Advances in Asian Human-Environmental Research

Keshav Lall Maharjan
Niraj Prakash Joshi

Climate Change, Agriculture and Rural Livelihoods in Developing Countries

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Advances in Asian Human-Environmental Research

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Preface

Climate change has now become an indisputable fact. It will affect the economies of developed as well as developing countries. However, owing to the high dependency of developing countries, more specifically the Least Developed Countries (LDCs), on naturally sensitive sectors such as agriculture and forestry, these developing countries are already exposed to a higher risk from any unusual changes in climate phenomena compared to the developed countries. Thus, any adverse impact on these sectors will have a significant bearing on the livelihoods of the majority in such countries. Moreover, their geographical disadvantages as well as the lack of economic strength to cope with and adapt to such adverse changes put them into a highly vulnerable position. Therefore, this book is prepared as course material for the Global Environment Leaders Education Program for Designing a Low-Carbon Society (GELs Program), Graduate School for International Development and Cooperation (IDEC), Hiroshima University, in order to provide basic information on climate change and its relation to agriculture and rural livelihoods as well as information on international climate change regimes related to agriculture.

In considering the above-mentioned facts, this book discusses the impact of climate change in developing countries, taking the case of Nepal as an example. In doing so, in Chap. 1 the book starts with a basic understanding of climate change and the relation of agriculture to climate. Chapter 2 deals with the emission of greenhouse gases from various sectors of economic activities in different countries. The effect of several aspects of climate change on plant and animal physiology is discussed in Chap. 3. Agriculture is an important sector in developing countries, and the inclusion of this sector in international climate change negotiations will have an impact on the economy of these countries. Hence, Chap. 4 describes agriculture in international climate change negotiations. Similarly, Chap. 5 discusses cost and opportunities resulting from mitigation and adaptation in agriculture through international climate change negotiations. Chapter 6 highlights some important methodologies to assess the impact of climate change in agriculture. With this basic understanding of climate change, agriculture, international climate change regimes, and methodologies to assess impact of climate change in agriculture, Chap. 7 discusses the effect of climate change in regional agriculture production, food prices, and food insecurity.

The case of Nepal is highlighted to discuss the above issues, i.e., climate change and its relation to agriculture and rural livelihoods in a local context, to enhance the understanding of the location specificity of climate change and its impact on agriculture and rural livelihoods through adaptation, mitigation, and resilience leading toward a low-carbon society. Thus, Chap. 8 and the following chapters analyze the particular case of Nepal. Chapter 8 provides an overview of several aspects of climate change in Nepal such as the emission scenario, the climate change scenario, and impacts of climate change in five different sectors as well as poverty and opportunities for revenue generation from international climate change negotiations. Similarly, Chap. 9 focuses on the effect of climate trends on yields of basic food crops in Nepal. Chapter 10, the final chapter of the book, discusses the perception and realities of climate change in rural Nepal based on preliminary data generated through household surveys.

We think that this book, in addition to being a course material for graduate students, will fulfill the needs of the people seeking to understand the issues of climate change and its relation to agriculture and rural livelihoods in general and those of developing countries in particular, international climate change regimes related to agriculture and their impact on the economy of developing countries, including the opportunities resulting from mitigation and adaptation activities. It will also help the people to know the methodologies to asses the impact of climate change in agriculture, especially the impact on the issues of production, food prices and food insecurity. The empirical discussions on Nepal to grasp the issue in a local context, an addition to the dearth of such works, will be useful, even to the professionals, to enhance the understanding of the issue and its location specificity in the developing countries. We will value these and other readers and appreciate any comments and advices to improve the contents of the book.

We would like to acknowledge Luni Piya (Ph.D.) for her contributions to Chaps. 8–10. We would also like to thank Ph.D. students (IDEC, Hiroshima University) Suman Lal Shrestha and Mrinila Singh for their contributions to Chaps. 4 and 5, respectively. Last but not least, we are grateful to the Hiroshima International Center for Environmental Cooperation (HICEC), Graduate School for International Development and Cooperation, Hiroshima University, for providing the opportunity for this manuscript to be prepared for publication as course material for GELs students.

Hiroshima, Japan

Keshav Lall Maharjan
Niraj Prakash Joshi

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Chapter 1
Background Information on Climate Change and Agriculture

Abstract This chapter intends to provide background information on climate change. It is done by providing a definition of climate change supplemented by some of the evidence suggested by the definition. We described the factors responsible for climate change, i.e., Greenhouse Gases (GHGs), their characteristics and sources, and changes in their concentration over time. In addition, brief description about how these GHGs warm earth surface through Greenhouse Gas effects is also provided. At the end of this chapter, relation of agriculture to climate is presented in the simplest terms.

