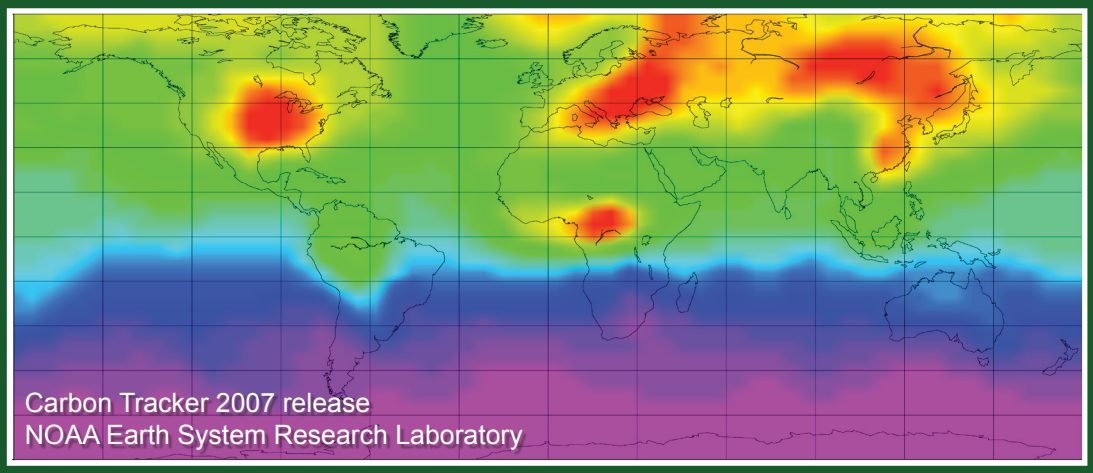
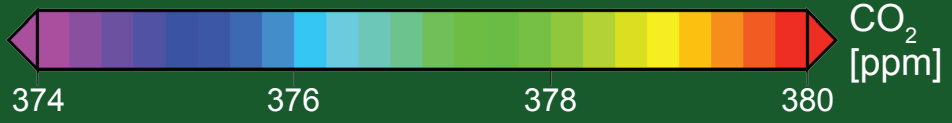
WMO
Greenhouse Gas Bulletin

The State of Greenhouse Gases in the Atmosphere Using Global Observations through 2006





Column averaged CO_2 mixing ratio (ppm) for 1 February 2005 calculated from NOAA's CarbonTracker model (see: http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/) and measurements from a number of sites in the WMO-GAW Global CO_2 network described in this Bulletin. Blue regions have relatively low CO_2 and red regions have relatively high CO_2. High CO_2 values, mostly from fossil fuel combustion, are observed over North America, Europe and East Asia. The passage of a frontal system is seen between eastern Europe and Asia. CO_2 from a biomass burning plume is being transported from Equatorial Africa towards the Atlantic Ocean.

Executive summary

The latest analysis of data from the WMO-GAW Global Greenhouse Gas Monitoring Network shows that the globally averaged mixing ratios of carbon dioxide (CO_2) and nitrous oxide (N_2O) have reached new highs in 2006 with CO_2 at 381.2 ppm and N_2O at 320.1 ppb. Atmospheric growth rates in 2006 of these gases are consistent with recent years. The mixing ratio of methane (CH_4) remains almost unchanged at 1782 ppb. These values are higher than those in pre-industrial times by 36%, 19% and 155%, respectively. Methane growth has slowed during the past decade. The NOAA Annual Greenhouse Gas Index (AGGI) shows that from 1990 to 2006 the atmospheric radiative forcing by all long-lived greenhouse gases has increased by 22.7%. The combined radiative forcing by CFC-11 and CFC-12 exceeds that of N_2O. They are decreasing very slowly as a result of emission reductions under the Montreal Protocol on Substances That Deplete the Ozone Layer.

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Global Atmosphere Watch

Overview

This is the third in a series of WMO-GAW Annual Greenhouse Gas Bulletins. Each year, these bulletins report the latest trends and atmospheric burdens of the most influential, long-lived greenhouse gases; carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), as well as a summary of the contributions of the lesser gases. These three major gases alone contribute about 88% of the increase in radiative forcing of the atmosphere by changes in long-lived greenhouse gases occurring since the beginning of the industrial age (~1750).

