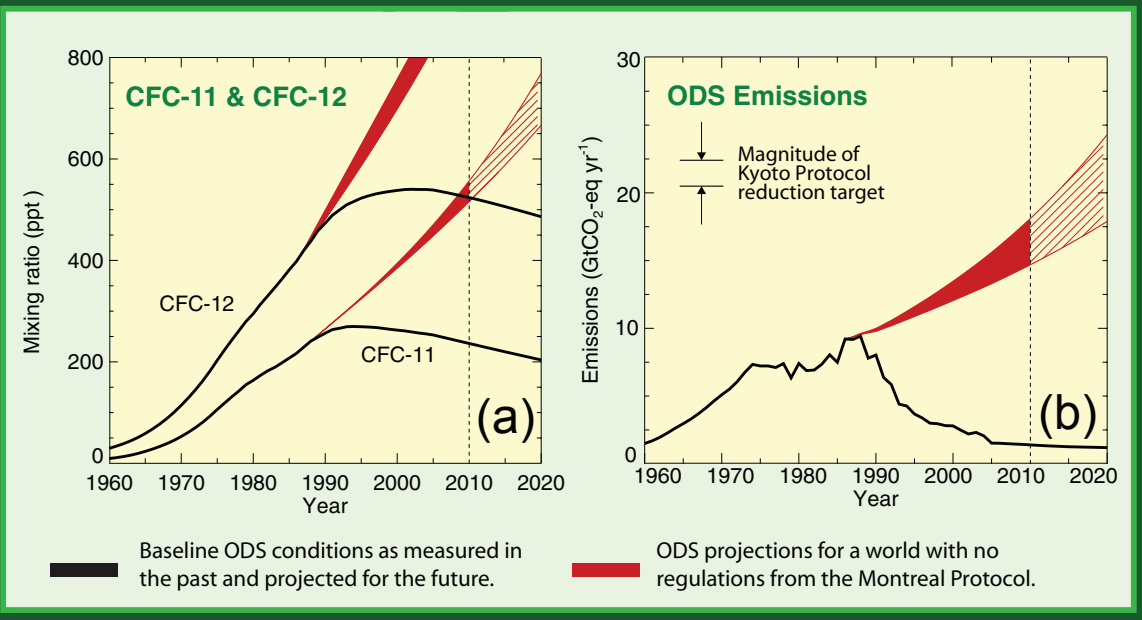
WMO Greenhouse Gas Bulletin

The State of Greenhouse Gases in the Atmosphere Using Global Observations through 2007



The Montreal Protocol (1987), resulted in reduced production and consumption of ozone depleting substances (ODSs). By 2010 this will have caused a reduction of greenhouse gas warming that is a factor of five greater than the reduction target of the first commitment period (2008-2012) of the Kyoto Protocol.

The Montreal Protocol controls the production and consumption of ODSs, the substances that cause stratospheric ozone depletion. Panel (a) shows how measured atmospheric abundances (black curves) of CFC-11 and CFC-12 declined starting in the early 1990s as a result of the protocol. For comparison the projected increases (red curves) in the absence of a Montreal Protocol is shown. The abundances in 2010 will be one half or less of what they would have been without the protocol. Panel (b) shows the sum over all ODS emissions expressed as an equivalent emission of CO_2. Starting in the late 1980s, ODS emissions fell sharply (black curve) compared to those expected without the protocol (red curve). By 2010, the Montreal Protocol will have reduced emissions from ODSs by an amount equivalent to ~11 Gton CO_2 per year (including offsets); this is 5 to 6 times the reduction target of the first commitment period (2008-2012) of the Kyoto Protocol (2 Gton CO_2 eq/yr). Based on Velders et al., Proc. Natl. Acad. Sci., 104, 4814- 4819, 2007. Figure prepared by E. Dlugokencky, D. Dailey-Fisher, and D. Fahey, NOAA ESRL.

