongly discontinuous responses to projected climate change and other stimuli would be triggered
- Understanding dynamic responses of ecosystems to multiple stresses, including climate change, at global, regional, and finer scales
- Development of approaches to adaptation responses, estimation of the effectiveness and costs of adaptation options, and identification of differences in opportunities for and obstacles to adaptation in different regions, nations, and populations
- Assessment of potential impacts of the full range of projected climate changes, particularly for non-market goods and services, in multiple metrics and with consistent treatment of uncertainties, including but not limited to numbers of people affected, land area affected, numbers of species at risk, monetary value of impact, and implications in these regards of different stabilization levels and other policy scenarios
- Improving tools for integrated assessment, including risk assessment, to investigate interactions between components of natural and human systems and the consequences of different policy decisions
- Assessment of opportunities to include scientific information on impacts, vulnerability, and adaptation in decision-making processes, risk management, and sustainable development initiatives
- Improvement of systems and methods for long-term monitoring and understanding the consequences of climate change and other stresses on human and natural systems

Cutting across these foci are special needs associated with strengthening international cooperation and coordination for regional impacts, vulnerability assessment, and adaptation, including capacity building for monitoring, assessment and data gathering, and training, particularly in and for developing countries (particularly in relation to the items identified above).

***Table SPM-1**: Examples of Impacts Resulting from Projected Changes in Extreme Climate Events.*

Projected Changes during the 21st Century in Extreme Climate Phenomena and their Likelihood[a]	**Representative Examples of Projected Impacts**[b] **(all *high confidence* of occurrence in some areas**[c]**)**
Simple Extremes	
Higher maximum temperatures, more hot days and heat waves[d] over nearly all land areas (*Very likely*[a])	• Increased incidence of death and serious illness in older age groups and urban poor [4.7] • Increased heat stress in livestock and wildlife [4.2 and 4.3] • Shift in tourist destinations [Table TS-2 and 5.7] • Increased risk of damage to a number of crops [4.2] • Increased electric cooling demand and reduced energy supply reliability [Table TS-4 and 4.5]
Higher [Increasing] minimum temperatures, fewer cold days, frost days and cold waves[d] over nearly all land areas (*Very likely*[a])	• Decreased cold-related human morbidity and mortality [4.7] • Decreased risk of damage to a number of crops, and increased risk to others [4.2] • Extended range and activity of some pest and disease vectors [4.2 and 4.3] • Reduced heating energy demand [4.5]
More intense precipitation events (*Very likely*[a], over many areas)	• Increased flood, landslide, avalanche, and mudslide damage [4.5] • Increased soil erosion [5.2.4] • Increased flood runoff could increase recharge of some floodplain aquifers [4.1] • Increased pressure on government and private flood insurance systems and disaster relief [Table TS-4 and 4.6]
Complex Extremes	
Increased summer drying over most mid-latitude continental interiors and associated risk of drought (*Likely*[a])	• Decreased crop yields [4.2] • Increased damage to building foundations caused by ground shrinkage [Table TS-4] • Decreased water resource quantity and quality [4.1 and 4.5] • Increased risk of forest fire [5.4.2]
Increase in tropical cyclone peak wind intensities, mean and peak precipitation intensities (*Likely*[a], over some areas)[e]	• Increased risks to human life, risk of infectious disease epidemics and many other risks[4.7] • Increased coastal erosion and damage to coastal buildings and infrastructure [4.5 and 7.2.4] • Increased damage to coastal ecosystems such as coral reefs and mangroves [4.4]
Intensified droughts and floods associated with El Niño events in many different regions (*Likely*[a]) [See also under droughts and intense precipitation events]	• Decreased agricultural and rangeland productivity in drought- and flood-prone regions [4.3] • Decreased hydro-power potential in drought-prone regions [5.1.1 and Figure TS-7]
Increased Asian summer monsoon precipitation variability (*Likely*[a])	• Increase in flood and drought magnitude and damages in temperate and tropical Asia [5.2.4]
Increased intensity of mid-latitude storms (Little agreement between current models)[d]	• Increased risks to human life and health [4.7] • Increased property and infrastructure losses [Table TS-4] • Increased damage to coastal ecosystems [4.4]

[a] Likelihood refers to judgmental estimates of confidence used by Working Group I: *very likely* (90-99% chance); *likely* (66-90% chance). Unless otherwise stated, information on climate phenomena is taken from the Summary for Policymakers of Working Group I.