The Global Atmosphere Watch (GAW) programme of the World Meteorological Organization (WMO) promotes systematic and reliable observations of the global atmospheric environment, including measurements of CO_2, CH_4, N_2O, and other atmospheric gases. Sites where some or all of these gases are monitored are shown in Figure 1. The measurement data are reported by participating countries and archived and distributed by the World Data Centre for Greenhouse Gases (WDCGG) at the Japan Meteorological Agency (JMA).

Statistics on the present global atmospheric abundances are given in Table 1. They are obtained from a global analysis method using a data set which is traceable to the WMO World Reference Standard (http://gaw.kishou.go.jp/wdcgg/products/bulletin.html). The values in Table 1 are slightly different from those in the Fourth Assessment Report of IPCC, mainly due to the different selection of stations employed.

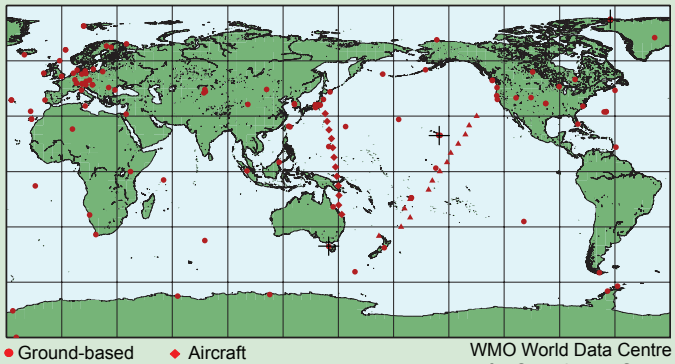

Figure 1. The WMO-GAW global greenhouse gas network for carbon dioxide. The network for methane is similar to this.

Table 1. Global abundances of key greenhouse gases as averaged over the twelve months of 2006 as well as trends from the WMO-GAW global greenhouse gas monitoring network.

	CO_2 (ppm)	CH_4 (ppb)	N_2O (ppb)
Global abundance in 2006	381.2	1782	320.1
2006 abundance relative to year 1750[1]	136%	255%	119%
2005-06 absolute increase	2.0	-1	0.8
2005-06 relative increase	0.53%	-0.06%	0.25%
Mean annual absolute increase during last 10 years	1.93	2.4	0.76

[1] Assuming a pre-industrial mixing ratio of 280 ppm for CO_2, 700 ppb for CH_4 and 270 ppb for N_2O.

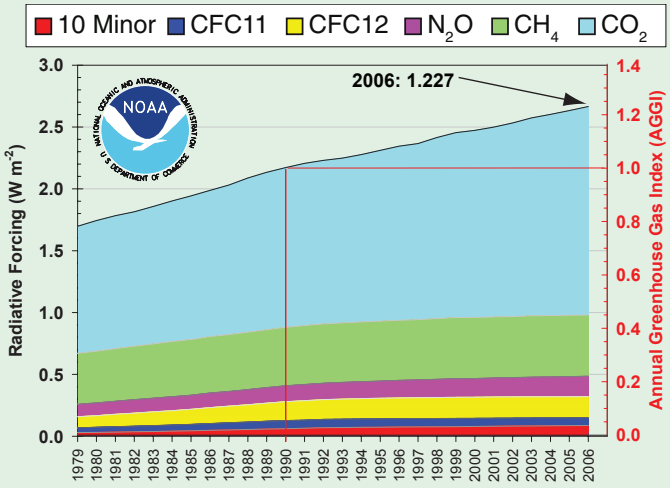

Figure 2. Changes in atmospheric radiative forcing by long-lived greenhouse gases and the 2006 update of the NOAA Annual Greenhouse Gas Index (AGGI). 1990 has been chosen as the year of reference for the Index.

