

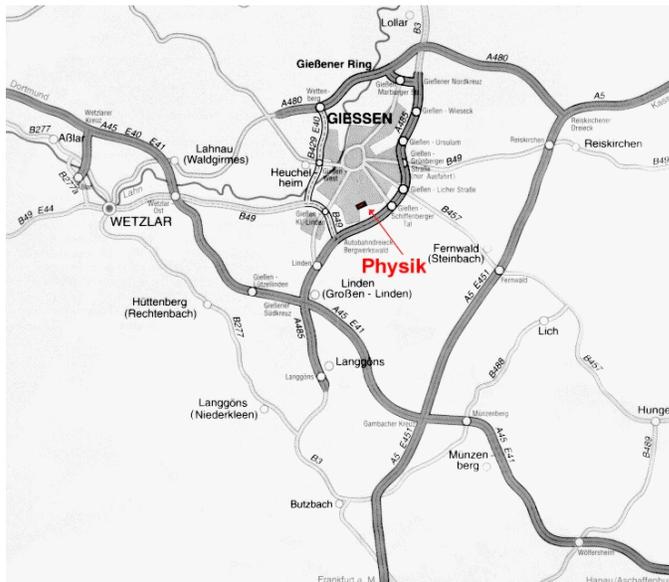
Who was W. Kreutz in Gießen?
or what's wrong with atmospheric CO₂?
By André Bijkerk

From August 1939 until January 1941, W. Kreutz did systematical research to the CO₂ content of the lower atmosphere for botanical/agricultural purposes, unaware of possible climate issues at that time. He makes a detailed analysis of the relation between weather factors and atmospheric CO₂. The remarkable issue is that the average CO₂ contents amounts to 438,5 ppmv. Moreover, there is a strong unusual spike around August 1940 which is hard to explain with anthropogenic elements. Similar aberrations have been recorded elsewhere.

While a global spike of short duration is considered to be highly impossible, the observations of Kreutz are usually dealt with as primitive and with unawareness of anthropogenic factors and hence to be discarded. Since the original article is written in highly elaborate redundant “hoch Deutsch” the readability is reduced. Therefore the following “translation/summarization” has been produced as a compromise between the inaccessible language of Kreutz and modern effective lean language with an attempt to preserve its original message, to show the considerations of the author.

For the moment, the paragraphs which are less relevant for that purposes, have only been summarized briefly as indicated with *Italics*. The original relevant figures have been pasted into the article. Original page numbers are included in the text as“(98)” etc.

Also note the location of the sampling site, the weather station:
note that the city and railway station is to the north.



Kreutz, 1941(?); Kohlendioxidgehalt der unteren Luftschichten in Abhängigkeit von Witterungsfaktoren. (aus den Agrarmeteorologischen Forschungsstelle Gießen des Reichsamts für Wetterdienst) *Angewandte Botanik*, XXIII pp 89-116

(89) Carbon dioxide levels of the lower air layers depending on weather factors. From the agrarian meteorological research location Gießen of the National Office for Weather.

A: Problem characterization and research methods

With this work a first contribution is made to the research of the carbon dioxide cycle depending on weather factors, which is continuous from August 1939. A large amount of literature (national and international) on the subject of carbon dioxide has accumulated. The various articles approach the questions from different points of view. The most interesting are those by plant biologists and botanical specialists, as well as those studying agriculture. For them the research on the factors that control the carbon dioxide assimilation has a practical purpose. Furthermore, carbon dioxide fertilization is used in agriculture). (90) Amongst others it's notably E. Reinau(1), who attempts to verify the efficacy of this fertilization method.....

An elaborating paragraph omitted

...The study of meteorological relationships had several interruptions due to different considerations of the CO₂ research. The meteorological research on the CO₂ question, began in the nineteenth century, with only small samplings contributing to our knowledge. This lack of early information makes it very difficult to identify the general trends over time. Moreover, the errors, generated by inferior sampling techniques and primitive equipment, often lead to contradictions. Later, more systematic research has begun to establish the proper meteorological study of the CO₂ question. The reason for this author's research is to make a fresh start to find correlations between meteorological conditions and the exchange of carbon dioxide, which are not explicitly known yet.

