Space and time variations of the CO_2 content of the troposphere and lower stratosphere

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ABSTRACT

Measurements of the CO_2 content in the troposphere and lower stratosphere are presented. The seasonal variations at 5 km, 7 km, 9 km and 11 km at 60° N are shown, at the last to levels both in tropospheric and stratospheric air. A comparison with previous data confirms that an annual increase of the CO_2 content of the atmosphere by 0.7 ppm occurs. Data from the Indian Ocean and the Atlantic Ocean (30° N) are presented.

The present report briefly summarizes the extensive measurements of the CO_2 content of the atmosphere up to about 12 km elevation over the North Polar cap down to about latitude 30° N, off the east coast of the United States and over the Indian Ocean in the vicinity of the Indian peninsula during the winter monsoon, which have been made at the International Meteorological Institute in Stockholm. Some comparisons of these data with those presented by BOLIN & KEELING (1963) are also given.

1. Seasonal variations

Altogether 275 air samples have been collected during flights over Scandinavia, the North Atlantic Ocean, and over polar regions between Copenhagen and Los Angeles and Copenhagen and Tokyo. On the basis of these data monthly mean values for four different altitudes have been computed and Fig. 1 shows the results. For the levels 9 and 11 km two series of values are displayed, one based on data collected when the tropopause is high and when thus these levels are still in the troposphere (open circles and squares), the other obtained from cases when the tropopause is low and these levels are found in the stratosphere (filled circles and squares). Regular seasonal variations are observed within the troposphere with a decreasing amplitude with elevation. While the total range is about 10 ppm (parts per million) at 5 km elevation, it is reduced to about 6 ppm in the uppermost parts of the troposphere. A very remarkable and abrupt change occurs across the tropopause from the troposphere to the stratosphere (compare also BISCHOF, 1965). The data so far available indicate that the seasonal variations in the stratosphere are less than 2 ppm. This undoubtedly is a reflection of the much less intense vertical exchange that occurs in the lower stratosphere as compared with the troposphere. Some care must be exercised in drawing conclusions because synoptic situations with high or low tropopause are for example associated with very definite patterns of vertical velocity. They are, however, presumably similar in summer and winter and therefore the conclusion drawn above still may be a valid one. In view of this preliminary result it would be very desirable to obtain observations the year around from levels which are always located in the stratosphere.

The maximum tropospheric content of CO_2 is observed in May (compare also BISCHOF, 1962; BOLIN & KEELING, 1963), while the minimum occurs in August and September. Possibly a slight delay of the minimum in the upper troposphere as compared with the 5 km level exists, but is by no means ascertained by the data available so far. Observe, however, how the open circles in Fig. 1 systematically lie above the crosses during the summer until

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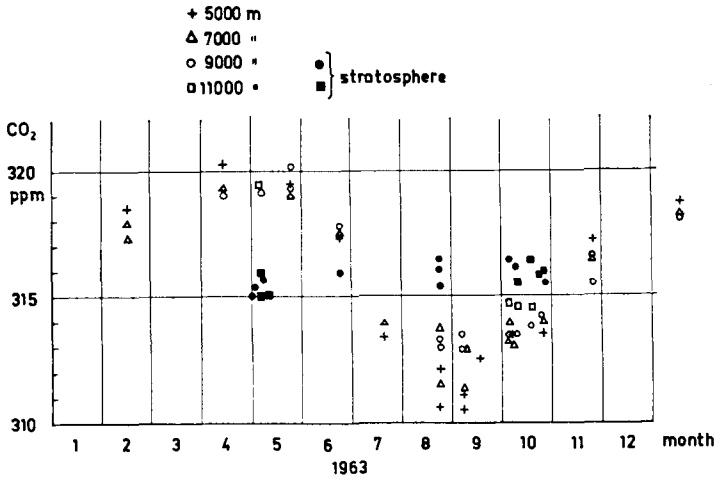

FIG. 1. CO_2 values for the upper troposphere and lower stratosphere during 1963 and 1964. The data have been collected over Scandinavia and on 2–4 May and 6–20 October during flights between Copenhagen and Los Angeles and between Copenhagen and Tokyo respectively.

September, while conditions are reversed during the autumn.

The striking difference between the troposphere and the lower stratosphere is also clearly displayed in the comparison of Figs. 2 and 3, where data collected during the flights Copenhagen–Los Angeles in May 1963 and Copenhagen and Tokyo in October 1963 are shown (BISCHOF, 1965). One notices that even if the monthly mean values for the stratosphere (cf. Fig. 1) do not show any seasonal variations, fluctuations of about ± 1.5 ppm around the mean value occur. These are most likely real, since the accuracy in the individual determinations is about 0.3 ppm.

