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CO2 concentration

Available data and

critical analysis

Extract of the white paper drawn up by the SCM

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I. Introduction

Many scientists are having doubts about the influence of greenhouse gases on the climate. Earth's atmosphere is composed mostly of atoms of nitrogen, oxygen and argon, and the three main greenhouse gases are water vapor, carbon dioxide (CO₂) and methane (CH₄). We shall be looking at the composition of the atmosphere more closely in Part 2 (Chapter 1, Section IV).

The particular feature of a greenhouse gas is its ability to heat up by absorbing the infrared rays coming from the Sun and the Earth. The factors that cause a gas to affect global warming are its capacity to absorb infrared rays, its life span, and its concentration in the atmosphere.

In this chapter, we shall be looking only at CO₂, because this is the gas deemed to be responsible for global warming. The infrared-absorption capacity of CO₂ is a quantifiable factor that can be measured in the laboratory, which is not true of its life span or concentration in the atmosphere. In fact, CO₂ is part of the carbon cycle (see Figure 14), with carbon atoms from CO₂ being transferred to various 'reservoirs'. There is a constant flow of exchange between reservoirs. During these transfers, reservoirs that release CO₂ into the atmosphere are called 'sources', and those that consume it are called 'sinks'. The sea, for example, is both a source and a sink.

The carbon cycle makes it difficult to determine the life span of CO₂ in the atmosphere, which is why scientists focus more on its concentration.

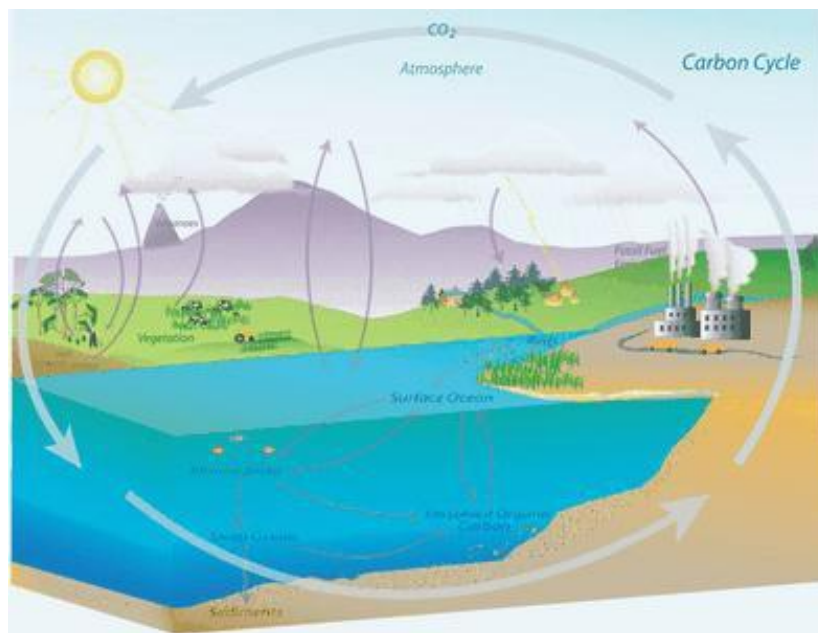


Figure 1. The carbon cycle (source: Barb Deluisi, NOAA)

The gross concentration of CO₂ does not make it possible to identify a trend as regards the gas, because the composition of the atmosphere depends on pressure, temperature and the dilution of other gases in water vapor. To obtain a measurement that is not dependent on these parameters, you have to measure the number of CO₂ molecules in one million molecules of dry air. This measurement is expressed in ppm (parts per million) and is called a mole fraction [see Tans and Thoning].

Several types of measurement are taken at the moment. In most cases, they reflect a local concentration of CO₂ and are taken at a certain altitude. We are going to demonstrate the variability of the values and the lack of standardization of the measurements.

II. Infrared measurements

The infrared measurements presented in this report come from the National Oceanic and Atmospheric Administration (NOAA), which gathers data from a network of more than 100 sites around the world. Samples are taken at variable intervals. The NOAA's aim is to create a 'map' of the concentration of greenhouse gases in the world, at various altitudes.

A. Sampling methods

Four methods are used to collect the samples analyzed by the NOAA:

1. Surface measurements

Air samples are taken weekly and contained in flasks. They come from various laboratories around the world (see Figure 15). These measurements make it possible to determine the concentration of greenhouse gases, and variations (both short- and long-term) at the sampling site. These samples are taken on the surface.

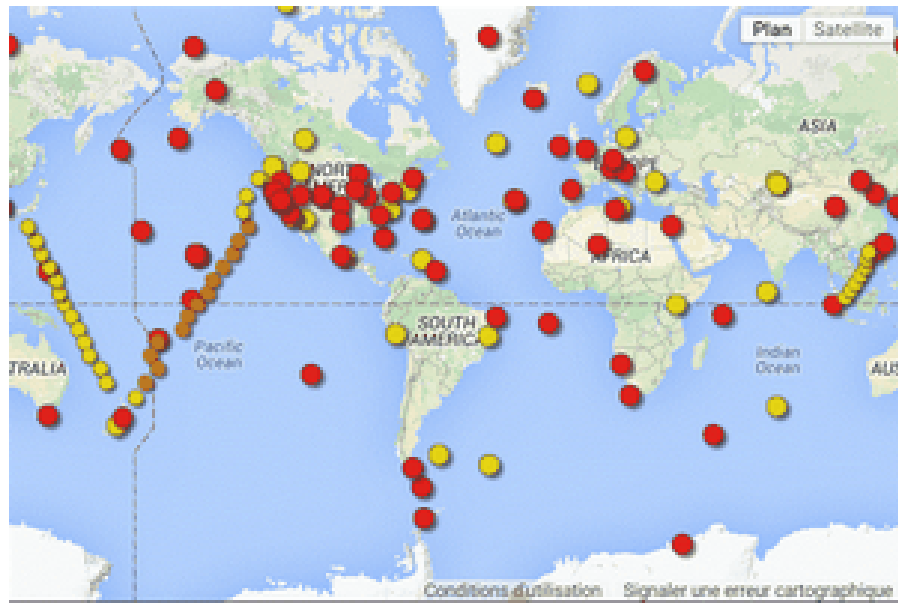


Figure 2. Location of laboratories taking flask samples. The red points are active sites, the yellow points are inactive sites, and the orange points are ship-based.

2. Air-based program

The air-based program makes it possible to take seasonal samples of air at various levels of the troposphere (over 8,000 meters). Sampling is concentrated mainly in North America (see Figure 16).



Figure 3. Location of air-based program measurement sites. Aircraft in yellow represent inactive sites.

3. Tall tower measurements

A network of tall towers provides daily CO₂ measurements for altitudes of about 500 meters. At this altitude, the air is mixed, and it is possible to measure an atmospheric ‘footprint’. Once again, sampling is concentrated mainly in North America (see Figure 17).



