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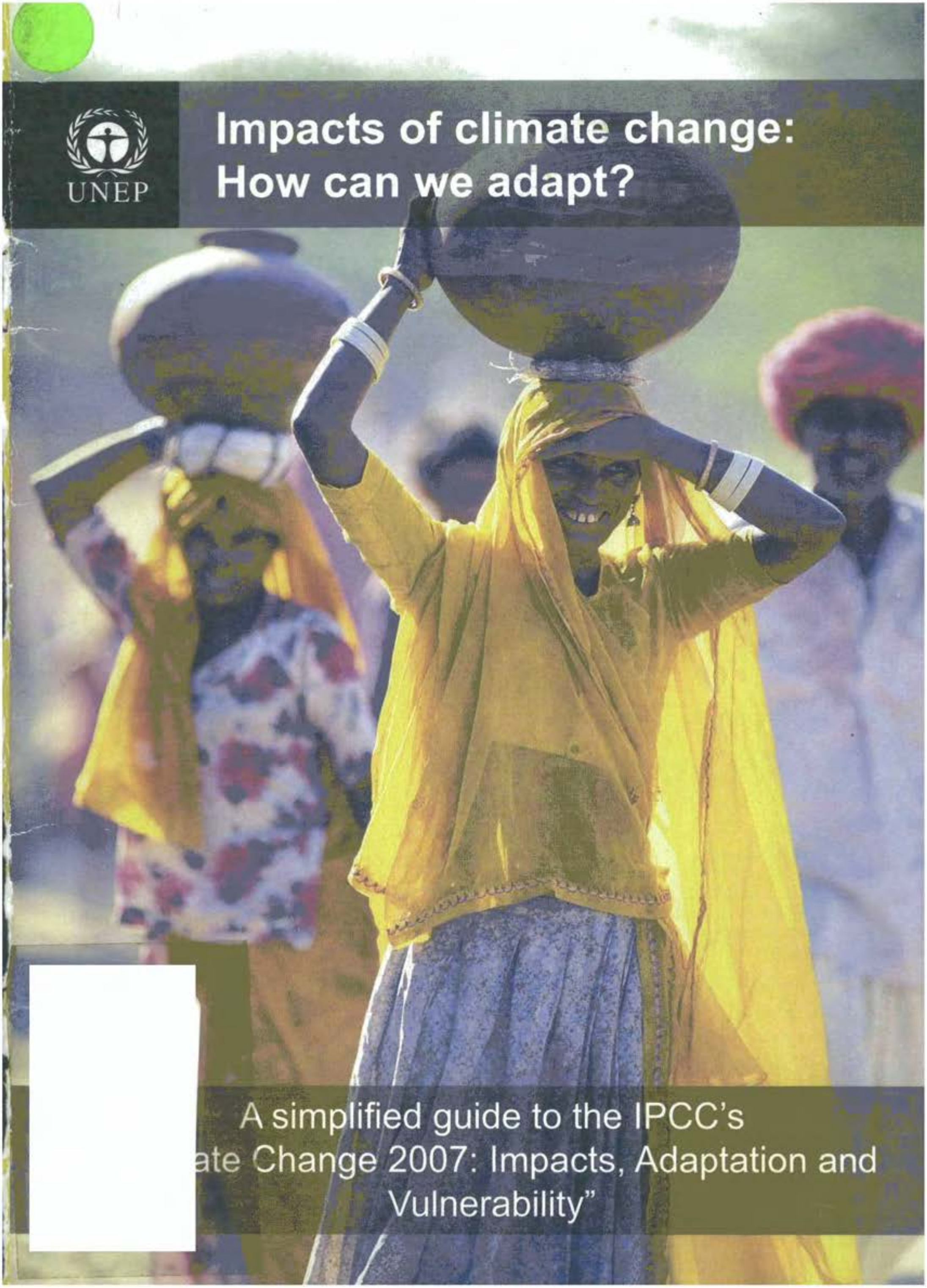
Impacts of climate change: How can we adapt?



A simplified guide to the IPCC's
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Impacts of climate change: How can we adapt?

A simplified guide to the IPCC's "Climate Change 2007: Impacts, Adaptation and Vulnerability"

Cover photo: © Charlie Westerman/Getty Images

The IPCC is a 2007 Nobel Peace Prize laureate.

Foreword and Summary

This booklet summarises the most recent assessment by the Intergovernmental Panel on Climate Change (IPCC) of the current knowledge concerning climate change impacts, adaptation and vulnerability.[1] This knowledge is summarised under sixteen Key Messages in the pages that follow.

1. Present-day climate change is affecting our physical and natural environment.
2. Magnitudes of impact can now be estimated more systematically for a range of climate changes.
3. Some systems and sectors will be especially affected by climate change.
4. Some places will be especially affected by climate change.
5. Within all areas, even those with high incomes, some people will be particularly at risk.
6. The aggregate effect of climate change is very likely to be negative.
7. Altered frequencies and intensities of extreme weather events are expected to have mostly adverse impacts.
8. Some large-scale climate events have the potential to cause very large impacts, especially after the 21st century.
9. Some adaptation to current and future climate change is occurring now, but on a limited basis.
10. Adaptation will be necessary to address impacts resulting from the warming which is already unavoidable due to past emissions.
11. A wide array of adaptation options is available, but more extensive adaptation is required.
12. Vulnerability to climate change can be exacerbated by other stresses.
13. Future vulnerability depends not only on climate change but also on development pathway.
14. Sustainable development may reduce vulnerability to climate change, and climate change may impede nations' abilities to achieve sustainable development pathways.
15. Many impacts can be avoided, reduced or delayed by mitigation.
16. We will need a mix of adaptation and mitigation measures to meet the challenge of climate change; designing this mix is hampered by a lack of information on the costs and benefits of adaptation.

Martin Parry, Osvaldo Canziani, Jean Palutikof and Clair Hanson. UK Met Office, Exeter, UK, September 2008

[1] IPCC, 2007a: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK.

The Present Day

The climate is changing now.

The IPCC Working Group I Fourth Assessment[2] concluded that warming of the climate system due to greenhouse gas emissions is unequivocal. Global average annual temperatures increased by 0.76°C between 1850-1899 and 2001-2005 (Figure 1). The warmest year was 1998, with a temperature of 0.55°C above the 1961-1990 mean. Twelve of the thirteen warmest years have now occurred in the past thirteen years (1995-2007).

The changes in our climate caused by increased concentrations of greenhouse gases are not restricted to temperature. Because there is more energy in the system, there is the potential for all aspects of our climate to change. The IPCC Fourth Assessment concluded that:

- heavy precipitation events have become more frequent over most areas during the twentieth century,
- the area affected by drought has increased in many regions since 1970,
- intense tropical cyclone activity has increased in some regions since 1970.