2. The annual increase of the CO_2 content of the atmosphere

Keeling has shown that an annual increase of the CO_2 content of the atmosphere of about 0.7 ppm seems to occur. The present data verify this conclusion. Fig. 4 shows a comparison

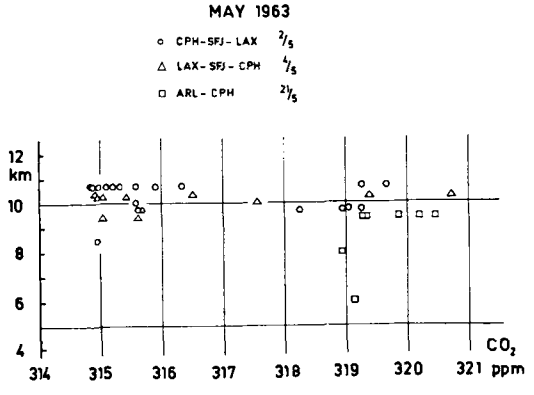

Fig. 2

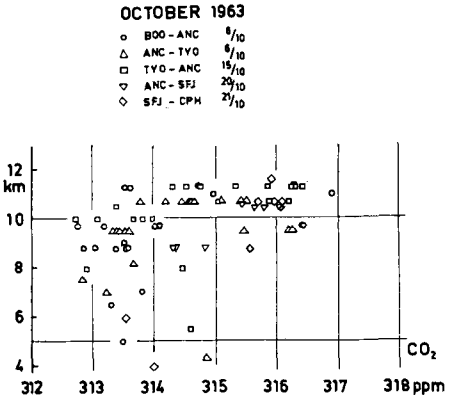

Fig. 3

FIG. 2. CO_2 values obtained during flight between Copenhagen and Los Angeles 2–4 May 1963 (BISCHOF, 1965).

FIG. 3. CO_2 values obtained during flight between Copenhagen and Tokyo via the North Pole and Alaska.

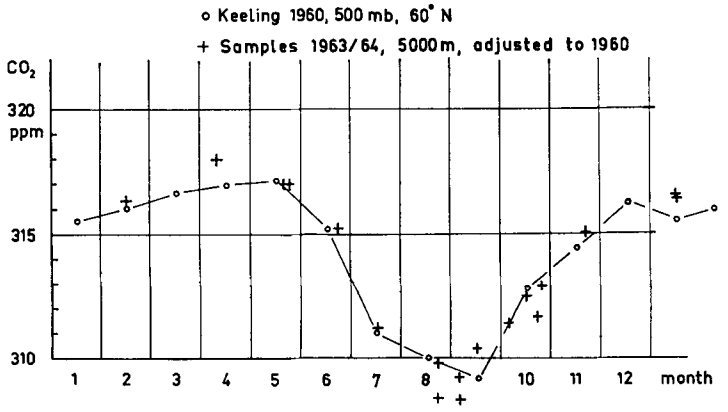

FIG. 4. Comparison between CO_2 data (representative for 1960) collected by Keeling over the Pacific Ocean at 500 mb (BOLIN & KEELING, 1963) and present data (collected 1963–1964) corrected by −2.4 ppm.

of our data from 5 km elevation and Keelings data (BOLIN & KEELING, 1963) from the 500 mb level over the Pacific Ocean. The latter were collected around 1960 and corrected to 1 January 1960, assuming an annual increase of 0.7 ppm, while a value of 2.4 ppm has been subtracted from the present data, which were collected in 1963 and 1964. Since on the average our data were collected 3.5 to 4 years after 1 January 1960, the annual increase has been 0.6–0.7 ppm. Fig. 4 also shows a somewhat larger seasonal variation than those of Keeling which possibly is due to the fact that Scandinavia is closer to the large Eurasian continent.

3. CO_2 content of the atmosphere over the Indian Ocean during the winter monsoon

During February and March 1964 some 200 samples were collected over the Indian Ocean between Bombay and latitude 4° S and between the surface and 4.5 km elevation. In the vicinity of the coast the local air circulation systems as land and sea breezes clearly influenced the values obtained but some flights were made where samples were obtained from air that undoubtedly had spent a long time (a week or more) over oceanic regions. Fig. 5 summarizes most of the data. Most of the values in the lowest 3 km are 322 ± 2 ppm. A few exceptions are, however, observed. Particularly noticeable are the results obtained during a flight at 500 m elevation from Bombay to Gan at latitude 4° S (19 Feb.) (cf. Fig. 6). While flying along the Indian coast rather high CO_2 values were observed, undoubtedly showing the influence of the nearby land mass, since the winds were easterly or north-easterly. The southernmost samples show values between 318 and 320, which is considerably less than any of the concentrations observed during other flights. As the map in Fig. 6 shows, it is likely that these samples represent a different air mass possibly originating from the Southern Hemisphere. The data are clearly insufficient for any definite conclusions but indicate the desirability of obtaining data well to the south of the equator and during the summer monsoon

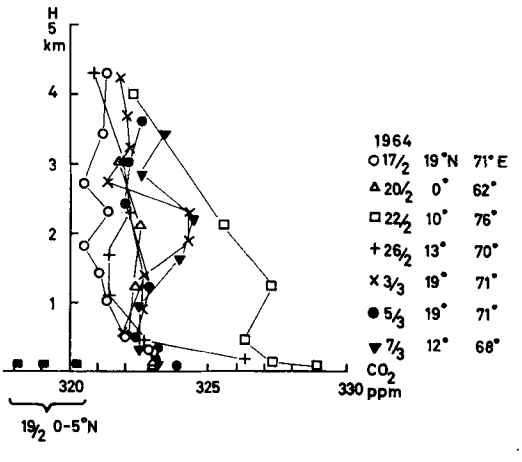

FIG. 5. CO_2 data from the Indian Ocean.