Figure 4. Location of towers. The yellow icon represents an inactive site.

4. Baseline observatories

Baseline observatories are laboratories that are isolated from civilization. Their location means they can take daily measurements of an atmosphere that is not ‘falsified’ by external pollution. There are six of these observatories, in Barrow (Alaska), Summit (Greenland), Trinidad Head (California), Mauna Loa (Hawaii), American Samoa, and the South Pole (Antarctic).

Of these observatories, the one in Mauna Loa is known for its CO₂ measurements, which are taken only in the high atmosphere. The results presented by the NOAA come mainly from this observatory, which is located in the US, in the south-west of the island of Hawaii (Big Island), the largest island in the archipelago and state of Hawaii.

In an article [see Eschenbach], Willis Eschenbach justifies the selection of this measurement station as representative of world concentrations as follows:

The local influence of CO₂ releases from vegetation and human activity on measurements has to be eliminated. This is why the laboratory is isolated on an island on a volcano at an altitude of 3,397 meters above sea level, and is surrounded by kilometers of volcanic land, with no plant life anywhere nearby.

The influence of gas releases associated with volcanic activity can be limited because there is an updraught during the day, and a downdraught at night. These air currents are created by the temperature difference between the island and the sea. During the day, the land heats up more quickly than the sea. So the air at ground level heats up more quickly

and creates a rising current because hot air, which is less dense, rises into the atmosphere. The problem is that, during the day, this current carries the air from the land and sea (which is influenced by plant life and humans) up to the level of the laboratory's sensors. In these conditions, the concentration measured is no longer a global concentration because it is affected by the local environment [see Eschenbach].

Conversely, at night, the island is colder than the sea, and a falling air current is created (see Figure 18). This makes it possible to measure air coming from very high altitude.

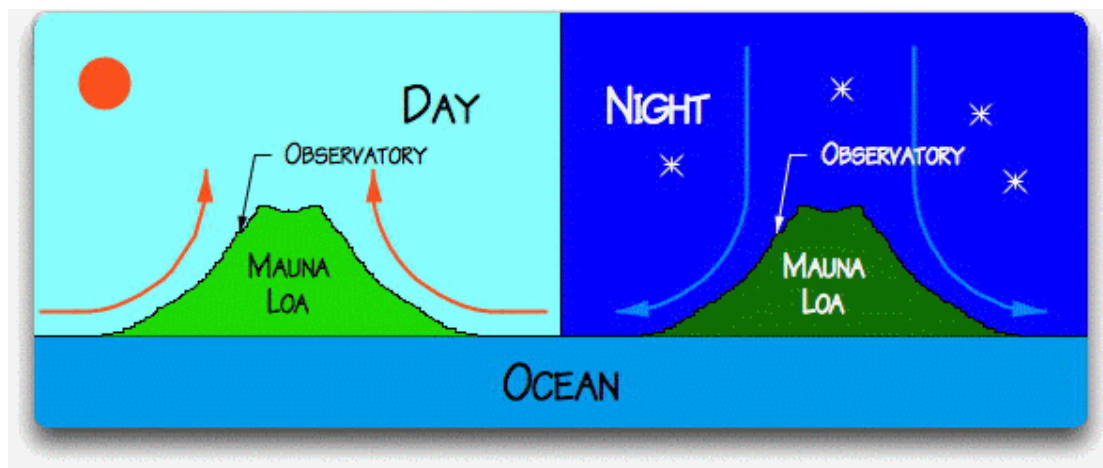


Figure 5. Air currents at Mauna Loa during the day and at night

Measuring at Mauna Loa began in 1958. Measurements are taken hourly. However, as we explained earlier, readings for only a few hours a day are selected for calculating daily average concentrations of CO₂.

In conclusion, sampling sites are not evenly distributed around the world. Some areas are very well provided with measurement stations (US and Western Europe), while others have hardly any (Africa and Asia).

B. Measurement by infrared absorption

The samples taken are then analyzed, with a different technique being used for each gas:

- infrared absorption for CO₂;
- fluorescence for CO;
- gas chromatography for CH₄, N₂O, SF₆ and H₂.

CO₂ is analyzed by infrared absorption, and the operating principle is that air is drawn into a cylinder. A transmitter sends out infrared light, which passes through the air sample to an infrared detector. The CO₂ atoms in the air sample will absorb some of the infrared radiation at a particular frequency. The higher the concentration of molecules, the more infrared will be absorbed, and the weaker will be the signal reaching the receiver. The detector's (electrical) signal is then translated into a quantity of CO₂. Hourly calibration ensures that the measurements are accurate.

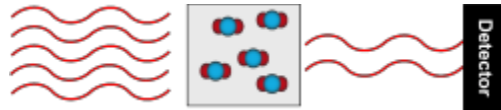


Figure 6. Diagram of infrared absorption

C. Processing the results

The infrared spectrometer provides raw data on CO₂ concentration for a particular site on a particular day. Data are then selected using a very precise method:

- firstly, the standard deviation over a minute must be less than 0.30 ppm;
- secondly, hourly data must not differ by more than 0.25 ppm from those for the previous hour;
- thirdly, data for hours when there is an updraught are not retained;
- and lastly, there is a method for eliminating outliers. A curve is adjusted in accordance with the data for preceding hours and, for each day, any hourly data that deviate from this curve by more than twice the standard deviation are withdrawn.

In all, data for an average of just 13.7 hours a day are retained.

The preliminary procedures for processing data are not neutral and are highly questionable scientifically. Their effect is, of course, to eliminate a number of variations, which might in fact be valid.

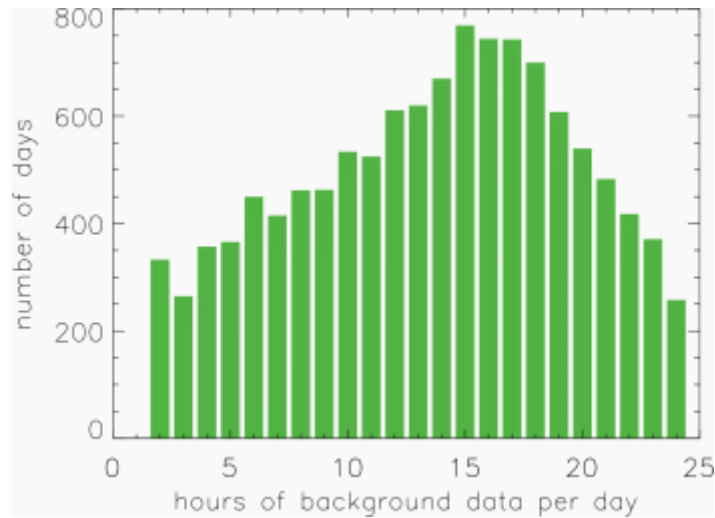


Figure 7. Distribution of number of hourly data retained

Figure 20 shows the distribution of the number of hourly data selected for processing, without taking account of days for which fewer than two hours of data have been retained. No data, or just one hour of data, have been retained for more than 6.5% of days.