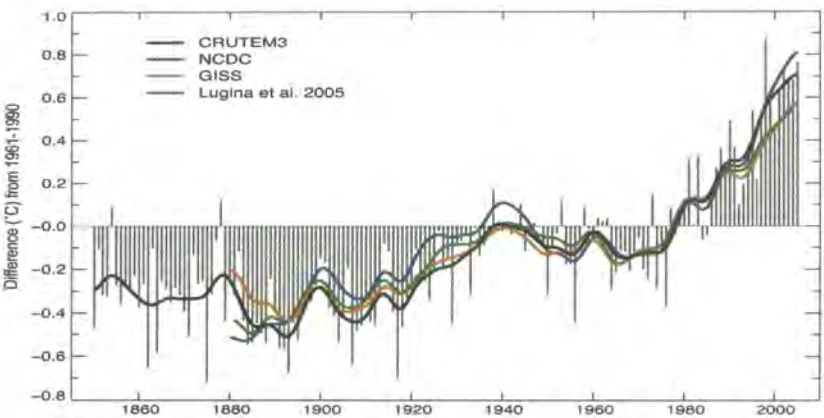

Figure 1: Annual anomalies of global land-surface air temperature (°C), 1850 to 2005, relative to the 1961-1990 mean from different databases. The smooth curves show decadal variations. Source: IPCC Working Group I Fourth Assessment.

[2] See References

Key Statement 1: Present-day climate change is affecting our physical and natural environment.

Physical and natural systems around the world are being affected by regional climate changes, particularly temperature increases. These temperature increases are very likely to be the result of anthropogenic emissions of greenhouse gases.

Most evident are reductions in snow, ice and frozen ground, which, in turn, are leading to enlargement and increased numbers of glacial lakes, and increased ground instability in permafrost and mountain regions. Although the greatest reduction in ice extent has occurred in the Arctic (Figure 2), some of the most obvious changes have been in tropical mountain environments. Figure 3 shows the ice margin of the Gangotri glacier in the Himalayas, which is the source of the Ganges river. This ice margin has retreated substantially since 1780.

Figure 3: Changes in the extent of the Gangotri glacier since 1780. Reproduced courtesy of NASA EROS Data Center, 9 September 2001. Source: IPCC Working Group II Fourth Assessment.

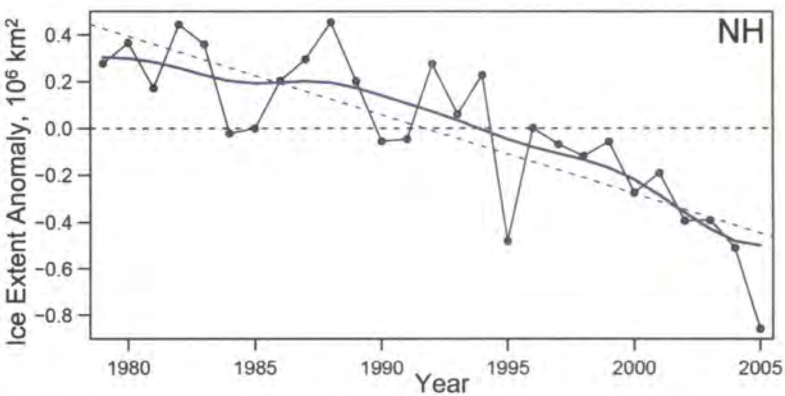

Figure 2: Vulnerability of the Arctic to global warming - observed changes in Northern Hemisphere sea-ice extent. Source: IPCC Working Group II Fourth Assessment.

There is extensive evidence that recent warming is strongly affecting terrestrial biological systems, including such changes as earlier timing of spring events (e.g., leaf unfolding, bird migration and egg laying - Figure 4) and shifts in ranges of plant and animal species. In the oceans, and mainly at high latitudes, we can currently observe shifts in ranges and abundances of algae, plankton and fish.

Probably the most important effect of increased greenhouse gas emissions is in the oceans, which have become increasingly acidic as sea water absorbs carbon dioxide, forming carbonic acid. So far, we have recorded an average pH reduction of 0.1. Increasingly, acidity is expected to have major effects on shell-forming organisms, but research on this is still in its early stages.

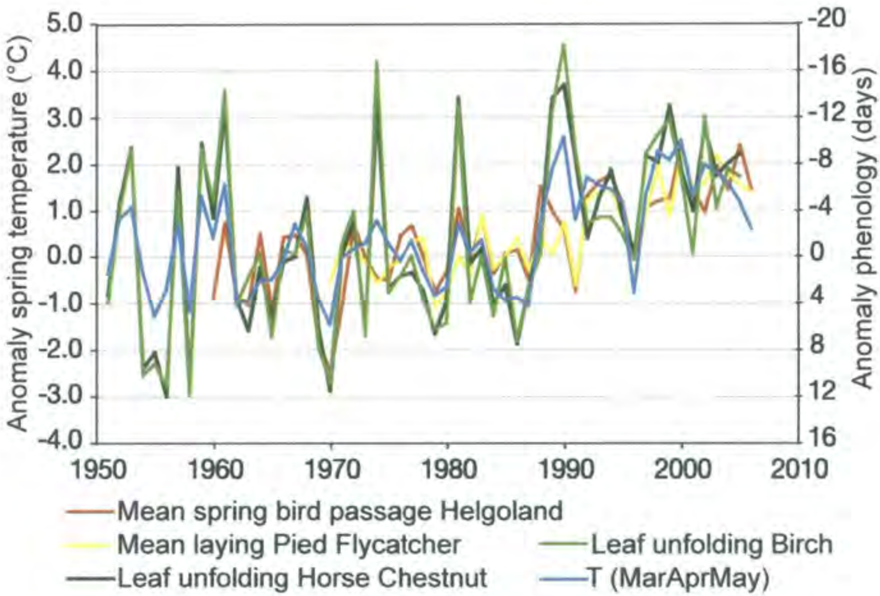

Figure 4: Anomalies of bird passage, egg laying and leaf unfolding in Germany. T = mean spring air temperature. Source: IPCC Working Group II Fourth Assessment.

It is much less easy to discern the effects of present-day climate change on human welfare and activities, mainly because our capacity to adapt acts to mask these effects. Areas where effects can be discerned include increases in forest fires in northern high latitudes, earlier spring planting of crops, and increased human mortality during heatwaves. It is estimated that the heatwave of August 2003 in western Europe resulted in 35,000 deaths. This was the hottest summer on record, and analysis suggests that human influence has at least doubled the risk of a heatwave of this magnitude or greater.

