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A spectroscopic study of the global space-time distribution of atmospheric CO

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ABSTRACT

The total background atmospheric column of CO was investigated spectroscopically using the Sun as a light source. According to north temperate zone observations of 1970–1976, the content of CO exhibits seasonal variations, it being 1.5 times higher in spring than in late summer. The measurements taken in the Antarctic during four months have also shown the presence of a minimum in the CO content in January and February, i.e., when it is summer in the southern hemisphere. The content of the gas in the north temperate zone in March and April was three times higher and in June and July two times higher than that in the Antarctic. A comparison with the data obtained by Shaw in the U.S.A. in 1952 speaks of an increase in the background content of CO in winter at a rate of about 2% a year and of its remaining constant in summer. Analysis of all the data leads to the conclusion that a noticeable role is played by anthropogenic factors in the cycle of CO in the northern hemisphere in winter and that natural processes prevail in summer.

1. Introduction

The investigation of the background content of atmospheric carbon monoxide (far from the cities) is of sufficiently great interest for a number of reasons. The industrial emission of CO grows on average by 4% a year, its overall production having attained $6.4 \cdot 10^{14}$ g a year by 1971 (Seiler, 1974). Human activity already has appreciably changed the background content of the gas in the northern hemisphere (Dianov-Klokov et al., 1978; Sze, 1977). Meanwhile, carbon monoxide plays an active part in atmospheric photochemistry; an increase in the content of CO may result in increasing tropospheric ozone concentration (Fishman et al., 1979), decreasing OH concentration, which in turn causes increases in CH_4, CH_3CCl_3 and other atmospheric constituents (Crutzen and Fishman, 1977).

The presence of CO in the "clean" atmosphere was first discovered by Migeotte (1949) who identified lines of this gas in the IR spectrum of solar radiation. In the early 1950s a number of authors (Migeotte and Neven, 1952; Locke and Herzberg, 1953; Shaw, 1958) determined from the IR spectra the value of the total content of CO in the vertical column of the atmosphere to be about $2.7 \cdot 10^{18}$ mol/cm^2 or 0.1 atm · cm (the thickness of a layer of the gas reduced to standard conditions: pressure $p_N = 1$ atm, temperature $T_N = 273$ K). Later on the content of CO was investigated mainly by local chemical methods (see a detailed review in Seiler, 1974). Integral (total column) methods using the sun as a light source give directly the space average of gas abundance. This circumstance allows one to reduce the influence of local sources on the results of measurements in comparing with local methods. In recent years integral spectral methods have been used to investigate NO_2 (Noxon, 1978), CO_2 (Brounshtein et al., 1979), HNO_3, freons and other gases (Bradford et al., 1976; Chang et al., 1978).

The aim of the present work is to review the results of measurements of the background abundance of CO by the total column spectral method which were taken mainly by us in the U.S.S.R. as well as by other researchers in Bulgaria and the U.S.A. Combination of these data with available data obtained by local methods allows to construct a model for space-time variations in the integral background content of CO on a global scale.

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2. Methods and observation areas

The IR absorption spectra of the entire thickness of the atmosphere in the spectral range of the fundamental absorption band of CO with a centre of about 4.67 μm were recorded with a diffraction grating spectrometer having a resolution of about 0.2 cm^{-1} (spectral slit-width). As a rule 10 to 20 spectra were recorded during a day, the number reaching 100 on some clear days.

The procedure we used to process the obtained spectra (Pugachyov et al., 1978) is a modified version of Goldberg's (1951) and Shaw's (1957, 1958) procedures. The area within the contour of the spectral line $R(3)$ of the fundamental CO absorption band, W, is measured. The relation between W and the adjusted to sea level total content of the gas in the vertical column of the air, U_z, is give by

$$U_z = \frac{W^2}{A_2 m}, \tag{1}$$

where the air mass is $m = \sec z$, z being the zenith angle of the sun. The A_2 values for different air humidities and temperatures have been obtained by Pugachyov et al. (1978) by processing the absorption spectra of the atmosphere that have been simulated by a computer using the spectral line parameters reported by McClatchey et al. (1973). Shaw (1957, 1958) used the coefficient A_1 (corresponding to our coefficient A_2) calculated analytically for a single line of CO $R(3)$, neglecting adjacent lines, in particular H_2O lines.

The relative error of a single CO content measurement amounted to $\pm$ 18–20%; that of daily mean values, to $\pm$ 12–15%. The abundance of the gas was calculated on the assumption of the CO mixing ratio r being constant regardless of altitude. Pugachyov et al. (1978) have shown that for the CO profiles actually measured in the atmosphere (Seiler, 1974) additional error due to the uncertainty of a profile does not exceed $\pm$ 10% (the content of CO being overestimated when r falls with altitude and underestimated when it rises). Systematic errors due to possible inaccuracies in the values of spectral constants can be discounted as of little significance in comparing data obtained by the same method.

In the case of the background measurements to be discussed, in what follows the standard deviations of individual values from the diurnal means, as a rule, did not exceed $\pm$ 10% (Yurganov and Dianov-Klokov, 1972) and were mainly due to random errors of measurements. Differences in CO content between some adjacent days are more significant, reaching 30–40% (see, for instance, Fig. 3(a)).