[b] These impacts can be lessened by appropriate response measures.

[c] *High confidence* refers to probabilities between 67 and 95% as described in Footnote 6.

[d] Information from Working Group I, Technical Summary, Section F.5.

[e] Changes in regional distribution of tropical cyclones are possible but have not been established.

Table SPM-2*: Regional Adaptive Capacity, Vulnerability, and Key Concerns*[a,b]

Region	
Africa	• Adaptive capacity of human systems in Africa is low due to lack of economic resources and technology, and vulnerability high as a result of heavy reliance on rain-fed agriculture, frequent droughts and floods, and poverty. [5.1.7] • Grain yields are projected to decrease for many scenarios, diminishing food security, particularly in small food-importing countries (*medium* to *high confidence*[6]). [5.1.2] • Major rivers of Africa are highly sensitive to climate variation; average runoff and water availability would decrease in Mediterranean and southern countries of Africa (*medium confidence*[6]). [5.1.1] • Extension of ranges of infectious disease vectors would adversely affect human health in Africa (*medium confidence*[6]). [5.1.4] • Desertification would be exacerbated by reductions in average annual rainfall, runoff, and soil moisture, especially in southern, North, and West Africa (*medium confidence*[6]). [5.1.6] • Increases in droughts, floods, and other extreme events would add to stresses on water resources, food security, human health, and infrastructures, and would constrain development in Africa (*high confidence*[6]). [5.1] • Significant extinctions of plant and animal species are projected and would impact rural livelihoods, tourism, and genetic resources (*medium confidence*[6]). [5.1.3] • Coastal settlements in, for example, the Gulf of Guinea, Senegal, Gambia, Egypt, and along the East–Southern African coast would be adversely impacted by sea-level rise through inundation and coastal erosion (*high confidence*[6]). [5.1.5]
Asia	• Adaptive capacity of human systems is low and vulnerability is high in the developing countries of Asia; the developed countries of Asia are more able to adapt and less vulnerable. [5.2.7] • Extreme events have increased in temperate and tropical Asia, including floods, droughts, forest fires, and tropical cyclones (*high confidence*[6]). [5.2.4] • Decreases in agricultural productivity and aquaculture due to thermal and water stress, sea level-rise, floods and droughts, and tropical cyclones would diminish food security in many countries of arid, tropical, and temperate Asia; agriculture would expand and increase in productivity in northern areas (*medium confidence*[6]). [5.2.1] • Runoff and water availability may decrease in arid and semi-arid Asia but increase in northern Asia (*medium confidence*[6]). [5.2.3] • Human health would be threatened by possible increased exposure to vector-borne infectious diseases and heat stress in parts of Asia (*medium confidence*[6]). [5.2.6] • Sea-level rise and an increase in the intensity of tropical cyclones would displace tens of millions of people in low-lying coastal areas of temperate and tropical Asia; increased intensity of rainfall would increase flood risks in temperate and tropical Asia (*high confidence*[6]). [5.2.5 and Table TS-8] • Climate change would increase energy demand, decrease tourism attraction, and influence transportation in some regions of Asia (*medium confidence*[6]). [5.2.4 and 5.2.7] • Climate change would exacerbate threats to biodiversity due to land-use and land-cover change and population pressure in Asia (*medium confidence*[6]). Sea-level rise would put ecological security at risk, including mangroves and coral reefs (*high confidence*[6]). [5.2.2] • Poleward movement of the southern boundary of the permafrost zones of Asia would result in a change of thermokarst and thermal erosion with negative impacts on social infrastructure and industries (*medium confidence*[6]). [5.2.2]
Australia and New Zealand	• Adaptive capacity of human systems is generally high, but there are groups in Australia and New Zealand, such as indigenous peoples in some regions, with low capacity to adapt and consequently high vulnerability. [5.3 and 5.3.5] • The net impact on some temperate crops of climate and CO_2 changes may initially be beneficial, but this balance is expected to become negative for some areas and crops with further climate change (*medium confidence*[6]). [5.3.3] • Water is likely to be a key issue (*high confidence*[6]) due to projected drying trends over much of the region and change to a more El Niño-like average state. [5.3 and 5.3.1] • Increases in the intensity of heavy rains and tropical cyclones (*medium confidence*[6]), and