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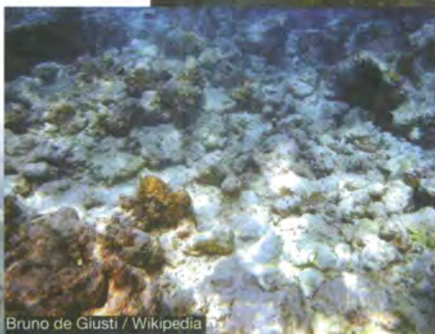


Bruno de Giusti / Wikipedia

Christopher Uglow / Still Pictures / UNEP

The Future

Key statement 2: Magnitudes of impact can now be estimated more systematically for a range of climate changes.

IPCC's Working Group I estimated that global average temperatures will increase by between 1.8°C and 4°C by 2090-2099 compared to 1980-1999; these figures are from the best estimate, depending on how human societies will develop during this time (Figure 5). In addition, the IPCC Fourth Assessment concluded that during the 21st century:

- Areas of snow cover and sea ice are projected to decrease. In some models, late summer sea-ice in the Arctic disappears almost entirely.
- Heatwaves and heavy precipitation events are expected to become more frequent.
- Tropical cyclones are likely to become more intense.
- Precipitation amounts are expected to increase at high latitudes and decrease in most subtropical land regions.
- Sea level is projected to rise by between 18 to 59 cm by 2100.

A summary of the key impacts expected in different sectors and regions is given in Figures 6 and 7.

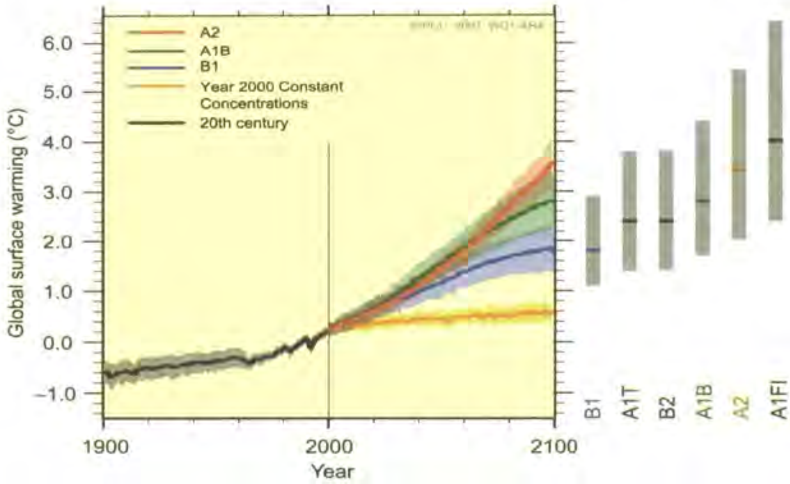


Figure 5: Projected global mean surface warming (relative to 1980–1999) for three development scenarios.† The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars to the right indicate the best estimate (solid line within each bar) and the likely range for 2100. Source: IPCC Working Group I Summary for Policymakers.

† See Appendix 1 for description of scenarios.

Key global impacts as a function of increasing global average temperature change

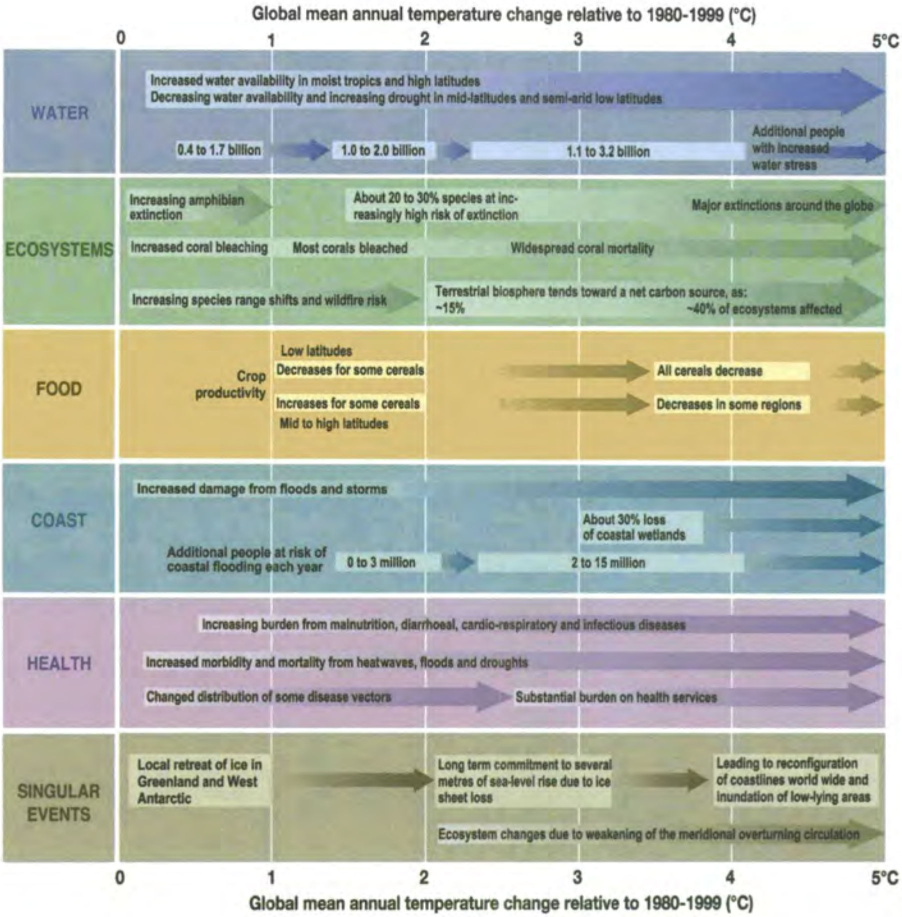


Figure 6: Global impacts projected for changes in climate (and sea level and atmospheric carbon dioxide where relevant) associated with different amounts of global average surface temperature change in the 21st century. Source: IPCC Working Group II Technical Summary.

Key regional impacts as a function of increasing global average temperature change