Executive summary

The latest analysis of data from the WMO-GAW Global Greenhouse Gas Monitoring Network, a comprehensive network of the Global Climate Observing System (GCOS), shows that the globally averaged mixing ratios of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) have reached new highs in 2007 with CO_2 at 383.1 ppm, CH_4 at 1789 ppb and N_2O at 320.9 ppb. These values are higher than those in pre-industrial times (before 1750) by 37%, 156% and 19%, respectively. Atmospheric growth rates in 2007 of CO_2 and N_2O are consistent with recent years. The mixing ratio of CH_4 shows the largest increase since 1998. The NOAA Annual Greenhouse Gas Index (AGGI) shows that from 1990 to 2007 the atmospheric radiative forcing by all long-lived greenhouse gases has increased by 24.2%. The combined radiative forcing by the most abundant ozone depleting substances, 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.

World Meteorological Organization
Weather • Climate • Water

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Global Atmosphere Watch

Overview

This is the fourth in a series of WMO-GAW Annual Greenhouse Gas Bulletins. Each year, these bulletins report the global consensus on the latest trends and atmospheric burdens of the most influential, long-lived greenhouse gases; carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and the two most abundant ozone depleting substances that are greenhouse gases, as well as a summary of the contributions of the lesser gases. These five major gases alone contribute about 97% 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) coordinates systematic observations and analysis of the global atmospheric environment, including measurements of greenhouse gases, and other atmospheric trace gases. Sites where greenhouse 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.

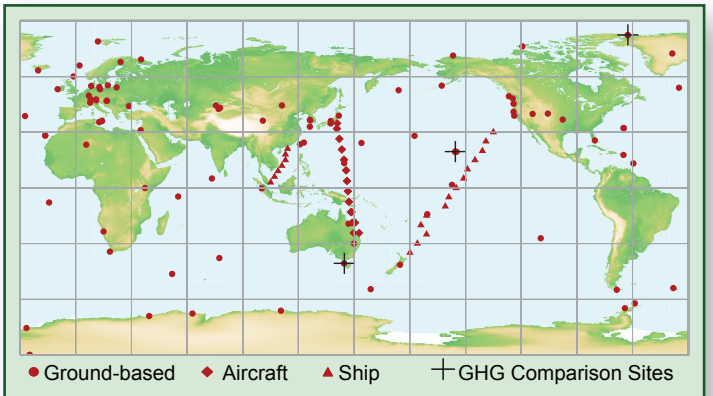

Figure 1. The WMO-GAW global greenhouse gas network for carbon dioxide. The network for methane is similar to this.

Table 1. Global abundances of key greenhouse gases as averaged over the twelve months of 2007 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 2007	383.1	1789	320.9
2007 abundance relative to year 1750[1]	137%	256%	119%
2006-07 absolute increase	1.9	6	0.8
2006-07 relative increase	0.50%	0.34%	0.25%
Mean annual absolute increase during last 10 years	2.00	2.7	0.77

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

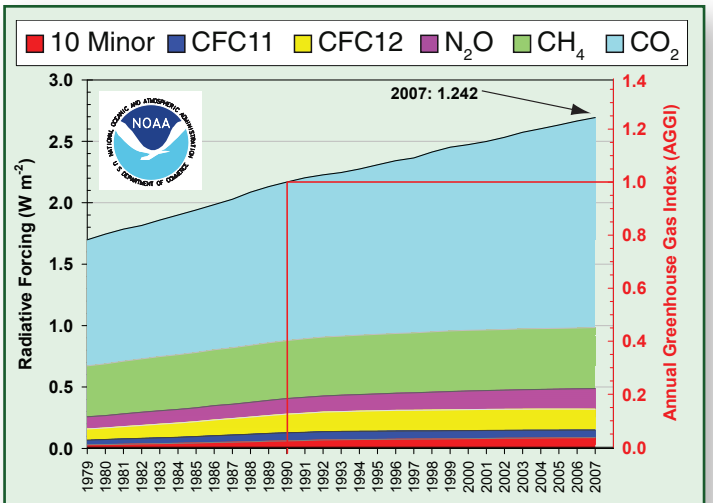

Figure 2. Changes in atmospheric radiative forcing by long-lived greenhouse gases and the 2007 update of the NOAA Annual Greenhouse Gas Index (AGGI). 1990 has been chosen as the year of reference for the Index.

