7. Carbon Monoxide (CO)

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Carbon monoxide (CO) is not a significant greenhouse gas, as it absorbs little infrared radiation from the Earth. However, it has an influence on oxidization in the atmosphere through interaction with hydroxyl radicals (OH), which react with methane and HCFCs, and eventually brings about changes in concentrations of important greenhouse gases.

CO measurement in ice cores indicates that CO concentration did not change much during the last two millennia over central Antarctica and that it has increased in northern high latitudes in Greenland since 1850 (Haan and Raynaud, 1998). Most of the significant sources and sinks of CO have been identified, but there are large areas of uncertainty in the CO budget (WMO,1999a). Sources of atmospheric CO include fossil fuel combustion and biomass burning along with oxidization of methane and non-methane hydrocarbons (NMHC), both natural and anthropogenic. Major sinks are primarily the reaction with OH and secondly soil uptake. Measurement of carbon isotopic partitioning in CO should provide constraints to reduce uncertainties.

The location map at the head of this chapter shows observation sites that submitted CO data to the WDCGG, including six *in situ* stations and others in the NOAA flask-sampling network.

7.1 Analysis for global, hemispheric, and zonal mean concentrations

Global, hemispheric, and zonal mean concentrations were calculated for the periods from 1992, except for the southern high latitude zone where CO measurement began in 1993. The calculation is based on data from stations with more than 2 years of records that were not seriously affected by the local environment. These stations are located not only in oceanic but also in continental regions.

Figure 7.1 shows monthly mean concentrations and their deseasonalized long-term trend for the globe and both hemispheres from 1992/1993 to 1996. Seasonal variation is seen in both hemispheres. The amplitude of the seasonal cycle is larger in the Northern Hemisphere than in the Southern Hemisphere. The annual global average concentration was about 90 ppb in 1996.

CO concentration increased slightly less than 1 %/year, but this increase appears to have been reversed in the late 1980s (WMO, 1999a). A decrease in CO concentrations was seen globally from 1990 to 1993 based on the data from the NOAA/CMDL flask-sampling network (Novelli *et al.*,1994). Figure 7.2 shows growth rates for the same areas as in Figure 7.1. The average global growth rate over this period (1993-1996) was -0.2 ppb/year. Over this period, the maximum global growth rate was 6 ppb/year in the spring of 1994 and a minimum was -4 ppb/year in the spring of 1995.

Figure 7.3 shows monthly mean concentrations and their deseasonalized long-term trend for each 30-degree latitudinal zone from 1992/1993 to 1996. Deseasonalized long-term trend curves clearly show that concentrations are high in the Northern Hemisphere and low in the Southern Hemisphere, suggesting anthropogenic CO emissions in the Northern Hemisphere. Figure 7.4 shows analytical results of the deseasonalized long-term trend, growth rates, and annual amplitudes of the seasonal cycle. Growth rates were negative in 1992 in all of the latitudes, in 1995 in northern latitudes, and in 1996 in southern latitudes. Positive growth rates are seen from 1993 to 1994 in northern latitudes. Novelli *et al.* (1998) pointed out a clear decline in CO concentrations from late 1991 through mid-1993 and subsequent partial recovery from mid-1993 through mid-1994. The decline in CO concentrations nearly coincides with the decreased growth rate in CH_4 concentrations. Enhanced stratospheric ozone depletion after the eruption of Mt. Pinatubo in 1991 may have increased CO reactions with OH (Dlugokencky *et al.* 1996).

Figure 7.5 draws average seasonal cycles for each 30-degree latitudinal zone. The seasonal cycle of CO is driven by seasonally varying OH concentration that acts as a CO sink, the timing and location of emissions from CO sources, and the large-scale transport of CO. In the absence of human activity, CO concentrations would be controlled largely by the balance between photochemical production and extinction by reaction with OH. Novelli et al. (1998) showed with a model of two boxes representing the well-mixed northern and southern boundary layer respectively that seasonal cycles are strongly affected by changes in emission from biomass burning in both hemispheres. Matsueda et al. (1998) showed with observation data for the upper troposphere that high seasonal CO concentrations in southern low latitudes from October to November were enhanced by tropical biomass burning. Concentrations are at a maximum in February or March in the Northern Hemisphere, and in September or October in the Southern Hemisphere. The timing of the maximum CO concentration is delayed by two or three months from the estimated period of the minimum amounts in OH. This delay is attributed to emissions from industrialization, accumulation of pollutants before spring, and large-scale transport in northern high and middle latitudes, as well as emissions from biomass burning in northern low and southern latitudes. CO concentrations are at a minimum in July or August in the Northern Hemisphere and in February or March in the Southern Hemisphere except in low latitudes. The timing of the minimum CO concentration concurs with the estimated period of maximum OH amounts through photochemical reaction. However, southern low latitudes experience a minimum concentration in May or June, significantly delayed after the estimated period of maximum OH amounts. Emission from biomass burning in the Northern Hemisphere and large-scale transport across the equator may cause its delay.

7.2 Analysis of individual stations

Time-series analysis was also used at stations representing global or regional situations: Point Barrow (Alaska, U.S.A.), Mauna Loa (Hawaii, U.S.A.), Cape Grim (Tasmania, Australia), the South Pole (Antarctica), Hohenpeissenberg (Germany), and Ryori (Japan). Figure 7.6 shows, for each station, a time-series of monthly mean concentrations, the deseasonalized long-term trend, growth rates, and amplitudes of the seasonal cycle and months with maximum and minimum values for each year. Figure 7.7 draws a detrended average seasonal cycle for each station. Negative growth rates prevailed until 1996 as a whole at Point Barrow, Mauna Loa, Cape Grim, the South Pole, and Ryori. Ryori experienced a distinct positive growth rate in 1997/1998 when an anomalously strong El Niño event occurred. However, the WDCGG has received no data for this period from other stations. Impacts of the El Niño event in 1997/1998 upon the growth rate in CO concentrations should be further examined by analyzing more data for this period. The amplitude of the seasonal cycle is large at Point Barrow, Ryori, and Hohenpeissenberg, while small at Cape Grim and the South Pole.