Variations in concentration of carbon dioxide in the free atmosphere[1]

By WALTER BISCHOF, *International Meteorological Institute in Stockholm.*

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ABSTRACT

Variations of carbon dioxide in the atmosphere have been investigated by the analysis of 186 flask samples taken from an airplane at heights up to 3 km during the period 1957 to 1961. The carbon dioxide concentration changes considerably from one time to another. Above 1000 m the range is 308 to 320 ppm, the average 314 ppm. The range and average both increase towards the ground. A seasonal variation in concentration is noted. The amplitude of the variation decreases with increasing height above the ground. The minimum occurs in summer and the maximum in the winter at all altitudes. Some of the seasonal variations at ground level as previously obtained from the Scandinavian network for carbon dioxide sampling do not show up in the analyses from upper levels.

Variations of the carbon dioxide concentration of the atmosphere are most pronounced in the lowest layers of the atmosphere. This is the result of the fact that the sources and sinks of carbon dioxide in the atmosphere, assimilation and respiration of vegetation and fossil fuel combustion are located at the surface of the earth. Due to turbulent mixing in the lowest layers of the atmosphere an exchange with upper levels takes place. Due to the mixing with uncontaminated air at upper levels variations of the carbon dioxide content should decrease with elevation above the ground. The variations observed at the surface of the earth show both regular seasonal variations and irregular fluctuations. Presumably conditions are similar at upper levels as is also indicated by the observations carried out by KEELING (1960). In order to understand better both the effect of existing sources and sinks for carbon dioxide in the atmosphere as well as turbulent motions of the atmosphere itself on the carbon dioxide concentration at anyone point at anyone time in the atmosphere it is particularly interesting to study both the regular and irregular fluctuations of the carbon dioxide concentration of the atmosphere as a function of elevation.

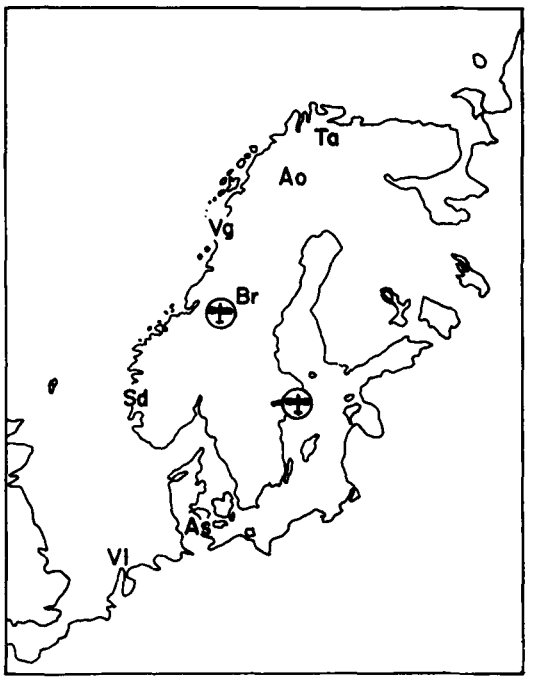

Fig. 1. Stations for sampling of atmospheric carbon dioxide. Stations for flight samples in the mountain district and Stockholm are shown by airplane in circle. The addition stations are from the Scandinavian ground station net (FONSELIUS, 1958).

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TABLE 1.

Height km	Number of measure-ments	Lower and upper limit of concen-tration CO_2 ppm	Average of all values ppm
0 -0.2	51	306–340	318
0.2–0.4	31	300–329	316
0.4–0.6	19	305–327	314
0.6–0.8	10	304–325	314
0.8–1.0	13	305–322	315
1.0–1.2	12	309–320	313
1.2–1.4	5	309–318	312
1.4–1.6	12	309–321	316
1.6–1.8	9	308–319	312
1.8–2.0	4	307–319	315
2.0–2.2	7	308–320	314
2.2–2.4	—	—	—
2.4–2.6	3	310–319	315
2.6–2.8	4	310–317	312
2.8–3.0	6	308–320	315
1.0–3.0	62	307–321	314

In order to study this vertical distribution of carbon dioxide air samples were collected with an airplane in 250 and 500 ml gas burettes during the period of 1957 to 1961. In 1957 and 1958 samples were analysed by a chemical method (FONSELIUS *et al.*, 1955), with an accuracy of about ±5 ppm. Most of the samples, however, were taken during the period 1959 to 1961 and were analysed by an infra-red gas analyser of type IRGA (FONSELIUS and WÄRME, 1960) with an accuracy of about ±2 ppm. Samples were taken near Stockholm in the middle of the day at locations at least 50 km windward of the city and a few were taken in a mountain district at abut 63° lat. (Fig. 1).