Keywords Anthropogenic • Climate • Greenhouse Gases • Temperature

1.1 Climate Change

The climate system is a complex, interactive system consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water and living creatures. Basically, the atmospheric component of the climate system characterizes climate. Climate, often defined as average weather, is described in terms of the mean and variability of temperature, precipitation, and wind over a period of time, more specifically the classical period of 30 years (Le Treut et al. 2007).

United Nations Framework Convention on Climate Change (UNFCCC) (UN 1992, p. 3) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability over comparable time periods." This definition is the narrow definition giving consideration only to the human activities. It is not only the human activities that alter the composition of the global atmosphere but it is also a natural variability itself. Therefore, the definition given by the Intergovernmental Panel on Climate Change (IPCC) in 2007 is accepted as the broader definition of climate change. IPCC (2007a, p. 30) defines climate change as

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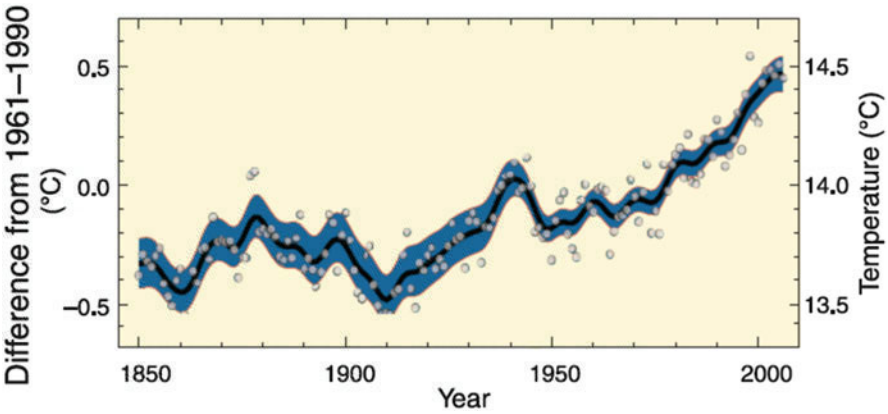

Fig. 1.1 Observed changes in global average surface temperature (IPCC 2007a). *Note*: Differences are relative to corresponding averages for the period 1961–1990. *Smoothed curves* represent decadal averaged values while *circles* show yearly values. The *shaded areas* are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties and from the time series

"a change in the state of the climate that can be identified by changes in the mean and/or variability of its properties that persists for an extended period, typically decades or longer." Thus, Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity.

Evidences suggest a clear indication of climate change in the earth. Warming of the earth is unequivocal. Over the last few decades global average surface temperatures have been rising (Figs. 1.1 and 1.2). The global temperature reached its peak in 1998. Moreover, 11 of the last 12 years (between 1995 and 2006) are among the warmest years in the instrumental record of global surface temperature since 1850. Such increase in temperature has caused changes in weather patterns, widespread melting of snow and ice, and rising of global average sea level (IPCC 2007a).

There is a rise in the 100-year linear trend even between 1901–2000 and 1906–2005. The coefficient rose from 0.6 to 0.74 between these periods. Moreover, the linear warming trend over the later 50 years from 1956 to 2005 is nearly twice than that for the 100 years from 1906 to 2005. All these suggest that there is a higher rate of temperature rise in the recent years. This rise, however, is not likely to be uniform across the earth. The temperature increase will be greater in the higher latitudes and also at the night than during the day. This means there will be a decrease in the range of temperatures both through the day and across latitudes. Similarly, it is expected to warm at a larger rate during winter compared to the summer season.

In consistence with the temperature rise, there is an increase in sea level and decrease in snow and ice extent as well. The global average sea level rose at an average rate of 1.8 mm per year over the period 1961–2003. The rise is more intense if we consider the period between 1993 and 2003. Between these periods, sea level

