2. Analysis

The WDCGG collects, archives and distributes observation data regarding concentrations of greenhouse gases, and provides analytical results on the collected data.

This publication presents long-term trends and seasonal variations in concentrations of CO_2, CH_4 and CO derived for the global, hemispheric and zonal means. For N_2O, halocarbons, surface O_3, NO_x and SO_2, only time series of monthly mean concentrations are presented because only a small number of stations have so far reported observation data.

The method of analysis for CO_2, CH_4 and CO is explained in the following sections. The respective chapters should be referred to for the other parameters.

2.1 Site selection for global, hemispheric and zonal mean concentrations

As ground-based stations observe air at a lower boundary layer, the measured concentrations of gases, such as CO_2, CH_4 and CO, which have sources and/or sinks on the earth's surface, may sometimes show localised characteristics in a lower boundary layer depending on weather conditions, etc.

These data incorporate very useful information for investigating the power of local sources and sinks. However, but for the purpose of global scale analysis, it is necessary to use data that can be considered as representative concentrations averaged over a reasonable geographical area and in a whole boundary layer, i.e., background data. Background data can usually be extracted from all the data through some selection criterion, which are chosen for each site.

In this study, observation sites that were considered to offer data appropriate for the purpose were selected. In some cases, *e.g.*, where the observatory was in a marine area, even data without any selection criterion may be regarded as background data. In contrast, in other cases where the observatory was located in woodland or near a populated city, it may be difficult to select background data.

Final site selection was conducted objectively as follows, based on data in a reasonable scattered range of all the data in the same latitudinal zone. The latitudinal distribution of the annual mean concentrations normalised to the South Pole, which were calculated from the monthly mean concentrations, was fitted with the loess model curve (Cleveland *et al.*, 1988). Sites with concentrations lying more than $\pm 3\sigma$ from that curve were rejected and this process was iterated until all of the remaining sites lay within $\pm 3\sigma$ from the fitted curve. The selected sites are listed in Plate 2 for CO_2 and Plate 4 for CH_4, with asterisks.

2.2 Trend analysis

A time series of greenhouse gas concentrations, which is often produced by removing local effects with very short-term variations, represents integration of variations on different time scales. The two major components of variation in CO_2 concentration are seasonal variations and

long-term trends. Many researchers have attempted to decompose observation data into these two components by objective curve fitting (Keeling *et al.*, 1989), digital filtering (Thoning *et al.*, 1989: Nakazawa *et al.*, 1991) or both (Conway *et al.*, 1994: Dlugokencky *et al.*, 1994).

In the present study, trend analysis approximating variations in the sum of seasonal variations by Fourier harmonics and long-term trends by low-pass filtering with a cut-off frequency of 0.48 cycles/year was performed for each selected site. Refer to the previous Summary (WDCGG No. 22) for details.

2.3 Estimation of value for periods without data for zonal mean calculation

The number of sites used for the trend analysis outlined above varied during the analysis period. Moreover, exclusion of data because of pauses in the observation occurred frequently. When the calculations are performed without considering changes in the number of the sites used in the analysis, the values, such as the zonal growth rate, fluctuate with the change in the number of available sites. These fluctuations were particularly evident in the early period when few sites were available.

If, to avoid this problem, we select only those sites for which there is data throughout the whole analysis period, the data from many newly established sites will not be reflected in the analysis. To use as many sites as possible and to avoid the gaps accompanying changes in the number of sites, the estimated values for the periods for which there were no data were included in the calculation of the zonal mean. The values were estimated by interpolation and extrapolation as follows.

First, the sites requiring interpolation were selected. A provisional seasonal variation was calculated from the longest consecutive data for each site with all the same Lanczos filters (Duchon, 1979) as in the previous Summary. Then, linear interpolation was performed for the data from which the provisional seasonal variation was subtracted. The complete variation was then retrieved by adding the provisional seasonal variation.

Next, the sites requiring extrapolation were selected. The provisional long-term trend and the seasonal variation were calculated from the interpolated data set with the same filter. Extrapolation was then performed for the long-term trend as its growth rate traces the zonal mean growth rate calculated from those of the other sites in the same latitudinal zone. Subsequently, the complete variation was retrieved by adding the site's own provisional seasonal variation. Here, each zone was created every 30° of latitude.

The zonal mean concentrations were calculated from the continuous data set, derived in the above procedure, by determining the arithmetic mean for the sites included in each latitudinal zone for every 20° or 30°. The zonal mean in the early stage of the analysis period may have lower accuracy than that in the latest stage. Although the data sets were partly estimated, the completeness of data was assumed to be advantageous for trend analysis of the zonal mean.

2.4 Calculation of global and hemispheric means

Global and hemispheric means were calculated by averaging the zonal means, taking into consideration the area ratio of each latitudinal zone.

The deseasonalised long-term trend and growth rate for the globe, both hemispheres and each latitudinal zone were calculated again with the filter from the global, hemispheric and zonal means. To derive the trend for the whole period, we assumed provisional data extending from both ends following the linear trend for the whole period. Therefore, it is necessary to be aware that analyzed trends at both ends may depart from the actual values.

Here, we summarize the characteristics of global, hemispheric and zonal mean concentrations by presenting the time series of monthly mean concentrations, deseasonalised long-term trends, annual growth rates and the averaged seasonal cycle.