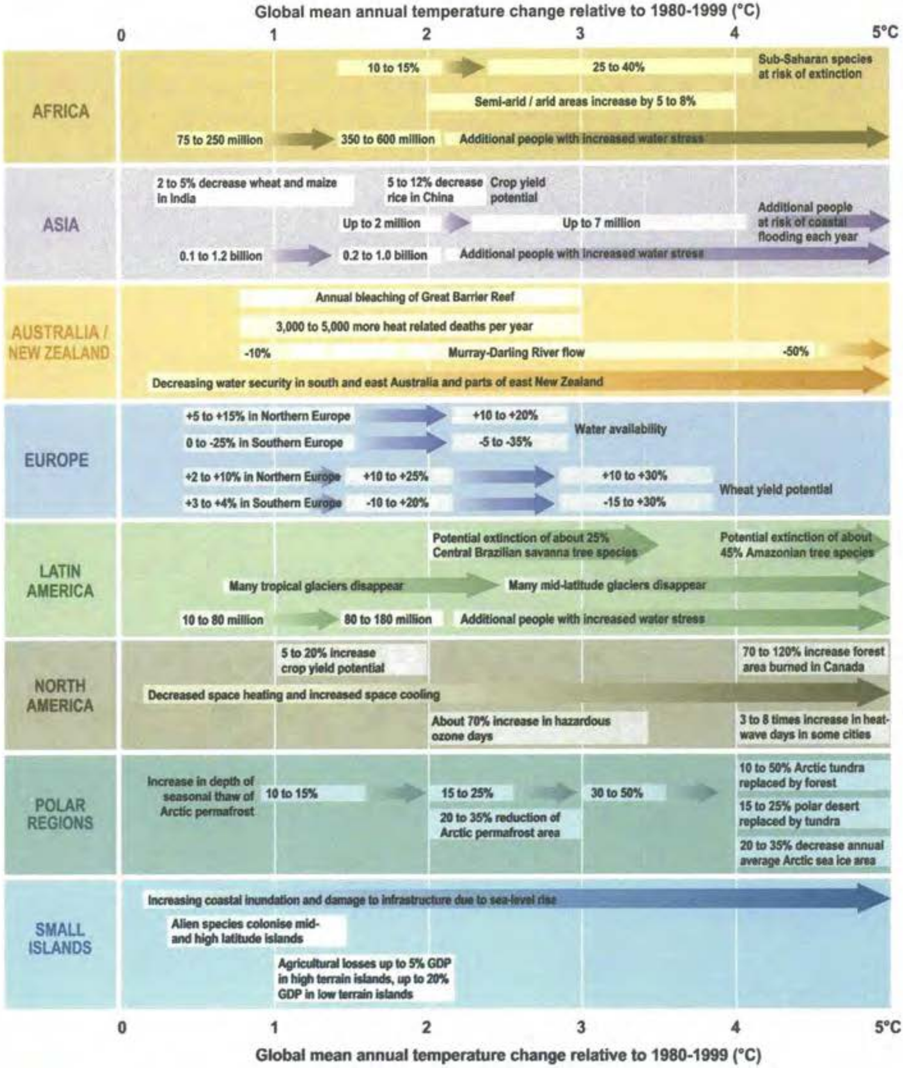


Figure 7: Regional impacts projected for changes in climate (and sea level and atmospheric carbon dioxide where relevant) associated with different amounts of global average surface temperature change in the 21st century. Source: IPCC Working Group II Technical Summary.

Key Statement 3: Some systems and sectors will be especially affected by climate change.

The most vulnerable ecosystems are those which occupy **marginal stressed evironments**.

- On land: tundra, boreal forest, mountain and mediterranean-type ecosystems
- Along coasts: mangroves and salt marshes
- In the oceans: coral reefs and the sea-ice biome.

Water resources in mid-latitude and dry low-latitude regions are also especially affected, because of decreases in rainfall and higher rates of evapotranspiration. Figure 8 shows the change in water availability for 2090-2099, relative to 1980-1999. This shows clearly, for example, that over much of northern and southern Africa, future water availability is projected to decline.

Agriculture in low latitudes may be especially affected, where crop yields are projected to decrease even for small amounts of warming. Figure 9 shows modelled wheat yelds. For mid- and higher latitudes, even wthout adaptation, the effects of warming on wheat yields are projected to be beneficial for local temperature increases up to 1-3°C.

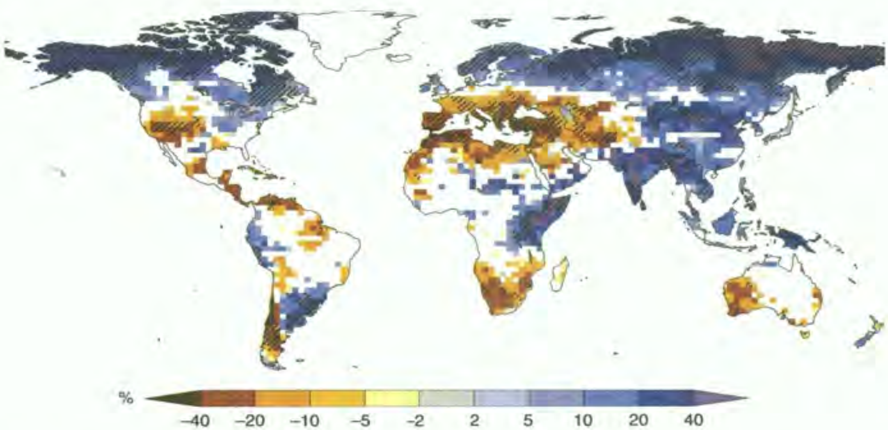


Figure 8: Changes in annual water availability for 2090-2099 relative to 1980-1999. White areas are where less than 66% of models agree on the sign of change; hatched areas are where more than 90% of models agree on the sign of change. Source: IPCC Fourth Assessment Synthesis Report.

Low-lying coasts are also likely to be especially affected, being threatened by:

- sea-level rise leading to increased risk of flooding and groundwater salinisation;
- increased frequency and severity of storms, tidal surges.

Finally, human health in areas of low adaptive capacity are likely to be especially affected. For example, if hospitals are under-resourced, they may find it difficult to cope with a sudden increase in admissions due to heat stress during heatwaves.

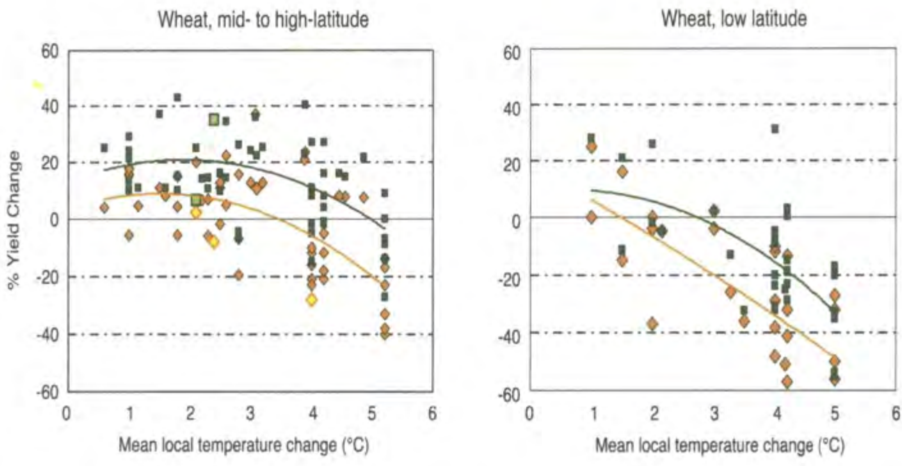


Figure 9: Modelled wheat yields in response to local temperature change. Responses are without (red dots) and with (dark green dots) adaptation. Source: IPCC Working Group II Fourth Assessment.

