

The CO₂ Content of the Upper Polar Troposphere between 1963–1979

WALTER BISCHOF

Atmospheric CO₂ has been measured from aircraft in the troposphere and lower stratosphere since 1963 (Bischof and Bolin, 1966; Bolin and Bischof, 1970; Bischof, 1973; Bischof, 1977). This data summary is concerned with the upper troposphere from where 1300 samples are available, which is about 30% of the total. Measurements have been made on flights over Scandinavia and on routes between Scandinavia and California via central Greenland. The upper troposphere may be considered to be reasonably well mixed at altitudes between 8 km and the tropopause, this data set is representative of the north polar atmosphere well above the local and regional influences due to the distribution of land and sea at the earth's surface.

All data are related to the Scripps 1959 manometric scale (Keeling *et al.*, 1976) and are based on stable standard gas concentrations (Bischof, 1977). To compare the present data set with those from Mauna Loa and the South Pole, which are included in this volume, a correction is necessary, due to the different gas standards being used. According to Keeling *et al.* (1976) this correction is estimated to be

$$3.71 + 0.03 \Delta C$$

where ΔC is the departure from 310 ppm. A correction for the possible slow drift of the reference gases at Scripps has not been applied.

The data (i.e. sample means for each individual flight) are plotted in Figure 1a. They can be described by means of a seasonal variation, which can be approximated by a Fourier expansion, and a trend given by a polynomial of fifth order

$$C_t = C_0 + a_1 t + \dots + a_5 t^5$$

where $t = 0$ for the middle of 1963 and

$$\begin{aligned} C_0 &= 316.7 \text{ ppm} \\ a_1 &= 7659.0 \quad \times 10^{-4} \\ a_2 &= -1362.7 \quad \times 10^{-4} \\ a_3 &= 390.34 \quad \times 10^{-4} \\ a_4 &= 33.01 \quad \times 10^{-4} \\ a_5 &= 0.905 \quad \times 10^{-4} \end{aligned}$$

Contribution No. 417 of the Department of Meteorology, Univ. of Stockholm.

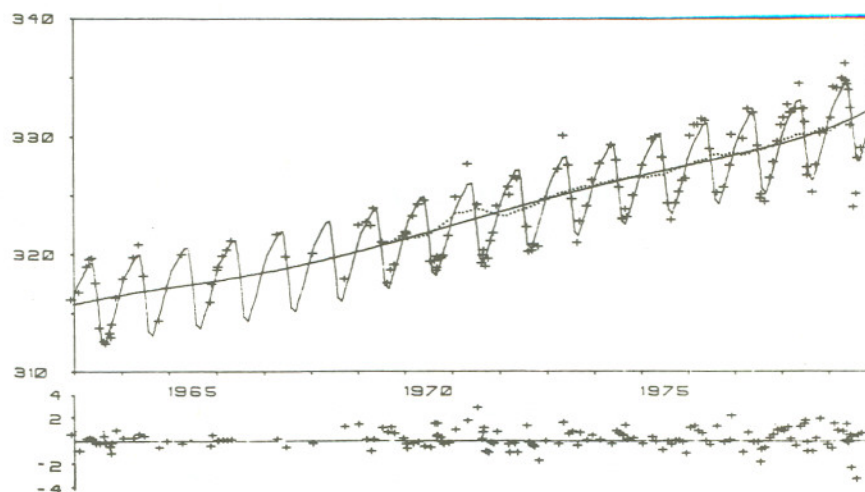
PPMV CO₂

Figure 1: Upper troposphere data

- a sample means (crosses), computed trend with and without seasonal variation (full lines),
 12 month running mean (dotted curve),
 b deviation between observed and analytically deduced values.

The full curves in Figure 1a give the CO₂ variations smoothed in the above way including and excluding the seasonal variations. In addition from 1969, data are numerous enough to permit the determination of a 12-month running mean, which is shown as a dotted curve in Figure 1A. However, because there are some observational gaps, the running mean may be somewhat uncertain. Thus the increase during the first half of 1971 may be erroneous, since data from February, March and May of that year are missing. We also show (Figure 1b) the deviations between the observations and the analytically deduced values. The mean square root deviation is 0.83 ppm, which shows real variations, since the variability of individual samples around the mean for a single flight is only 0.43 ppm.

It is also of interest to compare how the mean annual increase as computed analytically compares with those directly computed from observations, Figure 2. In view of the magnitude of the departures, it is likely that most of them are real.

