A VERY SHORT INTRODUCTION

FULLY UPDATED NEW EDITION

3 EDITION

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Mark Maslin

CLIMATE CHANGE

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THIRD EDITION

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Preface to the third edition

Climate change is one of the few scientific theories that makes us examine the whole basis of modern society. It is a challenge that has politicians arguing, sets nations against each other, queries individual lifestyle choices, and ultimately asks questions about humanity's relationship with the rest of the planet. The latest Intergovernmental Panel on Climate Change (IPCC) report states that the evidence for climate change is unequivocal; with evidence over the last 100 years of a 0.8°Celsius (C) rise in global temperatures and a 22 centimetres (cm) rise in sea level. Depending on how much we control future greenhouse gas (GHG) emissions the global mean surface temperature could rise between 2.8°C and 5.4°C by the end of the 21st century. In addition global sea level could rise by between 52 cm and 98 cm and there will be significant changes in weather patterns with more extreme climate events. This is not the end of the world as envisaged by many environmentalists in the late 1980s and early 1990s, but it does mean a huge increase in misery for billions of people.

Reducing GHG emissions is a major challenge for our global society. This should not be underestimated because despite 30 years of climate change negotiations there has been no deviation in GHG emissions from the business-as-usual pathway. The failure of the international climate negotiation, most notably at Copenhagen in 2009, set back meaningful global cuts in GHG emissions by at least a decade. Anticipation and hope is building for future negotiations and there are some glimmers of hope. China, now the largest GHG polluter in the World, has started discussing instigating a national carbon-trading scheme. While the USA, which has emitted a third of all the carbon pollution in the atmosphere, has placed the responsibility for regulating carbon dioxide emissions under the Environment Protection Agency, which places it at arm's length to the political wrangling in Washington.

Despite this lack of political agreement there is a strong economic argument for taking action. It is estimated that tackling climate change now would cost between 2–3 per cent of world GDP as opposed to over 20 per cent if we put off action till the middle of the century. Even if the cost–benefits were not so great, the ethical case for paying now to prevent the deaths of tens of millions of people and avoiding a significant increase in human misery must be clear. An international political solution is an imperative, without a post-2015 agreement we are looking at huge increases in global carbon emissions and severe climate change. Any political agreement will have to include developing countries, while protecting their right to develop, as it is a moral imperative that people in the poorest countries should be able to obtain a similar level of health care, education, and life expectancy as those living in the West. Climate change policies and laws based around the international negotiations must also be implemented at both regional and national level to provide multi-levels of governance to ensure these cuts in emissions really do occur. Novel ways of redistributing wealth, globally and well as within nation-states, are needed to lift billions of people out of poverty without huge increases in consumption, resource depletion, and GHG emissions. Support and money is also needed to help developing countries adapt to the climate changes that will inevitably happen.

Climate change, therefore, challenges the very way we organize our society. Not only does it challenge the concept of the nation-state versus global responsibility, but the short-term vision of our political leaders. Climate change also needs to be seen within the context of the other great challenges of the 21st century: global poverty, population growth, environmental degradation, and global security. To meet these 21st century challenges we must change some of the basic rules of our society, to allow us to adopt a much more global and long-term approach, and in doing so, develop a win-win solution that benefits everyone.

Abbreviations

AABW	Antarctic Bottom Water
AO	Arctic Oscillation
AOGCM	Atmosphere–Ocean General Circulation Model
AOSIS	Alliance of Small Island States
BINGO	Business and Industry Non-Governmental Organization
CCS	carbon capture and storage
CDM	Clean Development Mechanism
CFCs	chlorofluorocarbons
COP	Conference of the Parties
ENGO	Environmental Non-Governmental Organization
ENSO	El Niño–Southern Oscillation
ETS	Emissions Trading Scheme
GCM	General circulation model
GCR	galactic cosmic ray
GHCN	Global Historical Climate Network
GHG	greenhouse gas
GtC	Gigatonnes of Carbon
IPCC	Intergovernmental Panel on Climate Change
JUSSCANNZ	Japan, USA, Switzerland, Canada, Australia, Norway, and New Zealand
MAT	marine air temperature
NADW	North Atlantic Deep Water
NAO	North Atlantic Oscillation
NGO	non-governmental organization
NRC	National Research Council (USA)
OECD	Organization for Economic Cooperation and Development
OPEC	Organization of Petroleum Exporting Countries
PETM	Palaeocene–Eocene Thermal Maximum
ppbv	parts per billion by volume
ppmv	parts per million by volume
SRES	Special Report on Emission Scenarios by the IPCC (2000)
SSS	sea-surface salinity
SST	sea-surface temperature
THC	thermohaline circulation
UNFCCC	United Nations Framework Convention on Climate Change
VBD	vector-borne disease