The three major greenhouse gases have been increasing in the atmosphere since the beginning of the industrial age. Water vapour is a natural component of the climate and weather system that is indirectly affected by human activities through changes in temperature, land surface characteristics and aerosol effects on clouds. This Bulletin focuses on those greenhouse gases that are directly influenced by human activities and that are generally much longer lived in the atmosphere than water vapour.

According to the NOAA Annual Greenhouse Gas Index (AGGI), the total radiative forcing by all long-lived greenhouse gases has increased by 22.7% since 1990 and by 1.23% from 2005 to 2006 (see Figure 2 and http://www.esrl.noaa.gov/gmd/aggi).

Carbon Dioxide (CO_2)

CO_2 is the single most important infrared absorbing, anthropogenic gas in the atmosphere and is responsible for 63% of the total radiative forcing of Earth by long-lived greenhouse gases. Its contribution to the increase in radiative forcing is 87% for the past decade and 91% for the last five years. For about 10,000 years before the industrial revolution, the atmospheric abundance of CO_2 was nearly constant at ~280 ppm (ppm = number of molecules of the greenhouse gas per million molecules of dry air). This abundance represented a balance among large seasonal fluxes (on the order of 100 Gigatonnes (Gt) of carbon per year) between the atmosphere and biosphere (photosynthesis and respiration) and the atmosphere and the ocean (physical exchange of CO_2). Since the late 1700s, atmospheric CO_2 has increased by 36.1%, primarily because of emissions from combustion of fossil fuels (currently about 8.4 Gt carbon per year) and, to a lesser extent, deforestation

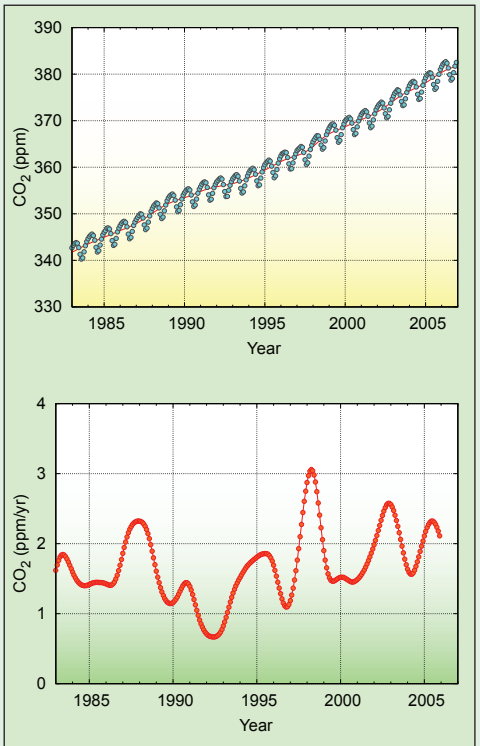

Figure 3. Globally averaged CO_2 (a) and its growth rate (b) from 1983 to 2006.

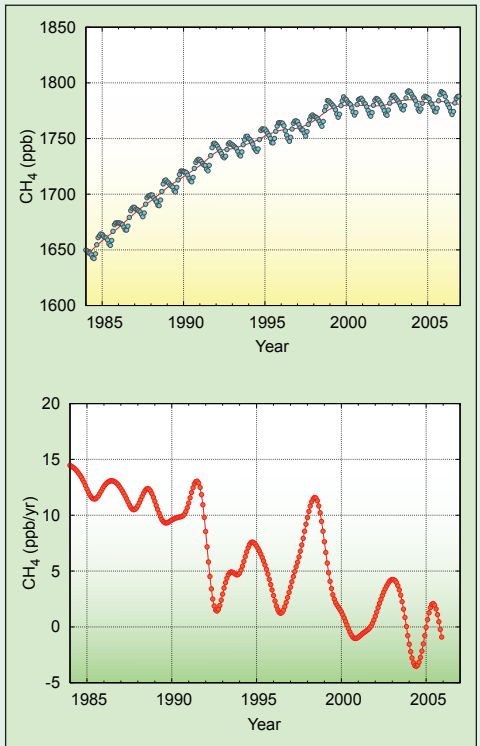

Figure 4. Globally averaged CH_4 (a) and its growth rate (b) from 1984 to 2006.