This question can also be approached from many different angles. For instance, one can argue about the height of the air sampling. In order to identify the carbon dioxide cycle in the lower air layers, we constructed four sampling locations on the site, one directly above the earth surface, then at heights of 0.5 and 2 meters and also one on the tower of the service building at 14 meter height. (91) The variation in weather which was observed was, (solar) radiation, wind, air and surface temperature, air and surface humidity, air pressure and precipitation. Apart from these the observations, we also made observations of clouds types, extension of cloud cover, ground fog, freezing frost and the condition of the earth surface.

The section with a description of the general meteorological equipment is omitted.

We realized from the beginning that the research of CO₂ behavior would require measurements over a longer period to be able to say something about the relationships in

annual variations. Therefore it was also necessary to find a suitable measurement technique which allowed us to make a large number of samples in a short period with a sufficient accuracy. We needed to take some 120 samples daily. After evaluation of several methods and equipment, we finally selected the Rico-carbon dioxide measuring device type C (3) of the manufacturer Fr Riedel & Co. This allowed a quick and sufficiently accurate measurement of trace gases....

A detailed description of the sampling omitted...

(92)... **(93)....**

B Evaluation of the results

*B starts with a elaboration on Daltons law and the stronger pressure gradient of heavier gasses with height, which means that CO₂ reduces to 0,02 (? % ?) at 15 km altitude and 0,00 at 30 km altitude. ...***(94)**

...The usual literature value of carbon dioxide ratios at ground level is 0.03 volume percent or 3 volume units per 10.000. Undoubtedly this could only be considered to be a general order of magnitude, because certainly the CO₂ content is subject to substantial difference. Its variation is essentially dependent on local factors, local sources and local mechanisms. The atmosphere receives CO₂ from volcanoes and hot sources, including large quantities of CO₂ escaping through combustion of coal and in more modest quantities by burning wood and peat. Consequently, industrial areas and large cities are identified as substantial CO₂ sources. Also the respiration of biota-- people, animals, plants and other organisms-- contributes CO₂ to the atmosphere. Not to be overlooked is the substantial CO₂ production of the soil, which can be highly variable, depending on type, fertilization and utilization. Opposing this production is the uptake of CO₂. This is solely a matter of higher plant orders, which only produce a modest amount of CO₂ but on the other hand consume large quantities of CO₂ as nutrition, under the influence of light. Now the effect of weather factors is to be evaluated, which have a partial direct and indirect effect on the production and consumption of CO₂ and the CO₂ cycle. These few examples should prove how CO₂ depends on many factors in the lower layers of the atmosphere.

1. General information about variation

a) Daily variation.

Next figure 1 represents the CO₂ variation at the Earth surface, at heights of 0.5m, 2 meter and 14 meter, as well as the progress in weather factors with 1.5 hourly sampling in the time frame 24 Sept 1940 to 28 September 1940. **(95)**

The weather factors under consideration are (solar) radiation, temperature, wind speed and precipitation. This example with limited observations should visualize the variation in the CO₂-contents during day and night, especially the occurrence of the maximum and minimum values. While the diurnal variation cycles of both radiation and temperature show the normal values, (96) we observe that the variation in CO₂ does not only show an irregular, not diurnal pattern but it also shows a much larger variation than expected. There is no sign of a regular curved behavior.