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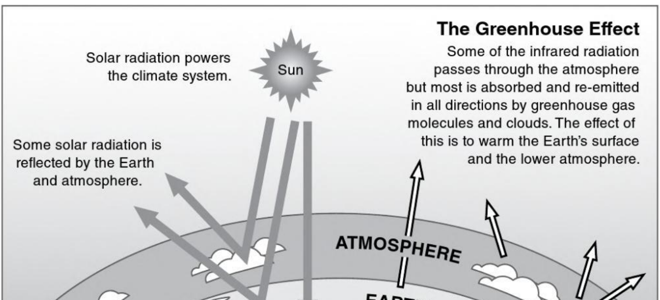
Chapter 1

What is climate change?

Future climate change is one of the defining challenges of the 21st century, along with poverty alleviation, environmental degradation, and global security. The problem is that 'climate change' is no longer just a scientific concern, but encompasses economics, sociology, geopolitics, national and local politics, law, and health just to name a few. This chapter will examine the role of greenhouse gases (GHGs) in moderating past global climate, why they have been rising since the industrial revolution, and why they are now considered dangerous pollutants. It will examine which countries have produced the most GHGs and how it is changing with rapid development. It will introduce the Intergovernmental Panel on Climate Change (IPCC) and how it regularly collates and assesses the most recent evidence for climate change.

The Earth's natural greenhouse

The temperature of the Earth is determined by the balance between energy from Sun and its loss back into space. Of Earth's incoming solar short-wave radiation (mainly ultraviolet (UV) radiation and visible 'light') nearly all of it passes through the atmosphere without interference (see Figure 1). The only exception is ozone that luckily for us absorbs energy in the high-energy UV band restricting how much reaches the surface of the Earth as it is very damaging to cells and DNA. About one-third of the solar energy is reflected straight back into space. The remaining energy is absorbed by both the land and ocean. This warms them up, and they then radiate this acquired warmth as long-wave infrared or 'heat' radiation. Atmospheric gases such as water vapour, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide are known as greenhouse gases (GHGs) as they can absorb some of this long-wave radiation, thus warming the atmosphere. This effect has been measured in the atmosphere and can be reproduced time and time again in the laboratory. We need this greenhouse effect because without it, the Earth would be at least 35°Celsius (C) colder, making the average temperature in the tropics about –10°C. Since the industrial revolution we have been burning fossil fuels (oil, coal, natural gas) deposited hundreds of millions years ago, releasing the carbon back into the atmosphere as CO_2 and CH_4, increasing the 'greenhouse effect' and elevating the temperature of the Earth. In effect we are burning fossilized sunlight.



