1 Global warming and climate change

A destroyed home in Union Beach, New Jersey, following Hurricane Sandy hitting the coast of New Jersey and New York in November 2012.

THE PHRASE 'global warming' has become familiar to many people as one of the most important issues of our day. Many opinions have been expressed concerning it, from the doom-laden to the dismissive. A more accurate but longer phrase to use is 'human induced climate change'. This book aims to state the current scientific position on global warming clearly, so that we can make informed decisions on the facts.

Is the climate changing?

In the year 2060 my grandchildren will be approaching 70 years old; what will their world be like? Indeed, what will it be like during the 70 years or so of their normal lifespan? Many new things have happened in the last 70 years that could not have been predicted in the 1940s. The pace of change is such that even more novelty can be expected in the next 70. It seems certain that the world will be even more crowded and more connected. A particularly important question is how the environment will be affected by the increasing scale of human activities. How much warmer will the world be? How is its climate likely to change?

Before addressing future climate changes, what can be said about climate changes in the past? In the more distant past there have been very large changes. The last million years has seen a succession of major ice ages interspersed with warmer periods. The last of these ice ages began to come to an end about 20 000 years ago and we are now in what is called an interglacial period. Chapter 4 will focus on these times far back in the past. But have there been significant changes in the very much shorter period of living memory – over the past few decades?

Variations in day-to-day weather are occurring all the time; they are very much part of our lives. The climate of a region is its average weather over a period that may be a few months, or from a season to a few years. Variations in climate are also very familiar to us. We describe summers as wet or dry, winters as mild, cold or stormy. In the British Isles, as in many parts of the world, no season is the same as the last or indeed the same as any previous season, nor will it be repeated in detail next time round. Most of these variations we take for granted; they add a lot of interest to our lives. Those we particularly notice are the extreme situations and the climate disasters (for instance, Figure 1.1 shows the significant climate events and disasters during the year 1998 – one of the warmest years on record). Most of the worst disasters in the world are, in fact, weather- or climate-related. Our news media are constantly bringing them to our notice as they occur in different parts of the world – tropical cyclones (called hurricanes or typhoons), windstorms, floods, tornadoes, also heatwaves and droughts whose effects occur more slowly, but which are possibly the most damaging disasters of all.

The last 40 years

Globally speaking, the last 40 years have been the warmest since accurate records began somewhat over 100 years ago (see Figure 4.1). The period has also been remarkable (just how remarkable will be considered later) for the frequency and intensity of extremes of weather and climate. Let me give a few examples, first from mid latitudes. In central Europe in the summer of 2003, there was an extremely unusual heatwave that led to the premature deaths of over 20 000 people (see Chapter 7). In central Russia in 2010 a persistent heatwave combined with extensive wildfires led to an estimated 55 000 premature deaths. Periods of unusually strong winds have also been experienced in western Europe. During the early hours of the