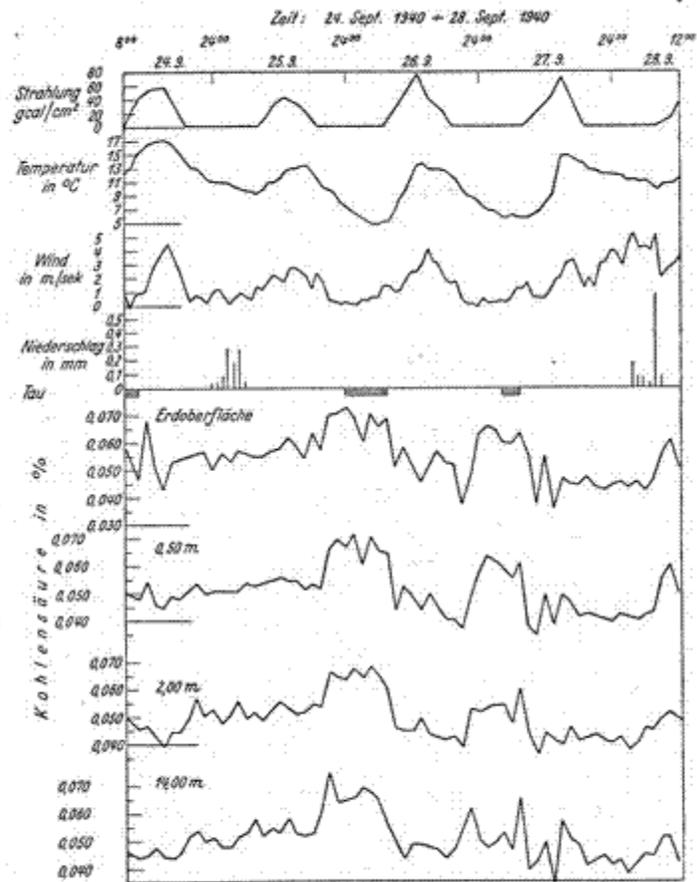


Abb. 1. Tagesverlauf der Kohlensäure und Witterungsfaktoren.

There is not even correlation of CO₂ concentration with the erratic variation of the wind speed. In addition, precipitation appears to give contradictory results. No more information can be extracted from this example

However it is remarkable that on the days and hours when dew built up (24,26 and 27-9), the CO₂ concentration decreased. This behavior has been confirmed by known similar observations. Similar behavior was also discerned with frost build-up. However, it is still too early to draw further conclusions from these apparent correlations, as we need more information about rates of dew and frost build-up, the total amount, and the duration.

Development of the daily averages

The next graph depicts the daily variation of carbon dioxide as the average of three daily measurements in the period 1 August 1939 to 1 August 1940 at the same four heights above the terrain.

