The IPCC Third Assessment: Impacts

The role of the Intergovernmental Panel on Climate Change is to provide the international community with expert guidance regarding scientific and technical aspects of the climate problem.

Since 1990, the Intergovernmental Panel on Climate Change (IPCC) has, at five-yearly intervals, assessed and reported on the current state of knowledge and understanding of the climate issue. These reports are intended to be used to provide policy makers with an objective assessment and review of the information available on climate change.

Given the importance of the IPCC reports as a global consensus on our understanding of the climate issue, we considered it to be appropriate and useful that *Tiempo* presents a summary of each Working Group Report.

Selected excerpts from the IPCC Working Group 1 Summary for Policymakers concerning the basic science of the climate issue were presented in the last issue of this bulletin (*Tiempo*, Issue 38/39, June 2001). In this issue, we present selected extracts from the Working Group II Summary for Policymakers on Impacts, Adaptation, and Vulnerability.

The following text is taken verbatim from the Policymakers Summary. All main conclusions are covered, though, where indicated, some detail has been omitted.

SUMMARY FOR POLICYMAKERS

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, *Climate Change 2001: Impacts, Adaptation, and Vulnerability.* 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...

Emergent findings

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. Associations between changes in regional temperatures and observed changes in physical and biological systems have been documented in many aquatic, terrestrial, and marine environments.

The studies... 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. In most cases where changes in biological and physical systems were detected, the direction of changes 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 (two or more decades) that are considered necessary for assessment of precipitation impacts.

The following words and phrases have been used to indicate judgmental estimates of confidence: very high (95% or greater chance); high (67-95%); likely (66-90%); medium (33-66%); low (5-33%); very low (5% or less). In other instances, a qualitative scale is used. well-established, established-but-incomplete, competing speculations, and speculative.

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 with the expected effects of regional changes in temperature. Thus, from the collective evidence, there is *high confidence* that recent regional changes in temperature have had discernible impacts on many physical and biological systems.

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.

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, 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* 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.

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.

Projected adverse impacts based on models and other studies include:

- A general reduction in potential crop yields in most tropical and subtropical regions for most projected increases in temperature
- A general reduction, with some variation, in potential crop yields in most regions in mid-latitudes for increases in annual-average temperature or more than a few °C
- Decreased water availability for populations in many water-scarce regions, particularly in the subtropics
- An increase in the number of people exposed to vector-borne (e.g. malaria) and water-borne diseases (e.g. cholera), and an increase in heat stress mortality
- 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
- Increased energy demand for space cooling due to higher summer temperatures.

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 °C
- A potential increase in global timber supply from appropriately managed forests
- Increased water availability for populations in some water-scarce regions – for example, in parts of southeast Asia
- Reduced winter mortality in mid- and high-latitudes
- Reduced energy demand for space heating due to higher winter temperatures.

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. 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...

The potential for large-scale and possibly irreversible impacts poses risks that have yet to be reliably quantified

Projected climate changes 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, *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.*

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 coastal sediments. The likelihood of many of these changes in Earth systems is not well-known...

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 and 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 m each over the next 1,000 years... Releases of terrestrial carbon from permafrost regions and methane from hydrates in coastal sediments, induced by warming, would further increase greenhouse gas concentrations in the atmosphere and amplify climate change.

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 factors 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.

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.

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.

Benefits and costs of climate change effects have been estimated in monetary units and aggregated to national, regional, and global scales. These estimates generally include 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 cancelling out losses for others and because the weights that are used to aggregate across individuals are necessarily subjective.

Notwithstanding the limitations expressed above, based on a few published estimates, increases in global mean temperature would produce net economic losses in many developing countries for all magnitudes of warming studied (*low confidence*), and losses would be greater in magnitude the higher the level of warming (*medium confidence*). In contrast, an increase in global mean temperature of up to a few °C would produce a mixture of economic gains and losses in developed countries (*low confidence*), with economic losses for larger temperature increases (*medium confidence*). 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*)...

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.

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.

