

## Chapter 2



# Understanding the Causes and Implications of Climate Change

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### *Key Points*

- Carbon Dioxide (CO<sub>2</sub>)—emitted through electricity generation, transport, agriculture, and forestry—is responsible for four-fifths of the warming effect of current emissions of long-lived greenhouse gases and will persist in the atmosphere for many decades, with a significant fraction remaining for more than a millennium. CO<sub>2</sub> levels are already higher than any time in at least the past 850,000 years.
- While the effects of climate change cannot be predicted with certainty because future emissions trajectories are not known and our understanding of the climate system (particularly feedbacks) is limited, we are already seeing significant climatic impacts, including: increasing mean ocean temperature and sea level; increasing extremes of heat and drought; changes in ranges of species; melting of ice sheets, Arctic sea ice, and glaciers; and increasing severity of some extreme climatic events.

### *Causes of Climate Change*

The basic scientific framework of the climate change issue is well understood: greenhouse gases (GHG) emitted in the process of electricity

generation, transport, agriculture, and forestry are accumulating in the atmosphere, gradually altering the heat balance of the Earth and inevitably changing its climate. The greatest concern arises from long-lived gases (carbon dioxide, methane, halocarbons, and nitrous oxide) because they persist in the atmosphere for a period ranging from decades to longer than a millennium after release. Of these, carbon dioxide is the most important because it accounts for about four-fifths of the warming effect of current emissions of the long-lived GHGs. Atmospheric carbon dioxide levels are already one-third greater than in preindustrial times, and higher than at any time in at least the past 850,000 years. Other trace constituents emitted from human activity affect the climate in important ways, but are much less persistent. These include ozone (a key component of smog) and soot and other particles, the latter having both warming and cooling effects.

All this we know with certainty. It is also certain that over the past century, the Earth has warmed by about three-fourths of a degree Celsius ( $^{\circ}\text{C}$ ). It is very likely that the combined influence of all these gases and particles has caused most of the observed warming of the past half-century.

Carbon dioxide from the combustion of fossil fuels (coal, oil, and natural gas) for electricity generation, transport, and other purposes produces almost 60% of the warming effect of the current emissions of long-lived gases. Another 20% comes from carbon dioxide and other gases emitted during the cutting and burning of forests for the purposes of conversion of lands for timber production, agriculture, pastoral use, and related settlement. Climate change cannot be slowed significantly, and the climate cannot be stabilized, without large reductions in emissions from fossil fuels and strong measures to curb deforestation.

### *Consequences of Climate Change*

There are two general sources of uncertainty in projecting future climate change. First, estimates of future emissions of the greenhouse gases vary widely, although most projections envision emissions continuing to grow for at least the first half of this century. The second source of uncertainty arises from our limited understanding of the climate system, particularly the responses (called feedbacks) of the individual components of the