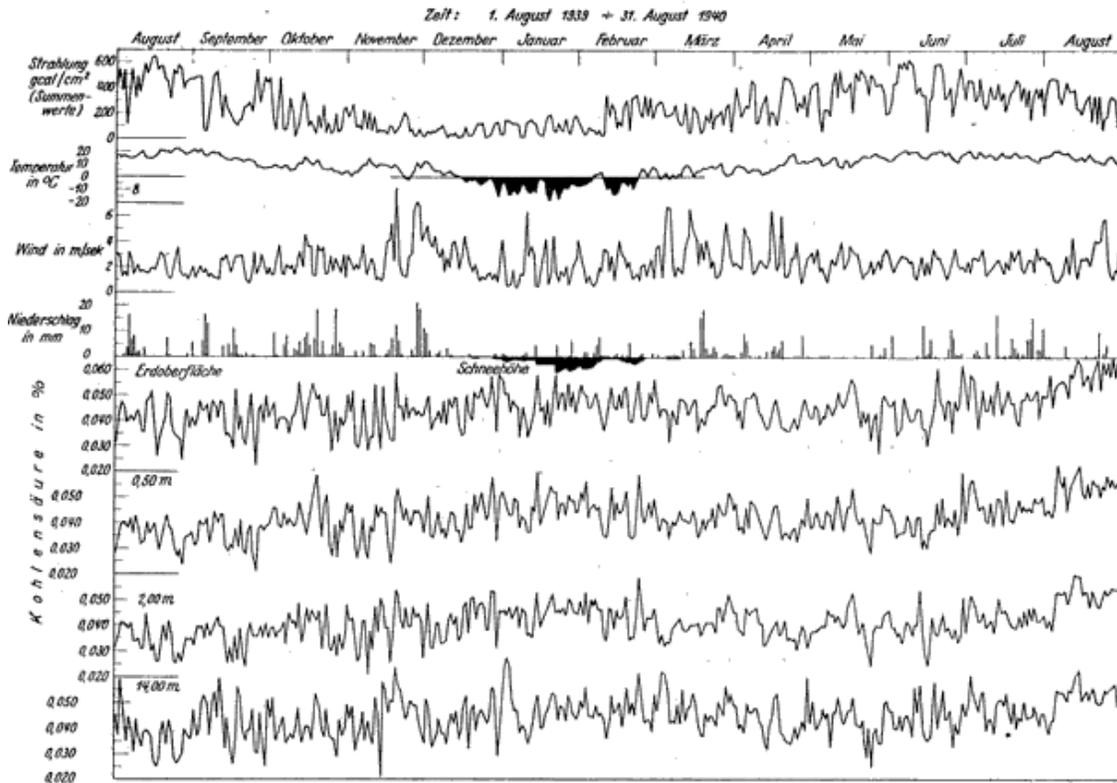


Abb. 2. Tagesmittel der Kohlensäure und Witterungsfaktoren.

To control the amount of data, we limited the period to one year. For the same reason we did not depict more meteorological factors. There is no doubt that the depicted progress is not consistently cyclic but shows the result of a large amount of factors. It can only be confirmed that the concentration at the different heights correlate. It is difficult to establish any other relationship obviously with many variable meteorological factors. For instance, it can be observed that a decrease in radiation goes together with an increase of CO₂ and vice versa, notably the CO₂ ratio increased markedly during the long cold and snow-rich winter of 1940. The graphs also reveal that in low wind situations the air gets more enriched with CO₂ while stronger winds lead to a decrease in CO₂. (98) However under stormier conditions things seem different. During a period of increased wind speeds up to 8.3 m/sec a few days in November a strong increase of CO₂ concentrations was observed. During a second period with increased wind conditions to 7 m/sec, the CO₂ later that month the concentration did not exhibit abnormal reactions. However in January, 1940, the CO₂ level decreased again during another period of increased wind speed to 6,3 m/sec. Yet another behavior of the gas was recorded in March. On one occasion with increased winds to 7.3 m/sec there was a decreasing tendency while on another occurrence of wind speeds to 6.5 m/sec a slight increase was recorded. Finally, in April we see a normal decrease again with increased winds (6.4 and 5.9 m/sec).

A similar erratic behavior can be observed at the variation in precipitation. Especially during very light precipitation the CO₂ concentration usually increases but the opposite behavior is also observed on several occasions. Similar behavior is recorded for very heavy precipitation over 10mm, when generally the increase of CO₂ prevails.