Key statement 4: Some places will be especially affected by climate change.

Four regions have been identified as the most vulnerable to climate change.

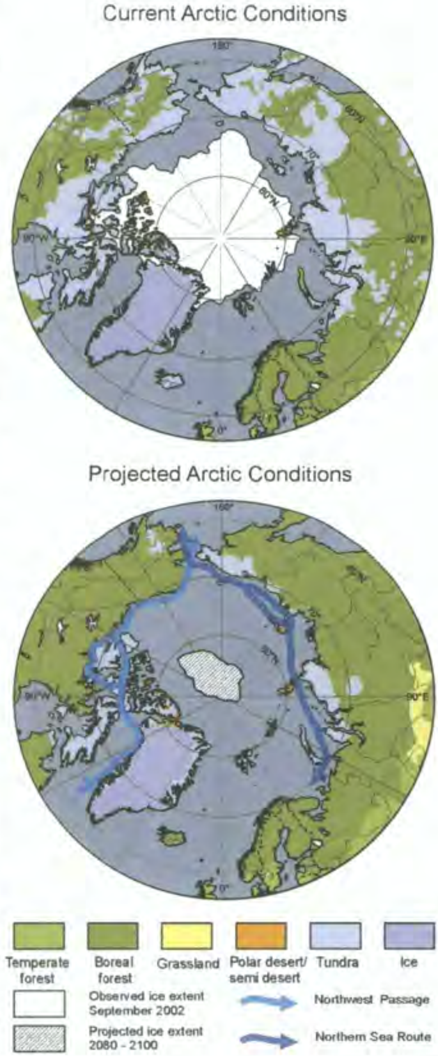


Figure 10: Present and projected minimum sea-ice extent and vegetation for the Arctic and neighbouring regions. Source: IPCC Working Group II Fourth Assessment.

The Arctic

The causes of enhanced vulnerability in the Arctic are due to:

- Large regional warming and associated ice melt (see Figure 10).
- The habitat of plant and animal species living along the ice margins, such as polar bears, will alter as the ice melts. The area of ice is already decreasing (see Figure 2) - since 1979, the Arctic has been losing summer ice at about 9% per decade - and this trend is expected to continue into the future (see Figure 10).
- Traditional ways of life of indigenous inhabitants are likely to be affected (e.g., those of the Inuit, which are based on hunting).

Ice melt associated with global warming will lead to improved transport links and opportunities to open up the Arctic to commercial activities, especially the exploitation of its mineral and oil wealth. However, these opportunities must be set against the threat to ecosystems and indigenous livelihoods, and the risk of extinction of some iconic species.

Africa

Much of Africa is already vulnerable to drought, due to high natural variability in the climate and high demand on natural resources from a population which is heavily dependent on agriculture for its livelihood. Thus, Africa is vulnerable to any increase in the frequency of occurrence, and/or severity, of drought due to global warming. The IPCC Fourth Assessment considered it likely that the area affected by drought would increase during the 21st century. These risks are compounded by structural problems: the quality of governance and the health and education levels of the population limit the capacity to adapt to climate change.

Asian and African megadeltas

The Asian and African (principally the Nile) megadeltas are areas of very high population density concentrated in low-lying areas prone to flooding and exposed to storm surge and tropical storms. These areas are vulnerable to rising sea level related to global warming, and to any changes in the severity of tropical storms and storm surge. By 2100, sea level is expected to rise between 18 and 59 cm and this rise could be up to 1 m within two to three centuries. The IPCC Fourth Assessment considered it likely that intense tropical cyclone activity will increase in the future.


R. Botev / Wikipedia


NASA's MODIS Rapid Response Team / Wikipedia

Small islands

Small islands are also vulnerable to rising sea levels and increasing storm severity. In future decades, higher mean sea levels may be sufficient to inundate some small islands.

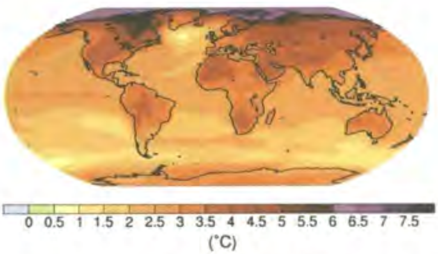
In the Caribbean and Pacific Islands, more than 50% of the population live within 1.5 km of the shore. Almost without exception, the air and sea ports, major road arteries, utilities and other critical infrastructure in the small islands of the Indian and Pacific Oceans and the Caribbean are restricted to coastal locations. Unlike deltas and other coastal areas, small islands have no hinterland to move to in the case of coastal land loss.

As sea level rises, it is not only coastal inundation that poses a threat to small islands. Contamination of freshwater supplies by salinisation of the groundwater may threaten the viability of settlements. Tourism is a major contributor to the economies of many small islands. Beach erosion, degradation of coral reefs and bleaching will all make small islands a less attractive destination for tourists.

Key statement 5: Within all areas, even those with high incomes, some people will be particularly at risk.

These include the poor, young children, the elderly and the sick. During the European heatwave of 2003 it was noted that, in the Paris area where a 130% increase in expected mortality was observed, the group who were preferentially affected were elderly people with chronic underlying disease(s) living alone in an apartment in poor socioeconomic conditions. In the Bangladesh cyclone of 1991, most deaths were from drowning, with the highest mortality among children and the elderly.

Key statement 6: The aggregate effect of climate change is very likely to be negative.



Surface temperature changes for 2090-2099 under the SRES A2 scenario. Source: IPCC Working Group I Fourth Assessment.

Some low-latitude regions will experience net costs even for small increases in temperature. It is very likely that all regions will experience either declines in net benefits or increases in net costs for increases in temperature greater than about 2-3°C.

Key statement 7: Altered frequencies and intensities of extreme weather events are expected to have mostly adverse impacts.

The IPCC Fourth Assessment Report concluded, with increased confidence over the Third Assessment, that some weather events, such as heatwaves, storms and droughts, which can have large impacts, are likely to become more frequent and widespread in future and, in some cases, more intense. The related impacts are expected to be negative, including increased risk of death and injury, and damage to crops and infrastructure. For example, it is a conclusion of the Fourth Assessment that intense tropical cyclone activity is likely to increase through the 21st century. Thus, it is reasonable to expect events such as Hurricane Katrina, which hit New Orleans in August 2005 and caused an estimated 4,000 fatalities, to occur more often in the future.


FEMA / Wikipedia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Key statement 8: Some large-scale climate events have the potential to cause very large impacts, especially after the 21st century.