Effects and vulnerability of natural and human systems

Hydrology and water resources

The effect of climate change on streamflow and groundwater recharge varies regionally and between climate scenarios, largely following projected changes in precipitation. A consistent projection across most climate change scenarios 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 (*medium confidence*); 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 evaporation, which can offset rainfall increases. The retreat of most glaciers is projected to accelerate, and many small glaciers may disappear (*high confidence*). In general, the projected changes in average annual runoff are less robust than impacts based solely on temperature change because precipitation changes vary more between scenarios. At the catchment scale, the effect of a given change in climate varies with physical properties and vegetation of catchments, and may be in addition to land-cover changes.

Approximately 1.7 billion people, one-third of the world's population, presently live in countries that are water-stressed (defined as using more than 20% of their renewable water supply, a commonly used indicator of water stress). This number is projected to increase to around 5 billion by 2025, depending on the rate of population growth. The projected climate change could further decrease the streamflow and groundwater recharge in many of these war-stressed countries – for example in central Asia, southern Africa, and countries around the Mediterranean Sea – but may increase it in some others...

Climate change is unlikely to have a big effect on municipal and industrial water 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, hence higher crop evaporative demand, mean that the general tendency would be towards an increase in irrigation demands...

The greatest vulnerabilities are likely to be in unmanaged water systems and systems that are currently stressed or poorly and unsustainably managed due to policies that discourage efficient water use and protection of water quality, inadequate watershed management, failure to manage variable water supply and demand, 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 use changes 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 (e.g. increasing flood defences, building weirs, utilizing water storage areas, including natural systems, improving infrastructure for water collection and distribution) are more widely used than demand-side approaches (which alter the exposure to stress); the latter is the focus of increasing attention. However, the capacity to implement effective management responses is unevenly distributed around the world and is low in many transition and developing countries.

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 carbon dioxide (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*). These advances, along with advances in research on agricultural adaptation, have been incorporated... into models used to assess the effects of climate change...

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.

When autonomous agronomic adaptation is included, crop modeling assessments indicate, with *medium* to *low confidence*, that climate change will lead to generally positive responses at less than a few °C warming and generally negative responses for more than a few °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...

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.

Terrestrial and freshwater ecosystems

Vegetation modeling studies continue to show the potential for significant disruption of ecosystems under climate change (*high confidence*). 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*). Distributions, population sizes, population density, and behaviour of wildlife have been, and will continue to be, affected directly by changes in global or regional climate and indirectly through changes in vegetation... 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 labelled "endangered or vulnerable" to become rarer, and thereby closer to extinction, in the 21st century (*high confidence*).

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.

Terrestrial ecosystems appear to be storing increasing amounts of carbon. At the time of the

***Sensitivity** is the degree to which a system is affected either adversely or beneficially, by climate-related stimuli. Climate-related stimuli encompass 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 change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.*

Assessment Report, 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*). 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*).

Contrary to the Second Assessment Report, 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*)...

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... Many marine ecosystems are sensitive to climate change. Climate trends and variability are 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.

Many coastal areas will experience levels of flooding, accelerated erosion, loss of wetlands and mangroves, and seawater intrusion into freshwater 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... Changes in relative sea level will vary locally due to uplift and subsidence caused by other factors.

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... Future sea surface warming would increase stress on coral reefs and result in increased frequency of marine diseases (*high confidence*).

Assessments of adaptation strategies for coastal zones have shifted emphasis away from hard protection structures of shorelines (e.g. seawalls, groins) towards soft protection measures (e.g. beach nourishment), managed retreat, and enhanced resilience of biophysical and socioeconomic systems in coastal regions. 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.

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.

Many vector-, food-, and water-borne infectious diseases are known to be sensitive to changes in climatic conditions. From results of most predictive model studies, there is *medium* to *high confidence* 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.

Projected climate change will be accompanied by an increase in heat waves, 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 the impact would be greatest in urban populations, affecting particularly the elderly, sick, and those without access to air-conditioning (*high confidence*). Limited evidence indicates that in some temperate countries reduced winter deaths would outnumber increased summer deaths (*medium confidence*)...

Extensive experience makes clear that any increase in flooding will increase the risk of drowning, diarrhoeal and respiratory diseases, and, in developing countries, hunger and malnutrition (*high confidence*).

For each anticipated adverse health impact there is a range of social, institutional, technological, and behavioural adaptation options to lessen that impact. Adaptations could, for example, encompass strengthening of the public health infrastructure, health-oriented management of the environment,... and the provision of appropriate medical care facilities. 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.