Having the integral content of gas U_z, it is easy to calculate an air-pressure-weighted mixing ratio by volume $\bar{r}$ neglecting temperature profile effects:

$$\bar{r} = \frac{\int_0^\infty r(h)\, p_{air}(h)\, dh}{\int_0^\infty p_{air}(h)\, dh} \approx \frac{\int_0^\infty p_{CO}(h)\, dh}{\int_0^\infty p_N \exp\left(-\frac{h}{H}\right) dh} = \frac{U_z}{p_N H}. \tag{2}$$

Here p_{air} is the air pressure; p_{CO}, the partial pressure of CO; h, the height above sea level; H, the height scale of the atmosphere (8.10^5 cm in the present work).

The observation points are shown on the map (Fig. 1). Regular observations were made at the Zvenigorod Research Station (Z.R.S.) of the Institute of Atmospheric Physics (I.A.P.) (Point 1, the coordinates $\varphi \approx 56°$ N, $\lambda \approx 37°$ E, ~200 m above sea level) from 1970 to 1976. The station is situated in a rural area 50 km to the west of the centre of Moscow and 5 km from Zvenigorod, a small nonindustrial town. In 1972–1975 there were a number of expeditions in the different regions of the U.S.S.R. (Points 2–8), and in 1978 there was one in Bulgaria (Point 9).

Under sea conditions measurements were taken in March–April 1976 abord the motorship *Mikhail Kalinin* en route from the Antarctic to Riga (half-blacked squares); in November 1977 aboard the motorship *Bashkiria* en route from Odessa to the Antarctic (empty squares) and in May–June 1978 aboard the research ship *Mikhail Somov* en route from the Antarctic to Leningrad (black squares). From December 1977 to April 1978 observations were made in the Antarctic continent (the *Molodyozhnaya* station, Point 10). When analyzing the results use was made also of column measurement data reported by Shaw (1958) (Columbus, Ohio, U.S.A.; Point 11) and by Bogdanov et al. (1979) (Sofia, Bulgaria; Point 12) as well as those relating to local measurements of the background CO mixing ratio by the mercury oxide chemical methods in Hawaii (Point 13) (Seiler et al., 1977).

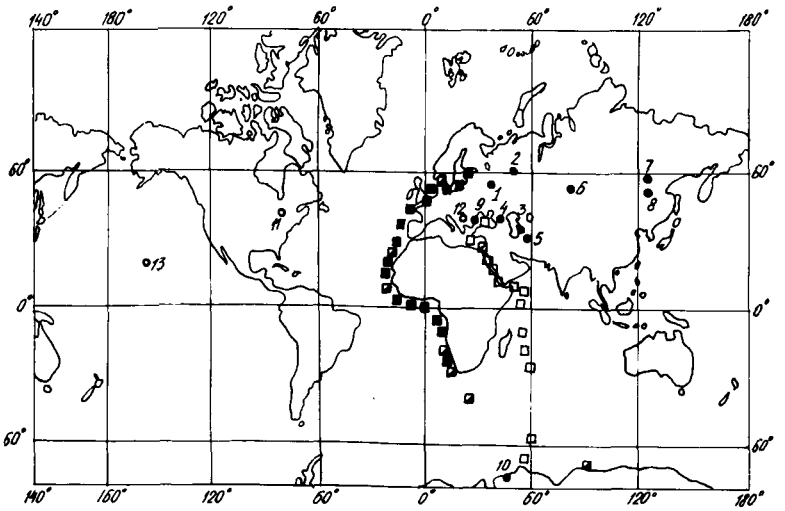

Fig. 1. Location of observation points. Circles indicate measurements on land; black, our measurements; empty, the other authors' measurements. Squares designate observation points aboard ships: half-blacked, the motorship *Mikhail Kalinin*; empty, the motorship *Bashkiria*; black, the research ship *Mikhail Somov*.

3. The choice of places for background measurements

The content of a gas will be considered background if the effect of local sources on it can be neglected. In this connection it may be appropriate to analyze the results of measurements in Zvenigorod from the viewpoint of their being influenced by CO emissions in Moscow. Fig. 2 gives January to April diurnal means for 1970–1976 of the total CO abundances over the Z.R.S. depending on wind direction at a 500 m level, the role of the anthropogenic factor being greatest during these months. The broken-line arcs show the averaged values of U_z. separately in each of the four sectors (the greater number of points in the western sector as compared to that in the eastern one is due to the predominant direction of wind towards Moscow). The mean values of U_z differ insignificantly from sector to sector, amounting to 0.132, 0.124, 0.123, 0.127 atm · cm in the northern, eastern, southern and western sectors respectively. The absence of increased CO content in the eastern sector allows us to consider as insignificant the effect of urban emissions on the results of our measurements.