The IPCC Fourth Assessment concluded that complete melting of the Greenland ice sheet would cause sea level to rise about 7 m. Models suggest that a warming in excess of 1.9-4.6°C above pre-industrial temperatures (depending on the model sensitivity), if sustained for millennia, would lead to the complete removal of the Greenland ice sheet. For the West Antarctic ice sheet, complete melting would contribute 5 m to sea-level rise, although current model studies project that the Antarctic ice sheet will remain too cold for widespread surface melting. These large-scale changes are projected to take place gradually, over millennia, and complete melting within the current century is not likely.

National Science Foundation / Wikipedia

Actions

Key statement 9: Some adaptation to current and future climate change is occurring now, but on a limited basis.

Throughout history, human societies have adapted to climate variability (see Box 1). Examples of current adaptation to present-day climate change include water management in Perth, Western Australia, (Box 2), prevention of glacial lake outburst flooding in Nepal (Box 3), and development of Heat Health Warning Systems in major European cities following the heatwave of 2003.

Examples of adaptation to anticipated future climate change are less common and generally address (a) risks which have higher probabilities of occurrence and (b) high-cost infrastructure projects with long design lifetimes. Thus, new coastal infrastructure with a projected lifetime of decades will generally be designed to accommodate rising sea levels. Some examples are given in Box 4.


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Box 1: Adaptation amongst pre-Colombian communities of Latin America.

For pre-Colombian indigenous civilisations in the highlands of present-day Latin America, one of the most critical limitations affecting development was the irregular distribution of water (and this is still true today). In large areas, human activities depended on seasonal rainfall, and a range of adaptive actions were developed to satisfy requirements.

Engineering activities included rainwater cropping, as shown in Figure 11, filtration and storage; the construction of surface and underground irrigation channels, including devices to measure the quantity of water stored, rectification of river courses and the building of bridges. Water was also used to cut stone blocks for construction: stones were cut in regular geometric shapes by leaking water into cleverly made interstices and freezing it during Altiplano nights which reach below zero temperatures.

These efforts enabled the subsistence of communities which, at the peak of the Inca civilisation, included some 10 million people in what is today Peru and Ecuador.

Figure 11: Nasca (southern coast of Peru) system of water cropping for underground aqueducts and feeding the groundwater. Source: IPCC Working Group II Fourth Assessment.

Box 2: Case study of the Perth water supply.

Figure 12 shows changes in the amount of water flowing into the supply system for Perth in Western Australia. It is clear that there has been a substantial downturn in the resource over time. The shortfall has been met through the construction of two dams, additional groundwater extraction, and construction of a desalination plant which supplies 140,000 m³/day with designed expansion to 250,000 m³/day.

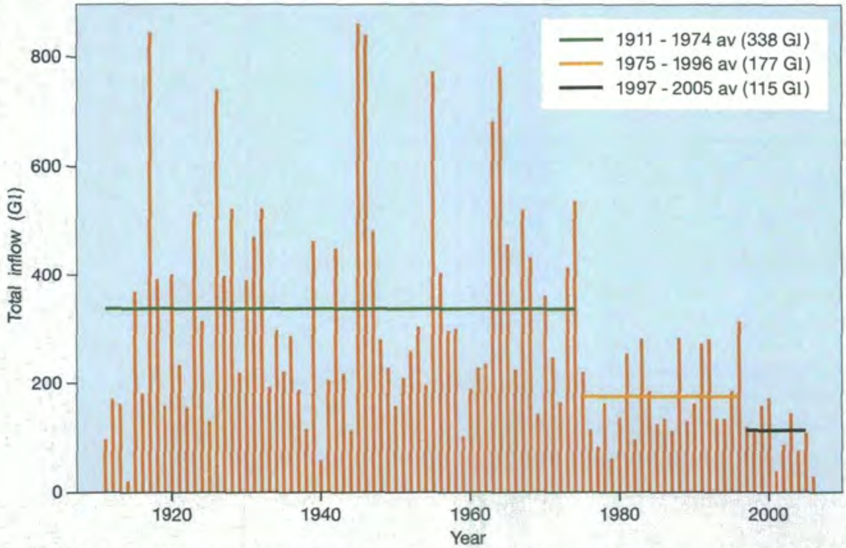

Figure 12: Annual inflow to Perth water supply system, 1911 to 2006. Source: IPCC Working Group II Fourth Assessment.

Box 3: Tsho Rolpa Risk Reduction Project in Nepal.

The Tsho Rolpa is a glacial lake located at an altitude of about 4,580 m in Nepal. Glacier shrinkage increased the size of the Tsho Rolpa from 0.23 km^2 in 1957/58 to 1.65 km^2 in 1997. The 90-100 million m^3 of water, which the lake contained by this time, were only held by a moraine dam – a hazard that called for urgent action to reduce the risk of a catastrophic glacial lake outburst flood (GLOF).

The Government of Nepal, with the support of international donors, initiated a project in 1998 to lower the level of the lake by 3 m by cutting a channel in the moraine. Meanwhile, an early warning system was established in 19 villages downstream in case a Tsho Rolpa GLOF should occur despite these efforts. In 2002, the four-year construction project was completed at a cost of US$3.2 million.

Box 4: Adaptation to rising sea level: some examples.

The Maeslantkering in the Netherlands is the largest moving structure on Earth. It protects the city of Rotterdam and the surrounding towns and agricultural areas against flooding from the sea. Completed in 1997, it is designed to close when a storm surge of 3 m above normal sea level is anticipated in Rotterdam. Under present-day conditions this should be once every ten years. In 50 years time, due to sea-level rise, this rate of closure is expected to increase to once every five years.

The 13 km-long Confederation Bridge, shown right, connects Prince Edward Island in eastern Canada to the mainland, and was completed in 1997. It is designed to withstand a 1 m rise in sea level during its 100-year design lifetime.

Wikipedia

Key statement 10: Adaptation will be necessary to address impacts resulting from the warming which is already unavoidable due to past emissions.

Some further warming due to past greenhouse-gas emissions, together with the associated climate changes, is unavoidable. The IPCC Fourth Assessment concluded that, even if present-day atmospheric concentrations of greenhouse gases were held constant, global temperatures would increase on average by a further 0.6°C by 2100, due primarily to the slow response of the oceans.

Holding atmospheric greenhouse-gas concentrations constant is clearly an unrealistic expectation. Even the most optimistic studies of mitigation anticipate a global temperature increase at equilibrium of 2.0 to 2.4°C above pre-industrial levels (1.4 – 1.8°C above present-day).

However successful we are at reducing emissions of greenhouse gases, some further level of global temperature increase is inevitable. Mitigation activities alone are insufficient - it will be necessary to adapt to the changes in climate which will result from global warming.

Beivushtang / Wikipedia

Joe Jones / Wikipedia

Fifo / Wikipedia

Key statement 11: A wide array of adaptation options is available, but more extensive adaptation is required.