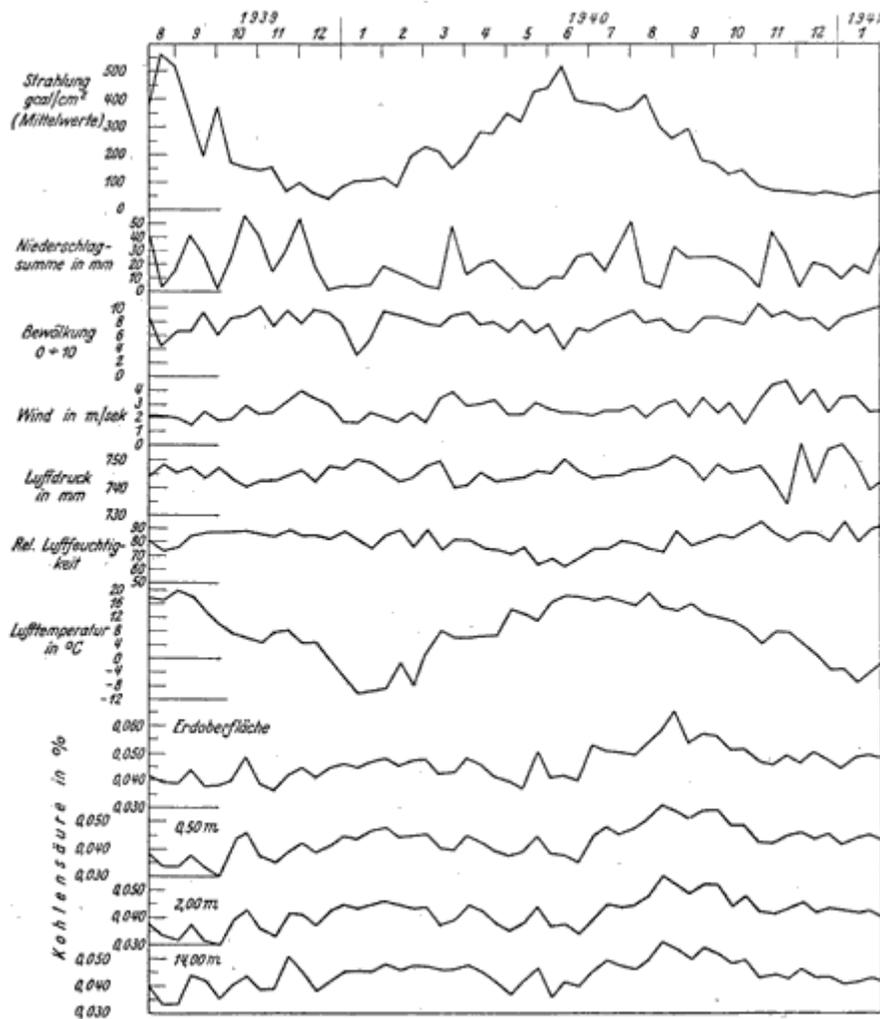


Abb. 3. Dekadenmittel der Kohlensure und Witterungsfaktoren.

We have compiled ten-day average values for CO₂ in fig 3, in order to obtain a clear picture of the CO₂ trends and to eliminate the effect of short aberrations during meteorological events, and to come to a better evaluation of the significance of sampling height. We also summarize the average air pressure, cloud cover and relative humidity. The sampling period is 1.5 years from August 1939 up to and including January 1941.

The smoothing of the curves facilitates the interpretation. It appears that the course of the CO₂ concentration is showing four stages/steps, which appear similar albeit with exceptions. It is also apparent that the curves at different heights are rather similar, suggesting that a regular mixing of gases with height occur. (99) We will elaborate later upon the mixing ratios.

The initial large excursions diminish during the winter months of 1939/1940. The curves come to rest.

(100)

After beginning in December 1939 it can be observed that the CO₂ increases gradually until the end of January followed by a general decrease ending in March. Correlations to meteorological factors are rather ambiguous at least when the relationship with a single element of the weather factors is attempted. The contributing meteorological factors accumulate and are partly contradictory and erratic and subject to seasonal changes which obscures a clear assessment. For instance, the positive correlation with precipitation is clear in the fall of 1939. The same is true for the winter months. But then a change occurs in March, July and August and November when the CO₂ level drops during heavy precipitation but still rises at light precipitation. An increase of CO₂ is also observed with decreasing temperatures. Examples are Oct – Dec 1939 Jan, Mar, Apr and Aug- Sep 1940. A correlation with the wind curve is hard to establish, there is a vague negative correlation with most of the time a slight decrease with increasing wind speeds.

The monthly average graph

Finally figure 4 depicts the monthly average curve. In this context also the average air pressure and density was investigated for a correlation with the CO₂. We observe that no obvious correlation can be found with these meteorological factors. However, as mentioned earlier, the different heights show similar records and confirm the vertical mixing. But other than that, no relationships can be found, although a few expected possibilities could be considered

Increased solar radiation would decrease the amount of CO₂ in the air and vice versa while precipitation tends to enrich the CO₂. An increased wind speed usually leads to depletion of the CO₂ contents. Furthermore an increasing air pressure tends to increase the CO₂ as well. When temperatures drop, then the CO₂ levels tend to increase but also with increasing temperatures we see increasing CO₂ albeit with delay.