Human settlements, energy, and industry

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

- 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.
- 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.
- Populations may be directly affected through extreme weather, changes in health status, or migration. The problems are somewhat different in the largest (million) and mid- to small-sized population centers.

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. Riverine and coastal settlements are particularly at risk (*high confidence*), 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...

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 to 200 million people depending on adaptive responses) for mid-range scenarios of a 40-cm sea-level rise by the 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 US$ for individual countries – for example, Egypt, Poland, and Vietnam...

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 diversified settlements (*high confidence*).

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.

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$ yr^{-1} in the 1950s to 40 billion US$ yr^{-1} in the 1990s (all in 1999 US$, unadjusted for purchasing power parity), with approximately one-quarter of the losses occurring in developing countries. The insured portion of these losses rose from a negligible level to 9.2 billion US$ yr^{-1} during the same period...

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...

Climate change and anticipated changes in weather-related events perceived to be linked to climate change would increase actuarial uncertainty in risk assessment (*high confidence*). 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...

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 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.

Vulnerability varies across regions

The vulnerability of human populations and natural systems to climate change differs substantially across regions and across populations with 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.

In light of the above, all regions are likely to experience some adverse effects of climate change (see Box, page 36 onwards). 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 then elsewhere in the region.

Regional adaptive capacity, vulnerability, and key concerns

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.

Grain yields are projected to decrease for many scenarios, diminishing food security, particularly in small food-importing countries (*medium to high confidence*).

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*).

Extension of ranges of infectious disease vectors would adversely affect human health in Africa (*medium confidence*).

Desertification would be exacerbated by reductions in average annual rainfall, runoff, and soil moisture, especially in southern, North, and West Africa (*medium confidence*).

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*).

Significant extinctions of plant and animal species are projected and would impact rural livelihoods, tourism, and genetic resources (*medium confidence*).

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*).

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.

Extreme events have increased in temperate and tropical Asia, including floods, droughts, forest fires, and tropical cyclones (*high confidence*).

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*).

Runoff and water availability may decrease in arid and semi-arid Asia but increase in northern Asia (*medium confidence*).

Human health would be threatened by possible increased exposure to vector-borne infectious diseases and heat stress in parts of Asia (*medium confidence*).

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*).

Climate change would increase energy demand, decrease tourism attraction, and influence transportation in some regions of Asia (*medium confidence*).

Climate change would exacerbate threats to biodiversity due to land-use and land-cover change and population pressure in Asia (*medium confidence*). Sea-level rise would put ecological security at risk, including mangroves and coral reefs (*high confidence*).

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*).

Latin America

Adaptive capacity of human systems in Latin America is low, particularly with respect to extreme climate events, and vulnerability is high.

Loss and retreat of glaciers would adversely impact runoff and water supply in areas where glacier melt is an important water source (*high confidence*).

Floods and droughts would become more frequent with floods increasing sediment loads and degrade water quality in some areas (*high confidence*).

Increases in intensity of tropical cyclones would alter the risks to life, property, and ecosystems from heavy rain, flooding, storm surges, and wind damages (*high confidence*).

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*).

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*).

Coastal human settlements, productive activities, infrastructure, and mangrove ecosystems would be negatively affected by sea-level rise (*medium confidence*).

The rate of biodiversity loss would increase (*high confidence*).

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.

The projected sea-level rise of 5 mm yr^{-1} 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*).

Islands with very limited water supplies are highly vulnerable to the impacts of climate change on the water balance (*high confidence*).

Coral reefs would be negatively affected by bleaching and by reduced calcification rates due to higher CO_2 levels (*medium confidence*); mangrove, sea grass bed, and other coastal ecosystems and the associated biodiversity would be adversely affected by rising temperatures and accelerated sea-level rise (*medium confidence*).

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 significance food source (*medium confidence*).

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*).

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*).

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.

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, estimate 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 decisionmaking 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 assessment of impacts, vulnerability, and adaptation, including capacity-building and training for monitoring, assessment, and data gathering, especially in and for developing countries (particularly in relation to the items identified above).

Further information: *The Working Group II "Summary for Policymakers" is available on the IPCC web site or can be obtained from the IPCC Secretariat at the address on page 41. The full Working Group II report, "Climate Change 2001: Impacts, Adaptation and Vulnerability," is published by Cambridge University Press.*