Much more adaptation is needed to reduce vulnerability to climate change. The array of potential adaptive responses available is very large, ranging from purely technological (e.g., sea defences) through behavioural (e.g., altered food and recreational choices), to managerial (e.g., altered farm practices) and to policy (e.g., planning regulations). Many adaptation actions have multiple drivers, such as economic development and poverty alleviation as well as response to climate change, and are embedded within broader development and planning initiatives such as water resources planning, coastal defence and disaster risk reduction strategies.

There are barriers, limits and costs to adaptation which are not fully understood, and so we do not know how effective various options are at fully reducing the risks. IPCC authors concluded that adaptive capacity cannot be expected to cope with all the projected effects of climate change, especially over the long term as most impacts increase in magnitude. This is why the combination of mitigation and adaptation measures will be essential to combat climate change.

Some adaptation options:

	Crops	Water resources	Human health	Industry and settlements
Drying/ Drought	New drought-resistant varieties; intercropping; crop residue retention; weed management; irrigation	Demand management; groundwater conservation	Grain storage; emergency feeding stations; safe drinking water and sanitation	Improved water supply systems
Increased rainfall/ Flooding	Improved drainage; promotion of alternative crops	Flood forecasting and warning	Early-warning systems; disaster preparedness planning; emergency relief	Improved flood protection; flood hazard mapping; flood warnings
Warming/ Heatwaves	New heat-resistant varieties; altered timing of cropping activities; pest control	Demand management; education for sustainable use	Surveillance systems for disease emergence; stronger public institutions and health systems	Assistance programmes for especially vulnerable groups; technological change
Wind speed/ Storminess	Wind-resistant crops e.g., vanilla	Coastal defences to protect supply against contamination	Early-warning systems; disaster preparedness planning; emergency relief	Early-warning systems; more resilient infrastructure; insurance

Key statement 12: Vulnerability to climate change can be exacerbated by other stresses.

Non-climatic stresses can increase vulnerability to climate change by reducing resilience and can also reduce adaptive capacity because of resource redeployment to competing needs.

Example 1: Coral reefs are experiencing bleaching and die-off due to multiple stresses. Climate change-related stresses include increasing water temperatures leading to coral bleaching and ocean acidification, which is expected to affect shell formation in corals. Non-climatic stresses on coral reefs include marine pollution, sediments draining from eroding river basins and chemical runoff from agriculture.

Example 2: Lower than normal receipts of rainfall in the Sahel have contributed to reductions in the area of Lake Chad over the past 30 years (see Figure 13). Equally important, however, are increased abstractions of water for large irrigation schemes from the rivers and streams that feed the lake. It is the combination of climate change and other trends that explains the lake's shrinkage.

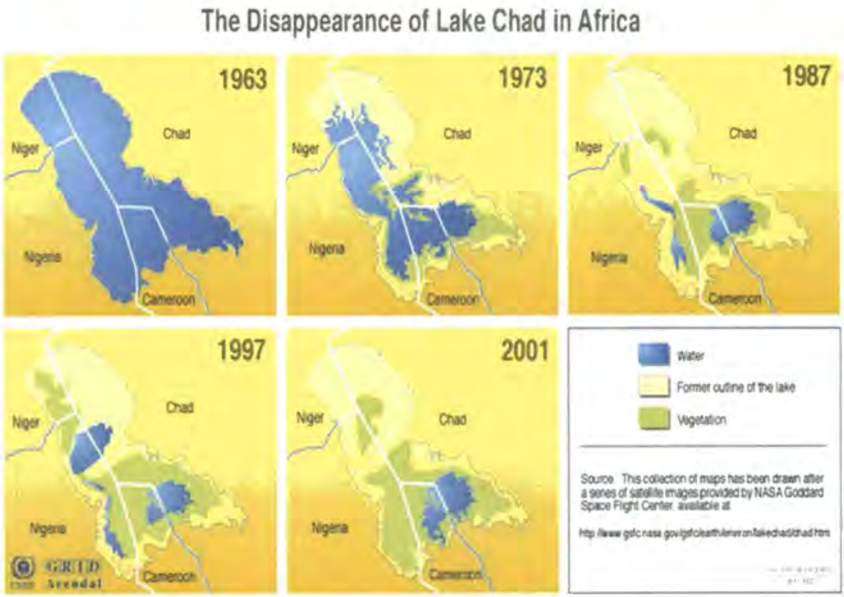

Figure 13: The disappearance of Lake Chad in Africa. Source: UNEP. See: http://www.grida.no/climate/vitalafrica/.

Key statement 13: Future vulnerability depends not only on climate change but also on development pathway.

Projected impacts of climate change can vary greatly depending on the future economic and social development pathway selected. To illustrate, Figure 14 shows estimates of the global number of people at risk of flooding under different assumptions of socio-economic development. In this figure, the blue bars are the numbers at risk without taking into account sea-level rise and purple bars are the additional numbers at risk when sea-level rise is taken into account. The differences in impact between these future conditions are largely explained, not by climate change, but by differences in vulnerability due to wealth, technology and population size. This is important, because it suggests that choice of development pathway can be a key to reducing impacts from climate change, not only because of lower emissions, but also by increasing resilience and reducing exposure.

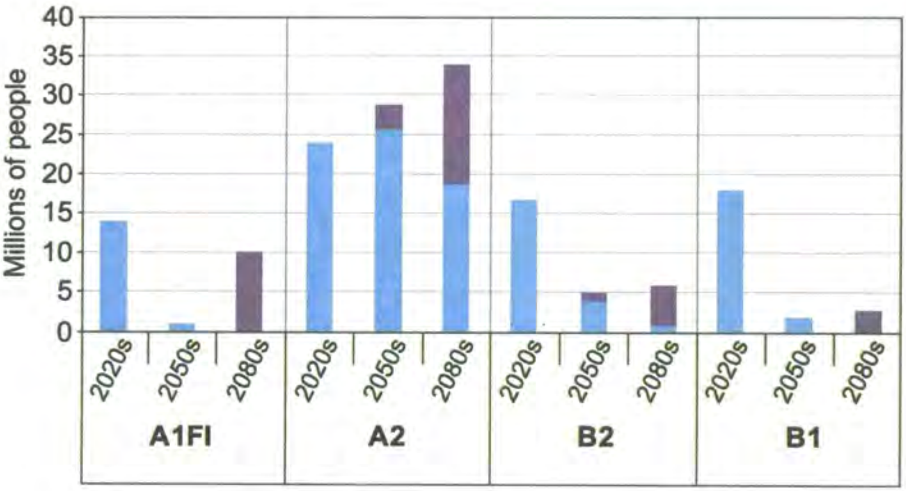

Figure 14: Estimated millions of people per annum at risk globally from coastal flooding. Blue bars: numbers at risk without sea-level rise; purple bars: numbers at risk with sea-level rise. Source: IPCC Working Group II Fourth Assessment.

