Summary

This issue of *Data Summary* covers the results of basic analyses on greenhouse gas concentrations reported to the WMO World Data Centre for Greenhouse Gases (WDCGG). The data for analysis reached the WDCGG by 2001 and the periods of observation ranged from 1968 to 2000. This *Data Summary* includes analyses of the monthly mean concentrations in global, hemispheric and zonal averages, and a time series of concentrations at some stations for greenhouse gases and related gases.

This is the fourth issue of *Data Summary* to be published by the WDCGG. In its first issue, the long-term trends for greenhouse gases at individual stations and zonal, hemispheric and global mean concentrations were analyzed. The second issue added analyses of seasonal cycles to the analyses in the first issue. The third issue emphasized global trends and other global aspects with a digital filter to derive long-term trends and variations. This, the fourth issue, is an improvement of the contents of the third issue. The produced analyses should provide useful information on the change in concentrations of greenhouse gases and related gases.

For the analyses in this publication, only monthly mean concentrations are used. The WDCGG considers it even better to adopt monthly mean data so that the analysis can incorporate more observation sites including a large number of stations in the NOAA flask-sampling network. Of course, it is also appreciated that some stations submit daily and hourly mean concentrations, which may be more appropriate for analyzing the variation in various time-scales. All the submitted data are available on the WDCGG web site (http://gaw.kishou.go.jp/wdcgg.html).

A time series of greenhouse gas concentrations, which is often produced by removing local effects with very-short-term variations, is an integration of the variation on different time scales. The two major components of variations in CO_2 concentration are a seasonal variation and a long-term trend. Annual growth rates are derived from the deseasonalized long-term trend.

Plates 1 and 3 show the variation in zonal mean concentrations, as well as deseasonalized concentrations and growth rates for CO_2 and CH_4, respectively. For both CO_2 and CH_4, the concentrations are clearly dependent on latitude and have a long-term increasing trend and seasonal variation. The amplitude and phase of the seasonal variation also depend on latitude and vary from year to year. The growth rate is also uneven in latitude and time. These differences in time and space are attributed to variations in the emission/production and removal/dissociation of CO_2, CH_4 and other related gases. Although these figures are the same as those in the last Summary, since the analysis method has been improved in this publication, they not only have a period extension but also display a slight difference in the patterns from the previous Summary. Especially, in the figure for growth rate, the difference in the previous pattern is particularly evident.

The analytical results are summarized for each greenhouse and related gas below:

1. Carbon Dioxide (CO_2)

The level of CO_2, which of all the greenhouse gases contributes most to global warming, has been increasing since the pre-industrial period. Global mean concentrations reflect an annual increase, and the annual mean concentration was 369 ppm in 2000. Concentrations peak in northern high and mid-latitudes, suggesting strong net sources in these areas.

The global growth rate is 1.6 ppm/year on average for the period 1983-2000. However, growth rates vary significantly interannually. The high growth rates in 1983, 1987/1988, 1994/1995 and 1997/1998 are associated with the warm events of El Niño-Southern Oscillation (ENSO). The anomalously strong El Niño event in 1997/1998 brought about worldwide high increases in 1998. The exceptionally low growth rates in 1992, including negative values also for northern high latitudes, were caused by low global air temperatures following the eruption of Mt. Pinatubo in 1991.

Amplitudes of the seasonal cycle are clearly large in northern high and mid-latitudes and small in the Southern Hemisphere. The northern seasonal cycle mainly reflects seasonal variation in the absorption/emission in the biosphere there, while the southern cycle reflects oceanic variations and biomass burning in addition to the influence of the biosphere. In southern low latitudes, an annual cycle cannot be seen clearly but a semiannual cycle can. This is probably due to two opposing factors, *i.e.*, the direct influence of sources and sinks there and the propagation of the out-of-phase seasonal variation from the Northern Hemisphere.

2. Methane (CH_4)

CH_4 is the second most significant greenhouse gas, and its level has been increasing since the beginning of the 19th century. Global mean concentrations reflect an annual increase, and the annual average concentration was 1784 ppb in 2000. The annual concentrations produce a peak in the northernmost latitudes and decrease toward the southernmost latitudes, suggesting significant net sources in northern latitudes.