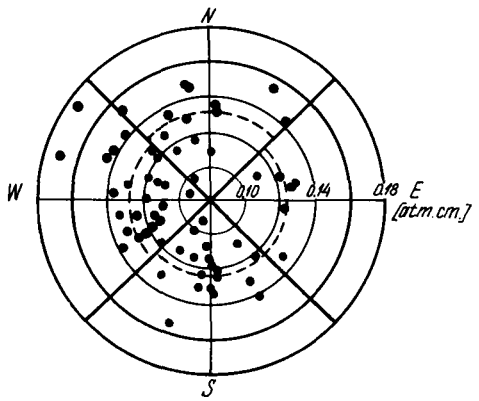

Fig. 2. Diurnal means of the total CO abundances at the Z.R.S. according to the winter–spring data for 1970–1976 as a function of wind direction at a height of 500 m above ground level. The broken-line arcs correspond to CO content means in each of the four sectors.

This conclusion is in agreement with the theoretical estimates of Novikov (1976) and experiments of Dianov-Klokov and Fokeyeva (1980). According to these authors the anthropogenic contribution to the total column content of passive admixture decreases 10–20 times at a distance of 4–5 radii of the city due to diffusion processes. Dianov-Klokov et al. (1978) have shown that the averaged anthropogenic contribution to the total CO abundance in the centre of Moscow for 1974–1976 is about 50% of the background value of U_z. Thus it may be expected that the average CO content in Zvenigorod should exceed the back-

ground by no more than 5%. The experience of Bogdanov et al. (1979) with measurement in Sofia has shown that background measurements are possible even at a point in the outskirts of the city, if one chooses days when the wind is blowing towards the centre of the city. The conclusion that Zvenigorod is sufficiently clean for our purposes is supported by a good agreement between the results of synchronous summer measurements at the Z.R.S. and in the most remote areas of the U.S.S.R. (Points 6, 7, 8) (Dianov-Klokov et al., 1978).

4. Results of measurements

4.1. *Continents of the northern hemisphere*

Plotted in Fig. 3(a) versus time of the year are diurnal means of CO abundances over Zvenigorod during 1974 and 1975, the most representative years as regards the quantity of measurements (black circles and triangles) (Dianov-Klokov et al., 1977, 1978). Seasonal variations in the CO content, with a maximum in spring and a minimum in late summer, are distinctly evident.

Also plotted in Fig. 3(a) are the diurnal means of U_z obtained by Shaw in the U.S.A. in 1952–1953 (Point 11). The values of W from the report of Shaw (1957) were decreased by 9%, to match Shaw's and our procedures for measuring the area of the line, and then processed according to the method of Pugachyov et al. (1978). One sees that in July–September both sets of data coincide. In December–April our values for U_z are higher than those of Shaw by 40–50%. The points in circles correspond to values of U_z which Shaw himself