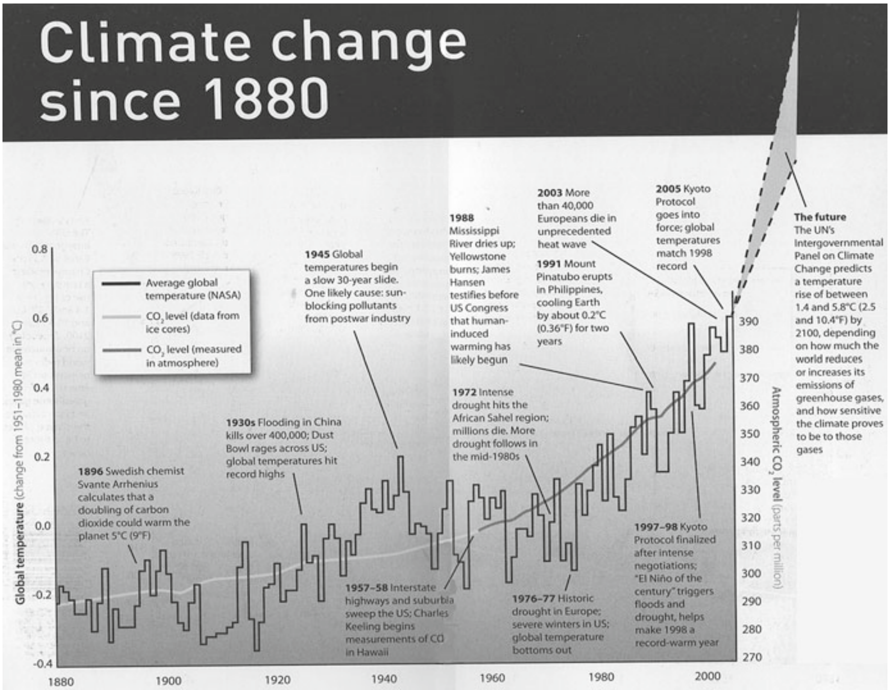

Fig. 1.2 Chronicles of climate change related indicators and responses at global scale (Henson 2006)

increased at the rate of 3.1 mm per year. Thermal expansion, decreases in glacier and ice caps, and losses from the polar ice sheets have contributed 57 %, 28 % and 15 %, respectively to the sea level rise since 1993 (IPCC 2007a).

There is annual shrinkage of the Arctic sea ice by 2.7 % per decade on average since 1978. The rate of decrease is larger in summer with an average loss of 7.4 % per decade. Similarly, mountain glaciers and snow covers also declined in both the hemispheres. In the Northern Hemisphere, seasonally frozen ground has decreased by about 7 % with decreased in spring of up to 15 % since 1900 (IPCC 2007a).

Besides, numerous long-term changes in weather patterns have also been observed. Over the period from 1900 to 2005, significant changes in precipitation trend are observed in many large regions. For instance, precipitation increased significantly in eastern parts of North and South America, northern Europe and northern and central Asia, whereas precipitation declined in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Moreover, it is more likely that the frequency of heavy precipitation events has increased over most areas causing water borne natural disaster in some areas and increased drought in the other. Similarly, there is an observational evidence of an increase in intense tropical cyclone activity together with a predicted increase in intense tropical cyclone activity.

1.2 Sources of Climate Change

Natural variability and human activities are the causes of climate change. The contribution of human activities to climate change, however, is increasing. The probability that human activities are the main cause for the increase in temperature since the mid-twentieth century has risen from 66 % in 2001 to more than 90 % in 2007 (IPCC 2001, 2007a). The increase in atmospheric concentration of GHGs is the major factor contributing to climate change caused by the human activities. Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), F-gases such as chlorofluorocarbons (CFC_{11}), hydro fluorocarbons (HFC_{23}) and carbon tetra fluoride (CF_4), and water vapors are the most prominent GHGs.

The concentration of CO_2 has risen significantly from 280 parts per million (ppm) before the pre-industrial era to 379 ppm in 2005 (Table 1.1). This is mainly contributed by increased use of fossil fuel (Fig. 1.3) in transportation, building,

Table 1.1 Concentration of Greenhouse Gases from pre-industrial to current time (IPCC 2007b; Blasing 2010)

GHGs	Before 1750	1998	2005	2010	Atmospheric lifetime (years)
Carbon dioxide (CO_2)	280 ± 20 ppm	365 ppm	379 ppm	386 ppm	50–200
Methane (CH_4)	~700 ppb	1,745 ppb	1,774 ppb	1,866 ppb	12
Nitrous oxide (N_2O)	~ 270 ppb	314 ppb	319 ppb	323 ppb	114