The global growth rate is 8 ppb/year on average for the period 1984-2000, but the rates show a distinct decrease from the 1980s to 1990s. Growth rates decreased significantly in some years, including 1992, when large negative values were recorded in northern high latitudes, and 1996, when growth almost stopped in many regions. However, both hemispheres experienced high growth rates in 1998, caused by an exceptionally high global mean air temperature. In the 1990s, CH_4 growth rates varied in parallel with anomalies in the global mean air temperature on an annual mean basis.

Monthly mean concentrations have a seasonal variation with high concentrations in winter and low ones in summer. Unlike CO_2, amplitudes of the seasonal cycle are large for CH_4 not only in the Northern Hemisphere but also in southern high and mid-latitudes. In southern low latitudes, a distinct semi-annual component with a secondary maximum in boreal winter overlays the annual component. This is attributed to the large-scale transportation of CH_4 from the Northern Hemisphere.

3. Nitrous Oxide (N_2O)

Nitrous oxide is an important greenhouse gas, and its level is increasing on a global scale. Data for N_2O reported to the WDCGG show that concentrations are increasing in both hemispheres.

4. Halocarbons

Halocarbons, most of which are anthropogenic, are effective greenhouse gases and some also act as ozone-depleting compounds. Levels of some of the halocarbons (CFCs, etc.) increased in the 1970s and 1980s, but have now almost ceased increasing due to the regulation of production and emission under the Montreal Protocol on Substances that Deplete the Ozone Layer and its Adjustments and Amendments.

The following descriptions are about long-term trends for CFC-11, CFC-12, CFC-113, HCFC-141b, HCFC-142b, CCl_4 and CH_3CCl_3 in the 1990s based on data reported to the WDCGG:

Concentrations of CFC-11 were at a maximum around 1993 and then started decreasing. CFC-12 increased slowly, but growth has almost stopped in recent times. CFC-113 increased slightly, but growth has almost stopped at this point. Concentrations of HCFC-141b and HCFC-142b are linearly increasing. Concentrations of CCl_4 are decreasing slowly. Concentrations of CH_3CCl_3 were at a maximum around 1991 and then started to clearly decrease.

5. Carbon Monoxide (CO)

CO is not a significant greenhouse gas, but brings about changes in the concentrations of greenhouse gases by interacting with hydroxyl radicals (OH). Concentrations of CO have increased in northern high latitudes since 1850, but have not changed significantly over Antarctica during the last two millennia before that. The annual average concentration was about 95 ppb in 1996. The annual mean concentration is high in the Northern Hemisphere and low in the Southern Hemisphere, suggesting substantial anthropogenic emissions in the Northern Hemisphere.

The level of CO was increasing before the mid-1980s but this trend appears to have been reversed in the late 1980s. The average global growth rate was –0.4 ppb/year for 1993 to 1996. Growth rates were negative in 1992 in all latitudes, in 1995 in northern latitudes and in 1996 in southern latitudes, while the rates were positive from 1993 to 1994 in northern latitudes.

Monthly mean concentrations show a seasonal variation with large amplitudes in the Northern Hemisphere and small ones in the Southern Hemisphere. This seasonal cycle is driven by variations in OH concentration as a sink, emission by industries and biomass burning, and transportation on a large scale.

6. Nitrogen Monoxide (NO) and Nitrogen Dioxide (NO_2)

Nitrogen oxides (NO_x, i.e., NO and NO_2) are not greenhouse gases, but bring about changes in the concentrations of other important greenhouse gases by interacting with hydroxyl radicals (OH). In the presence of NO_x, CO and hydrocarbons are oxidized to produce ozone (O_3), which affects the Earth's radiative balance as a greenhouse gas and the oxidization capacity of the atmosphere by reproducing OH.

Most of the stations reporting NO_x data to the WDCGG are located in Europe. NO_x has a large variability in time and space, and it is difficult to identify a long-term trend. But, in Europe NO_2 concentrations are generally higher in southern regions than in northern regions.

7. Sulfur Dioxide (SO_2)

SO_2 is not a greenhouse gas but a precursor of atmospheric sulfuric acid (H_2SO_4) aerosol. Sulfuric acid aerosol is produced by SO_2 oxidation through photochemical gas-to-particle conversion. SO_2 has been a major source of acid rain and deposition throughout industrial times.

All of the stations reporting SO_2 data to the WDCGG are located in Europe. Generally, in Europe, SO_2 concentrations are higher in the southern regions than in northern regions.