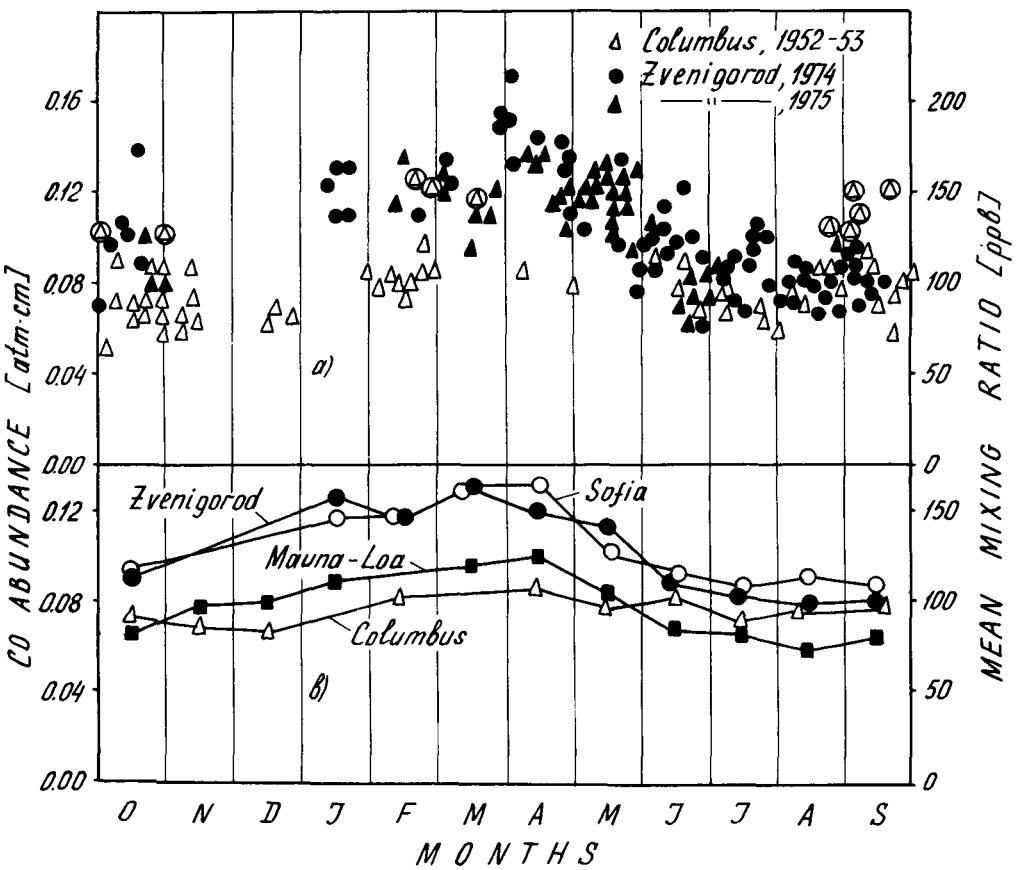

Fig. 3. Dependence of CO total content on the season of the year. The relations between the scales of total gas abundance (left) and of air-pressure-weighted mixing ratio by volume (right) is given, here and in Fig. 4, by equation (2), with H = 8 km (a) diurnal means of CO content: (b) monthly averages of CO abundance. Encircled triangles indicate abnormally high contents of the gas.

considered to be abnormally high (they may have been affected by urban emissions). In calculating monthly means of U_z these points were not taken into account.

The picture illustrated by Fig. 3(a) may be interpreted as an increase over the past twenty years in the background CO content in winter and of its remaining constant in summer.

In Fig. 3(b) monthly averages for the CO content are given. Apart from our Zvenigorod data for 1970–1976 ($\varphi \approx 56°$ N) and Shaw's 1952–1953 data for Columbus ($\varphi \approx 40°$ N) also presented are the results of integral background measurements made by Bogdanov et al. (1979) in Sofia ($\varphi \approx 43°$ N) in 1977–1978. The latter workers' results were multiplied by 1.05 to adjust to sea level. The Sofia data obtained by the procedures developed at the I.A.P. were specially analyzed by its authors for the effects of urban emissions, and from the entire bulk of results only those data were picked which characterize the background CO abundance. Plotted on the same Fig. 3(b) for purposes of comparison are the results of local measurements (Seiler et al., 1977) at Mauna–Loa Observatory in Hawaii in 1975 ($\varphi \approx 20°$ N).

Fig. 3 provides convincing evidence for the existence at present of seasonal variations in CO content in the northern hemisphere, with maximum in spring and minimum in late summer. It is noteworthy that such variations were discovered independently by different authors, using two different methods and at different points of the hemisphere. Here systematic differences between the data for the north temperate zone (Zvenigorod and Sofia) and those for the subtropical zone (Mauna-Loa) reflect the actual latitudinal distribution of CO rather than differences in procedures (see below).

4.2. *Latitudinal distribution of carbon monoxide*

The results of measurements taken by Yurganov et al. (1979) under sea conditions are presented in Fig. 4 as a gas content-latitude dependence. Plotted on the same graph as a dotted line is the latitudinal distribution of CO mixing ratio obtained by Seiler (1976) by averaging a great number of local data relating to different seasons and different heights in the troposphere. All the data are characterized by a fall in the CO content from north to south. The fall in November 1977 and in May–June 1978 is less

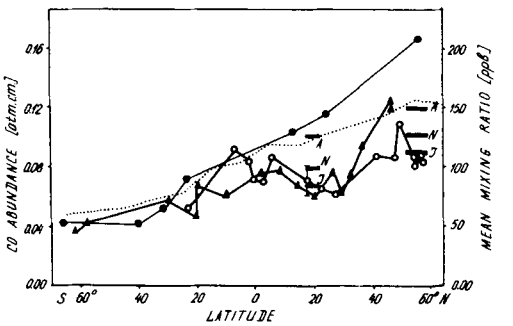

Fig. 4. Dependence of CO content on geographical latitude. Dots correspond to our measurements aboard the ships: black circles, *Mikhail Kalinin*, March and April 1976; triangles, *Bashkiria*, November 1977; empty circles, *Mikhail Somov*, May and June 1978. The dotted curve is drawn according to Seiler (1976). The thick line segments correspond to monthly averages of CO content taken from Fig. 3(b) for Zvenigorod ($\varphi \approx 56°$ N) and Mauna-Loa ($\varphi \approx 20°$ N); A, April; N, November; J, June.

abrupt than that of March–April 1976, due to a seasonal drop in the CO content in the northern hemisphere. This is confirmed by corresponding monthly averages for the CO abundances in Zvenigorod and Mauna-Loa plotted in Fig. 4 as thick line segments.

It should be noted that a direct effect of man-made emissions on the results of our measurements was noticeable at least in two cases: in the Odessa harbour (two triangles, $\varphi = 47°$ N) and in the English Channel (empty circle, $\varphi = 50°$ N). In the latter case the CO content was by 20–30% higher than on the previous two days in the Bay of Biscay and on the subsequent days over the North and Baltic Seas. An abnormally high CO content over the North Sea in April 1976 (black circle, $\varphi = 57°$ N) may have also been due to a large-scale atmospheric pollution.

In June and November the latitudinal CO distribution has a double-humped character, with maxima in the equatorial and the north temperate zones. In spring this effect is imperceptible, the CO abundance falling monotonously from north to south. In the southern hemisphere the results of all measurements overlap.