	region-specific changes in the frequency of tropical cyclones, would alter the risks to life, property, and ecosystems from flooding, storm surges, and wind damage. [5.3.4] • Some species with restricted climatic niches and which are unable to migrate due to fragmentation of the landscape, soil differences, or topography could become endangered or extinct (*high confidence*[6]). Australian ecosystems that are particularly vulnerable to climate change include coral reefs, arid and semi-arid habitats in southwest and inland Australia, and Australian alpine systems. Freshwater wetlands in coastal zones in both Australia and New Zealand are vulnerable, and some New Zealand ecosystems are vulnerable to accelerated invasion by weeds. [5.3.2]
Europe	• Adaptive capacity is generally high in Europe for human systems; southern Europe and the European Arctic are more vulnerable than other parts of Europe. [5.4 and 5.4.6] • Summer runoff, water availability and soil moisture are likely to decrease in southern Europe, and would widen the difference between the north and drought-prone south; increases are likely in winter in the north and south (*high confidence*[6]). [5.4.1] • Half of alpine glaciers and large permafrost areas could disappear by the end of the 21st century (*medium confidence*[6]). [5.4.1] • River flood hazard will increase across much of Europe (*medium* to *high confidence*[6]); in coastal areas, the risk of flooding, erosion, and wetland loss will increase substantially with implications for human settlement, industry, tourism, agriculture, and coastal natural habitats. [5.4.1 and 5.4.4] • There will be some broadly positive effects on agriculture in northern Europe (*medium confidence*[6]); productivity will decrease in southern and eastern Europe (*medium confidence*[6]). [5.4.3] • Upward and northward shift of biotic zones will take place. Loss of important habitats (wetlands, tundra, isolated habitats) would threaten some species (*high confidence*[6]). [5.4.2] • Higher temperatures and heat waves may change traditional summer tourist destinations and less reliable snow conditions may impact adversely on winter tourism (*medium confidence*[6]). [5.4.4]
Latin America	• Adaptive capacity of human systems in Latin America is low, particularly with respect to extreme climate events, and vulnerability is high. [5.5] • Loss and retreat of glaciers would adversely impact runoff and water supply in areas where glacier melt is an important water source (*high confidence*[6]). [5.5.1] • Floods and droughts would become more frequent (*high confidence*[6]) with floods increasing sediment loads and degrade water quality in some areas. [5.5] • Increases in intensity of tropical cyclones would alter the risks to life, property, and ecosystems from heavy rain, flooding, storm surges, and wind damages. [5.5] • Yields of important crops are projected to decrease in many locations in Latin America, even when the effects of CO_2 are taken into account; subsistence farming in some regions of Latin America could be threatened (*high confidence*[6]). [5.5.4] • The geographical distribution of vector-borne infectious diseases would expand poleward and to higher elevations, and exposures to diseases such as malaria, dengue fever, and cholera will increase (*medium confidence*[6]). [5.5.5] • Coastal human settlements, productive activities, infrastructure, and mangrove ecosystems would be negatively affected by sea-level rise (*medium confidence*[6]). [5.5.3] • The rate of biodiversity loss would increase (*high confidence*[6]). [5.5.2]
North America	• Adaptive capacity of human systems is generally high and vulnerability low in North America, but some communities (e.g., indigenous peoples and those dependent on climate-sensitive resources) are more vulnerable; social, economic, and demographic trends are changing vulnerabilities in subregions. [5.6 and 5.6.1] • Some crops would benefit from modest warming accompanied by increasing CO_2, but effects would vary among crops and regions (*high confidence*[6]), including declines due to drought in some areas of Canada's Prairies and the U.S. Great Plains, potential increased food production in areas of Canada north of current production areas, and increased warm-temperate mixed forest production (*medium confidence*[6]). However, benefits for crops would decline at an increasing rate and possibly become a net loss with further warming (*medium confidence*[6]). [5.6.4]