The three greenhouse gases in Table 1 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 24.2% since 1990 and by 1.06% from 2006 to 2007 (see Figure 2 and http://www.esrl.noaa.gov/gmd/aggi).

Carbon Dioxide (CO_2)

CO_2 is the single most important infrared radiation 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 90% 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 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 37%, primarily because of emissions from combustion of fossil fuels (currently about 8.4 Gt carbon per year) and, to a lesser extent, deforestation (~1.5 Gt carbon per year). High-precision measurements of atmospheric CO_2 begin-

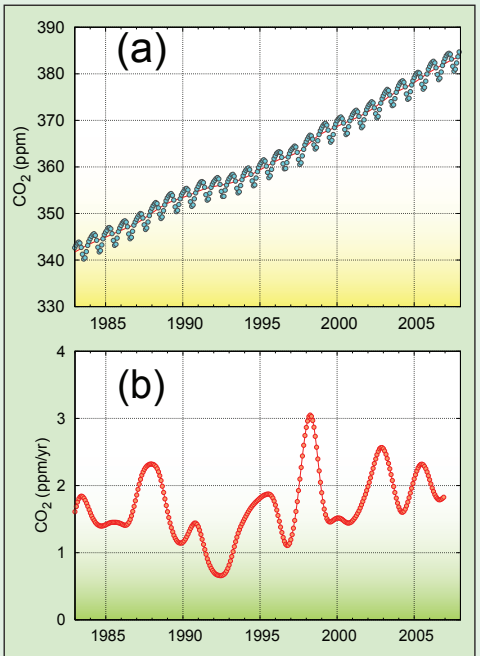

Figure 3. Globally averaged CO_2 (a) and its growth rate (b) from 1983 to 2007.

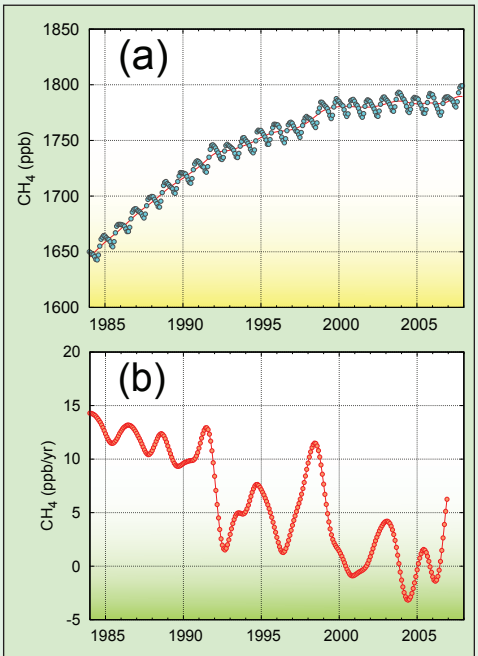

Figure 4. Globally averaged CH_4 (a) and its growth rate (b) from 1984 to 2007.

ning 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 2007 was 383.1 ppm and the increase from 2006 to 2007 was 1.9 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 18.5% 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 (~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 primarily 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 gas per billion (10^9) molecules of dry air). Increasing emissions from anthropogenic sources are responsible for the factor of 2.6 increase in CH_4. The cycling of methane, however, is complex and accounting for its atmospheric burden requires an understanding of its many sources and sinks. Globally averaged CH_4 in 2007 was 1789 ppb, which means an increase of 6 ppb since 2006 and it exceeds the highest value so far, which was recorded in 2003 (Figure 4). Methane was increasing by up to 13 ppb per year during the late 1980s, while the growth rate slowed during the past decade. The 6 ppb rise from 2006 to 2007 is the highest annual increase observed since 1998. However, it is still too early to state with certainty that this increase represents the beginning of a new upward trend of methane.