4.3. *The Antarctic*

The diurnal means of CO content over the *Molodyzhnaya* station during 34 sunny days of Antarctic summer and autumn are presented in

Fig. 5 (Yurganov et al., 1979). Our data agree in absolute value with the results of sporadic local measurements (Seiler, 1974) made by mercury oxide methods aboard a ship in December 1971 and in March 1972 in approximately the same area (r = 50 p.p.b.). The results obtained by Wilkniss et al. (1973) in the South Pacific Ocean by gas chromatographic methods in December 1972 (r = 31 p.p.b.) are substantially lower than both our data and those of Seiler.

It is seen from our data that between December and February the CO content over the *Molodyozhnaya* station in the Antarctic dropped by 30% and then went up again. It is early yet to give a final judgment about seasonal variations in the total CO abundance in the Antarctic. Nevertheless the character of these variations seems to be the same as in the northern hemisphere, i.e., CO content has a maximum in winter or spring and a minimum in summer.

In contrast to the carbon monoxide the total abundances of CH_4 and N_2O remained constant within the errors of measurements during our studies (Fig. 5).

5. A model for space-time distribution of CO

Summarizing the above data it is possible to draw a number of conclusions about space-time variations in the total column abundance of atmospheric carbon monoxide.

One can consider seasonal variations in the abundance of CO within the northern hemisphere, with a maximum in spring and a minimum in late summer, a reliably established fact. There is at

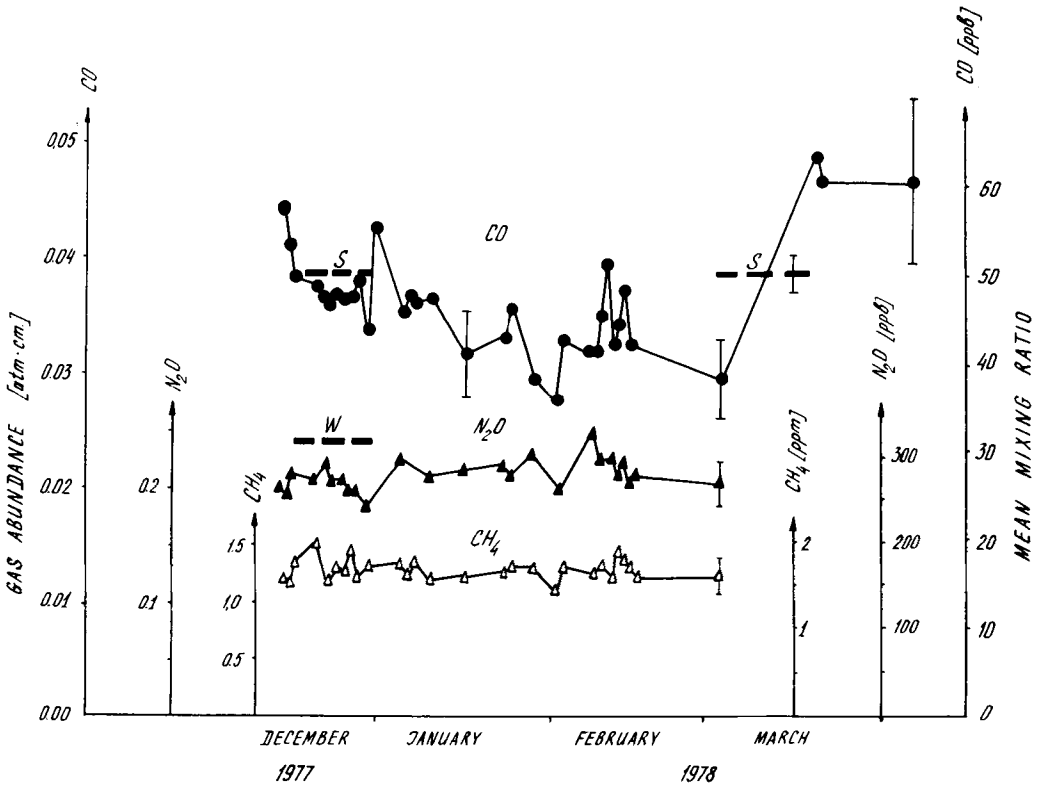

Fig. 5. Time dependence of diurnal means of CO, CH_4 and N_2O abundances over the *Molodyozhnaya* station in the Antarctic. Mean values of CO mixing ratio obtained in the Antarctic by Seiler (1974) (S) and Wilkniss et al. (1973) (W) using local methods are shown by segments of horizontal broken lines. Vertical strokes indicate random errors of diurnal means of CO content. The value H = 7.7 km was used in calculating the relation between the left and right scales of ordinates (eq. (2)).

present not enough data about seasonal variations in the southern hemisphere, although sporadic measurements point to the same nature of variations as in the northern hemisphere.

The space distribution of CO is characterized by a considerable difference in content (by 2–3 times) between the hemispheres, depending on the season (latitudinal variations). Sufficiently long observations in the north moderate zone (Dianov-Klokov et al., 1978) indicate a uniform longitudinal distribution of CO content at least at summer. There have appeared data, however, of local measurements made on an aircraft flight around the world (Gauntner et al., 1979) according to which the CO mixing ratio in the upper troposphere over the tropical Atlantic Ocean is higher than in the same zone over the Pacific. Nevertheless it seems premature to make any final conclusions about the longitudinal distribution of CO within the tropical zone.

