Summary

This issue of *Data Summary* covers the results of basic analyses of greenhouse gas concentrations reported to the WMO World Data Centre for Greenhouse Gases (WDCGG). The observations range from 1968 to 2002, and only data that reached the WDCGG by December 2003 were analyzed. This *Data Summary* includes analyses of the monthly mean concentrations of global, hemispheric and zonal greenhouse and related gases, and provides useful information on the change in concentrations of these gases.

Only monthly mean concentrations were used in the analyses so that data from many observation sites, including a large number of stations in the NOAA flask-sampling network, are included. Of course, it is also appreciated that some stations submit daily and hourly mean concentrations, which may be more appropriate for analyzing the variations on 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 factors that can vary in a very short time, was made by integrating the variation in concentration on different time scales. The CO_2 concentration can be seen on both a seasonal scale and a long-term scale. Annual growth rates are derived from the deseasonalised long-term trend.

Plates 1 and 3 show the variation in zonal mean concentrations, as well as deseasonalised 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 a seasonal variation. The amplitude and phase of the seasonal variation also depend on latitude. The growth rate also fluctuates with 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.

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

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 have increased annually, and was 374 ppm as of 2002. Concentrations peak in northern high and mid-latitudes, suggesting strong net sources in these areas.

The global growth rate varies significantly interannually and was 1.6 ppm/year on average for the period 1983-2002. The high growth rates in 1983, 1987/1988, 1994/1995, 1997/1998 and 2002 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 for northern high and mid-latitudes, were caused by low global 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 the 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—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 averaged concentration was 1782 ppb in 2002. The annual concentrations peak in the northernmost latitudes and fall toward the southernmost latitudes, suggesting significant net sources in northern latitudes.

The global growth rate was 7 ppb/year on average for the period 1984-2002, but the rates decreased markedly from the 1980s to the 1990s. Growth rates decreased significantly in some years, including 1992, when 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 temperature. And the global growth rates decreased to almost zero in 2000-2001.

Monthly mean concentrations have a seasonal variation with high concentrations in winter and low concentrations 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 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 as a result regulation of production and emission under the Montreal Protocol on Substances that Deplete the Ozone Layer and its Adjustments and Amendments.

Concentrations of CFC-11 peaked around 1992 and then started decreasing. CFC-12 increased slowly, but growth has almost stopped in recent times. CFC-113 growth stopped in the early 1990s, and over the last decade has shown a trend of decreasing slightly. Concentrations of HCFC-141b and HCFC-142b are increasing linearly. Concentrations of CCl_4 are decreasing slowly. Concentrations of CH_3CCl_3 peaked around 1992 and then clearly started to decrease.

5. Surface Ozone (O_3)

Ozone plays important roles in the atmospheric environment through radiative and chemical processes. It absorbs UV radiation in the stratosphere, making a temperature profile, and circulates the atmosphere with its absorbed energy. It also absorbs IR radiation in the troposphere, and is thus one of the greenhouse gases.

Variation in the concentration of ozone near the surface, so-called surface ozone, reflects various processes there. While some of the ozone in the troposphere comes from the stratosphere, the rest is chemically produced there through oxidation of CO or hydrocarbons in the presence of rich NO_x.

Many stations at various locations measure the concentration of surface ozone. As the seasonal and interannual variations are relatively large, it is difficult to identify a global long-term trend.

6. Carbon Monoxide (CO)

CO is not a greenhouse gas, but brings influences the concentrations of greenhouse gases by affecting hydroxyl radicals (OH). Its concentration in northern high latitudes has been increasing since the mid-19th century. The mean global concentration was 98 ppb in 2002. The concentration is high in the Northern Hemisphere and low in the Southern Hemisphere, suggesting substantial anthropogenic emissions in the Northern Hemisphere.

Although the global concentration of CO was increasing before the mid-1980s, the growth stopped or the concentration decreased after then (WMO, 1999a). There was large fluctuation in the growth rate, however, with high positive rates followed by high negative rates in northern latitudes and southern low latitudes from 1997 to 1999. The growth rates in the Northern Hemisphere increased again in 2002.

Monthly mean concentrations show a seasonal variation with large fluctuations in the Northern Hemisphere and small fluctuations in the Southern Hemisphere. This seasonal cycle is driven by variations in OH concentration which acts as a sink, industrial emissions, biomass burning, and large-scale transportation.

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

Nitrogen oxides (NO_x, i.e., NO and NO_2) are not greenhouse gases, but influence concentrations of important greenhouse gases by affecting 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 large temporal and geographic variability, and it is difficult to identify a long-term trend. In

Europe, NO_2 concentrations are generally higher in southern regions than in northern regions.

8. Sulphur Dioxide (SO_2)

SO_2 is not a greenhouse gas but a precursor of atmospheric sulphate (H_2SO_4) aerosol. Sulphate 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.

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