Table 1 summarizes the annual averages of the data for the period 1963–1979 and Table 2 shows the average seasonal variation observed during this same period.

Table 1: Average carbon dioxide concentration in the north polar upper troposphere (1963–1979) computed from annual averages and by analytical smoothing.

Year	Observational averages ppm	Analytical smoothing ppm
1963	316.2	316.17
1964	317.0	316.84
1965	317.2	317.42
1966	318.0	318.05
1967	318.5	318.80
1968	320.0	319.69
1969	320.97	320.72
1970	321.73	321.84
1971	323.00	323.01
1972	323.93	324.17
1973	325.59	325.28
1974	326.52	326.31
1975	327.05	327.26
1976	328.50	328.18
1977	329.13	329.16
1978	330.32	330.35
1979	(331.8)	(331.99)

To permit a comparison between these data and those given by Keeling and Bacastow (this volume) a correction should be added to the values given in the table above. According to Keeling *et al.* (1976) this correction is estimated to be $3.71 + 0.03 \Delta C$ where ΔC is the departure from 310. ppm.

Table 2. Mean seasonal variation in the north polar upper troposphere 1963–1979.

Month	Departure from annual average ppm
Jan	1.01
Feb	1.69
March	2.23
April	2.77
May	3.34
June	2.33
July	-1.55
Aug	-4.06
Sep	-3.51
Oct	-2.49
Nov	-1.50
Dec	-0.29

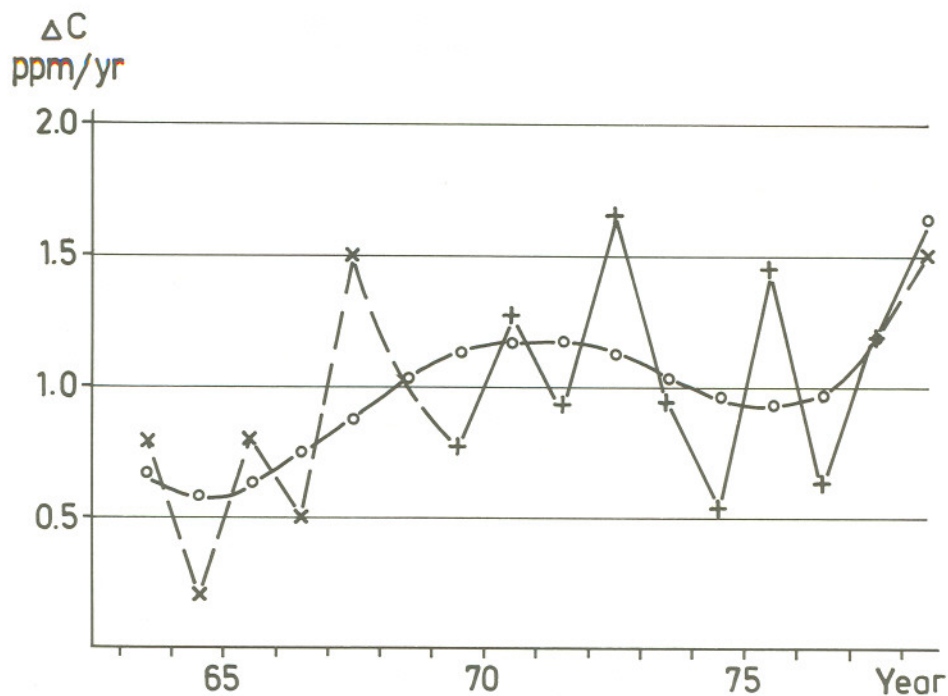


Figure 2: Annual increase rates.

Comparison between values computed analytically (circles) and from observations (+ from annual means, x interpolated from years having somewhat inadequate data coverage).

REFERENCES

- Bischof, W (1973). Carbon dioxide concentration in the upper troposphere and lower stratosphere, Part 3. *Tellus*, 25, 305-308.
- Bischof, W. (1977). Comparability of CO₂ measurements. *Tellus*, 29, 435-444.
- Bischof, W. and B. Bolin, (1966). Space and time variations of the CO₂ content of the troposphere and the lower stratosphere, *Tellus*, 18, 155-159.
- Bolin, B. and W. Bischof, (1970). Variation of carbon dioxide content of the atmosphere in the Northern hemisphere. *Tellus*, 22, 431-442.
- Keeling, C.D., Adams, J., Ekdahl, C.A. Guenther, P.R. (1976). Atmospheric carbon dioxide variations at Mauna Loa. *Tellus*, 28, 538-000.