

B The greenhouse effect and CO₂

The Sun's energy reaching the ground warms the Earth, and transforms into **infrared radiation**. Just like the panes of a greenhouse – hence the name given to this mechanism – some of the gases present in the atmosphere trap part of this radiation, tending to warm the planet. Thus, in terms of power, the Earth receives, on average, slightly less than 240 **watts/m²**. Without the **greenhouse effect**, mean temperature on Earth would stand at $-18\text{ }^{\circ}\text{C}$, and very little water would be present in liquid form. This effect thus has a beneficial influence, since it allows our planet to experience a mean temperature of $15\text{ }^{\circ}\text{C}$.

However, from the beginning of the industrial era, i.e. for more than a hundred years, humans have been releasing into the atmosphere gases (**carbon dioxide**, **methane**, **nitrogen oxides**, etc.) that artificially augment the greenhouse effect. Since 1750, this increase, with respect to “well-mixed” gases, has amounted to 2.43 W/m^2 . Contributing as it does an “additional radiative forcing” of 1.46 W/m^2 , carbon dioxide (CO₂) accounts for more than half of this “additional greenhouse effect,” well ahead of methane (0.48 W/m^2), **halocarbons** [chlorofluorocarbons [CFCs], hydrochlorofluorocarbons [HCFCs], and hydrofluorocarbons [HFCs]), accounting for 0.34 W/m^2 , and nitrogen dioxide (0.15 W/m^2). Further, the **ozone** in the troposphere exhibits a *positive* radiative forcing of 0.35 W/m^2 (however, it is estimated that depletion of the stratospheric ozone layer observed between 1979 and 2000 has resulted in a *negative* radiative forcing, of 0.15 W/m^2).

This addition to the natural greenhouse effect (155 W/m^2) is small, correspon-

ding to an increase of about 1%. Nevertheless, it is practically certain that this has contributed to the rise in mean temperature, for our planet, of about $0.5\text{ }^{\circ}\text{C}$, observed over the 20th century (see Figure 1). If nothing is done to curb these emissions, carbon dioxide concentration in the atmosphere (see Figure 2) could double by 2100. From current world consumption ⁽¹⁾ of **fossil** fuels (7,700 Mtoe), the mass of CO₂ currently produced may easily be computed: 20 billion tonnes per year!

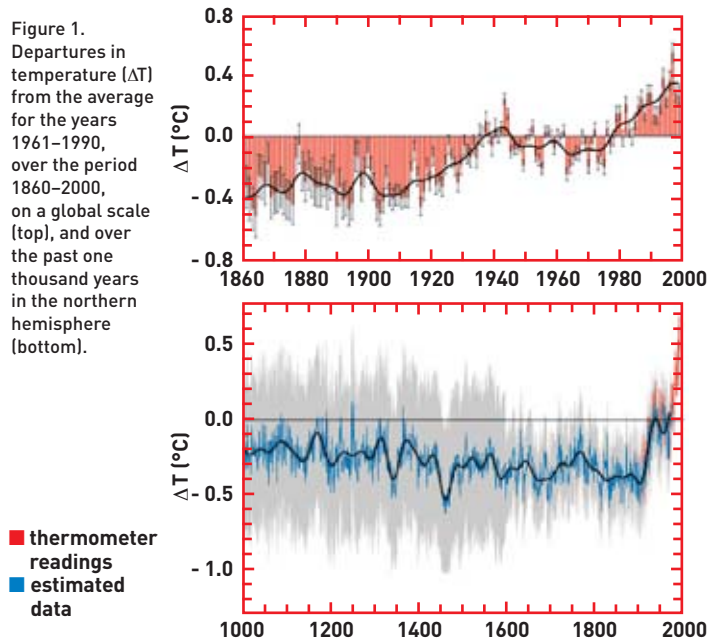
This could result in a substantial increase in the greenhouse effect, causing, through nonlinear amplifying effects,

(1) European Community, Directorate General for Energy (DG XVII), “Conventional Wisdom” scenario (*European Energy to 2020: A scenario approach*, 1996).

profound alterations in climate. Most models predict that doubling the present carbon dioxide concentration would result, by the end of the 21st century, in a rise in temperature of some $2\text{--}3\text{ }^{\circ}\text{C}$. Some models even yield a bracket of $1.5\text{--}4.5\text{ }^{\circ}\text{C}$, meaning dramatic consequences could be foreseen for the environment, such as a substantially rising sea level.