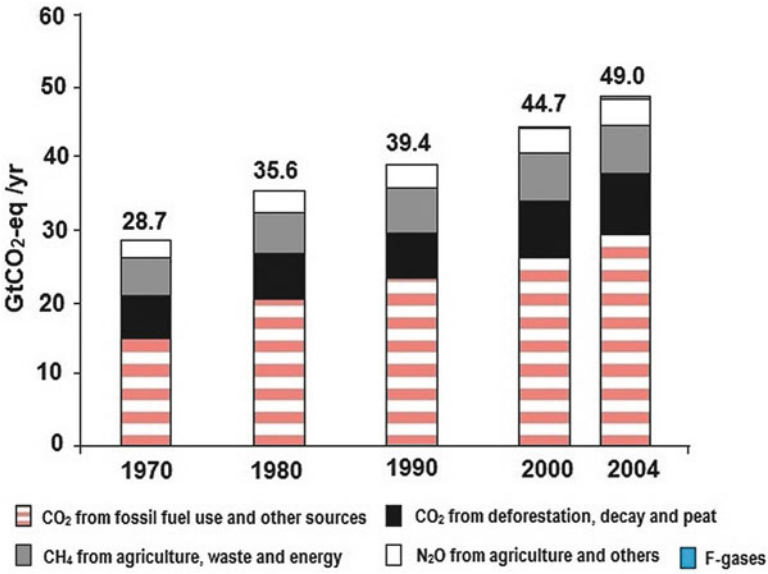

Fig. 1.3 Type of Greenhouse Gases from various sources (IPCC 2007a)

heating and cooling, and the manufacture of cement and other goods. Plants and ocean soak up a huge amount of CO_2, which check the level of CO_2 from increasing rapidly. However, deforestation has resulted in an imbalance of such natural process of the CO_2 sink (Fig. 1.3). Besides decay of plant matter and respiration process of both human and animal also releases CO_2 as part of natural processes.

Concentrations of CH_4 and N_2O have also risen significantly (Table 1.1). It has risen from 770 parts per billion (ppb) to 1,745 ppb and 270 ppb to 314 ppb for CH_4 and N_2O, respectively. CH_4 emission is the outcome of human activities related to agriculture, natural gas distribution and landfills. Emissions from paddy field, ruminant livestock, as well as improper management of animal excreta are the major agricultural activities contributing to increasing concentration of CH_4. A natural process that occurs in wetlands is also contributing to increased concentration of $CH_{4.}$ CH_4 is perceived as a powerhouse GHG as it absorbs 21 times more infrared energy within its atmospheric lifetime of 12 years compared to what CO_2 does over roughly a century.

Use of external input such as fertilizer and fossil fuel burning contributes to increased concentration of N_2O in the atmosphere. Natural processes in soils and the ocean also release N_2O. The total CO_2-eq of these prominent GHGs is estimated to be around 455 ppm CO_2-eq in 2005. Unless the concentration is stabilized below 550 CO_2-eq, a harmful irreversible consequence of climate change through a temperature rise of more than 2 °C is inevitable (IPCC 2007a).

1.3 Greenhouse Gas Effects

The idea of greenhouse effects emerged from the evidence that although the sun's light and heat easily pass through glass and other transparent materials, heat from other non-transparent sources does not. Thus, solar radiation is the main component that powers the climate system. There are three fundamental ways that change the radiation balance of the earth (Fig. 1.4), which are as follows:

1. By changing the incoming solar radiation
2. By changing the fraction of solar radiation that is reflected, which is called "albedo" and is caused by the changes in cloud cover, atmospheric particles or vegetation, and
3. By altering the long-wave radiation from the earth back towards space, which is mainly caused by changes in Greenhouse Gas concentration

The long term balance between the amounts of incoming solar radiation absorbed by the earth and the atmosphere is maintained by the earth and the atmosphere by releasing the same amount of outgoing long-wave radiation. The surface absorbed around 47 % of the incoming solar radiation (Trenberth et al. 2009). This energy is transferred to the atmosphere by warming the air in contact with the surface, by evapo-transpiration and by long-wave radiation that is absorbed by clouds and Greenhouse Gases. The atmosphere in turn radiates long-wave energy back to earth as well as out to space.