A pictorial idea of the character of variations in the content of CO can be obtained from consideration of the three-dimensional graph (Fig. 6) plotting the total CO content versus season and latitude. The thick solid lines indicate averaged measurement data for Zvenigorod and the Antarctic Continent; the thick broken lines, smoothed results of measurements taken during our sea expeditions. The dotted lines have been drawn according to the experimental data (Seiler, 1976; Seiler et al., 1977). The dot-and-dash line shows the seasonal variation of U_z in Sofia (Bogdanov et al., 1979). It can be seen that an absolute maximum of CO content is attained in the north temperate zone in March and that an absolute minimum is attained in the Antarctic Continent in January. About the same time there is the largest difference in CO content between the hemispheres. Between June and September, due to seasonal variations (a decrease in the CO abundance in the northern hemisphere and an increase in the southern), the difference between the hemispheres decreases, although it does not disappear entirely.

It should be stressed that the plot of Fig. 6 has been constructed on the basis of limited experimental material and must therefore be regarded as a first step on the way to constructing a true global pattern of CO distribution. Further studies should in the first place have been concentrated on the research of seasonal and longitudinal variations in the content of CO in the southern hemisphere and near the Line.

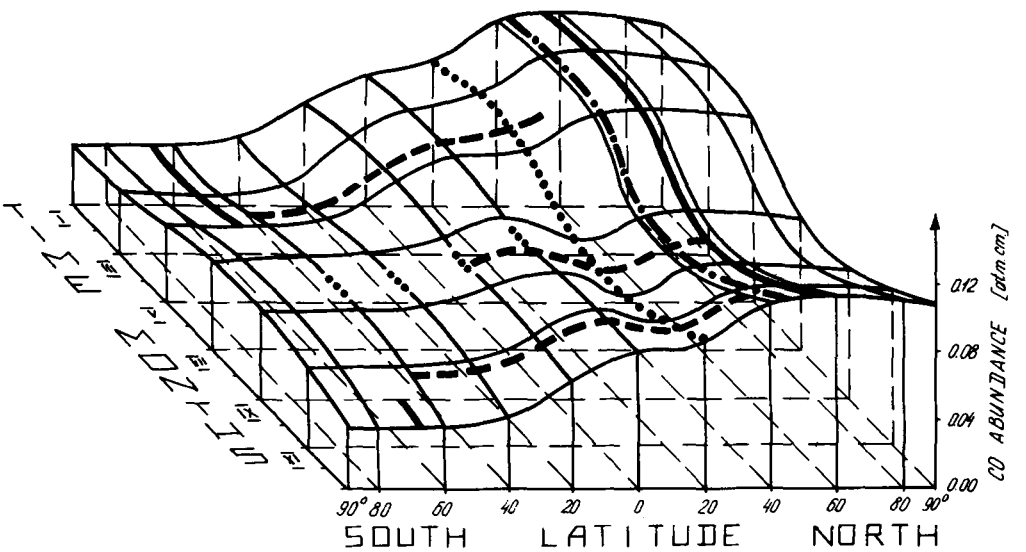

Fig. 6. Model for latitude-time distribution of the total content of CO. The thick solid lines are traced from our data for the Z.R.S. and the Antarctic continent; the thick broken lines, from the results of our sea expeditions; the thick dotted lines, from the data (Seiler, 1976; Seiler et al., 1977); the dot-and-dash line, from the results of Bodganov et al. (1979).

6. Discussion

A latitudinal averaging of the CO content plotted in Fig. 6 separately for each hemisphere (taking into account a decrease from equator to poles in the area between adjacent parallels) allows one to obtain seasonal variations in the total amount of CO in the atmosphere of the hemispheres M (Fig. 7(a)).

The rate of anthropogenic emissions of CO in the northern hemisphere is set equal to $P_A = 5.4 \cdot 10^{14}$ g/year (Seiler, 1974) (Fig. 7(b)). The flux from the northern hemisphere into the southern hemisphere is