Such figures may seem small, entailing only minor consequences for the climate; that, however, is not the case. To understand this point, one should bear in mind that during the “little ice age,” from 1450 to 1880, mean temperature only fell, in France, by $1\text{ }^{\circ}\text{C}$, on average. Some 6,000–8,000 years ago, as Western Europe experienced a war-

Figure 1. Departures in temperature (ΔT) from the average for the years 1961–1990, over the period 1860–2000, on a global scale (top), and over the past one thousand years in the northern hemisphere (bottom).



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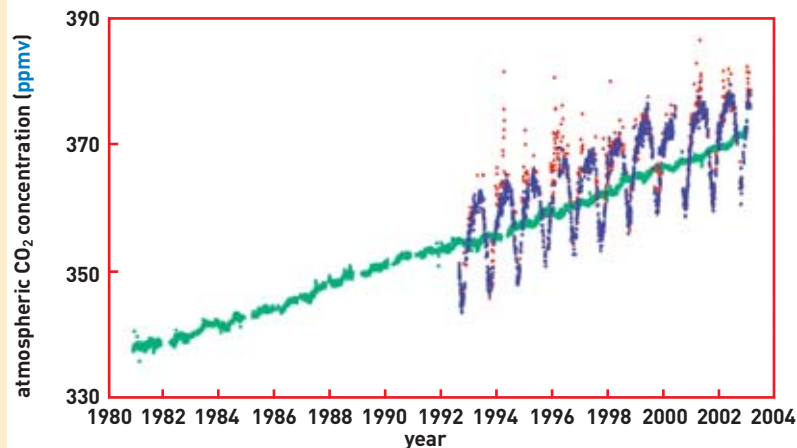


Figure 2.

Evolution of atmospheric CO₂ concentration since 1980, as measured on a daily basis by the automatic stations of the Climate and Environmental Science Laboratory (LSCE: Laboratoire des sciences du climat et de l'environnement), since 1981 on Amsterdam Island (Indian Ocean), and since 1992 at Mace Head, on the western coast of Ireland.

Readings on Amsterdam Island (shown in green), well away from any direct perturbation of human origin, essentially evidence the constant rise in concentration. The Mace Head site basically measures oceanic atmosphere (under normal conditions, westerly winds: blue). When wind conditions are reversed, the site receives a continental atmosphere, showing a strong excess in CO₂ (red plots), compared to oceanic atmosphere. Over the mean rise in CO₂ concentration is superimposed a marked seasonal modulation, due to plant vegetative cycle (chlorophyll photosynthesis), plants being CO₂ emitters in winter, and CO₂ absorbers in summer.

mer spell, with a mean temperature 2–3 °C higher than it is today, the Sahara was not a desert, but a region of abundant rainfalls. It is not so much the rise in temperature that gives cause for concern, as its rapid variation (in the course of one century). The large variations previously observed in nature all occurred over much longer timescales, for those at least of a global character. Thus, the last glaciation lasted 100,000 years, and the corresponding deglaciation took 10,000 years. The rapid variation we are currently experiencing may induce major, unexpected perturbations in the climate and the ecosystem, which will not always have time to adapt.

From Rio to Kyoto: the major conferences on the global environment

The evolution of the global environment has led to major conferences being organized, starting in the closing decade of the 20th century.

At the Earth Summit, held in **Rio de Janeiro** (June 1992), the United Nations Framework Convention on Climate Change was signed, this setting the goal of a stabilization of **greenhouse gas** emissions (this convention came into force on 21 March 1994).

At the Kyoto Conference (December 1997), the protocol was signed providing for a global reduction in emissions of such

gases, by an average 5.2% in the period 2008–2012, compared to 1990 levels, for **OECD** countries and Eastern European countries (including Russia). Reduction targets for the **European Union** and France are set at 8% and 0% respectively. The ways and means to meet these targets were debated, unsuccessfully, in November 2000 at **The Hague**. Subsequent conferences, held in **Marrakech** (2001), **Johannesburg** (Earth Summit held in August–September 2002), **New Delhi** (October 2002), **Moscow** (September–October 2003), and **Milan** (December 2003) had still not enabled, by 2004, this **Kyoto Protocol** to be brought into force, until Russia finally decided to ratify the document, at last allowing this enforcement in February 2005.

Under the impetus provided by the United Nations Environment Program (**UNEP**), the issues raised by substances that deplete the ozone layer in the atmosphere were addressed in **Vienna** (1985), and most importantly in **Montreal** (1987), where the protocol was signed, imposing a reduction in production and use



The Mace Head monitoring station, Ireland.

of chlorofluorocarbons (CFCs). This protocol was specified by amendments adopted in **London** (1990), imposing a ban on CFCs from 1 January 2000, and extending controls to other compounds (including HCFCs), **Copenhagen** (1992), **Montreal** (1997), and **Beijing** (1999).