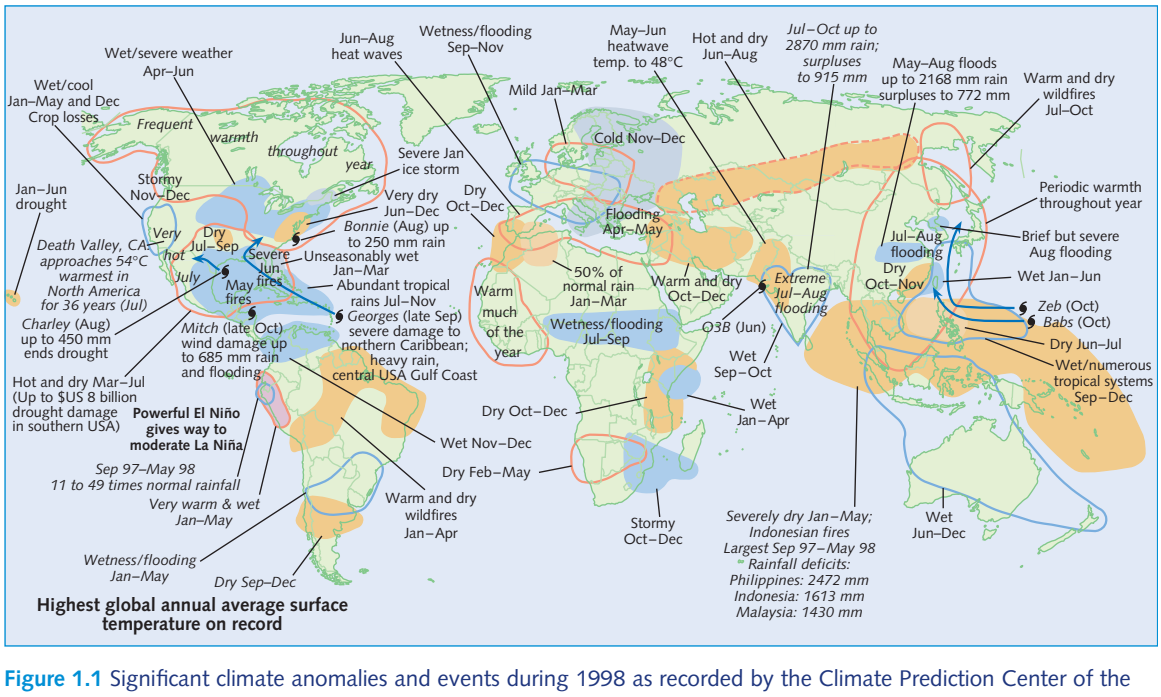
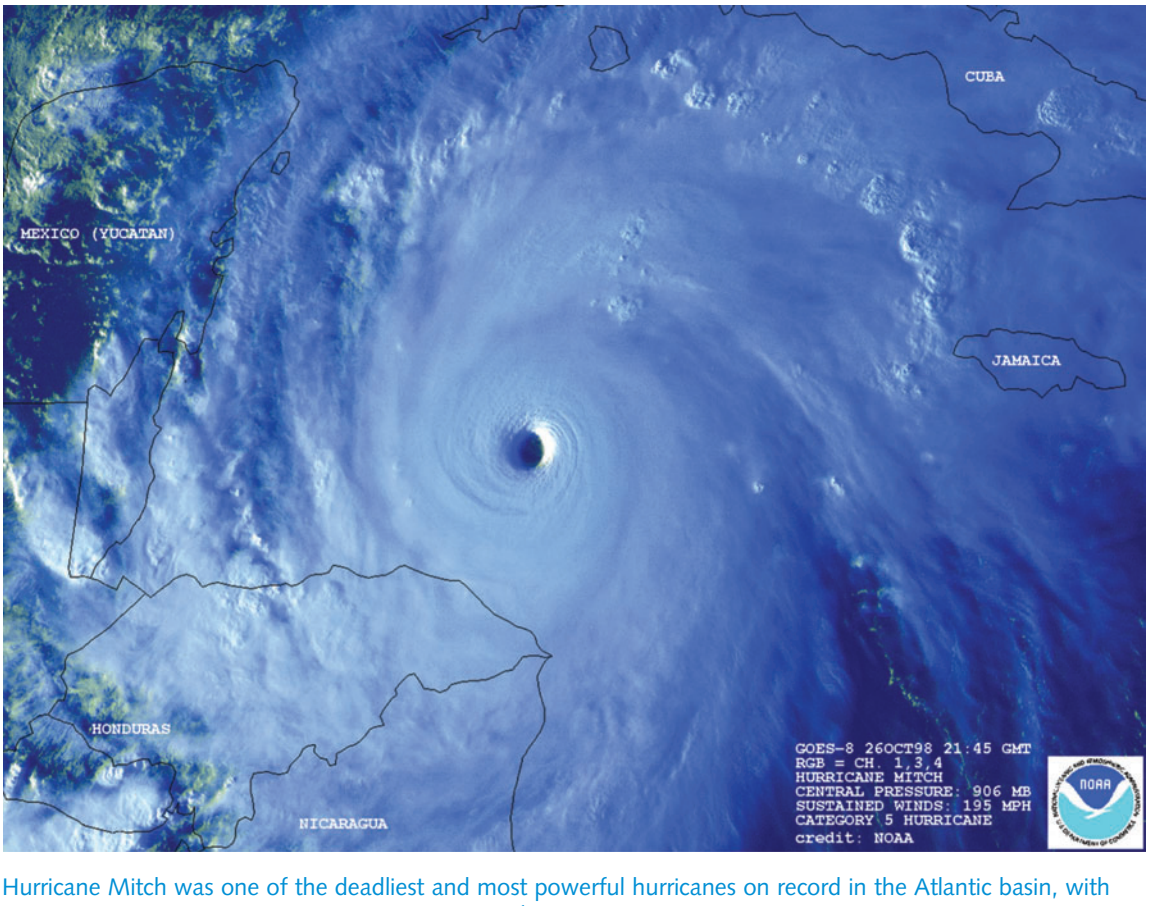


Figure 1.1 Significant climate anomalies and events during 1998 as recorded by the Climate Prediction Center of the National Oceanic and Atmospheric Administration (NOAA) of the United States.

morning of 16 October 1987, over 15 million trees were blown down in southeast England and the London area. The storm also hit northern France, Belgium and the Netherlands with ferocious intensity; it turned out to be the worst storm experienced in the area since 1703. In the USA in 2013, superstorm Sandy devastated parts of New Jersey and New York city causing around $US50 billion worth of damage.