D. Results

The data collected on the NOAA website give the following results:

- there is an increase in the concentration of CO₂ in various parts of the world;
- the variation in concentration depends on the location of the sampling site (longitude and latitude);
- there is a seasonal fluctuation.

The accuracy of the data depends partly on the way in which samples are taken. Results are more detailed for baseline observatories than they are for surface measurement stations.

1. Baseline observatories

Measurements have been taken from 1974 to 2013 at four observatories: Barrow (Alaska), Mauna Loa (Hawaii), American Samoa, and the South Pole (Antarctic).

The data for each observatory are available on the NOAA website in the form of text files. Three files are available for each laboratory: hourly, daily and monthly averages.

The files contain several columns:

- code corresponding to the site's name;
- date, from 1974 to 2013: year, month, hour, minutes, seconds;
- concentrations: a value of -999.99 is given when a value is missing;
- standard deviation on concentration measurements;
- number of points taken into account to calculate the average;
- latitude, longitude and altitude;
- type of measurement.

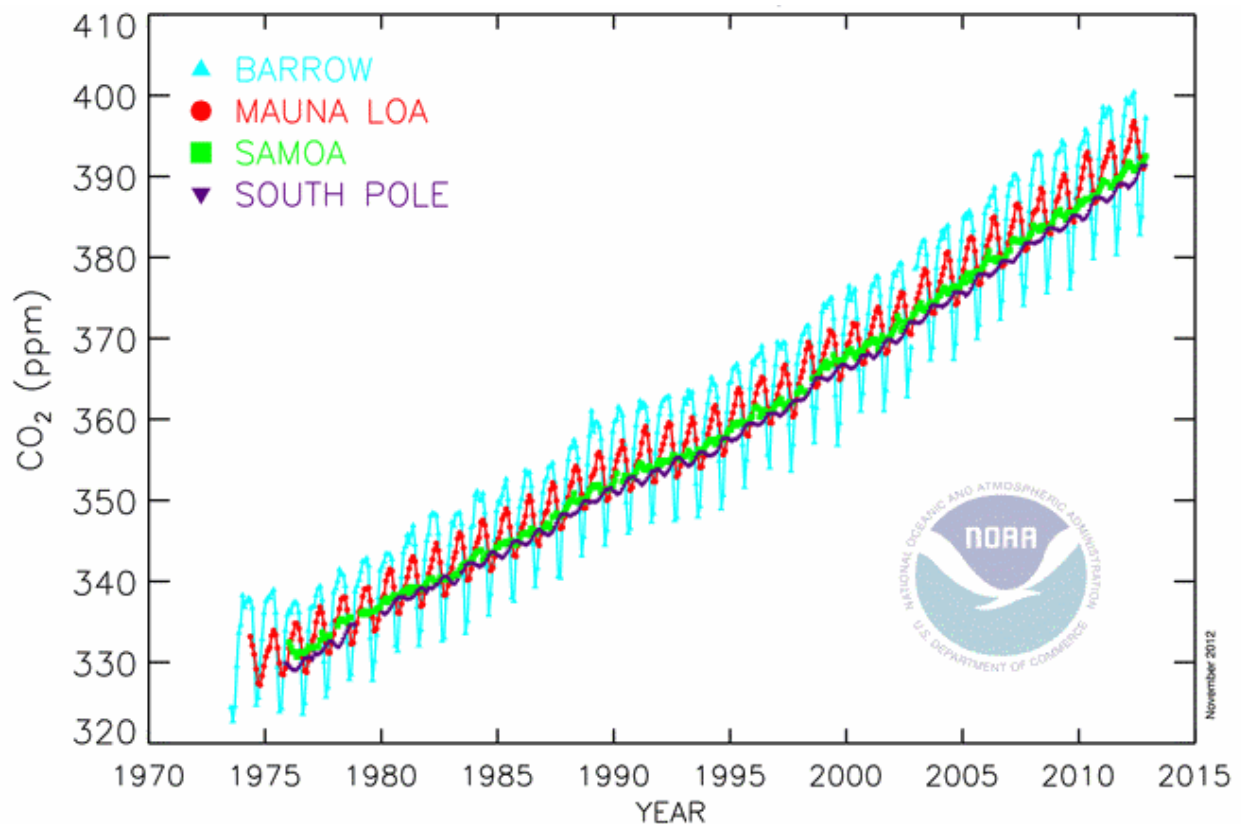
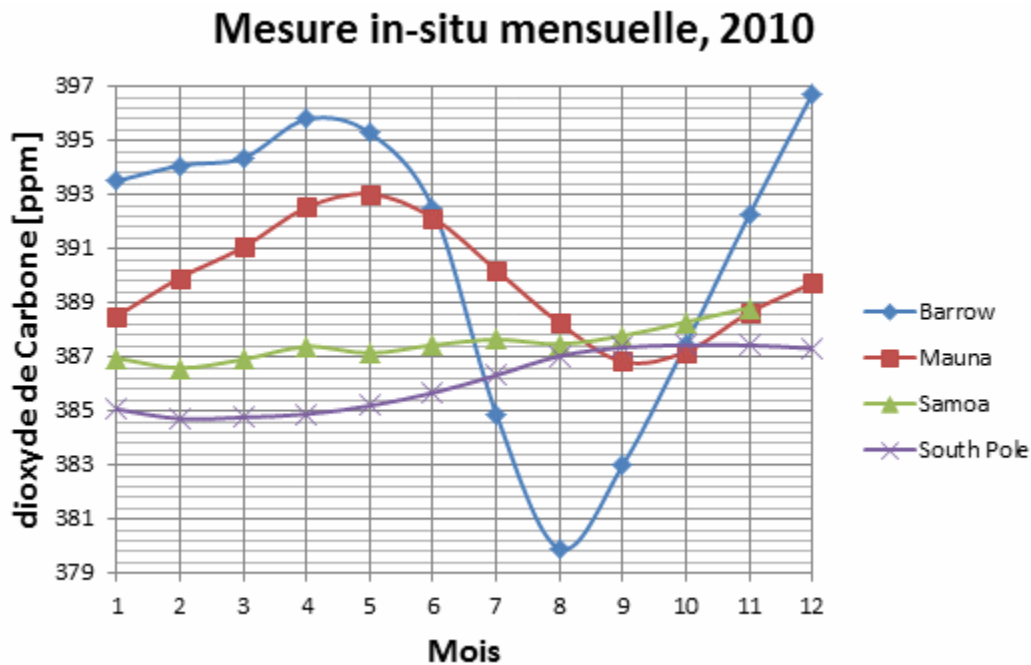


Figure 8. Monthly average CO₂ concentrations for various laboratories. The three observatories differ in location (longitude and latitude) [Tans].