	• Snowmelt-dominated watersheds in western North America will experience earlier spring peak flows (*high confidence*[6]), reductions in summer flows (*medium confidence*[6]), and reduced lake levels and outflows for the Great Lakes-St. Lawrence under most scenarios (*medium confidence*[6]); adaptive responses would offset some, but not all, of the impacts on water users and on aquatic ecosystems (*medium confidence*[6]). [5.6.2] • Unique natural ecosystems such as prairie wetlands, alpine tundra, and cold water ecosystems will be at risk and effective adaptation is unlikely (*medium confidence*[6]). [5.6.5] • Sea-level rise would result in enhanced coastal erosion, coastal flooding, loss of coastal wetlands, and increased risk from storm surges, particularly in Florida and much of the US Atlantic coast (*high confidence*[6]). [5.6.1] • Weather-related insured losses and public sector disaster relief payments in North America have been increasing; insurance sector planning has not yet systematically included climate change information, so there is potential for surprise (*high confidence*[6]). [5.6.1] • Vector-borne diseases—including malaria, dengue fever, and Lyme disease—may expand their ranges in North America; exacerbated air quality and heat stress morbidity and mortality would occur (*medium confidence*[6]); socioeconomic factors and public health measures would play a large role in determining the incidence and extent of health effects. [5.6.6]
Polar	• Natural systems in polar regions are highly vulnerable to climate change and current ecosystems have low adaptive capacity; technologically developed communities are likely to adapt readily to climate change, but some indigenous communities, in which traditional lifestyles are followed, have little capacity and few options for adaptation. [5.7] • Climate change in polar regions is expected to be among the largest and most rapid of any region on the Earth, and will cause major physical, ecological, sociological, and economic impacts, especially in the Arctic, Antarctic Peninsula, and Southern Ocean (*high confidence*[6]). [5.7] • Changes in climate that have already taken place are manifested in the decrease in extent and thickness of Arctic sea ice, permafrost thawing, coastal erosion, changes in ice sheets and ice shelves, and altered distribution and abundance of species in polar regions (*high confidence*[6]). [5.7] • Some polar ecosystems may adapt through eventual replacement by migration of species and changing species composition, and possibly by eventual increases in overall productivity; ice edge systems that provide habitat for some species would be threatened (*medium confidence*[6]). [5.7] • Polar regions contain important drivers of climate change. Once triggered, they may continue for centuries, long after greenhouse gas concentrations are stabilized, and cause irreversible impacts on ice sheets, global ocean circulation, and sea-level rise (*medium confidence*[6]). [5.7]
Small Island States	• Adaptive capacity of human systems is generally low in small island states, and vulnerability high; small island states are likely to be among the countries most seriously impacted by climate change. [5.8] • The projected sea-level rise of 5mm per year for the next 100 years would cause enhanced coastal erosion, loss of land and property, dislocation of people, increased risk from storm surges, reduced resilience of coastal ecosystems, saltwater intrusion into freshwater resources, and high resource costs to respond to and adapt to these changes (*high confidence*[6]). [5.8.2 and 5.8.5] • Islands with very limited water supplies are highly vulnerable to the impacts of climate change on the water balance (*high confidence*[6]). [5.8.4] • Coral reefs would be negatively affected by bleaching and by reduced calcification rates due to higher carbon dioxide levels (*medium confidence*[6]); mangrove, sea grass beds, other coastal ecosystems and the associated biodiversity would be adversely affected by rising temperatures and accelerated sea-level rise (*medium confidence*[6]). [4.4 and 5.8.3] • Declines in coastal ecosystems would negatively impact reef fish and threaten reef fisheries, those who earn their livelihoods from reef fisheries, and those who rely on the fisheries as a significant food source (*medium confidence*[6]). [4.4 and 5.8.4] • Limited arable land and soil salinization makes agriculture of small island states, both for

	domestic food production and cash crop exports, highly vulnerable to climate change (*high confidence*[6]). [5.8.4] • Tourism, an important source of income and foreign exchange for many islands, would face severe disruption from climate change and sea-level rise (*high confidence*[6]). [5.8.5]

[a] Because the available studies have not employed a common set of climate scenarios and methods, and because of uncertainties regarding the sensitivities and adaptability of natural and social systems, the assessment of regional vulnerabilities is necessarily qualitative.

[b] The regions listed in Table SPM-2 are graphically depicted in Figure TS-2 of the Technical Summary.