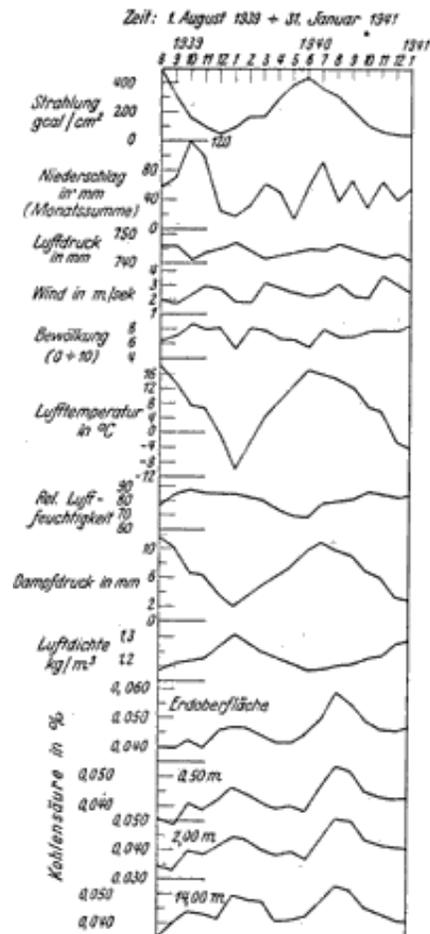


Abb. 4. Monatsmittel der Kohlen- säure und Witterungsfaktoren.

Finally, increasing air density seems also to increase the CO₂ level. But in general the CO₂ records demonstrate that the CO₂ trends do follow a different logic than the meteorological records as we see both a strong spike in wintertime and in summertime. It's also perceived that the meteorological conditions change yearly and this seems also the case for CO₂. **(102)** In the past, the general CO₂ trend was increasing, whereas in 1940 a decrease was noted in the same period. In January 1940, the CO₂ trend was increasing but in January 1941, a clear decreasing trend was noted at the higher sampling positions. Only a multi-annual sampling period could clarify the general trend.

2 Numerical report of the records.

The value of 0.03 volume percent which is noted in the literature has been proven to be too low compared with the results in Gießen. In the next tables we give the average values of all the samples in thousands of percents during the period 1.5 years. The overall average of more than 25,000 samples is 43.85 (438.5 ppmv)

Table 1a
Average CO₂ values from August 1th, 939 to 31 January 1941

	0m	0.5m	2.0m	14.0m	Average
Morning	42.8	41.7	40.5	43.2	42.1
Afternoon	52.9	45.0	43.0	46.4	46.8
Evening	42.5	42.5	41.6	44.0	42.7
Daily	46.1	43.1	41.7	44.4	43.85

Table 1b
For the year 1940

	0m	0.5m	2.0m	14.0m
Average	46.8	45.1	43.4	46.2
Maximum	64	62	62	68
Minimum	27	28	24	24
Var σ (abs)	6.42	6.11	6.12	6.59
Var σ (%)	13.7	13.6	14.1	14.3

(103)

Table 1a shows the CO₂ content at the four levels during the daily cycle. Table 1b shows the daily averages in the year 1940. The variance of some 14% is consistent with the values of Lundegårdh (2). The extremes of the daily averages in table 1b are remarkable. Also, contrary to 1939, the August values in 1940 were very high. This shows that CO₂ values are subject to substantial variations, which are not currently explained.

Closer inspection of the values shows some regular patterns.

1. It is observed that the afternoon values are highest, while the levels decreased in the morning and evening.

2. The CO₂ level tends to decrease from surface level to the lower heights but increases again at the greater height at all times.