Key

In-situ monthly measurements, 2010

Vertical axis: Carbon dioxide (ppm)

Horizontal axis: Month

*Figure 9. Average monthly CO₂ for various laboratories, 2010.
The observatories differ in location (longitude and latitude).*

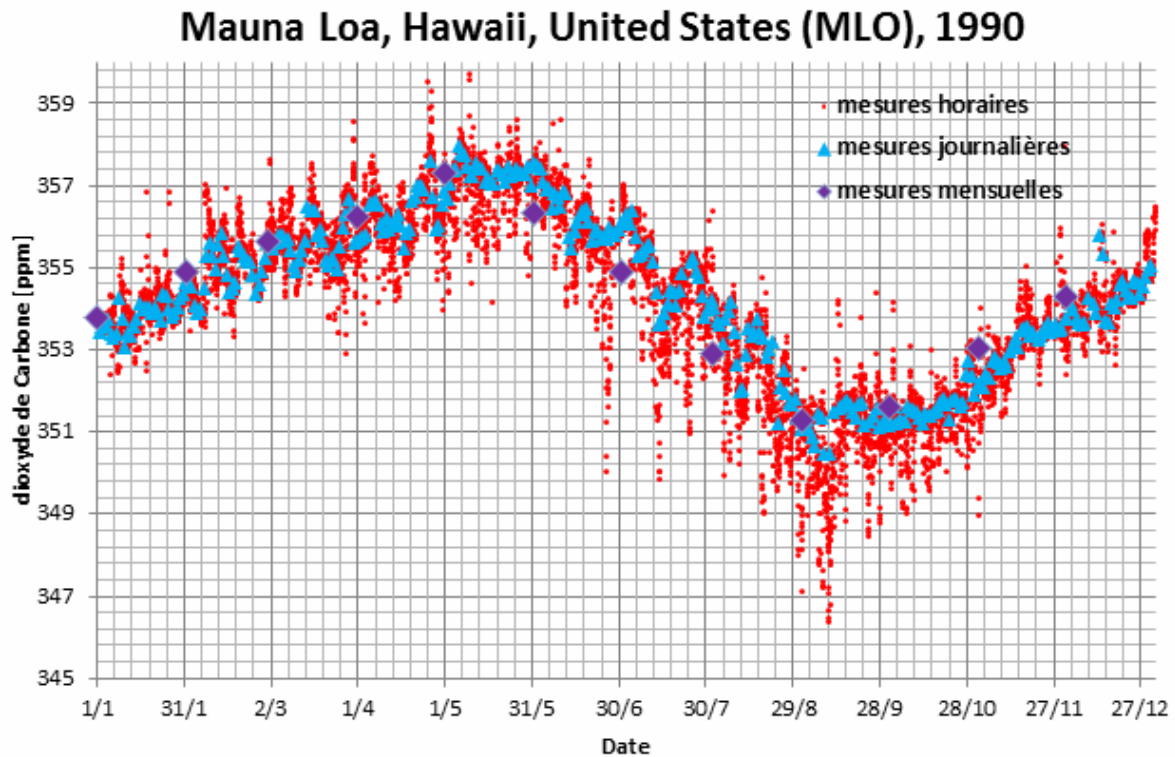
The results from these observatories show a rise in CO₂ concentrations that is independent of latitude (Figure 21). There are annual fluctuations in CO₂ concentrations, which are caused by seasonal changes and plant photosynthesis. During the summer, photosynthesis is very significant and CO₂ concentrations are high; the opposite is true in winter. The seasonal cycle is stronger in the northern hemisphere because the land surface is greater.

Figure 22 shows that the variation in CO₂ concentrations is not the same throughout the world. For example, the maximum CO₂ level recorded does not occur on the same date for Barrow and the South Pole. The variation in concentrations is also different at each site: the lower the observatory's latitude, the smaller the variation.

Let us come back to Mauna Loa. The measurements recorded there during 1990 are given in Figure 23. They show a daily variability of the order of 3 ppm and, once the data have been processed, there is a discrepancy between the monthly and daily values: monthly values are higher than daily values when there is an upward trend, and lower when there is a downward trend. This is explained by the choice of date for the monthly average: for example, for January, the date is the first of the month rather than 15 January (in the

middle of the month).

Also, Figure 24 shows the seasonal nature of CO₂ concentrations. Maximum concentration is reached in May, with minimum concentration in September. The NOAA explains that this difference is caused by plant photosynthesis.



Key

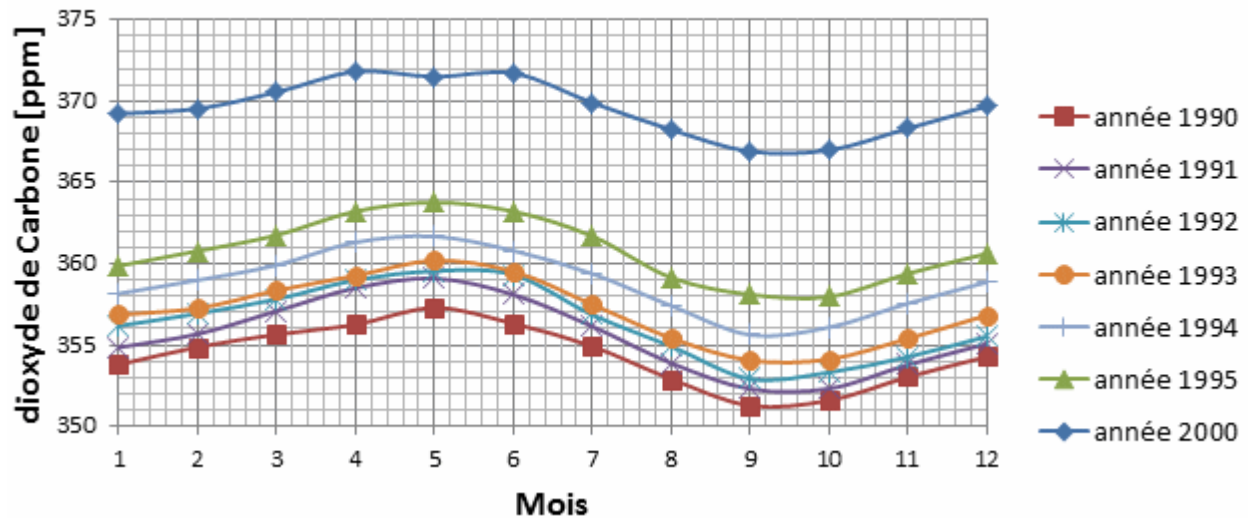
Top right: hourly measurements
daily measurements
monthly measurements

Vertical axis: Carbon dioxide (ppm)

Horizontal axis: Date

Figure 10. Measurements of CO₂ concentrations at Mauna Loa, 1990

Mauna Loa, Hawaii, United States (MLO)



Key

Right: year 1990, etc

Vertical axis: Carbon dioxide (ppm)

Horizontal axis: Month

Figure 11. CO₂ measurements at Mauna Loa, 1990-2000

2. Tall towers

The data for tall-tower samples are not provided. Only the results given in Figures 25 and 26 are available.