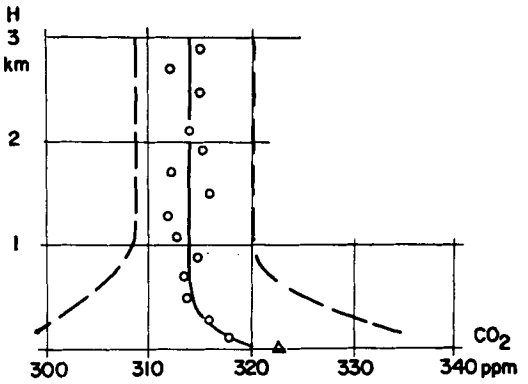

Fig. 2. Maximum, minimum and average concentrations of atmospheric carbon dioxide as a function of height over Scandinavia, 1957 to 1961.

The data, grouped into 200 m height intervals, are given in Table 1. Minima, maxima and average concentrations of carbon dioxide corresponding to each interval are also shown in Fig. 2. The average value for the ground concentration has been taken as the mean of the yearly average values of the Scandinavian network over the period 1957 to 1960 (BISCHOF, 1960). The average and range both decrease with height to about 1000 meters above the ground.

Examples of different types of vertical distribution of carbon dioxide are given in Figs. 3–5. Both positive and negative gradients have been observed. Indeed, both have been found during the same month. Examination of the data reveals a greater frequency of occurrence of negative gradients during the period of observation. Added evidence of the excess of negative over positive gradients is shown by

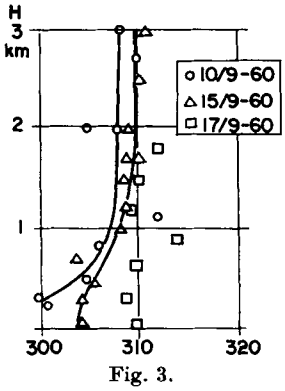

Fig. 3.

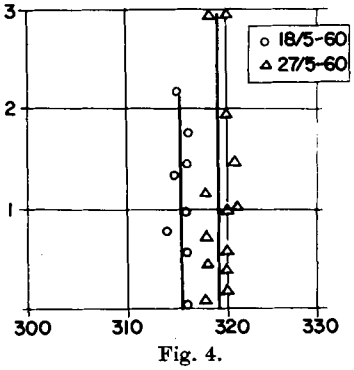

Fig. 4.

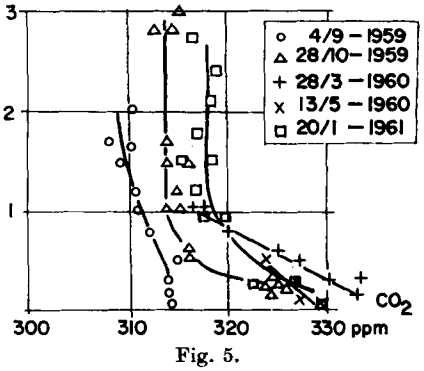

Fig. 5.

Fig. 3–5. Examples showing different tendencies in the vertical distribution of carbon dioxide.

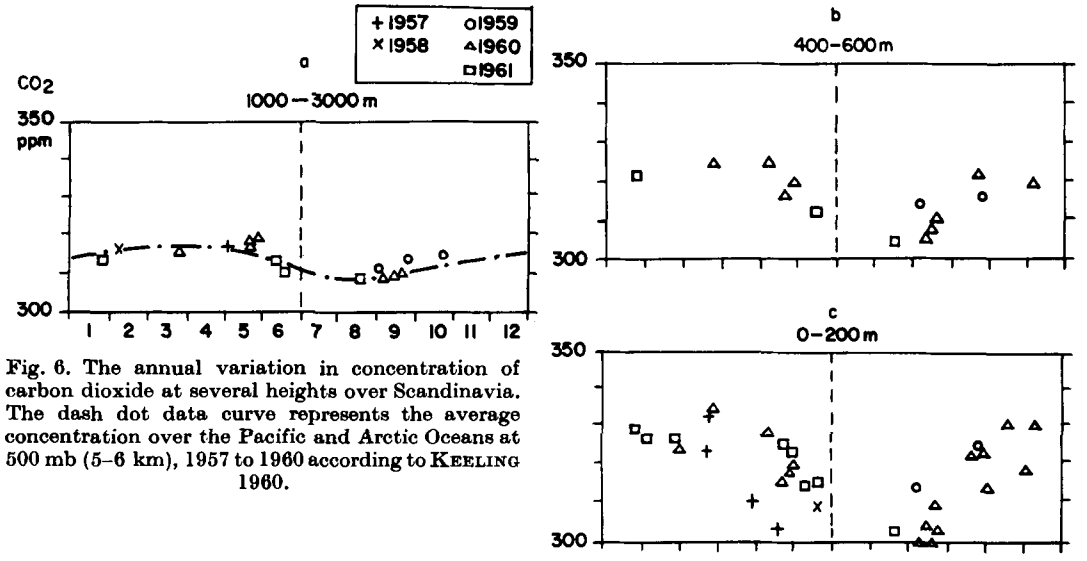

Fig. 6. The annual variation in concentration of carbon dioxide at several heights over Scandinavia. The dash dot data curve represents the average concentration over the Pacific and Arctic Oceans at 500 mb (5–6 km), 1957 to 1960 according to KEELING 1960.

the fact that the average of all observations also results in a negative gradient (Fig. 2). This shows that the ground acts as a carbon dioxide source and due to turbulent motions in the lowest layer of the atmosphere a transfer of carbon dioxide takes place towards higher levels.

The annual variation in concentration of carbon dioxide at several levels is shown in Fig. 6. The values plotted in this figure are averages from available airplane samples for each height interval. The amplitude of seasonal variation clearly decreases with height. The values from the uppermost layer are in agreement with the data given by KEELING (1960) for the 500 mb level (5 to 6 km) above the Pacific and Arctic Oceans.

A comparison between the annual variation as given in Fig. 6 and the corresponding variations at ground level as obtained from the Scandinavian project (for the years 1955–59, see BISCHOF (1960) and for 1960, see Fig. 7) reveals similarities but also some marked differences particularly during the winter. This is probably due to local influences and some lack of representativeness of the ground stations. It clearly shows that a study of the annual cycle of carbon dioxide in the atmosphere as well as of possible long periodical trends requires either upper air sampling or a very careful selection of sampling sites.

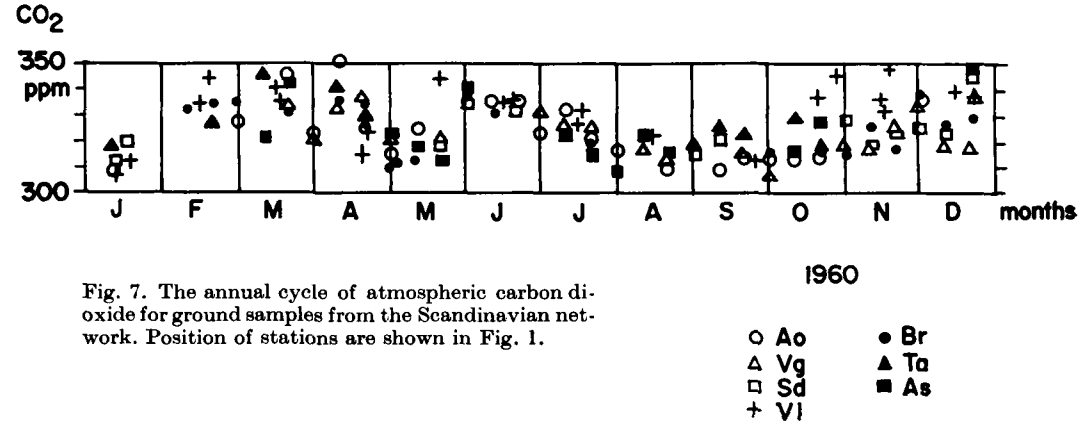

Fig. 7. The annual cycle of atmospheric carbon dioxide for ground samples from the Scandinavian network. Position of stations are shown in Fig. 1.

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