But those storms were mild by comparison with the much more intense and damaging storms tropical regions have experienced during these years. About 80 hurricanes and typhoons – other names for tropical cyclones – occur around the tropical oceans each year, familiar enough to be given names: Hurricane Gilbert caused devastation on the island of Jamaica and the coast of Mexico in 1988, Typhoon Mireille hit Japan in 1991, Hurricane Andrew caused a great deal of damage in Florida and other regions of the southern United States in 1992, Hurricane Katrina caused record damages as it hit the Gulf Coast of the United States in 2005 and Typhoon Haiyan, probably the most intense ever to make landfall, caused enormous devastation in the Philippines in 2013 and left about 2 million homeless.

Low-lying areas such as Bangladesh are particularly vulnerable to the storm surges associated with tropical cyclones; the combined effect of intensely low atmospheric pressure, extremely strong winds and high tides causes a surge of water which can reach far inland. In one of the worst such disasters in the twentieth century over 250 000 people were drowned in



Hurricane Mitch was one of the deadliest and most powerful hurricanes on record in the Atlantic basin, with maximum sustained winds of 180 mph (290 km h^{-1}). The storm was the thirteenth tropical storm, ninth hurricane and third major hurricane of the 1998 Atlantic hurricane season.

Bangladesh in 1970. The people of that country experienced another storm of similar proportions in 1999 as did the neighbouring Indian state of Orissa also in 1999, and smaller surges are a regular occurrence in that region.

The increase in storm intensity during recent years has been tracked by the insurance industry, which has been hit hard by recent disasters. Until the mid 1980s, it was widely thought that windstorms or hurricanes with insured losses exceeding $US1 billion (thousand million) were only possible, if at all, in the United States. But the gales that hit western Europe in October 1987 heralded a series of windstorm disasters that make losses of $US10 billion seem commonplace. Hurricane Andrew, for instance, left in its wake insured losses estimated at nearly $US21 billion (1999 prices) with estimated total economic losses of nearly $US37 billion. Figure 1.2 shows the costs of weather-related disasters[1] over the past 30 years as calculated by