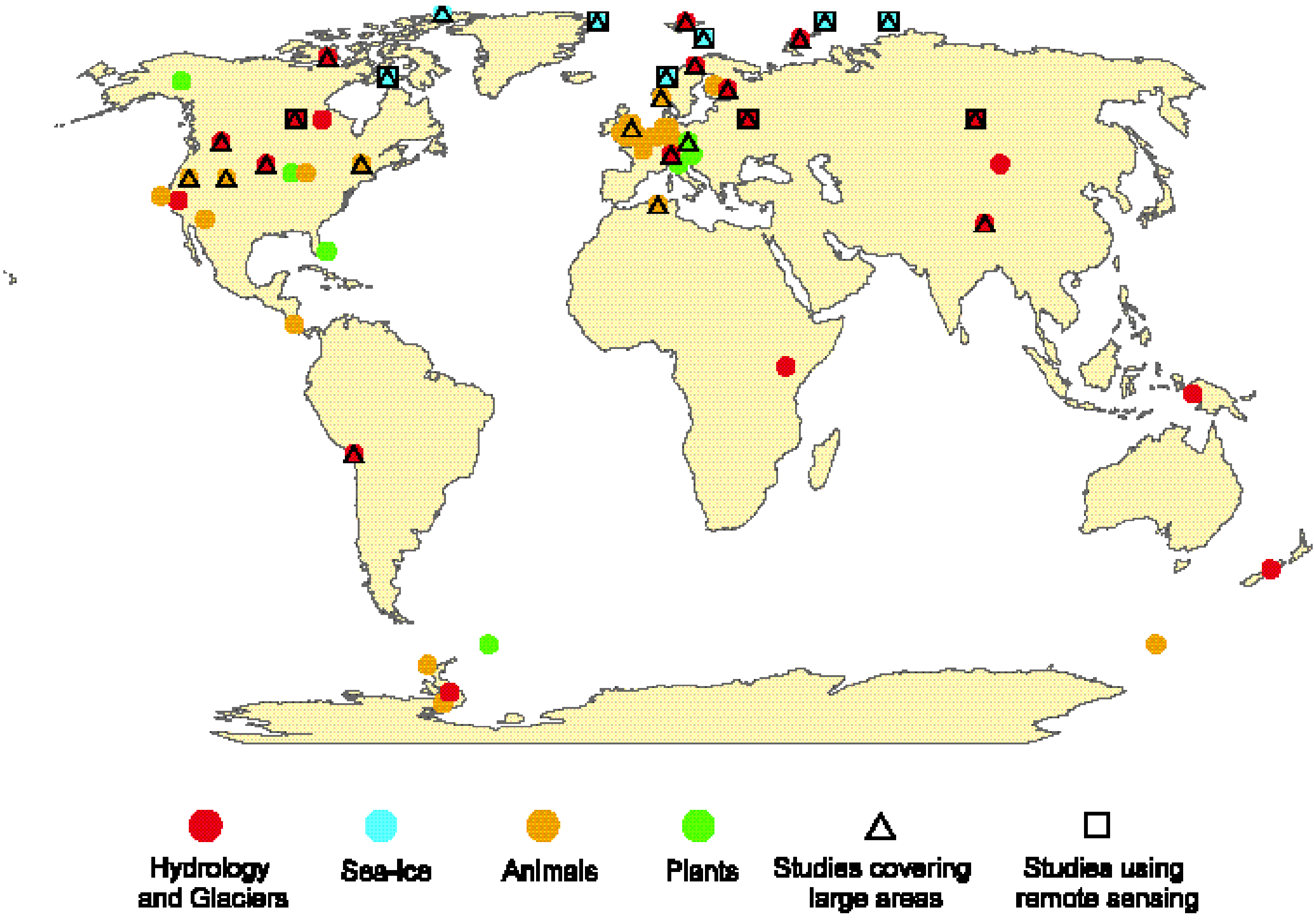

Figure SPM-1: Locations at which systematic long-term studies meet stringent criteria documenting recent temperature-related regional climate change impacts on physical and biological systems. Hydrology, glacial retreat, and sea-ice data represent decadal to century trends. Terrestrial and marine ecosystem data represent trends of at least 2 decades. Remote-sensing studies cover large areas. Data are for single or multiple impacts that are consistent with known mechanisms of physical/biological system responses to observed regional temperature-related changes. For reported impacts spanning large areas, a representative location on the map was selected.