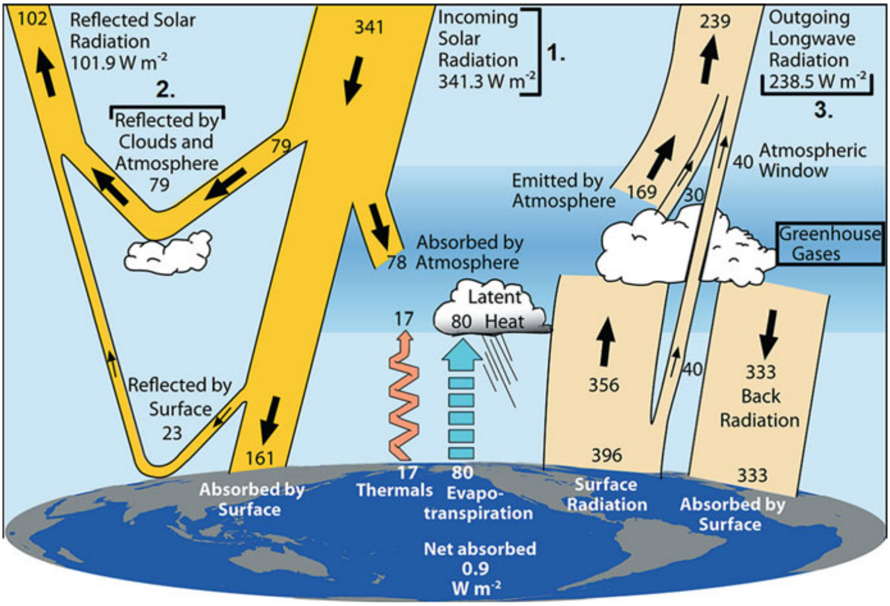

Fig. 1.4 Estimate of the earth's annual and global mean energy balance (Trenberth et al. 2009)

Box 1.1 Greenhouse Gas Effect

The Sun powers Earth's climate, radiating energy at very short wavelengths, predominately in the visible or near-visible (e.g., ultraviolet) part of the spectrum. Roughly one-third of the solar energy that reaches the top of Earth's atmosphere is reflected directly back to space. The remaining two-third is absorbed by the surface and, to a lesser extent, by the atmosphere. To balance the absorbed incoming energy, the Earth must, on average, radiate the same amount of energy back to space. Because the Earth is much colder than the Sun, it radiates at much longer wavelengths, primarily in the infrared part of the spectrum (see Fig. 1.4). Much of this thermal radiation emitted by the land and ocean is absorbed by the atmosphere, including clouds, and reradiated back to Earth. This is called the greenhouse effect. The glass walls in a greenhouse reduce airflow and increase the temperature of the air inside. Analogously, but through a different physical process, the Earth's greenhouse effect warms the surface of the planet. Without the natural greenhouse effect, the average temperature at Earth's surface would be below the freezing point of water. Thus, Earth's natural greenhouse effect makes life possible in the Earth. However, human activities, primarily the burning of fossil fuels and clearing of forests, have greatly intensified the natural greenhouse effect, causing global warming.

Source: Le Treut et al. (2007).

The ability to generate an artificial warming of the Earth's surface was demonstrated in a simple greenhouse experiment to provide analogy of the greenhouse effect. It recognized that the air itself could also trap thermal radiation. Joseph Fourier in 1824, argued that "the temperature [of the earth] can be augmented by the interposition of the atmosphere, because heat in the state of light finds less resistance in penetrating the air, than in repassing into the air when converted into non-luminous heat." Later, John Tyndall (1861) identified that the thermal radiation is absorbed by complex molecules (cited from IPCC 2007b). He noted that changes in the amount of any of the radiatively active constituents of the atmosphere such as H_2O or CO_2 could have produced "all the mutations of climate which the researches of geologists reveal." In the 1970s some other radiatively active gases (Greenhouse Gases) such as CH_4, N_2O and CFCs were widely recognized as the important anthropogenic Greenhouse Gases. The increased concentration of these gases has resulted in an increase in proportion of long-wave radiation bounced back to the earth's surface from the atmosphere. The proportion has increased from 83 % on average of 5 years during the mid-1980s to 84 % on average during 2000 to 2004 (Kiehl and Trenberth 1997; Trenberth et al. 2009). In a nutshell, other remaining the same, the more Greenhouse Gases there is the less radiation can escape from the earth to the space, and the warmer we get.