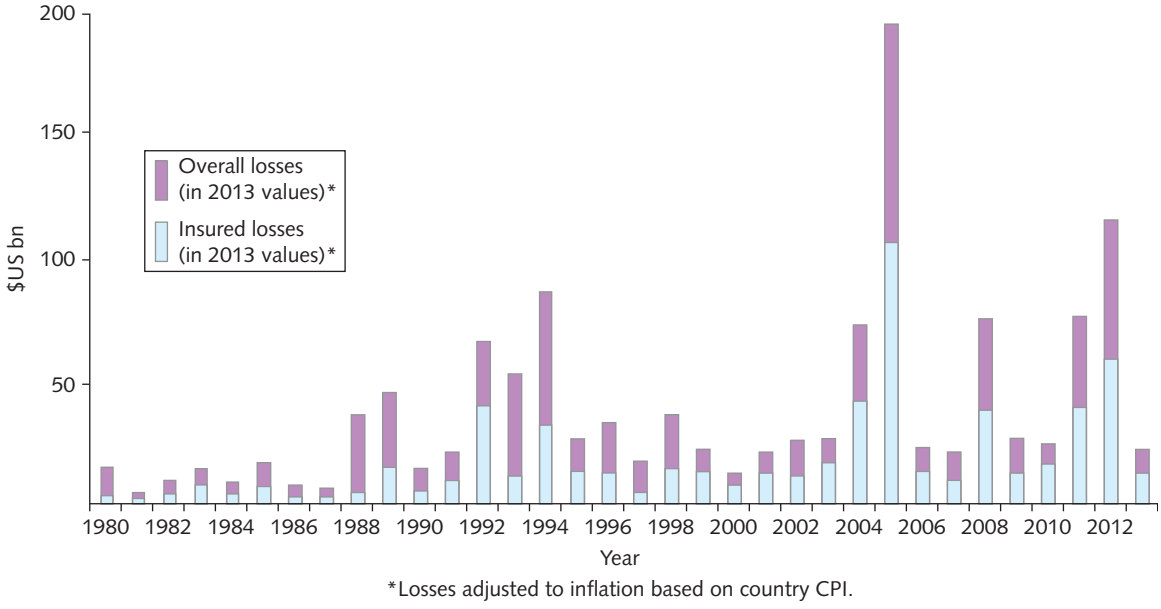


Figure 1.2 The total economic costs and the insured costs of catastrophic weather events for the period 1980 to 2013 as recorded by the Munich Re insurance company. The figures for 2005 – about $US200 billion for economic losses and over $US80 billion for insured losses – show the financial impact of Hurricane Katrina in the USA. Both economic and insured costs show a rapid upward trend in recent decades.

the insurance industry. It shows a very substantial increase in economic losses in real terms in such events between the 1980s and the present day. Some of this increase can be attributed to the growth in population in particularly vulnerable areas and to other social or economic factors; the world community has undoubtedly become more vulnerable to disasters. However, a significant part of it has also arisen from the increased storminess in the recent years compared with the 1980s.

Windstorms or hurricanes are by no means the only weather and climate extremes that cause disasters. Floods due to unusually intense or prolonged rainfall or droughts because of long periods of reduced rainfall (or its complete absence) can be even more devastating to human life and property. These events occur frequently in many parts of the world especially in the tropics and sub-tropics. There have been notable examples during the last two decades. Let me mention a few of the floods. In 1988, the highest flood levels ever recorded occurred in Bangladesh, and 80% of the entire country was affected; China experienced devastating floods affecting many millions of people in 1991, 1994–5 and 1998; in 1993, flood waters rose to levels higher than ever recorded in the region of the Mississippi and Missouri rivers in the United States, flooding an area equivalent in size to one of the Great Lakes; major floods in Venezuela in 1999 led to a large landslide and left 30 000 people dead; two widespread floods in Mozambique occurred within a year in 2000–1 leaving over half a million homeless; and in

Flooded McDonald's, Festus, Missouri in 1993. The spot where this photo was taken is nearly 1.5 miles (2.5 km) and 30 feet (9 m) above the river.

The Great Flood of 1993 occurred in the American Midwest, along the Mississippi and Missouri rivers from April to October 1993. The flood was among the most costly and devastating to ever occur in the United States, with $US15 billion in damages, and a flooded area of around 30 000 square miles (80 000 km^2). The images on this page and page 8 from Landsat-5 Thematic Mapper show the Mississippi near St Louis before and during the flood.

2010 Pakistan experienced the worst floods in its history, when exceptional monsoon rains left one-fifth of Pakistan's total land area under water, affecting 20 million people. Droughts during these years have been particularly intense and prolonged in areas of Africa, both north and south. It is in Africa especially that they bear on the most vulnerable in the world, who have little resilience to major disasters. Figure 1.3 shows that in the 1980s droughts accounted for more deaths in Africa than all other disasters added together and illustrates the scale of the problem.

We have seen significant warming and an increase in storminess and climate extremes over the past few decades. But do we know how exceptional are such events in the context of much longer periods and do we have the evidence that this is linked with the development of human activities and industry over the last 200 years? What is important is that careful comparisons are made between observations of the climate and its changes and what scientific knowledge leads us to expect. It was during the 1980s that the possibility that human activities might be seriously affecting the climate began to be widely realised. It was then also that the scientific tools became available for climate scientists to be able to study in depth what this might mean. Later chapters will look in detail at the science of global warming and at the changes in climate that have already occurred and those that can be expected in the future. First, however, I present a brief outline of our current scientific understanding.

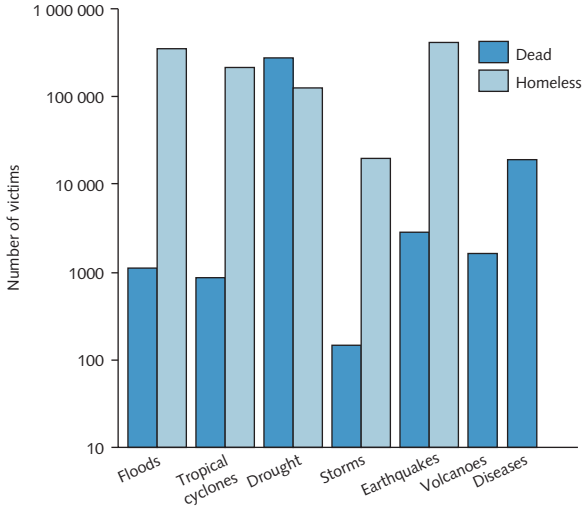


Figure 1.3 Recorded disasters in Africa, 1980–9, estimated by the Organization for African Unity. Note the logarithmic scale.