1. The greenhouse effect

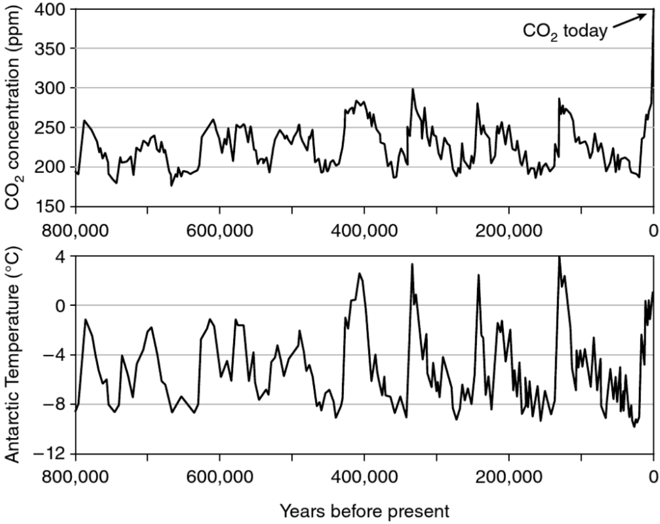
Past climate

Climate change in the geological past has been reconstructed using a number of key archives, including marine and lake sediments, ice cores, cave deposits, and tree rings. These various records reveal that over the last 50 million years the Earth's climate has been cooling down, moving from the so-called 'greenhouse world' of the Eocene, with warm and gentle conditions, through to the cooler and more dynamic 'ice house world' of today. It may seem odd that in geological terms our planet is extremely cold, while this whole book is concerned with our rapid warming of the planet. This is because the very fact that there are huge ice sheets on both Antarctica and Greenland, and nearly permanent sea ice in the Arctic Ocean, makes the global climate very sensitive to changes in GHGs.

The long-term global cooling of the Earth kicked off with glaciation of Antarctica about 35 million years ago and then the great Northern Hemisphere ice ages, which began 2.5 million years ago. Since the beginning of the great northern ice ages, the global climate has cycled from conditions that were similar or even slightly warmer than today, to full ice ages, which caused ice sheets over 3 kilometres (km) thick to form over much of North America and Europe. Between 2.5 and 1 million years ago, these glacial–interglacial cycles occurred every 41,000 years, and since 1 million years ago they have occurred every 100,000 years. These great ice-age cycles are driven primarily by changes in the Earth's orbit with respect to the Sun. In fact, the world has spent over 80 per cent of the last 2.5 million years in conditions colder than the present. Our present interglacial, the Holocene Period, started about 10,000 years ago, and is an example of the rare warm conditions that occur between each ice age. The Holocene began with the rapid and dramatic end of the last ice age: in less than 4,000 years global temperatures increased by 6°C, relative sea level rose by 120 metres (m), atmospheric CO_2 increased by one-third, and atmospheric CH_4 doubled. Still, this is much slower than changes we are seeing today. James Lovelock in his book *The Ages of Gaia* suggests that interglacials, like the Holocene, are the fevered state of our planet, which clearly over the last 2.5 million years prefers a colder average global temperature. Lovelock sees global warming as humanity just adding to the fever. These large scale past changes in global climate are discussed in more detail in my other book *Climate: A Very Short Introduction*.

Past variations in carbon dioxide

One of the ways in which we know that atmospheric CO_2 is important in controlling global climate is through this study of past climate. Evidence for these past variations in GHGs and temperature come from ice cores drilled in both Antarctica and Greenland. As snow falls, it is light and fluffy and contains a lot of air. When this snow is slowly compacted to form ice, some of this air is trapped. By extracting these air bubbles trapped in the ancient ice, scientists can measure the percentage of GHGs that were present in the past atmosphere. Scientists have drilled over two miles down into both the Greenland and Antarctic ice sheets, which has enabled them to reconstruct the amount of GHGs that have been generated in the atmosphere over the last half a million years. By examining the oxygen and hydrogen isotopes in the frozen water that make up the ice core, it is possible to estimate the air temperature above the ice sheet when the water first froze. The results are striking, as GHGs such as atmospheric CO_2 and CH_4 co-vary with temperatures over the last 800,000 years (see Figure 2). The cyclic changes in climate from glacial to interglacial periods can be seen both in temperatures and the GHG content of the atmosphere. This strongly supports the idea that GHGs in the atmosphere and global temperature are closely linked, that is, when CO_2 and CH_4 increase, the temperature is found to increase and vice versa.