(~1.5 Gt carbon per year). High-precision measurements of atmospheric CO_2 beginning in 1958 show that the average increase of CO_2 in the atmosphere corresponds to ~55% of the CO_2 emitted by fossil fuel combustion. The remaining fossil fuel-CO_2 has been removed from the atmosphere by the oceans and the terrestrial biosphere. Globally averaged CO_2 in 2006 was 381.2 ppm and the increase from 2005 to 2006 was 2.0 ppm (Figure 3). This growth rate is larger than the observed average for the 1990s (~1.5 ppm/yr), mainly because of increasing emissions of CO_2 from fossil fuel combustion.

Methane (CH_4)

Methane contributes 18.6% of the direct radiative forcing due to long-lived greenhouse gases affected by human activities. Its chemistry also indirectly affects climate by influencing tropospheric ozone and stratospheric water vapour. Methane is emitted to the atmosphere by natural processes (~40%, e.g., wetlands and termites) and anthropogenic sources (~60%, e.g., fossil fuel exploitation, rice agriculture, ruminant animals, biomass burning, and landfills); it is removed from the atmosphere by reaction with the hydroxyl radical (OH) and has an atmospheric lifetime of ~9 years. Before the industrial era, atmospheric methane was at ~700 ppb (ppb = number of molecules of the greenhouse gas per billion (10^9) molecules of dry air). Increasing emissions from anthropogenic sources are responsible for the factor of 2.5 increase in CH_4. The cycling of methane, however, is complex and managing its atmospheric burden requires an understanding of its emissions and its budget of sources and sinks. Globally averaged CH_4 in 2006 was 1782 ppb, which means a decrease of 1 ppb since 2005 and a decrease of 2 ppb since 2003. (Figure 4). By contrast, methane was increasing by up to 13 ppb per year during the late 1980s. The average growth rate has been 2.4 ppb per year over the past ten years.

Nitrous Oxide (N_2O)

Nitrous oxide (N_2O) contributes 6.2% of the total radiative forcing from long-lived greenhouse gases. Its atmospheric abundance prior to industrialization was 270 ppb. N_2O is emitted into the atmosphere from natural and anthropogenic sources, including the oceans, soil, combustion of fuels, biomass burning, fertiliser use, and various industrial processes. One-third of its total emissions is from anthropogenic sources. It is removed from the atmosphere by photochemical processes in the stratosphere. Globally averaged N_2O during 2006 was 320.1 ppb, up 0.8 ppb from the year before (Figure 5). The mean growth rate has been 0.76 ppb per year over the past 10 years.

Other Greenhouse Gases

The ozone depleting chlorofluorocarbons (CFCs) also contribute to the radiative forcing of the atmosphere. Their overall contribution to the global radiative forcing is significant (12% of the total; http://www.esrl.noaa.gov/gmd/aggi).

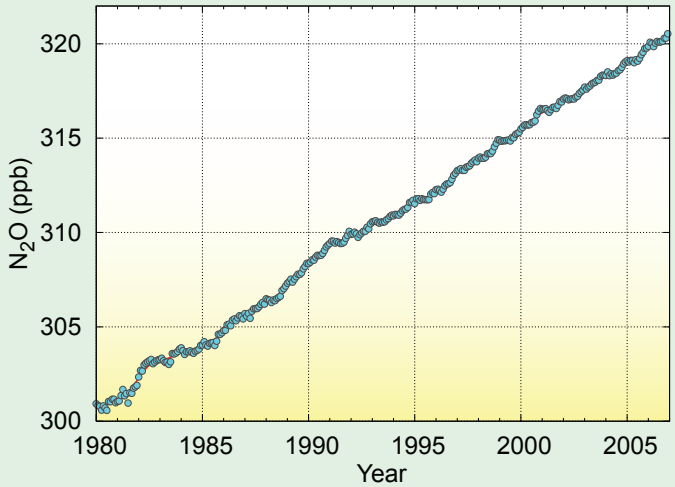

Figure 5. Time series of monthly mean mixing ratios of N_2O from 1980 to 2006.