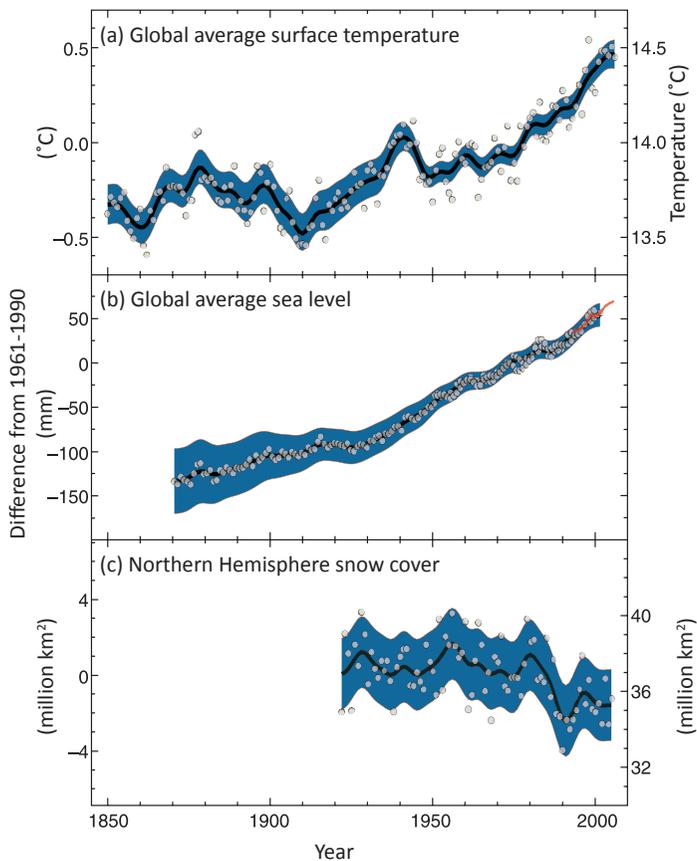


Fig. 2.1. Changes in temperature, sea level, and Northern Hemisphere snow cover. Observed changes in (a) global average surface temperature, (b) global average sea level from tide gauge and satellite data, and (c) Northern Hemisphere snow cover for March–April. All differences are relative to corresponding averages for the period 1961–1990. Smoothed curves represent decadal averaged values, while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c). (Source: *Climate Change 2007: Synthesis Report; Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Figure SPM.1, IPCC, Geneva, Switzerland)

Earth system—including clouds, ice sheets, and ocean circulation—to the initial greenhouse warming. The range of possibilities is enormous.

If prompt action is taken to stem emissions, it remains possible that a modest additional global warming of not much more than 1°C would occur. Even if limited to this level, such warming would be greater and faster than any global climate change during the history of civilization, and would doubtless cause disruption of ecosystems and risk of extinction of some species, as well as problems for many nations, especially developing countries in coastal or semi-arid regions. On the other hand, unconstrained emissions would lead to a warming that could reach as high as six degrees, which would present us with an unmitigated worldwide disaster.

Either of these scenarios, and any in between, would be expected to result in intensification of all of the current climate trends. Atmospheric warming has already resulted in a mean ocean temperature increase of nearly 0.8°C. Polar ice sheets in Greenland and Antarctica are shrinking at their peripheries. Summer Arctic sea ice is retreating, opening navigation routes around the North Pole. The 2007 Report of the Intergovernmental Panel on Climate Change (IPCC) estimates that a global warming of about 3–4°C by 2100 (in the middle of the projected range) would cause the Arctic to become largely free of summer ice, while more recent estimates suggest this outcome could occur before midcentury. The oceans are becoming more acidic as they absorb some of the carbon dioxide added to the atmosphere. The resulting effects are likely to translate into increased difficulty for shell-forming organisms, like coral, and substantial effects on marine ecosystems, food chains, and all those that depend on them, including humans.

With a somewhat lesser degree of certainty, we can say that extremes of heat and drought have increased. When precipitation does occur, there is a tendency for it to fall with greater intensity, increasing the potential for flooding. The IPCC indicates that a 3–4°C warming and associated drought probably would significantly reduce agricultural productivity in developing countries in the tropical and subtropical regions, where malnutrition and episodic starvation are already endemic. Of particular concern is the potential reduction of water available on the Asian subcontinent as Himalayan glaciers shrink, with the outcome that some of the major rivers, including the Ganga, may maintain significant flow only seasonally. Extreme heat waves of the sort that struck Western Europe in 2003—associated with the deaths of at least 35,000 people—would

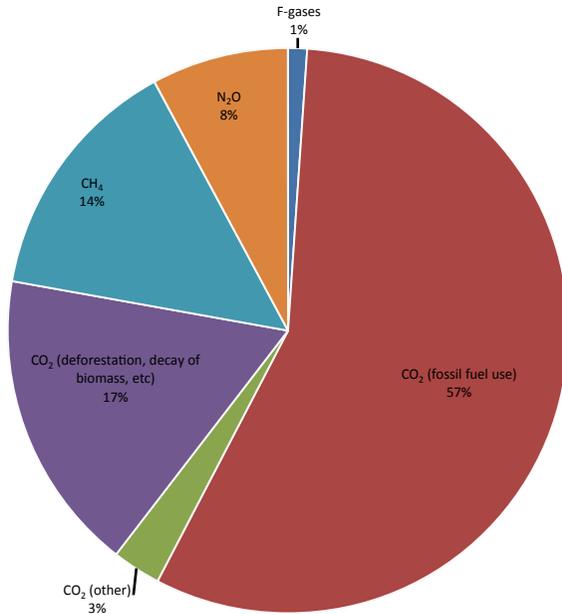


Fig. 2.2. Global anthropogenic GHG emissions (2004). (Source: *Climate Change 2007: Mitigation of Climate Change; Working Group III Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Figure TS.1b, Cambridge University Press)