The results of a study conducted at Wisconsin Tower (US) demonstrate the influence of altitude on measurements of CO₂ concentrations (Figure 25). The variability of the measurements increases when they are taken at low altitude. The explanation offered by the NOAA is that the influence of human beings and plant life is felt more strongly at lower altitudes: concentrations reach a maximum during the day, and are at their lowest at night.

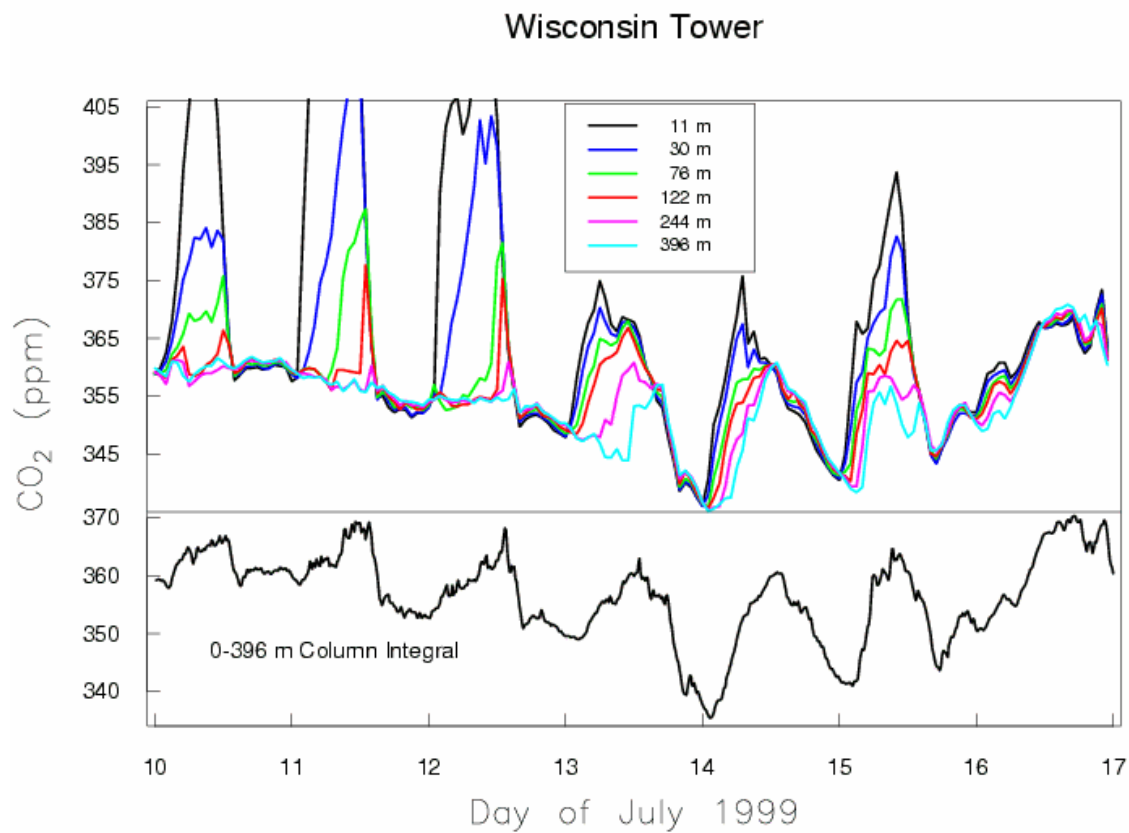


Figure 12. Measurements of CO₂ concentrations for a week in July 1999, Wisconsin Tower

Figure 26 shows the influence of the seasons on the variability of measurements at various altitudes. In January, altitude has no impact on the concentrations recorded: there is less vegetation and less 'plant respiration'.

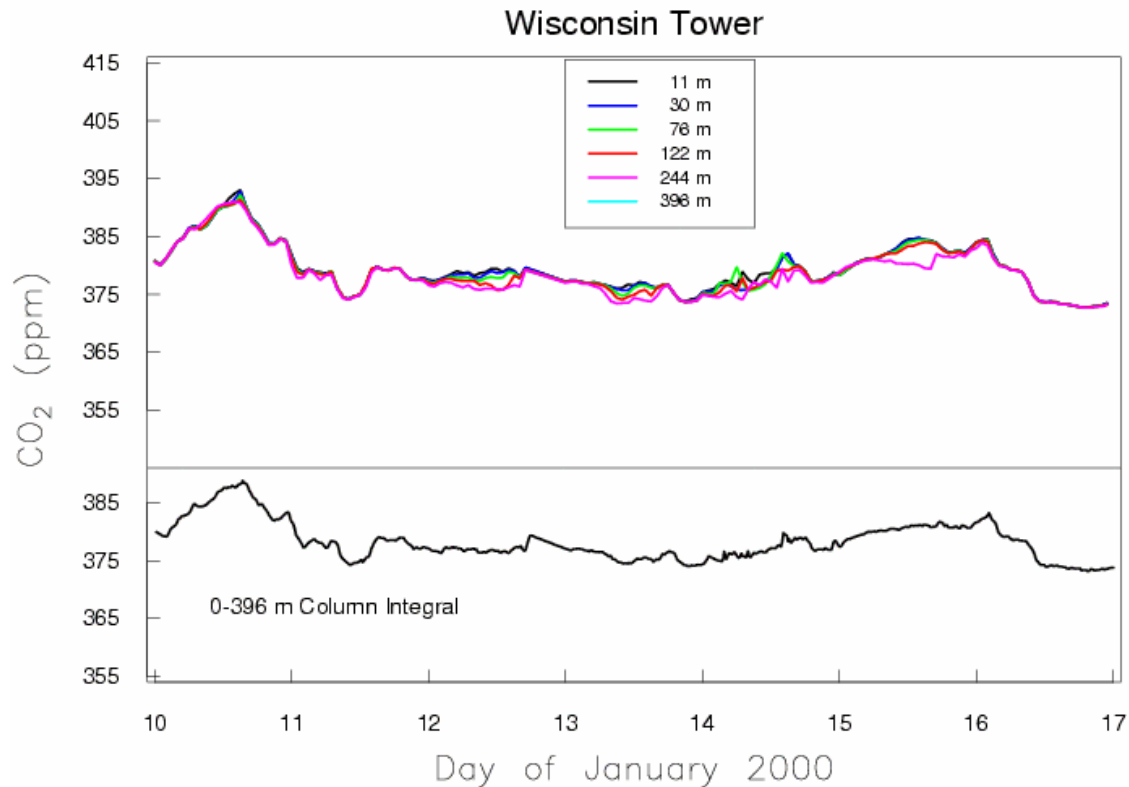


Figure 13. Measurements of CO₂ concentrations for a week in January 2000, Wisconsin Tower

3. Surface measurements

Samples are taken at various laboratories around the world and placed in flasks.