1.4 GHGs and Global Warming

As we discussed in the earlier section, GHGs like CO_2, CH_2, and N_2O etc. has a greenhouse effect on the earth. This means that the higher concentration of GHGs in the atmosphere will result in the warming of the earth. However, there is also a chance that the heating and cooling itself could cause changes in GHGs concentration in the atmosphere. For instance, when global temperatures become warmer CO_2 is released from the oceans. Thus, increasing CO_2 concentration may amplify the warming by enhancing the greenhouse effect. Inversely, with cooling of the earth CO_2 enters the ocean and contributes to additional cooling through reduced CO_2 concentration. Figure 1.5 shows the long term (650,000 years) changes in CO_2 level and temperature. During this period there have been seven major climate shift; approximately one about every 100,000 years. Both warming and cooling phases have taken place even in the absence of human activities. But it is evident that throughout the period of more than 650,000 years there is a strong correlation between temperatures and CO_2. Though this correlation does not imply causation, a high degree of correlation provides safe logic to assume that one variable likely affects the other, directly or indirectly. Over these long natural cycles, CO_2 increases have lagged temperature increases at the beginning of a cycle, but then the increasing CO_2 content in the atmosphere caused further temperature increase.

The further increase in temperature due to the increasing CO_2 content can be established by the more recent relation of CO_2 concentration and global temperature (Fig. 1.6). This is further indicated by both the basic physics of the greenhouse

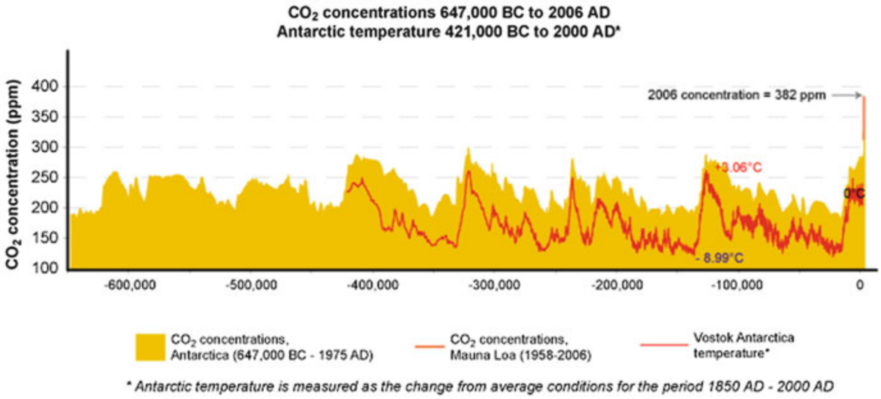

Fig. 1.5 Fluctuations in temperature (*solid line*) and the atmospheric concentration of CO_2 (*shaded area*) over the past 649,000 years (EPA 2010). *Note*: The *vertical bar* at the end is the increase in atmospheric CO_2 levels over the past two centuries and before 2007

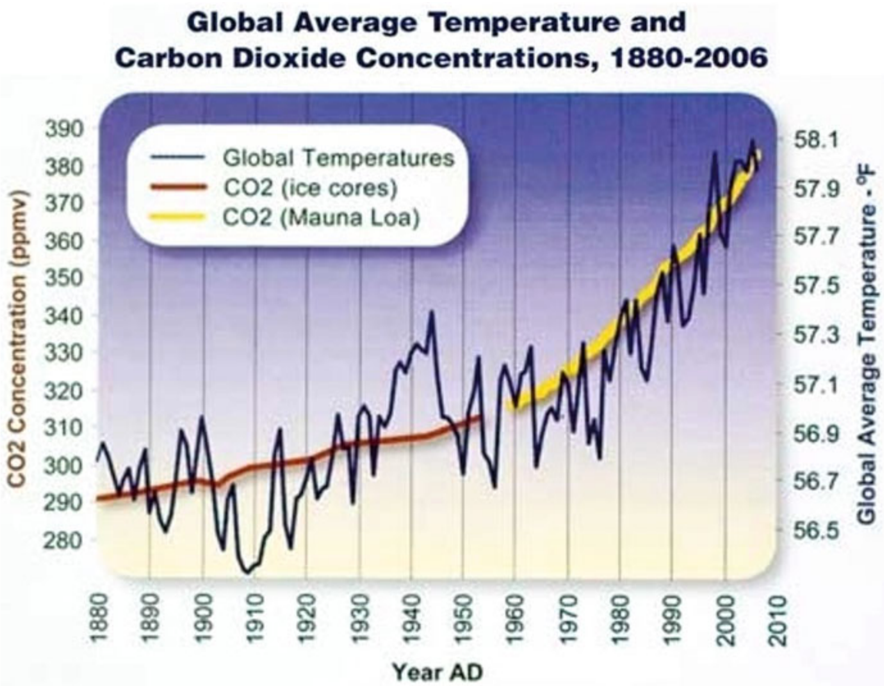

Fig. 1.6 Global average temperature and carbon dioxide concentrations, 1880–2006 (Cherry and Braasch 2008)