Summary

This issue of *Data Summary* covers 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 data centre by June 1999 and the periods of observation ranged from 1968 to 1998. This *Data Summary* includes analyses of monthly mean concentrations in global, hemispheric, and zonal averages, and a time series of concentrations at some stations for greenhouse and related gases.

This is the third issue of *Data Summary* that has been published by the WDCGG. In its first issue, 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. This, the third issue, emphasizes global trends and other global aspects while adopting a new method with a digital filter to derive long-term trends and variations. The analyses produced should provide useful information on the change in concentrations of greenhouse and related gases.

For analyses in this publication, only monthly mean concentrations are used. Some stations also report daily and hourly mean concentrations, which may be more appropriate for analyzing variations in various time-scales. But the WDCGG believes that it is better to incorporate more monthly observation data for the analysis by including a large number of stations in the NOAA flask-sampling network.

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

Plates 1 and 2 show variation of 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. Amplitude and phase of the seasonal variation also depend on latitude and vary from year to year. Growth rate is also uneven in latitude and time. These differences in time and space are attributed to variations in emission/production and removal/dissociation of CO_2, CH_4, and other related gases.

Analytical results are summarized for each greenhouse and related gases below:

1. Carbon Dioxide (CO_2)

The level of CO_2, which contributes the most to global warming of all the greenhouse gases, has been increasing since the pre-industrial period. Global mean concentrations reflect an annual increase, and the annual mean concentration was 363 ppm in 1997. Concentrations peak in northern high and mid-latitudes, suggesting strong net sources in these areas.

The global growth rate is 1.5 ppm/year on average for 1983-1997. However, growth rates

vary significantly interannually. The high growth rates in 1983, 1987/1988, 1994/1995, and 1997 are associated with warm events of El Niño-Southern Oscillation (ENSO). The anomalously strong El Niño event in 1997/1998 brought about record-breaking high increases in 1998 at Mauna Loa in Hawaii, U.S.A. and Ryori in Japan. However, the data reported to the WDCGG so far have not proved that such high growth rates will appear worldwide. The exceptionally low growth rates in 1992, including negative values as well 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 low latitudes and the Southern Hemisphere. The northern seasonal cycle mainly reflects seasonal variation in 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 diffusion 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 levels have been increasing since the beginning of the 19th century. Global mean concentrations reflect an annual increase, and the annual average concentration was 1749 ppb in 1998. The annual concentrations produce a peak in the northernmost latitudes and decrease toward the southernmost latitudes, suggesting significant net sources in northern high latitudes.

The global growth rate is 9 ppb/year on average for 1984-1998, 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 exceptionally high global mean air temperature. In the 1990s, CH_4 growth rates varied in parallel with anomalies in 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 transport of CH_4 from the Northern Hemisphere. This phenomenon is seen at stations in the western Indian Ocean and the western to central equatorial Pacific.

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 increased at about 0.7-0.8 ppb/year from 1987 to 1989 in the Northern Hemisphere, and that this long-term increase continued in the 1990s.

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 at 5 %/year or more in the 1970s, 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 long-term trends for CFC-11, CFC-12, CFC-113, 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 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 concentrations of greenhouse gases by interacting with hydroxyl radicals (OH). Concentrations of CO have increased in northern high latitudes since 1850, but did not change significantly over Antarctica during the last two millennia. The annual average concentration was about 90 ppb in 1996. The annual mean concentration is high in the Northern Hemisphere and low in the Southern Hemisphere, suggesting anthropogenic emissions in the Northern Hemisphere.

In the past, the level of CO was increasing but this trend appears to have been reversed in the late 1980s. The average global growth rate was –0.2 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. During the anomalously strong El Niño event in 1997/1998, CO increased significantly at Ryori in Japan. Impacts of the El Niño event in 1997/1998 upon the growth rate for the CO concentration should be further examined by analyzing more data for this period.

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 transport 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 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) in the troposphere, affecting, as a greenhouse gas, the Earth's radiative balance and, by reproducing OH, the oxidization capacity of the atmosphere.

Thirty stations located in Europe have reported NO_x data to the WDCGG. For concentrations of NO_2, a decrease has been seen in Eastern Europe. Generally, NO_2 concentrations are higher in southern regions than in northern regions. Reported data suggests that NO_2 concentrations are low in Northern Europe. It is difficult to identify a long-term trend for NO concentrations.

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.

Thirty-one stations located in Europe have reported SO_2 data to the WDCGG. Generally, in Europe SO_2 concentrations are higher in southern regions than in northern regions. The annual mean SO_2 concentrations in the central and eastern part of Europe were lower in 1997 than in the early 1990s.