The data for each laboratory are available on the NOAA website in the form of text files (91 files). Each laboratory submits a text file containing the (already processed) monthly results. Sampling periods vary from one laboratory to another: for example, measurements for France cover the period 1982-2013, while those for Germany cover 2006 to 2013.

The files contain several columns:

- code corresponding to the site's name;
- date: year and month;
- concentrations: a value of -999.99 is given when a value is missing.

The files are much less detailed than those for the baseline observatories. It is possible to find the location of laboratories on the NOAA website, but not in the text files themselves.

Let us take the example of the following laboratories:

Code	Name	Country	Latitude	Longitude	Altitude [m]
KZM	Plateau Assy	Kazakhstan	43.250	77.880	2519.0
KCO	Kaashidhoo	Republic of Maldives	4.970	73.470	1.0
CRZ	Crozet Island	France	-46.434	51.848	197.0

Table 1. Location of three laboratories taking surface measurements

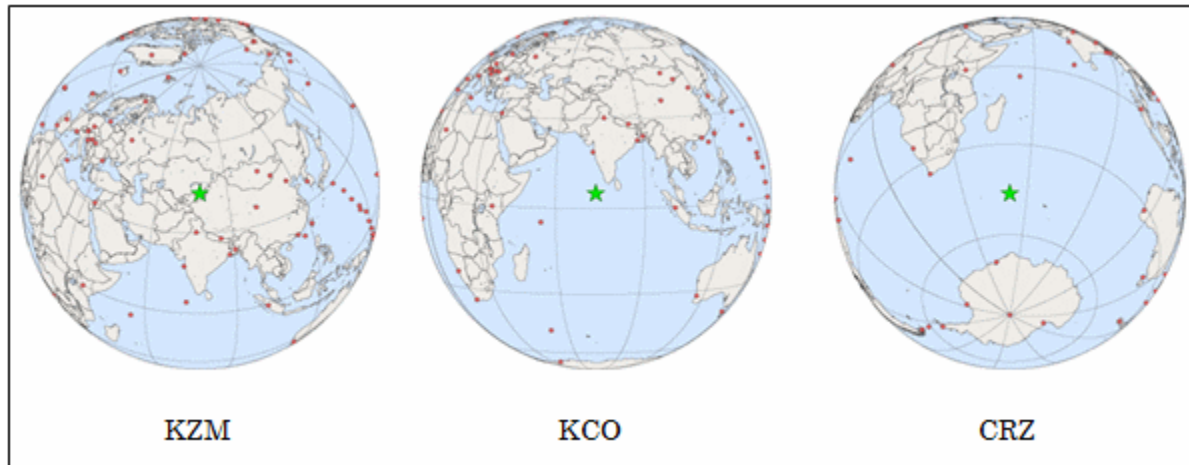
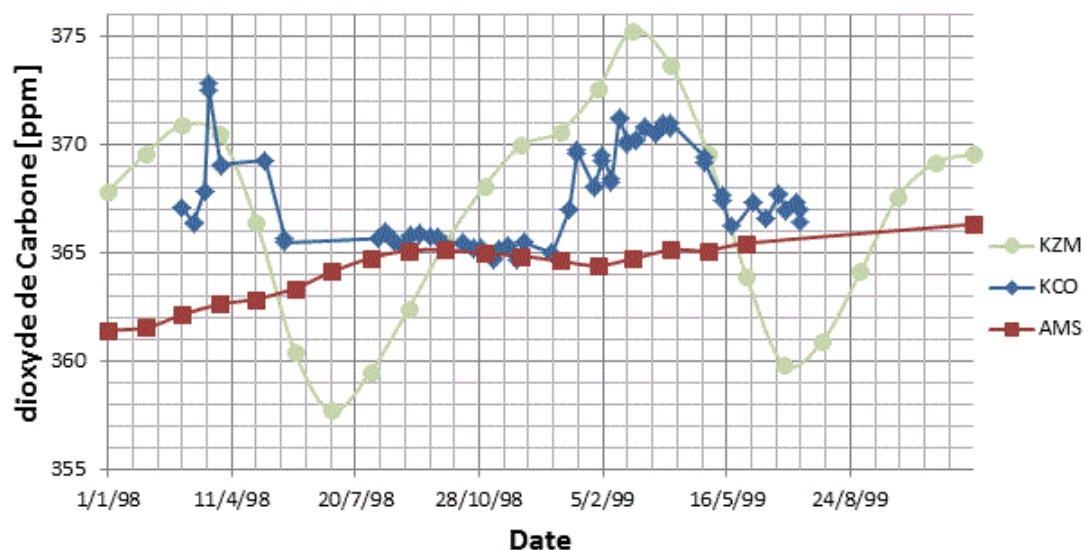


Figure 14. Location of laboratories belonging to France, Kazakhstan and the Republic of Maldives

These three laboratories are all located at about the same longitude (Table 1). If we combine the data for 1998 and 1999, we can see the same phenomena as in Figure 23. The variations in concentration are greater at higher latitudes. Unlike the measurements taken at the baseline observatories, the frequency of measurements at these three laboratories is less consistent.

Mesure en surface mensuelle, 1998 - 1999



Key

Monthly surface measurements, 1998-1999

Vertical axis: Carbon dioxide (ppm)

Horizontal axis: Date

Figure 15. Monthly CO₂ average for various laboratories, 1998-1999

E. Conclusion

- Poor distribution of sensors

The global distribution of measurements is far from even, with nearly all measurement stations being located in Europe or the US.

The choice of the Mauna Loa measurement station to represent the world's entire atmosphere is contestable, despite the arguments put forward by some scientists. Measurements are taken at just one place, in the high atmosphere, on a volcano. It would be possible to compare the Mauna Loa data with other measurements, over a long period, to see if they are representative, but this has never been done.

It has never been proven that CO₂ is distributed evenly above a certain altitude. The amount of CO₂ found in the low atmosphere cannot, in any event, be discounted in a global assessment. Nobody would think of discounting surface temperature measurements and

looking only at high-altitude measurements.

- Insufficient data

The first problem is the way in which CO₂ samples are analyzed. Only 13.7 hours of measurements are retained each day at Mauna Loa, which is just a little more than half a day.

Two further problems arise when it comes to global readings. Firstly, the only data available for each site are monthly measurements; daily measurements are not available.

Also, each laboratory/observatory edits and selects its own data, which means the results are specific to each site's location.

For the Mauna Loa station, only night-time measurements are retained. As we explained earlier, this is 'justified' by air flows.

- Data processing

The data in the text files have already been processed, and it is explicitly stated that missing values have been replaced with averages or interpolations. The earlier curves are based directly on NOAA data.

The published data show an increase in CO₂ concentrations, but the fact that measurements are not uniform and the way in which they have been processed before publication deprive them of any scientific value: you have to have the raw data to validate the way in which they have been processed.