Nitrous Oxide (N_2O)

Nitrous oxide (N_2O) contributes 6.2% of the total radiative forcing from increases in 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 2007 was 320.9 ppb, up 0.8 ppb from the year before (Figure 5). The mean growth rate has been 0.77 ppb per year over the past 10 years.

Other Greenhouse Gases

The ozone depleting chlorofluorocarbons (CFCs), together with minor halogenated gases, 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). While atmospheric CFCs are now decreasing slowly, some of the CFCs still have a serious impact on the atmospheric greenhouse effect. As highlighted on the cover page, they would have had a much greater effect if measures to reduce ODSs had not happened. Some species, such as hydrochlorofluorocar-

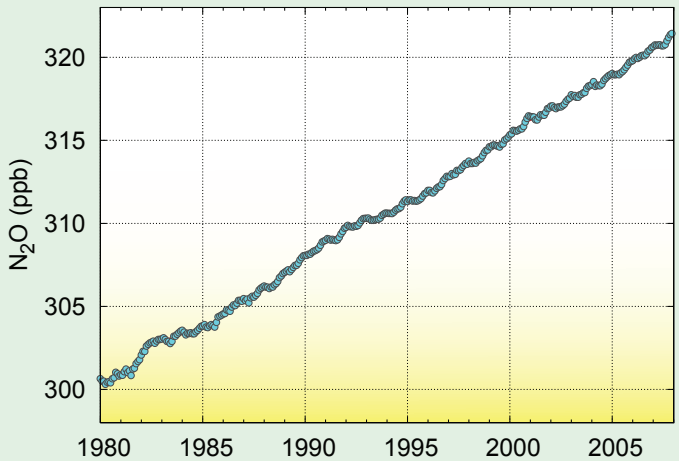

Figure 5. Time series of monthly mean mixing ratios of N_2O from 1980 to 2007.

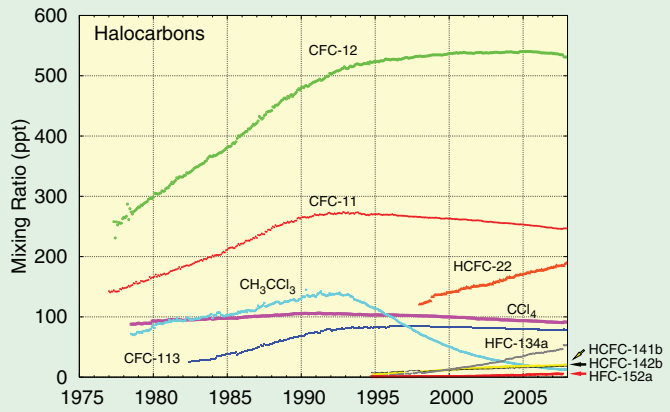

Figure 6. Time series of monthly mean mixing ratios of the most important halocarbons from 1977 to 2007.

bons (HCFCs), which are strong infrared absorbers, are increasing at rapid rates, although still low in abundance (Figure 6). Ozone in the troposphere does not have a long lifetime, but the atmospheric greenhouse effect of the ozone increase due to human activiites is comparable to that 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/) 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. Approximately 70% of the measurement records submitted to GAW are obtained at sites in the NOAA ESRL cooperative air sampling network. 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/). They are also described in the GAW Station Information System (GAWSIS) (http://gaw.empa.ch/gawsis/) operated by Switzerland.

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2. World Data Centre for Greenhouse Gases, Japan Meteorological Agency, Tokyo.
   E-mail: wdcgg@met.kishou.go.jp
   Web site: http://gaw.kishou.go.jp/wdcgg/

Selected greenhouse gas observatories

The GAW observatory at Jungfraujoch (3580 masl) in Switzerland.

The GAW observatory at the Zeppelin Mountain, 474 masl, in Spitsbergen, Norway.

The AGAGE/GAW observatory at Ragged Point, Barbados.