In Draft...Final Technical Adjustments to be Made to Illustration

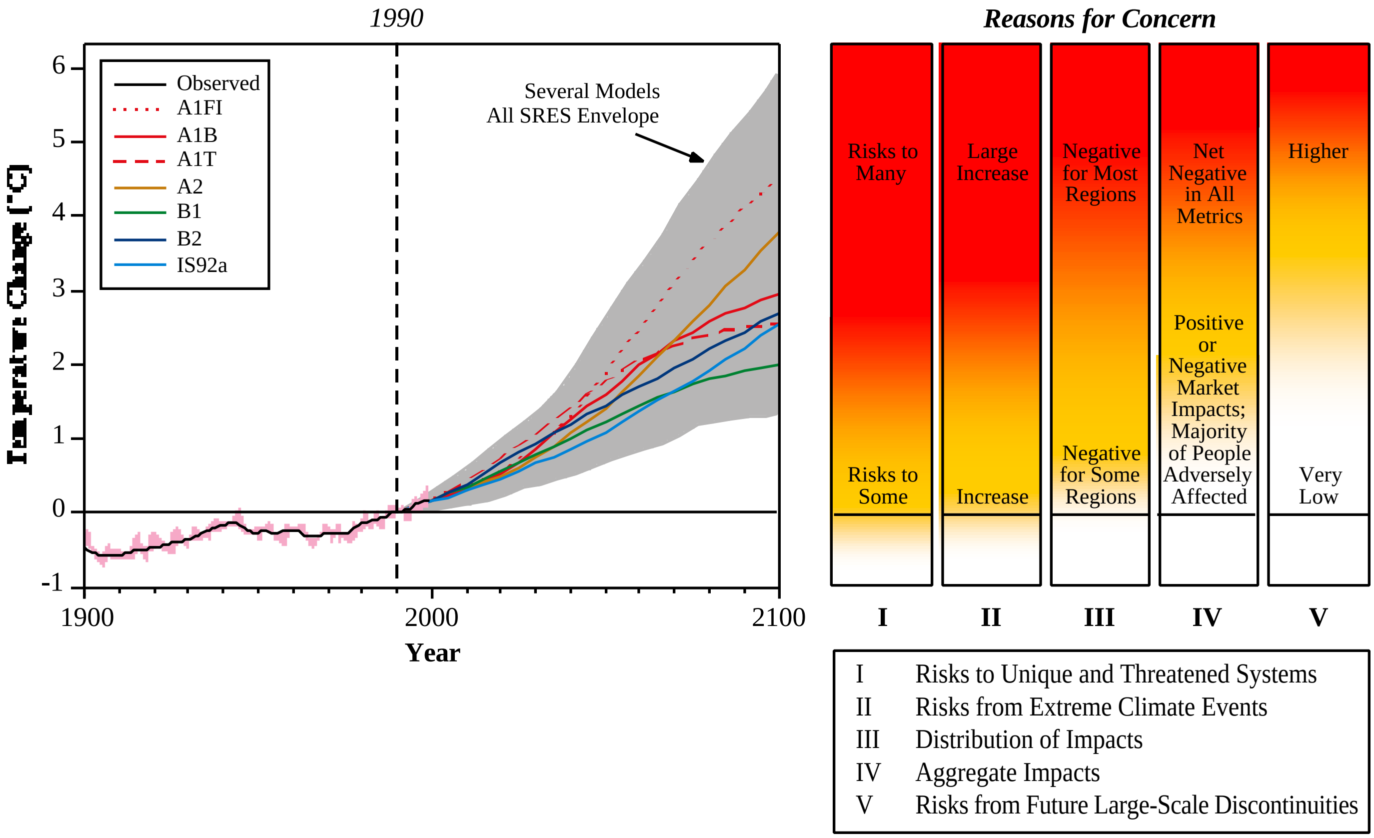

Figure SPM-2: Reasons for concern about projected climate change impacts. The risks of adverse impacts from climate change increase with the magnitude of climate change. The left part of the figure displays the observed temperature increase relative to the pre-industrial period and the range of projected temperature increase as estimated by Working Group I of the IPCC for scenarios from the *Special Report on Emissions Scenarios*. The right panel displays conceptualizations of five reasons for concern of climate change risks evolving through 2100. White indicates neutral or small negative or positive impacts or risks, yellow indicates negative impacts for some systems or low risks, and red means negative impacts or risks that are more widespread and/or greater in magnitude. The assessment of impacts or risks takes into account only the magnitude of change and not the rate of change. Global mean annual temperature change is used in the figure as a proxy for the magnitude of climate change, but projected impacts will be a function of, among other factors, the magnitude and rate of global and regional changes in mean climate, climate variability, and extreme climate phenomena, social and economic conditions, and adaptation.