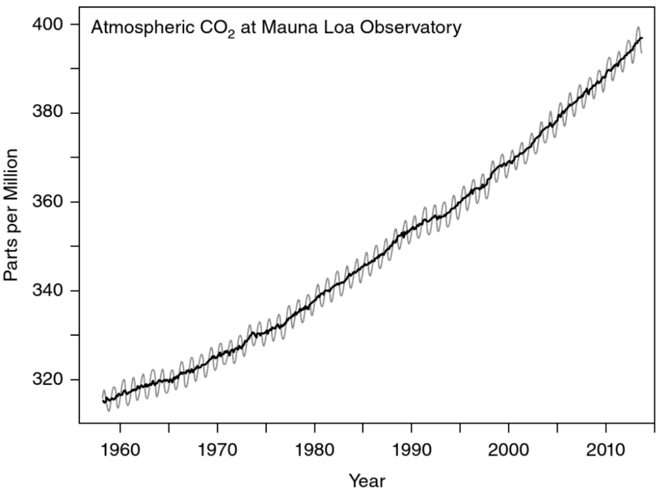
2. Greenhouse gases and temperature for the last eight glacial cycles recorded in ice cores

Early farmers

The very high-resolution ice-core evidence from Greenland and the continental margins of Antartica also show that GHGs in the atmosphere rose a small amount before the industrial revolution in the 1700s. Bill Ruddiman, Professor of Palaeoclimatology at the University of Virginia, suggested that early agriculturalists caused a reversal in natural declines of atmospheric CO_2 starting about 7,000 years ago and atmospheric CH_4 starting about 5,000 years ago. This idea has caused a huge amount of controversy, but like all good theories it has been tested again and again, and no one has yet been able to disprove it. So essentially it says that early human interactions with our environment increased atmospheric GHGs just enough that even prior to the industrial revolution there was enough influence to delay the onset of the next ice age, which would otherwise have started gently to occur anytime in the next 1,000 years.

The industrial revolution

There is clear evidence that levels of atmospheric CO_2 have been rising ever since the beginning of the industrial revolution. The first measurements of CO_2 concentrations in the atmosphere started in 1958 at an altitude of about 4,000 m, on the summit of Mauna Loa Mountain in Hawaii. The measurements were made here to be remote from local sources of pollution. The record clearly shows that atmospheric concentrations of CO_2 have increased every single year since 1958. The mean concentration of approximately 316 parts per million by volume (ppmv) in 1958 has risen to over 400 ppmv now (see Figure 3). The annual variations in the Mauna Loa observatory are mostly due to CO_2 uptake by growing plants. The uptake is highest in the Northern Hemisphere springtime; hence every spring there is a drop in atmospheric CO_2, which



3. Mauna Loa observatory atmospheric carbon dioxide measurements

unfortunately does nothing to change the overall trend towards ever higher values.

This CO_2 data from the Mauna Loa observatory can be combined with the detailed work on ice cores to produce a complete record of atmospheric CO_2 since the beginning of the industrial revolution. This shows that atmospheric CO_2 has increased from a pre-industrial concentration of about 280 ppmv to over 400 ppmv at present, representing an increase of over 40 per cent. To put this increase into context, ice-core evidence shows that over the last 800,000 years the natural change in atmospheric CO_2 has been between 180 and 300 ppmv. The variation between warm and cold periods is about 80 ppmv—less than the CO_2 pollution that we have put into the atmosphere over the last 100 years. It demonstrates that the level of pollution that we have already caused in one century is comparable to the natural variations which took thousands of years.

Who produces the pollution?

The United Nations Framework Convention on Climate Change (UNFCCC) was created to produce the first international agreement on reducing global GHG emissions. However, this task is not as simple as it first appears, as CO_2 emissions are not evenly produced by countries. According to the Intergovernmental Panel on Climate Change (see Box 1) the first major source of CO_2 is the burning of fossil fuels, since four-fifths of global CO_2 emissions comes from energy production, industrial processes, and transport. These are not evenly distributed around the world because of the unequal distribution of industry and wealth; North America, Europe, and Asia emit over 90 per cent of the global, industrially produced CO_2 (see Figure 4). Moreover, historically the developed nations have emitted much more than less developed countries.

The second major source, accounting for one-fifth of global CO_2 emissions, is as a result of land-use changes. These emissions