While atmospheric CFCs are now decreasing slowly, some of the CFCs still have a serious impact on the atmospheric greenhouse effect. Some species, such as hydrochlorofluorocarbons (HCFCs), which are strong infrared absorbers, are increasing at rapid rates, although still low in abundance. Ozone in the troposphere does not have a long lifetime, but it has an atmospheric greenhouse effect that is comparable to those of the CFCs. Although tropospheric ozone is important for the atmospheric greenhouse effect, it is difficult to estimate the global distribution and trend due to its very uneven geographic distribution. All the gases mentioned here are also monitored as part of the WMO-GAW network.

Distribution of the bulletins

The Secretariat of the World Meteorological Organization (WMO) prepares and distributes Bulletins in cooperation with the World Data Centre for Greenhouse Gases at the Japan Meteorological Agency and the GAW Scientific Advisory Group for Greenhouse Gases, with the assistance of the NOAA Earth System Research Laboratory. The Bulletins are available through the Global Atmosphere Watch programme web page at http://www.wmo.int/pages/prog/arep/gaw/gaw_home_en.html, and on the home pages of WDCGG (http://gaw.kishou.go.jp/wdcgg.html) and the NOAA Carbon Cycle Greenhouse Gases Group (http://www.esrl.noaa.gov/gmd/ccgg).

Acknowledgements and links

Forty-four countries are registered in GAWSIS as having contributed CO_2 data to the GAW WDCGG. Of these, many are associated with the NOAA Cooperative Global Air Sampling Network. NOAA-supported sites represent approximately 70% of the countries submitting data to GAW. The rest of the network is maintained by Australia, Canada, China, Japan and many European countries (see the national reports in GAW Report #168 from the Sept. 2005 Experts Meeting). All of the WMO Global Atmosphere Watch (GAW) monitoring stations contributing to the data used in this Bulletin are shown on the map (Figure 1) and listed in the List of Contributors on the WDCGG web page at (http://gaw.kishou.go.jp/wdcgg.html). They are also described in the GAW Station Information System (GAWSIS) (http://www.empa.ch/gaw/gawsis/) operated by Switzerland.

Contacts

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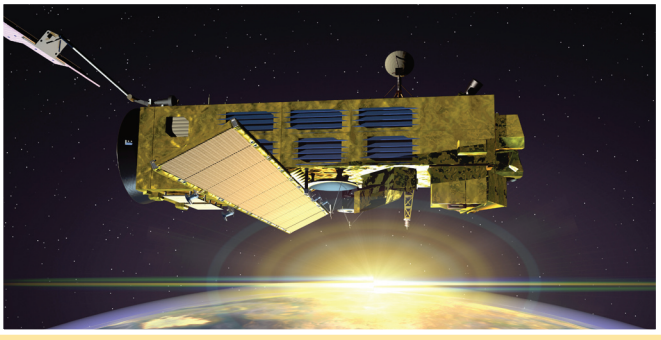
   Web site: http://www.wmo.int/pages/prog/arep/gaw/gaw_home_en.html
2. World Data Centre for Greenhouse Gases, Japan Meteorological Agency, Tokyo.
   E-mail: wdcgg@hq.kishou.go.jp
   Web site: http://gaw.kishou.go.jp/wdcgg.html

Selected greenhouse gas observatories

A small two-engine aircraft is equipped by USA's National Oceanic and Atmospheric Administration for measurements of greenhouse gases.

The GAW Global Observatory at Mace Head, operated by the University of Galway, is located on the west coast of Ireland. Its exposure to the North Atlantic Ocean makes it an ideal location to study both natural and man-made trace constituents in marine and continental air masses.

The GAW Global Observatory at Mt. Waliguan (3810 masl) in Western China is operated by the Chinese Meteorological Administration. Its location on a mountain top and far away from big cities makes it an ideal site for global pollution monitoring.



The ESA-operated ENVISAT satellite, which carries the SCIAMACHY instrument, measures total column methane and several other parameters.