$$D_F = \frac{M_N - M_S}{\tau_e}, \tag{3}$$

where M_N and M_S are the total amounts of CO in

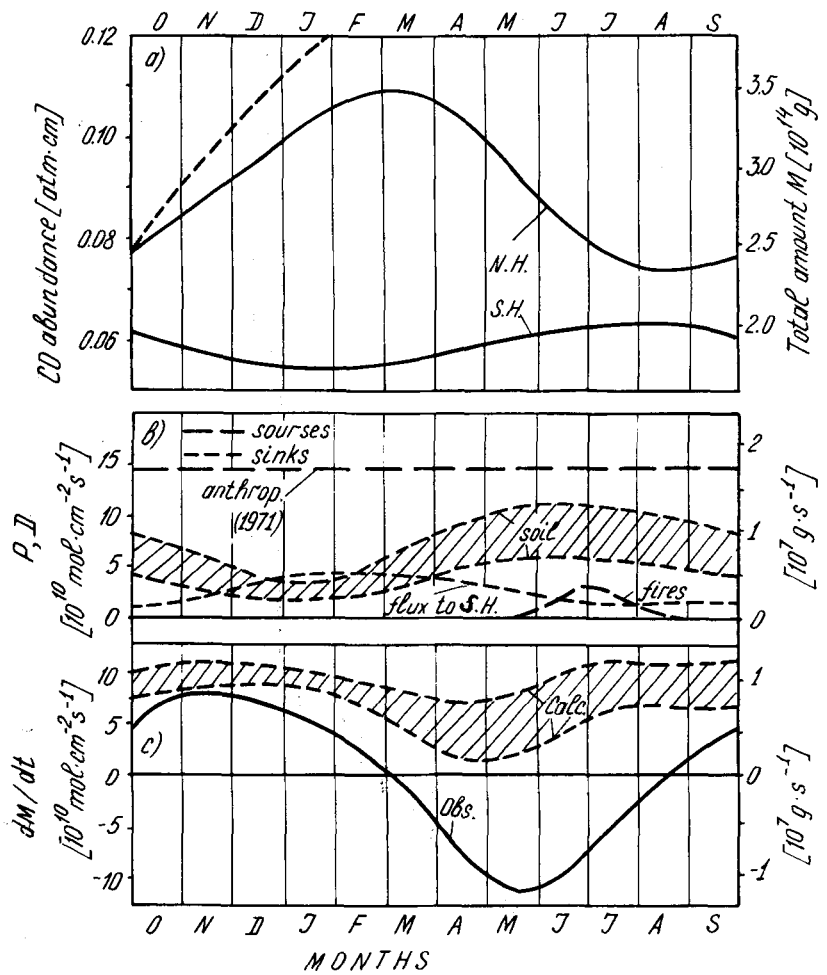

Fig. 7. (a) Dependence of the mean-hemispheric value of CO abundance (left-hand scale) or the total amount of CO (right-hand scale) on the season of the year for the northern and southern hemispheres. The increase in the northern hemispheric content of the gas, taking into account the anthropogenic production of CO and its fluxes into the southern hemisphere and the stratosphere, is shown by the broken line. (b) Seasonal dependence of the rates of some CO sources and sinks in the northern hemisphere (see also table). (c) Time dependence of the rate of variation in the total northern hemispheric amount of CO dM/dt: continuous curve has been obtained by differentiating the experimental curve $M(t)$ (Fig. 7(a)), the dashed curve, by summing up the rates of the known sources and sinks (eq. 5), Table, Fig. 7(b)).

the northern and southern hemispheres respectively (see the continuous curves in Fig. 7(a)). τ_e = 14 months (Singh, 1977, Newell et al, 1969) is the mean time of interhemispheric exchange. The value of D_F versus time is shown in Fig. 7(b). The broken line of Fig. 7(a) shows the increase in the CO content owing to the anthropogenic factor minus the fluxes into the southern hemisphere and the stratosphere. In the colder part of the year (between October and March) the broken line qualitatively describes the picture observed, but in March the content of CO stops increasing and then begins to fall rapidly, which indicates that much stronger sinks of CO than the fluxes mentioned above start acting.

One such sink, appreciably varying during the year, is the uptake by soil (Liebl and Seiler, 1976) caused by the activity of soil bacteria (Zavarzin and Nozhevnikova, 1977; Nozhevnikova and Yurganov, 1978). In the present work the destruction of CO on the soil surface, D_s, was calculated by summation over the latitudinal belts 0–10°, 10°–30°, 30°–50°, 50°–70° of northern latitude:

$$D_s = \frac{1}{S}\sum_i L \cdot r_i \cdot g_i(\theta) \cdot A_i. \qquad (4)$$

Here L is the Loschmidt number; r_i is the mixing ratio of CO of Fig. 6, $g_i(\theta)$ is the deposition velocity of CO as a function of soil temperature θ (taken from Liebl and Seiler, 1976; on the average about $8 \cdot 10^{-2}$ cm/s under laboratory conditions and about $4 \cdot 10^{-2}$ cm/s under field conditions); the seasonal dependence of soil temperature is mean-climatic (Alisov and Poltaraus, 1962); A_i is the land area of a given latitudinal belt (Geographical Atlas, 1967); S is the area of the hemisphere.

It should be noted that calculations of CO uptake by soil are characterized by considerable uncertainty. Here as the upper and the lower limits of this uptake we have taken respectively the laboratory and the field results of Liebl and Seiler (the shaded zone of Fig. 7(b)).