What is global warming?

We know for sure that because of human activities, especially the burning of fossil fuels, coal, oil and gas, together with widespread deforestation, the gas carbon dioxide has been emitted into the atmosphere in increasing amounts over the past 200 years and more substantially over the past 50 years. Every year these emissions currently add to the carbon already present in the atmosphere at least a further 8000 million tonnes, much of which will remain there for a period of 100 years or more. Because carbon dioxide is a good absorber of heat radiation coming from the Earth's surface, increased carbon dioxide acts like a blanket over the surface, keeping it warmer than it would otherwise be – see Figure 4.1, Chapter 4 and Chapter 2 for further explanation. With the increased temperature the amount of water vapour in the atmosphere also increases, providing more blanketing and causing it to be even warmer. The gas methane is also increasing because of different human activities, for instance mining and agriculture, and adding to the problem.

Being kept warmer may sound appealing to those of us who live in cool climates. However, an increase in global temperature will lead to global climate change. If the change were small and occurred slowly enough we would almost certainly be able to adapt to it. However, with rapid expansion taking place in the world's industry the change is unlikely to be either small or slow. The estimate presented in later chapters is that, in the absence of more substantial efforts to curb the rise in the emissions of carbon dioxide, the global average temperature will rise by a third of a degree Celsius or more every ten years – or three or more degrees in a century.

This may not sound very much, especially when it is compared with normal temperature variations from day to night or between one day and the next. But when we talk of global warming, it is not the temperature at one place but the temperature averaged over the whole globe that will rise. It does not mean that there will be uniform or even similar warming everywhere; there will continue to be large variations in temperature over different areas of the Earth's surface that will continuously vary from day to day and from year to year.

The predicted rate of change of 3°C a century is probably faster than the global average temperature has changed at any time over the past 10 000 years. And as there is a difference in

global average temperature of only about five or six degrees between the coldest part of an ice age and the warm periods in between ice ages (see Figure 4.9), we can see that a few degrees in this global average can represent a big change in climate. It is to this change and especially to the very rapid rate of change that many ecosystems and human communities (especially those in developing countries) will find it difficult to adapt.

Scientists are confident about the fact of global warming and climate change due to human activities. Although there are still uncertainties concerning the detail regarding the pattern of change in different parts of the world, it is clear that the most noticeable adverse impacts will concern sea level rise (water expands as it becomes warmer), more heatwaves and because of increased energy in the atmospheric circulation, more intense rainfall and more extreme events such as we have already mentioned. As described in later chapters, intensive research is needed to improve confidence in the detail of scientific predictions being pursued.

Adaptation and mitigation

An integrated view of anthropogenic climate change (climate change resulting from human activities) is presented in Figure 1.4 where a complete cycle of cause and effect is shown. Begin in the box at the bottom where economic activity, both large and small scale, whether in developed or developing countries, results in emissions of greenhouse gases (of which carbon dioxide is the most important) and aerosols. Moving in a clockwise direction around the diagram, these emissions lead to changes in atmospheric concentrations of important constituents that alter the energy input and output of the climate system and hence cause changes in the climate. These climate changes impact both humans and natural ecosystems altering patterns of resource availability and affecting human livelihood and health. These impacts in their turn affect human development in all its aspects. Anticlockwise arrows illustrate possible development pathways and global emission constraints that would reduce the risk of future impacts that society may wish to avoid.

Figure 1.4 also shows how both causes and effects can be changed through *adaptation* and *mitigation*. In general adaptation is aimed at reducing the effects and mitigation is aimed at reducing the causes of climate change, in particular the emissions of the gases that give rise to it. Both adaptation actions and mitigation actions are urgently required in response to human-induced climate change.

International cooperation in climate science

A particularly important day for climate science was 4 October 1957 when The Soviet Union launched the first Sputnik that circled in space around the Earth with 15 orbits per day. Most of the Earth's surface was seen by Sputnik twice per day, demonstrating the possibility of observations from space of the atmosphere and the oceans with a coverage in space and time