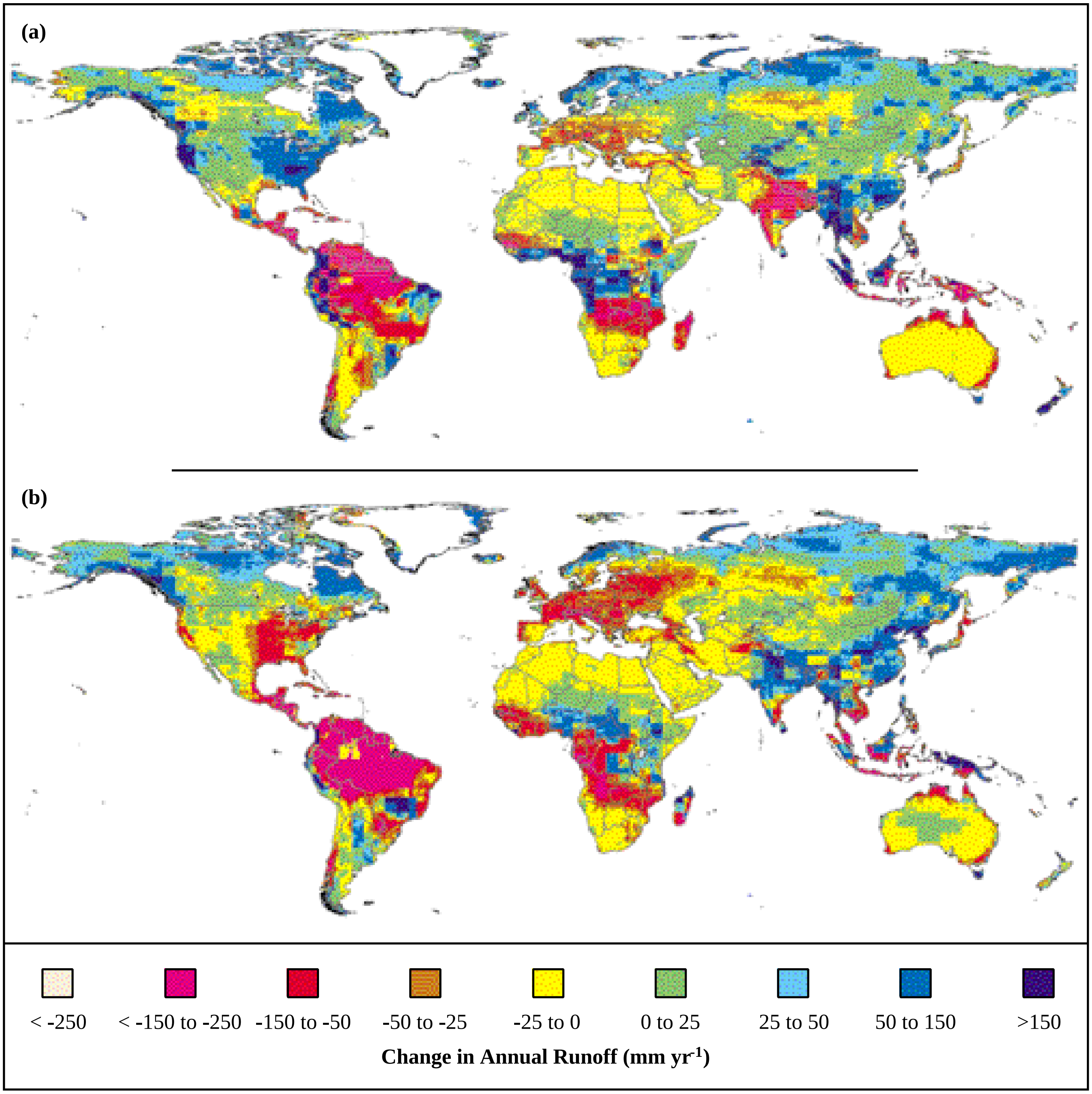

Figure SPM-3: Projected changes in average annual water runoff by 2050, relative to average runoff for 1961–1990, largely follow projected changes in precipitation. Changes in runoff are calculated with a hydrologic model using as inputs climate projections from two versions of the Hadley Centre atmosphere-ocean general circulation model (AOGCM) for a scenario of 1% per annum increase in effective carbon dioxide concentration in the atmosphere: (a) HadCM2 ensemble mean and (b) HadCM3. Projected increases in runoff in high latitudes and southeast Asia, and decreases in central Asia, the area around the Mediterranean, southern Africa, and Australia are broadly consistent across the Hadley Centre experiments, and with the precipitation projections of other AOGCM experiments. For other areas of the world, changes in precipitation and runoff are scenario- and model-dependent.