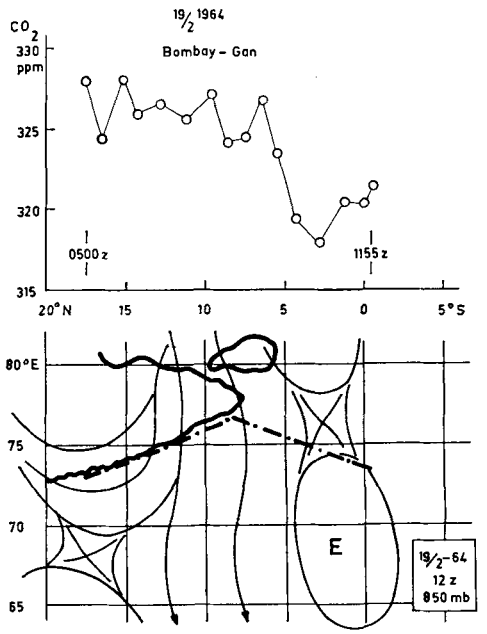

FIG. 6. CO_2 data from a flight at 500 m elevation between Bombay (18° N) and Gan (4° S) 19 February 1964.

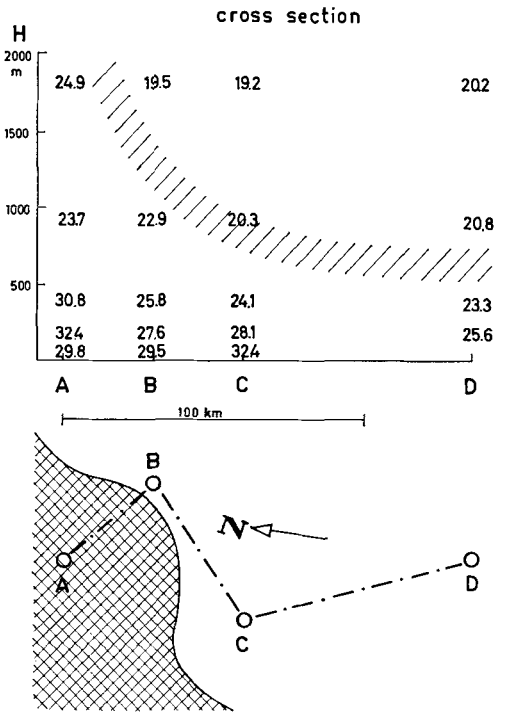

FIG. 7. Cross section from the U.S. Coast eastwards 19 March 1965 showing CO_2 values at five levels between the ocean surface and 2000 m (300 ppm should be added to all given values).

season, when a permanent flow from the southern to the northern hemisphere occurs in these regions of the world.

4. Air mass studies off the East Coast of the United States

About 70 samples have been collected during flights from South Carolina out over the Atlantic Ocean during a synoptic situation in which a moderate north-westerly current brought air from the continent out over the ocean. Simultaneous measurements of other parameters were made in an aim to study the air mass modification. Here only a few preliminary results will be reported. Fig. 7 shows a cross section from the coast (close to point A) south-eastwards. The high CO_2 content in the lowermost parts of the troposphere is very obvious and originates with all likeliness from the release in the soil and from industry on the American continent. The values at higher levels are close to the normal values for the season (cf. Fig. 1). It is interesting to observe the increasing thickness of the contaminated layer as one approaches the continent. Obviously a more detailed study of such distribution during *consecutive* days might yield information of the vertical transfer processes.

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ИЗМЕНЕНИЯ В ПРОСТРАНСТВЕ И СО ВРЕМЕНЕМ СОДЕРЖАНИЯ CO_2 В ТРОПОСФЕРЕ И НИЖНЕЙ СТРАТОСФЕРЕ

Представлены измерения содержания CO_2 в тропосфере и нижней стратосфере. Показаны сезонные изменения на высотах в 5 км, 7 км, 9 км и 11 км при 60° с. ш., причем последние два уровня могли находиться как в тропопаузе, так и в стратосфере. Сравнение с предыдущими данными подтвердило, что имеет место годовое увеличение содержания CO_2 в атмосфере на 0,7 ppm. Представлены данные с Индийского и Атлантического океанов.

Настоящий доклад кратко резюмирует результаты обширных измерений содержания CO_2 в атмосфере до высоты в 12 км над уровнем моря. Эти измерения были выполнены Международным Метеорологическим Институтом в Стокгольме над северным полушарием до 30-й параллели с. ш., а также во время зимнего муссона вблизи западного берега США и окрестности Индийского полуострова. Дано сравнение с результатами, представленными в 1963 г.