III. Direct chemical measurements of CO₂

A. Measurement technology

Direct measurements of CO₂ concentrations, collected by various scientists, have been compiled by Ernst-Georg Beck in '180 years of atmospheric CO₂ gas analysis by chemical methods'.

Several techniques have been used, including titration and volumetric analysis, which make it possible to obtain a measurement that is accurate to within 3 ppm. These techniques have been well established since 1812 and have since been improved.

Measurements are taken in rural areas or on the outskirts of major towns or cities. This means they are subject to significant local variability caused by the absorption or release of CO₂ by the land or sea, plant photosynthesis, industry, local atmospheric pressure, wind, or various natural fluctuations. To be able to interpret this type of measurement, you would have to measure CO₂ in every cubic kilometer around the world.

Chemical measurements in the troposphere show variabilities of more than 400 ppm over a period of less than five years, which implies that an abnormal amount of CO₂ was released into the atmosphere during this period. These measurements therefore do not reflect the global concentration of CO₂.

B. Distribution of measurements over space and time

These measurements have been taken in various parts of the world, mostly in the northern hemisphere, since 1812. The temporal density of measurement points varies enormously from one place to another.

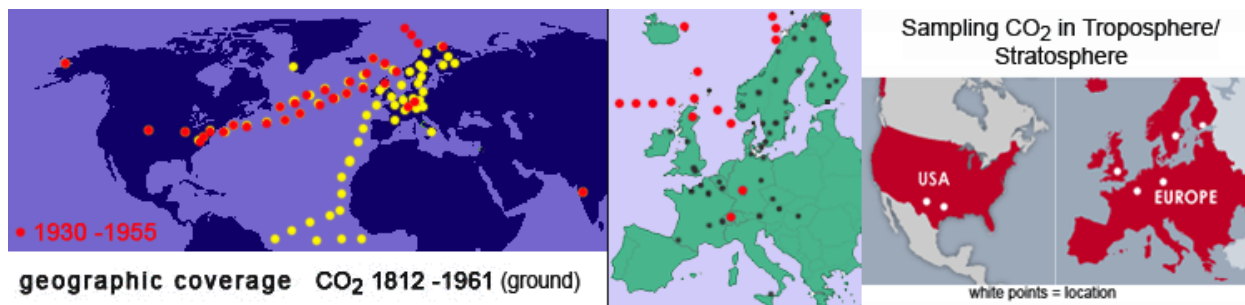


Figure 16. Distribution of chemical measurements

C. Results

The measurements compiled by Ernst-Georg Beck indicate CO₂ concentrations in excess of 400 ppm on various occasions in the past.

These data show a significant variability in CO₂ concentrations over the past 150 years, and contradict the data from ice-core samples, which indicate a strictly upward trend with very little variability.

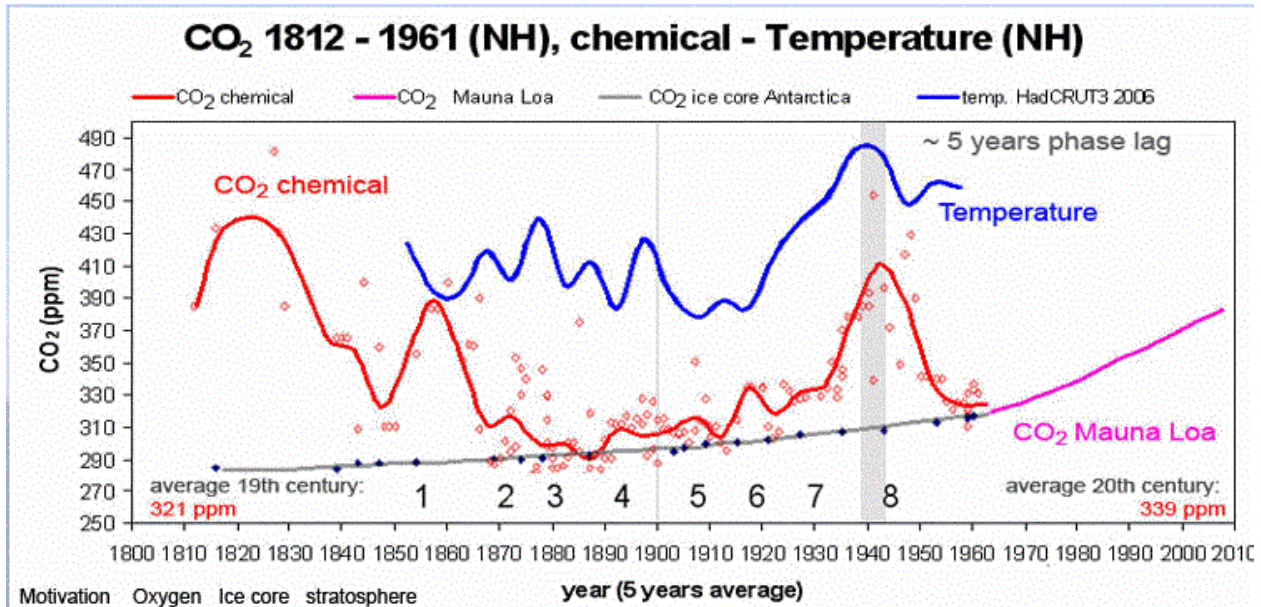


Figure 17. Comparison of various techniques (Beck et al, 2008)

D. Conclusion

This method of measuring CO₂ is well established, but measurement stations are not distributed evenly and there are clearly not enough of them, given the great variability of CO₂ concentrations. We shall simply note that the data collected by this method do not make it possible to conclude that CO₂ concentrations are rising.

IV. Ice-core measurements

A. Measurement technology

The concentration of air bubbles is measured by spectroscopy, the absorption of laser beams, and gas chromatography. Ice samples weighing 40 grams are placed in a vacuum and crushed. The air that escapes is captured and analyzed.

This measurement method is not very reliable [see Delmas]. The measurements are indirect and do not necessarily reflect the original composition. CO₂ can dissolve over time and be absorbed. Acid-carbonate reactions can occur, as can oxidation of organic matter by H₂O₂. These processes are encouraged by the presence of impurities in the ice. There are far fewer impurities in the ice in the Antarctic than there are in Greenland.

The absence of any recently released gases (such as SF₆) in ice cores makes it possible to

conclude that they are perfectly hermetic and have not been recently contaminated by the air.

B. Distribution of measurements in space and time

In areas where temperatures are below 0°C, falling snow does not melt but builds up and gradually turns into ice. In doing so, it traps tiny air bubbles and dust. Today, ice-core analyses enable us to determine the CO₂ concentration in these tiny air bubbles back as far as 800,000 years ago.

Snowfall in Antarctica is rare, which limits the amount of data available.

