2. Analysis

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

In this publication, long-term trends and seasonal variations in concentrations of CO_2, CH_4 and CO are derived for the global, hemispheric and zonal mean as well as for several stations representing global or regional situations. For N_2O, halocarbons, NO_x and SO_2, only time series of monthly mean concentrations are presented because 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. For the other parameters, please refer to the respective chapters.

2.1 Calculation method of the time series of global, hemispheric and zonal mean concentrations of CO_2, CH_4 and CO, and their growth rates

2.1.1 Site selection

Since ground based stations observe air in a lower boundary layer, the measured concentration for gases, which have sources and/or sinks on the earth surface, such as CO_2, CH_4 and CO, may sometimes show localized characteristics in a lower boundary layer depending on weather conditions, etc.

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

In this analysis, those observation sites, which are considered to offer data appropriate for the purpose, are selected. In some cases, where the observatory is in a marine area, for example, even the data without any selection may be regarded as background data. On the contrary, in other cases where the observatory is located in woodland or near a populated city, it may be difficult to select background data.

Final site selection was conducted manually on the basis of data being settled into a reasonable scattered range of all the data in the same latitudinal zone. The selected sites are listed in Plate 2 for CO_2, and Plate 4 for CH_4, with asterisks.

2.1.2 Trend Analysis

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

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

In this publication, the trend analysis which approximates the variation in the sum of seasonal variation by the Fourier harmonics and a long-term trend by a low pass filter having a cut-off frequency of 0.48 cycle/year is performed for every selected site. Please refer to the previous Summary (WDCGG No. 22) for details.

2.1.3 Estimation of value for the period of no data for zonal mean calculation

The number of the sites used for the above-mentioned trend analysis varies within the analysis period. Moreover, cutting of the data because of a pause in the observation is often seen. In the previous Summaries, since the calculations were made without taking into consideration of the change in the number of the sites used in the analysis, the analysis values such as the zonal growth rate have fluctuated with the change in the number of sites. Especially, in the early period when there were few sites, these fluctuations were particularly evident.

If we select only the sites which have the data throughout the whole analysis period in order to avoid this problem, the data of many newly established sites cannot be reflected in the analysis. In order to use as many sites as possible and to avoid the gaps accompanying changes in the number of sites, the estimated values for the period of no data were included in the calculation of the zonal mean. The value was estimated in accordance with the interpolation and extrapolation procedures as follows:

First, the sites requiring interpolation are picked out. A provisional seasonal variation is calculated from the longest consecutive data for each site with all the same Lanczos filters as in the previous Summary. And then, linear interpolation is conducted for the data from which the provisional seasonal variation was subtracted. Then, complete variation is retrieved by adding the provisional seasonal variation.

Next, the sites requiring extrapolation are picked out. The provisional long-term trend and seasonal variation are calculated with the same filter from the interpolated data set. Then, extrapolation is conducted 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. After that, the complete variation is retrieved by adding the site's own provisional seasonal variation. Here, each zone is divided every 30 degrees of latitude.

As a result, the zonal mean in the early stage of the analysis period may have less accuracy than that in the latest stage. Although the data sets are partly estimated, the completeness of data succession has a great advantage for the trend analysis of the zonal mean.

2.1.4 Calculation of global, hemispheric and zonal mean

The deseasonalized long-term trend curve and growth rate are calculated with the filter again from the continuous data set derived by the above-mentioned procedure. In order to derive trend curve for whole period, we assume provisional data that extent from the both ends following linear trend for whole period. So, we must be aware that analyzed trend at the both ends may depart from the actual one.

The zonal mean of concentrations are calculated by performing an arithmetic mean for the sites included in each latitudinal zone for every 20 degrees or 30 degrees. Global and hemispheric means are calculated by averaging the zonal means, taking into consideration of the area ratio of each latitudinal zone.

This publication summarizes the characteristics of global, hemispheric and zonal mean concentrations by presenting the time series of monthly mean concentrations, the deseasonalized long-term trend curve and the time series of annual growth rates.