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. For N_2O, halocarbons, surface O_3, 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, the respective chapters should be referred.

2.1 Site selection for global, hemispheric and zonal mean concentrations

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 geographical 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 objectively as follows on the basis of data being settled into a reasonable scattered range of all the data in the same latitudinal zone. The latitudinal distribution of the annual mean concentrations normalized to the south pole which were calculated from the monthly mean concentrations was fitted with loess model curve (Cleveland *et al.*, 1988). The sites with concentrations lying more than $\pm 3\sigma$ from that curve were rejected and this process was iterated until all the remained sites lay in $\pm 3\sigma$ 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, 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 a 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. The previous Summary (WDCGG No. 22) should be referred for details.

2.3 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. When the calculations are made without taking into consideration the change in the number of the sites used in the analysis, the analysis values such as the zonal growth rate fluctuate with the change in the number of available sites. Especially, in the early period when there were few sites available, these fluctuations are 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 (Duchon, 1979) as in the previous Summary. And then, linear interpolation is conducted for the data from which the provisional seasonal variation was subtracted. Then, the complete variation is retrieved by adding the provisional seasonal variation.

Next, the sites requiring extrapolation are picked out. The provisional long-term trend and the 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 created every 30 degrees of latitude.

The zonal mean concentrations are calculated from the continuous data set, which are derived in the above-mentioned procedure, by performing an arithmetic mean for the sites included in each latitudinal zone for every 20 degrees or 30 degrees. 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 are partly estimated, the completeness of data succession is assumed to have a great advantage for the trend analysis of the zonal mean.

2.4 Calculation of global and hemispheric mean

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

The deseasonalized long-term trend and growth rate for the globe, both hemispheres and each latitudinal zone are calculated with the filter again from the global, hemispheric and zonal means. In order to derive trend for whole period, we assume provisional data that extend 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.

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, the annual growth rates and the averaged seasonal cycle.