become the norm rather than a rare occurrence, and even more extreme events are expected to occur. While human ability to adapt to such impacts may improve over time, it is likely that many other species will fail to adjust successfully. The IPCC estimates that 30% or more of all species will become at risk of eventual extinction at a persistent warming below 3–4°C.

Perhaps the broadest threat from a geographic perspective relates to the projected rise in sea level. IPCC’s projection, a rise of 18–59 cm over this century, accounts for two of the three major drivers of sea level rise: expansion of ocean water and melting of glaciers. However, it does not fully account for the potential contribution from ice sheets because, at the time, there was no satisfactory way to do so. But over the past two years, a variety of preliminary estimates of how large the contribution from

the ice sheets of Greenland and Antarctica may become have appeared in the literature, resulting in a possible total sea level rise of as much as 1–2 meters during this century, with a further multi-meter increase during the remainder of the millennium. Such a sea level rise would devastate wetlands; obliterate many low-lying, densely populated deltaic areas, including much of Bangladesh; and wreak havoc along coastlines in the developed world as well, where monumental amounts of permanent infrastructure would be at risk, forcing a costly (if gradual) retreat. A sea level rise of this sort appears to have occurred in the distant past when Earth warmed to similar levels, but at that time fixed human settlement had not yet evolved and retreat would have been far easier.

A close examination of the full range of potential impacts indicates that the most serious risks begin to increase markedly once warming exceeds 1–2°C above recent temperatures. Based on such findings, the EU has adopted a long-term objective of limiting warming to no more than 2°C above recent temperatures (corresponding to about 1.2°C above pre-industrial temperatures). This goal was endorsed by the major emitting countries, both developed and developing, meeting in July 2009 at an unusual joint conference held at the annual G-8 meeting.

The opportunity to avert such a warming shrinks markedly with every year of further delay in reducing emissions. Of particular concern is the rapid growth in emissions from large developing countries like China, India, and Brazil. Unless developed countries are able to reduce their emissions substantially over the coming decade as a first step, and unless developing countries are able to lower their emissions significantly below business as usual expectations during the following decade, there is little chance that such a warming would be averted.

### *Responses to Climate Change*

With these concerns in mind, we should quickly develop and implement policies and institutions (both internationally and domestically) to rapidly change our carbon emissions trajectory and provide the means to cope with the inevitability of some additional warming. These include:

1. Institutions and financing that would facilitate adaptation—already a key issue—even in developed countries.

2. Policies that would effectively impose a continuously increasing price on carbon. Such policies must include a stringent cap in the 2020 timeframe, along with subsequent reductions on emissions from all developed countries. The US, Canada, Australia, Japan, and many European countries have yet to act to reduce their emissions.
3. A collaborative decision on the part of countries with large emissions on the respective roles and responsibilities of developed and developing countries in achieving emissions limitations, along with adoption and implementation of a treaty that embodies these concepts in specific numerical obligations, accompanied by enforcement provisions and appropriate financing mechanisms. Rapid agreement on reduction of deforestation is an important supplement to limitations on fossil fuel emissions.
4. Funding and collaborative arrangements sufficient to provide incentives for research and development, and commercialization of emerging low-carbon technologies.

These objectives offer a stark challenge requiring immediate and focused attention by governments. An honest reading of the scientific evidence provides no excuse for hesitation. Prompt and effective action to reduce emissions is our only option.

#### FURTHER READING

Intergovernmental Panel on Climate Change, Fourth Assessment Report (2007), Full Report available at [http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4\\_syr.pdf](http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf), Summary for Policymakers available at [http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4\\_syr\\_spm.pdf](http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf).