SHORTER CONTRIBUTION

Carbon dioxide concentrations in the upper troposphere and lower stratosphere. I[1,2]

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The content of CO_2 of the atmosphere is not constant, but changes somewhat as a result of seasonal processes at the earth's surface owing to assimilation in vegetation and combustion of organic matter (KEELING, 1960) (BISCHOF, 1962). CO_2 has, however, conservative characteristics and can therefore be suitably used as a tracer for study of mixing and transport processes in the atmosphere (BOLIN & KEELING, 1963). From the accumulated global data material of BOLIN & KEELING with samples up to the 500 mb level it can be seen how extensive parts of the troposphere are affected by the

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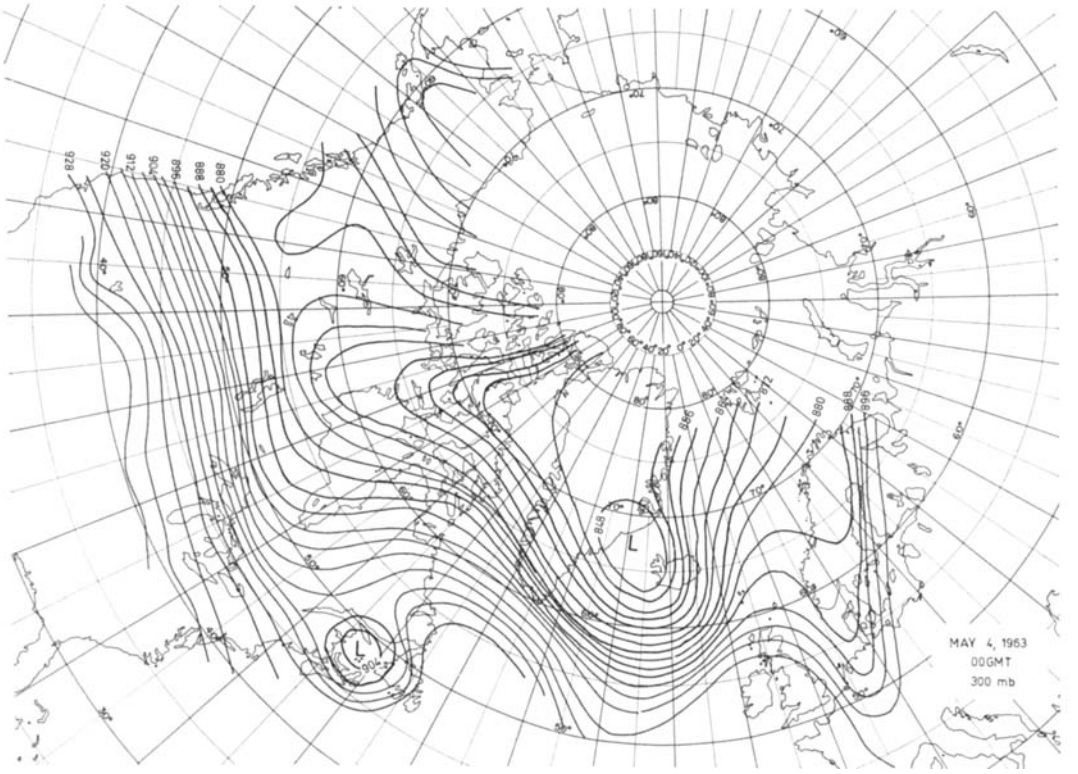

FIG. 1. 300 mb chart 00 GMT, May 4, 1963.

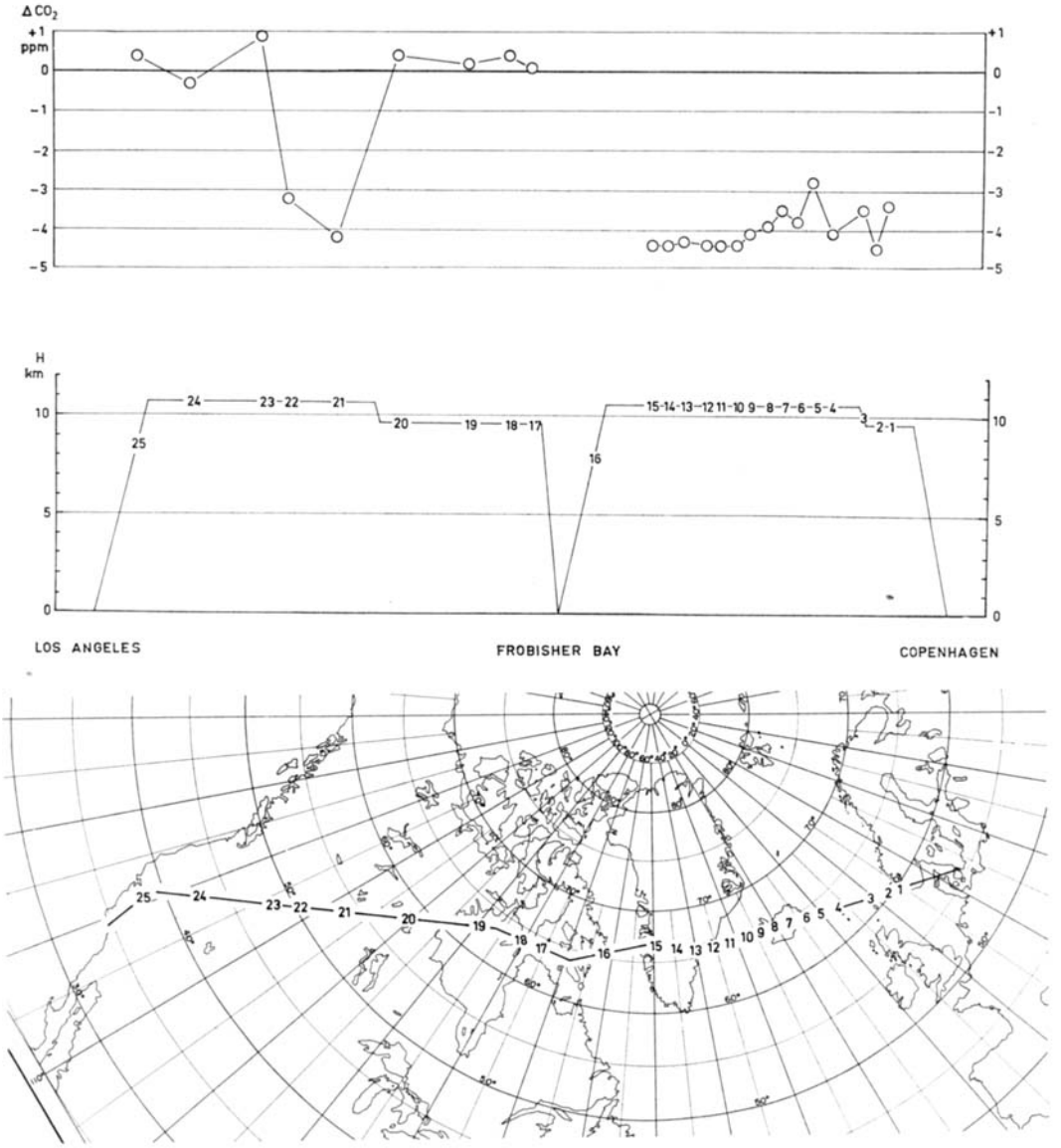

FIG. 2. The route of the flight of May 3, 1963, 00 to 13 GMT, between Copenhagen and Los Angeles, location of sampling and analysis data. CO_2 values in relation to a constant base value, see text.

CO_2 processes at the earth's surface. The measurements reported in this note as well as other recent studies by the author show that this effect extends up to the tropopause at least within the northern hemisphere.

In order to demonstrate the role of the tropopause as a damping layer for vertical exchange, some data from a flight between Copenhagen and Los Angeles, May 1963, where the spot values of the CO_2 content were taken around the tropopause level, will be presented. As seen from the 300 mb map shown in Fig. 1 and the route and the level of the flight indicated in Fig. 2, the samples were collected both north and south of the polar jet stream and, as a more detailed analysis shows, were representative of stratospheric and tropospheric air respectively. The route of the flight is shown

TABLE 1

Day 1963	Sample No.	Time GMT	Alitude (m)	Position Lat.	Position Long.	Δ CO_2 (ppm)
Copenhagen–Los Angeles						
3/5	1	00,00	9,700	54.4 N	5.0 E	−3.4
	2	00,15	9,700	60.5	2.2	−4.5
	3	00,30	10,000	61.2	0.5 W	−3.5
	4	01,00	10,700	62.8	6.1	−4.1
	5	01.15	10,700	63.3	9.0	−2.8
	6	01,30	10,700	64.0	12.4	−3.8
	7	01,45	10,700	64.5	15.2	−3.5
	8	02,00	10,700	65.0	19.8	−3.9
	9	02,15	10,700	65.2	23 0	−4.1
	10	02,30	10,700	65.5	27.0	−4.4
	11	02,45	10,700	65.6	30.4	−4.4
	12	03,00	10,700	65.7	34.2	−4.4
	13	03,15	10,700	65.8	40.0	−4.3
	14	03,30	10,700	66.3	43.8	−4.4
	15	03,48	10,700	66.8	47.3	−4.4
	16	04,30	8,000	65.7	61.0	(+2.5)
	17	07,10	9,700	63.9	75.0	+0.1
	18	07,55	9,700	63.9	80.8	+0.4
	19	08,50	9,700	62.7	90.0	+0.2
	20	09,30	9,700	58.0	101.5	−0.6
	21	10,30	10,700	54.0	108.0	−4.2
	22	11,00	10,700	50.7	112.0	−3.2
	23	11,30	10,700	48.5	114.2	+0.9
	24	12,15	10,700	43.0	118.8	−0.3
	25	12,45	8,500	38.0	120.7	+0.4
Los Angeles–Copenhagen						
3/5	26	21,45	10,000	50.0 N	99.0 W	−1.8
	27	23,10	10,300	57.5	87.5	−3.9
	28	23,55	10,300	62.8	72.0	+0.1
4/5	29	03,10	10,700	65.6	35.0	−4.4
	30	04,00	10,700	65.3	25.0	−4.3
	31	04,20	10,700	64.2	14.0	−4.4
	32	04,40	10,700	62.7	6.0	−2.8
	33	05,15	9,400	61.8	0.2 E	−3.7
	34	05,40	9,400	58.2	7.7	−4.4

in Figs. 2 and 3 and is also given in the table. The analyses have been made at the Institute of Meteorology in Stockholm. The accuracy of measurement is about ±0.3 ppm. The CO_2 values quoted in the table are the difference between the respective samples and a constant base value. A comparison with the standards used by BOLIN and KEELING (1963) yields 317.5±1 ppm for this base value. This presentation was chosen because of the less accurate determination of the absolute values which calls for a careful treatment when comparing with other data.

As indicated in Fig. 3 the concentration distribution observed on the flight on May 3 from Copenhagen to Los Angeles seems to have been displaced towards the east one day later, which may be connected with the general motion of the weather systems during the time elapsed between these two flights. Fig. 4 is a summary of all observations including two flights over Scandinavia which were made during the same month. The figure may be considered as a reasonable representation of the vertical distribution of CO_2 over NW Europe and the North Atlantic during this time of the year. The CO_2 concentration is clearly lower close to the earth's surface than in the main part of the

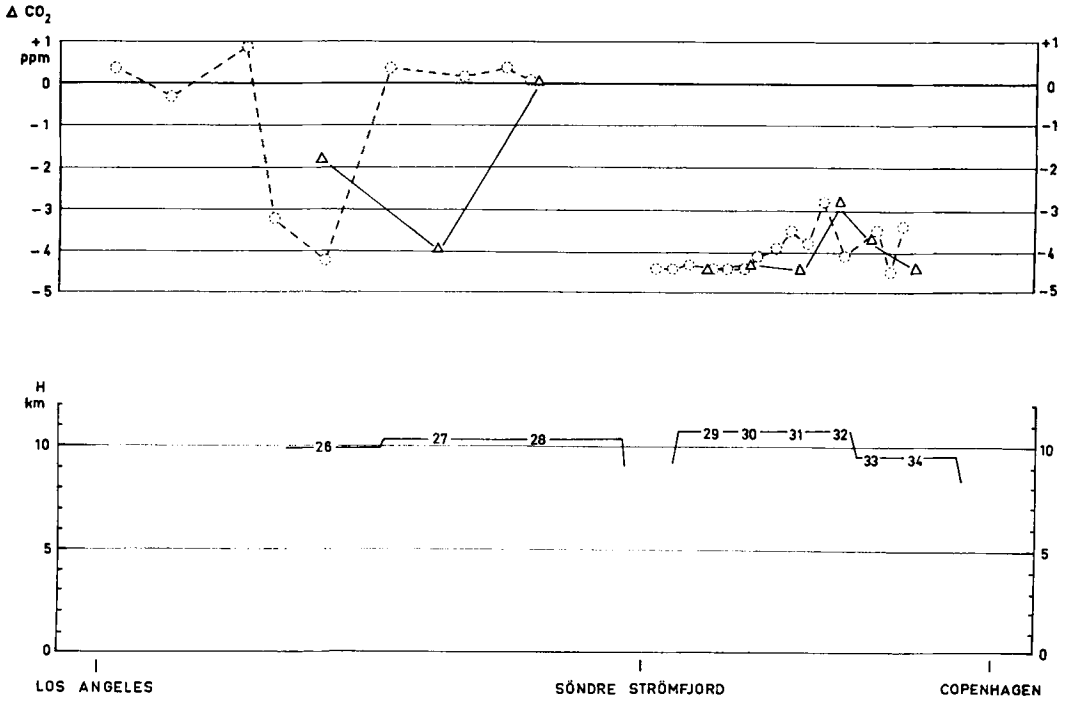

FIG. 3. Flight level and analysis data for May 4, 1963, 21 to 06 GMT, between Los Angeles and Copenhagen. The route of the flight is nearly the same as in Fig. 2. CO_2 values in relation to a constant base value, see text.

troposphere, presumably due to the consumtion by vegetation, which has been going on for a few weeks at this time of the year. The measurements at about 10 km elevation fall in two groups with a difference of approximately 4 ppm in the CO_2 concentration. Almost without exception the samples with a comparatively high concentration have been collected below the tropopause, while those with a low concentration are from the lower stratosphere. Before any general conclusions can be drawn from this marked difference between tropospheric and stratospheric air further measurements during other times of the year and at other latitudes are very desirable. It should for example be remarked that the yearly range of the CO_2 concentration in the troposphere in these northerly latitudes is about 8 ppm (compare BOLIN and KEELING, 1963) and the concentrations in the upper troposphere in the late summer or early fall, when the CO_2 concentration reaches its minimum, may be about 4 ppm less than the value for the stratospheric air as observed here. The seasonal variations of CO_2 in the lower stratosphere therefore probably are much less than in the upper stratosphere.

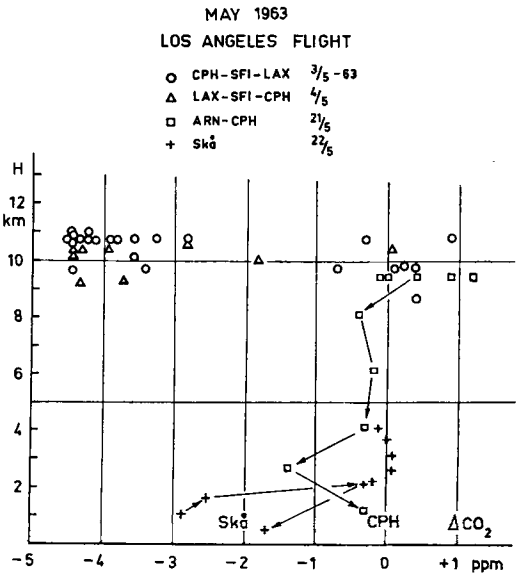

FIG. 4. CO_2 vertical distribution for all values of the Los Angeles flight, with two flights within Scandinavia: May 21, 1963, between Arlanda (Stockholm) and Copenhagen, and May 22 from Skå, in the vicinity of Stockholm.

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