Key statement 14: Sustainable development may reduce vulnerability to climate change, and climate change may impede nations' abilities to achieve sustainable development pathways.

Sustainable development can reduce vulnerability to climate change by enhancing adaptive capacity and increasing resilience. At present, however, few plans for promoting sustainability have explicitly included either adapting to climate change impacts or promoting adaptive capacity. On the other hand, it is very likely that climate change can slow the pace of progress towards sustainable development, either directly through increased exposure to adverse impacts or indirectly through erosion of the capacity to adapt. For example, it may make it more difficult to achieve the Millennium Development Goals such as ensuring environmental sustainability and eradicating extreme poverty.

Key statement 15: Many impacts can be avoided, reduced or delayed by mitigation.

Bringing together the conclusions of Working Groups II and III[3] can enable us to envisage what impacts might be avoided by differing amounts of emissions reduction.

Figure 15 shows, for a range of sectors, the expected impacts scaled against climate change. By plotting the unmitigated temperature change by 2100 (line a) on this figure, we can see the impacts likely to be experienced by that date if no efforts are made to reduce our emissions of greenhouse gases. Line b shows the temperature change by 2100 if mitigation measures are put in place, specifically a 50% cut in emissions by 2050 (leading to stabilisation at around 450-550 ppm CO_2). This would not avoid major global impacts – there is an even chance of around 2 billion people being short of water by 2100. Limiting impacts to acceptable levels by the end of the century would require an 80% cut in emissions by 2050 (leading to stabilisation at around 400-470 ppm). Compared with 50%, an 80% target would substantially reduce the harm caused by climate change: for example, it would halve the population put at risk of water stress and flooding.

References

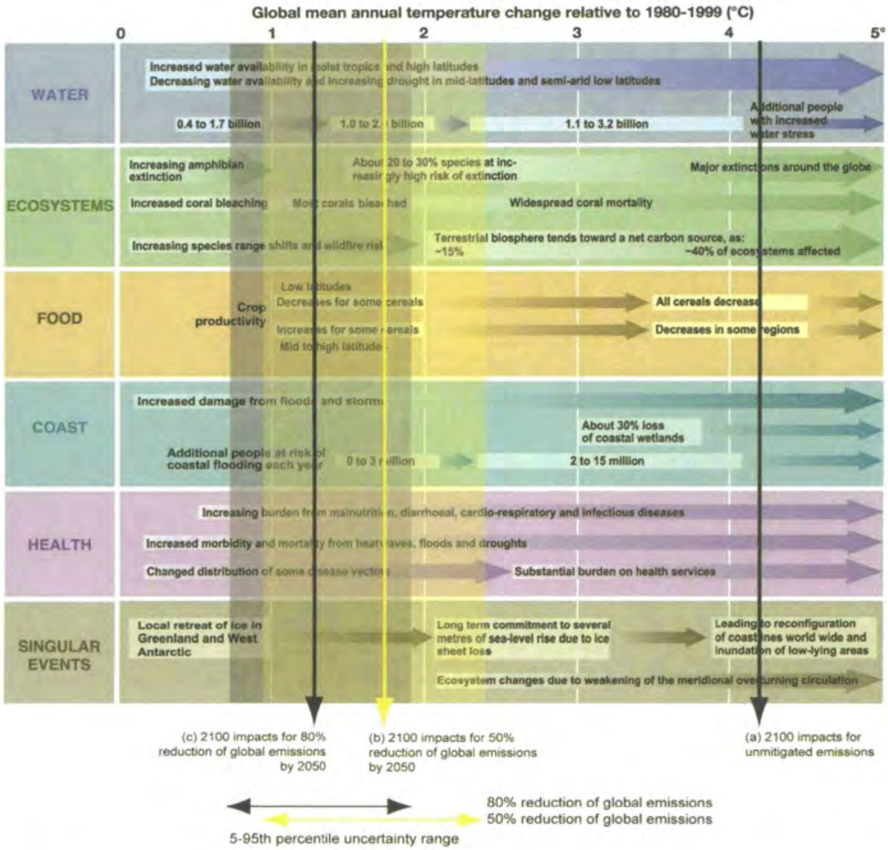

Figure 15: Selected global impacts from warming associated with various reductions in global greenhouse gas emissions. Vertical lines indicate likely impacts of the median warming expected to result from indicated emissions scenarios (% cuts are from 1990 levels). Source: Parry et al., 2008.[4]

[4] See References

Conclusions

Key statement 16: We will need a mix of adaptation and mitigation measures to meet the challenge of climate change; designing this mix is hampered by a lack of information on the costs and benefits of adaptation.

Even the most stringent mitigation efforts cannot avoid some impacts of climate change over the next few decades. Indeed, we are beginning to see these impacts now. This makes adaptation essential, particularly in addressing near-term impacts. However, unmitigated climate change would, in the long term, be likely to exceed our capacity to adapt.

It is essential, then, to develop a portfolio or mix of strategies that includes mitigation, adaptation, technological development (to enhance both adaptation and mitigation) and research (on climate science, impacts, adaptation and mitigation).

Analysis of the benefits of various mixes of strategy is severely restricted at present by lack of information on potential costs of impacts and of the costs of adaptation and mitigation measures, by lack of information on the damages avoided by adaptation and by lack of understanding of how these impacts will vary under different socio-economic development pathways. We need more observations to support the detection of climate change, and its impacts at the present day. It is important that these gaps in our knowledge are filled comprehensively and quickly.

Windcatcher, Yazd, Iran. Image courtesy of Fabien Dany - www.fabiendany.com.

Aloxe / Wikipedia

Appendix I: The IPCC SRES Scenarios

To explore future climate change, we need to consider how human societies may develop in the future, since this will affect the amount of greenhouse-gas emissions from industry, agriculture etc. The IPCC Fourth Assessment based its future climate projections on four principal storylines describing population and economic growth, and technological development: the SRES[5] A1, A2, B1 and B2 storylines:

- *The A1 storyline:* very rapid economic growth with increasing globalisation, an increase in general wealth and reduced differences in regional per capita income; rapid technological change; low population growth. Three variants within this family make different assumptions about sources of energy: fossil intensive (A1F), non-fossil fuels (A1T) or a balance across all sources (A1B).
- *The A2 storyline:* a regionally-diverse, market-led world, with less rapid population and economic growth than A1. Population growth is high.
- *The B1 storyline:* the same low population growth as A1, but development takes a much more environmentally sustainable pathway, with global-scale cooperation and regulation. Clean and efficient technologies are introduced.
- *The B2 storyline:* population increases at a lower rate than A2, development follows environmentally, economically and socially sustainable, locally-orientated, pathways.

Each storyline has a scenario of greenhouse-gas emissions associated with it, which in turn affects the projections of future anthropogenic climate change.

[5] See References

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Notes

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