This result appears to be remarkable at first sight. However an explanation can be found when the correlation of those values is considered. With linear regression via minimum squares the next trend lines describe the relationships of the CO₂ contents between ground level (C_0) and the three different heights (C_1 , C_2 , C_3):

- a) At 0.5m height: $C_1 = 0.92 * C_0 + 0.2$
- b) At 2m height: $C_2 = 0.84 * C_0 + 2.8$
- c) At 14m height: $C_3 = 0.69 * C_0 + 12.9$

From these results it appears obvious that there are two main sources of the CO₂ contents in these layers. The first one, the factor trend factor 0.92 – 0.84 – 0.69 diminishes with height and hence is clearly related to a source from the soil. The second value, the displacement constant, which is independent of the ground level value, 0.2 – 2.8 – 12.9 increases strongly with height and must have an external source. It is clear that this value is depending on the emission of industries of the cities, etc. **(104)** This component increases so strongly with height that it prevails eventually.

3. Dependence of carbon dioxide on meteorological factors.

For the main objective, researching the influence of weather on CO₂ patterns, we use the 2-meter values of CO₂ because most weather observations are made at this height. The problem is very complicated because of the sheer number of possible factors. Moreover phase lag and inertia effects could obscure correlations further as well as random changes in sources and sinks like changes in land use. Hence it is clear that conclusions cannot be drawn from a rather short series of observations. It is unclear if the current series of 1.5 years is sufficient to establish unambiguous correlations between weather and carbon dioxide. Therefore this chapter reflects only some possibilities tentatively as examples. The observations continue of course, and it would certainly be desirable for an automatic sampling method to become available.

Research by Calculations

For the investigation of the relationship between weather factors and CO₂ correlation tables have been calculated for:

(105)

1. Radiation and duration of insolation
2. Air pressure and humidity
3. Rain type and amount
4. Air pressure and temperature
5. Wind speed and direction

The next results are observed:

Table 2
Radiation and duration of solar insolation

Radiation

Rad gcal/cm ²	0-100	100-200	200-300	300-400	400-500	500-600	>600
CO2	42.6	42.8	42.5	42.0	40.7	36.2	35.6

Duration of sunny conditions

Hours	0	0-2	2-4	4-6	6-8	8-10	10-12	12-14	>14
CO2	42.8	41.3	42.7	43.2	42.0	40.4	37.7	43.1	37.6

The author observes no particular correlation with duration but a distinct negative correlation with radiation but cautions against drawing hasty conclusions, because of the apparent contradiction with diurnal cycles etc

Similar calculations and remarks are made for the other factors
(106) – (110)

To 5 Finally, the comparisons have been made for wind speed and directions

Table 6a Wind direction.

Table 6b Wind speed

1	40,7	43,3	43,2	42,2
2	39,8	42,7	41,9	41,6
3	42,2	42,6	41,2	42,2
4	38,2	41,8	43,3	41,6
5	41,2	44,3	34	42,4
6	36	45	39,6	41,1
7		54		54

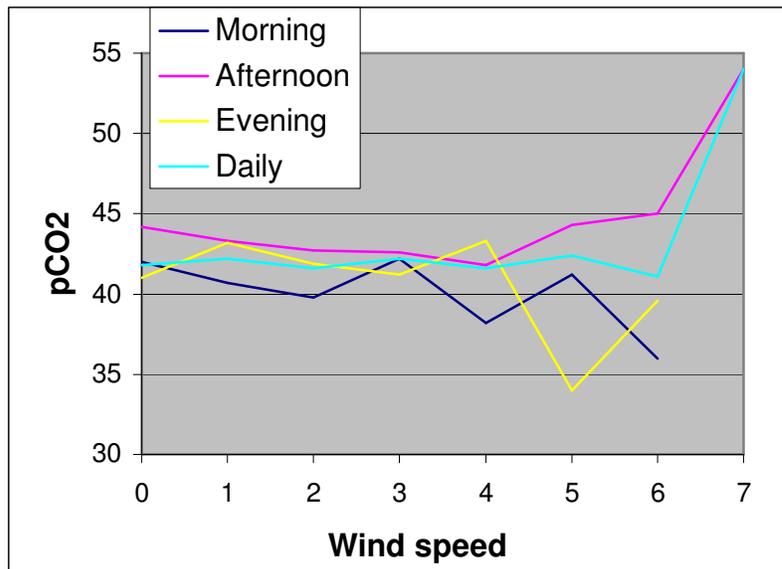


Fig-9 Division of diurnal average with wind direction and speed.