Also, for the oldest periods, the ice has compacted under its own weight, which makes it more difficult to date with any accuracy. This means that the concentrations measured are averages over very long periods. It is possible for there to be a difference of as much as 6,000 years between the age of air bubbles and the age of the ice in which they are trapped, and this age gap has yet to be gauged with any precision.

Ice-core data are available on the NOAA website in text files. These files have several columns: age of air measured, age of ice, depth of ice, and CO₂ concentration, with associated uncertainty. The main sources of raw data are as follows:

- 1) The Vostok data [Vostok Data] are dated from 420,000 BC to 2000 AD. The age of the air is calculated with a precision of +/-5,000 years, sometimes extending beyond 10,000 years, and temporal samples vary between 2,400 and 4,500 years in the deepest layers [see Fisher].
- 2) The study going back farthest in history was conducted by the European EPICA project in Antarctica [Dome C Data]. The ice core extracted measures 3.1 km and makes it possible to measure CO₂ concentrations 800,000 years ago. Uncertainty about age 800,000 years ago is +/-6,000 years. Different dating methods have been used (LR04 and EDC2), and do not give the same result, showing a discrepancy of the order of 20,000 years [see Parrenin].
- 3) Measurements have also been made using ice cores at the Law Dome [Law Dome Data]. They are dated between 1948 and 1992. The data are smoothed out over 10 years for the deepest layers.

C. Results

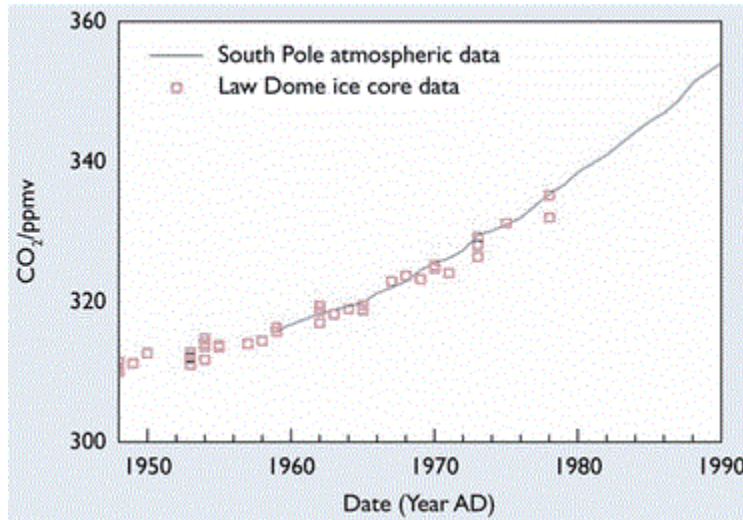


Figure 18. Direct measurements of CO₂ compared with ice-core measurements

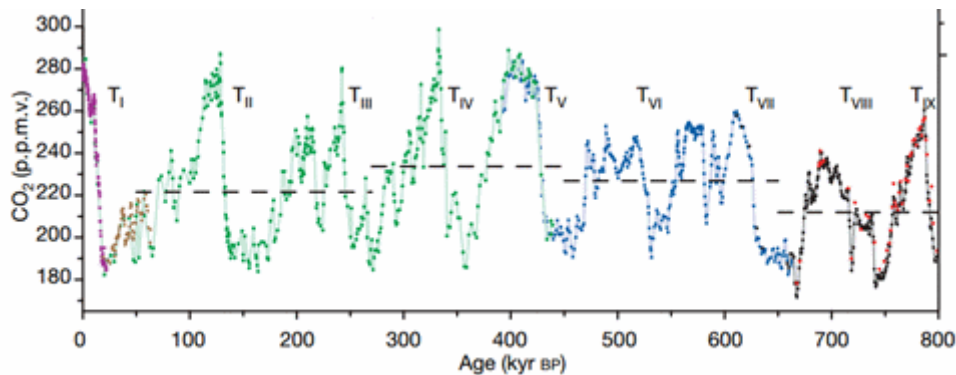


Figure 19. CO₂ measurements at Dome C (violet, blue and black), Taylor Dome (brown) and Vostok (green)

The CO₂ measurements indicate a relatively stable concentration of between 180 and 280 ppm (Figure 32). The ice-core data have been compared with direct atmospheric measurements at the South Pole, and these measurements seem to be in agreement on the annual level (Figure 31). The concentrations measured at the Law Dome concur with those measured at Vostok.

D. Conclusion

There are several methodological problems here:

- firstly, the method is open to criticism. It is an indirect measurement method, and the composition of the ice cores is not strictly representative of the atmosphere at the time. Also, there is enormous uncertainty about the actual age of the trapped gas;
- secondly, measurements are clearly limited to the areas in which samples are taken, and therefore cannot reflect global concentrations of CO₂.

V. Measurements using the stoma of fossilized plants

A. Measurement technology

Stoma are microscopic pores in the leaves of fossilized plants. They are used for gas exchanges, and there is an empirical relationship between the density of stoma and the concentration of CO₂. These indirect measurements are not very accurate, with uncertainty of up to 60 ppm.

B. Results

These measurements indicate a much greater variability of CO₂, and very often much higher concentration levels, than ice-core measurements do. Also, the various studies analyzing this type of data do not agree. In [Beerling], the concentration range is between 225 ppm and 310 ppm for the period 9,000 years ago, whereas it is 250-360 ppm in [Wagner].

C. Conclusion

The uncertainty of these measurements is far too great for them to be used.

VI. Critical analysis

There is nothing that enables us to support the commonly-held conclusion that CO₂ concentrations are constantly rising and are higher than anything that might have been seen before the industrial age.

In fact, CO₂ concentrations constantly vary, from one place to another and from one time to another, just as temperatures do. To claim that the data collected at a small number of observatories (one hundred of them!), and then processed and expurgated in the ways we have described, are representative of the global value is an absurdity. This restricted view comes from a consensus of experts, and has never been validated.

The different measurement methods give different results, which is not at all surprising given the variability of the phenomenon. Reference to cores extracted from the ice is an absurdity: these ice cores are representative of the CO₂ concentration at the place of extraction (and over a very long period, as well!), and can tell us nothing about concentrations elsewhere.

There is a consensus within a certain community to present as ‘scientific’ the results obtained by the methods it recommends, even though these methods have never been validated and evidently suffer from major methodological defects.

Our conclusion is very clear: the entire methodology used to observe CO₂ has to be overhauled before we can even think about the results that have been obtained by these observations. The first step is to correctly document the natural variability of CO₂ concentrations (what affects them, and how do they manifest?). We must not forget that the aim here is to make a global assessment of CO₂ concentrations in the entire atmosphere.

Let us use a simple comparison to explain this. Let us imagine that we want to document incidents of sins committed by human beings. Before concluding that ‘we can restrict our investigations to the areas around cathedrals’, which would at least have the merit of simplicity, we would have to find out about the ‘natural’ variability of sin. Perhaps, in fact, more sins are committed far away from cathedrals?