The rate of variation in the total mass of the gas M in the atmosphere of the northern hemisphere is

$$\frac{dM}{dt} = \sum P - \sum D, \qquad (5)$$

where $\sum P$ and $\sum D$ are the summarized rates of production and destruction of the gas respectively averaged over the hemisphere. The algebraic sum of the rates for the CO sources and sinks that have been taken into account (Table 1) is shown in Fig. 7(c) as a shaded zone whose boundaries are determined by the accepted bounds for the CO uptake by soil. The continuous curve is the result of graphic differentiation of the observed time dependence of the quantity M for the northern hemisphere (Fig. 7(a)). It can be seen that while in the

Table 1. *Annual means of rates of CO production and loss (northern hemisphere)*

	Rate (10^{14} g/year)	References
Sources		
Anthropogenic	5.4	Seiler, 1974
Oceans	0.2	Seiler, 1978
Forest fires	0.4	Seiler, 1974; Molchanov, 1973
Continental plants	0.9	Seiler, 1978
Lightnings	0.01	Chameides, 1979
Liberation by Earth's crust	0.07	Nozhevnikova and Yurganov, 1978
Oxidation of non-methane hydrocarbons	uncertain	
Sinks		
Uptake by soil	1.4–2.8	Liebl and Seiler, 1976; this paper
Flux into the stratosphere	0.9	Seiler, 1974
Flux into the southern hemisphere	1.0	Newell et al, 1969; Singh, 1977; this paper

colder period of the year (from October to March) the sink deficit is not too large (not greater than $5 \cdot 10^{10}$ mol/cm$^2 \cdot$ s), between April and August it is as high as $(10–15) \cdot 10^{10}$ mol/cm$^2 \cdot$ s.

A very intensive sink of carbon monoxide is its oxidation by tropospheric hydroxyl. According to recent estimates (Fishman et al., 1979) reaction with OH assures an average annual rate of CO loss in the northern hemisphere of $28.6 \cdot 10^{10}$ mol/cm$^2 \cdot$ s. Subtracting from this quantity the rate of photochemical production of CO from CH_4($5.2 \cdot 10^{10}$ mol/cm$^2 \cdot$ s), the average net sink per year will amount to $23.4 \cdot 10^{10}$ mol/cm$^2 \cdot$ s. Unfortunately, no data on the seasonal dependence of photochemical production and loss of CO have been published.

According to Fishman et al. (1979), carbon monoxide is a source for tropospheric ozone, so the difference in CO content between the hemispheres results in a similar difference in the trophospheric O_3 content. It is worth noting in this connection that according to our data (Fig. 7(c)) the rate of CO destruction is greatest in the period between May and August, i.e., precisely when there is a seasonal maximum in the concentration of tropospheric ozone (Fishman et al., 1979).

7. Conclusions

1. The measurements of the background total column abundance of carbon monoxide in the atmosphere taken to date by the total column (integral) spectral method have shown its effectiveness in application to problems of global monitoring of the atmosphere. An important advantage of the method is a reduction in the background-station locating requirements, which allows background measurements to be taken at relatively small distances from cities and towns.

2. At present both integral and local measurements reveal seasonal variations in the background content of CO in the northern hemisphere, with a maximum in spring and a minimum in late summer.

3. Measurements by column method confirm the presence of the difference between the hemispheres in CO content, revealed earlier by local methods (see, for instance, Seiler, 1974).

4. The amount of available data is enough to construct an approximate pattern of global space-time variations in the total CO content in the vertical column of the atmosphere.

5. The obtained pattern was analysed on the basis of the simplest box model. An increase in the total northern hemispheric amount of CO during winter was explained in the main by anthropogenic emissions not sufficiently balanced by natural sinks. In the warmer half of the year the uptake of CO by soil bacteria cannot, even by maximum estimates, fully account for the observed decrease in the CO content. Taking into account photochemical processes will apparently make it possible to close the budget of carbon monoxide.

6. A comparison with the results of integral measurements of 1952 and 1953 (Shaw, 1958) indicates that over the past 20 or 25 years the winter background content of the gas has increased by about 40%, whereas the summer content has remained unaltered within the experimental errors. This demonstrates a substantially higher rate of CO turnover in summer as compared with winter. A study of variations in the isotopic composition of atmospheric CO has led Stevens et al. (1972) to a similar conclusion. With the existing rates of growth in the anthropogenic production of CO, it may be expected (Dianov-Klokov et al., 1978) that in the spring of 2000 the background content of the gas will be three times its value for 1952.

8. Acknowledgements

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ИССЛЕДОВАНИЕ ГЛОБАЛЬНОГО ПРОСТРАНСТВЕННО-ВРЕМЕННОГО РАСПРЕДЕЛЕНИЯ ОКИСИ УГЛЕРОДА СПЕКТРАЛЬНЫМ МЕТОДОМ

Интегральное фоновое содержание CO в толще атмосферы исследовалось спектральным методом с использованием Солнца в качестве источника света. По наблюдениям 1970–1976 г.г. в умеренных широтах северного полушария содержание CO испытывает сезонные вариации; весной оно в 1,5 раза выше, чем в конце лета. Измерения в течение четырех месяцев в Антарктиде также показали наличие минимума содержания CO в январе—феврале, т.е. летом южного полушария. Содержание этого газа в умеренных широтах северного полушария в марте—апреле в 3 раза, а в июне—июле—в 2 раза больше, чем в Антарктиде. Сравнение с данными Шоу, полученными в 1952 г. в США, говорит о возрастании фонового содержания CO зимой со скоростью около 2% в год и постоянстве его летом. Анализ всех данных приводит к выводу о заметной роли антропогенных факторов в цикле CO в северном полушарии зимой и превалировании естественных процессов-летом.