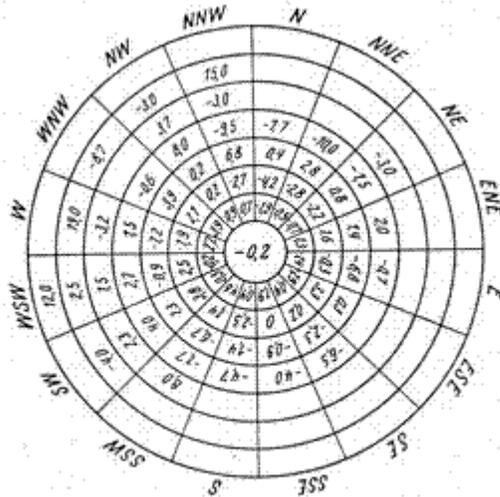


Abb. 9. Verteilung der Tagesmittel nach Windrichtung und -stärke.

This is given in a circular radar table with three-dimensional effect. Depicted are the aberrations of the average CO₂ value with increasing wind speed. The center depicts no wind. In general there are no relationships apparent. A positive correlation could be derived only at midday for westerly winds. (113) Therefore we investigate the daily averages further. In figure 10 the aberration of the average CO₂ is depicted depending on the wind direction.

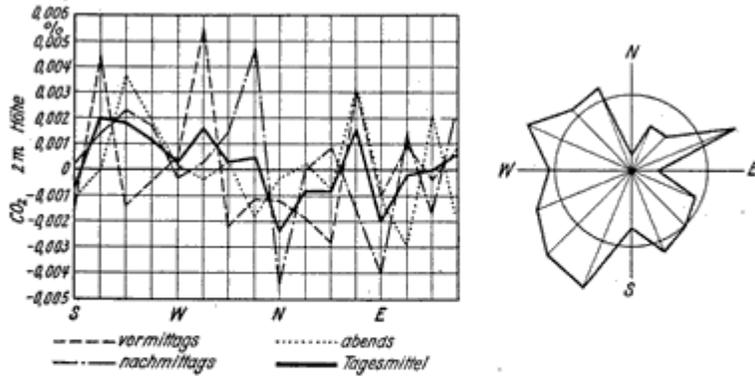


Abb. 10. Windrichtung und CO₂-Abweichung vom Mittelwert.

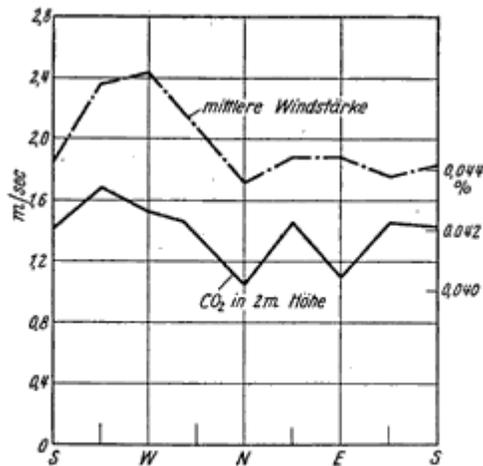


Abb. 11. CO₂ und mittlere Windstärke in Abhängigkeit von der Windrichtung.

Figure 11 shows the absolute value and the average wind speed depending on the direction.

From these figures it is apparent that westerly winds carry slightly higher CO₂ contents than other directions....The correlation coefficient $r = 0.75$ which indicates that the westerly directions that bring the strongest wind also cause the stronger enrichment of CO₂

b) Research of multiple correlations

A description of possible multiple linear regressions and a discussion about the lack of correlation in high resolution data, whereas the 10 day-averages show much better correlations. However the number of 10 day periods is marginal for such an operation. Moreover, linear relationships are required, which is not apparent at this time. The results suggest that the series are too short and a much longer period is required.

In the conclusion the vague possible correlations are summed up

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