

The first International Polar Year (1882–1883): French measurements of carbon dioxide concentrations in the atmosphere at Bahia Orange, Hoste Island, Tierra del Fuego

F.W.G. Baker

La Combe de Sauve, Venterol, 26110, France (mike.baker@wanadoo.fr)

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ABSTRACT. During the first International Polar Year (1882–1883) the French expedition to Bahia Orange, Hoste Island, Tierra del Fuego carried out a series of 39 measurements of concentrations of carbon dioxide in the atmosphere. These were supplemented by 6 measurements during the return voyage to Cherbourg. In addition 20 similar measurements were made at 4 stations in the northern hemisphere and 17 at 3 stations in the southern hemisphere that were participating in the transit of Venus observations.

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G.S. Golitsyn (1985) gives concentrations of 260 ppm to 280 ppm for the first half of the 19th century and the French measurements fit within this range. However, Duplessy and Morel (1990: 215), give 280 ppm to 290 ppm based on measurements of the concentrations obtained from air bubbles in Arctic ice cores, and suggest that the higher levels might be caused by CO₂ from northern hemisphere industries.

Introduction

Although the series of measurements of the concentrations of carbon dioxide (CO₂) begun by C.D. Keeling in the International Geophysical Year (1957–1958) is well known, the series made 75 years previously in 1882–1883 by the French first International Polar Year (IPY) expedition is not. In this, the fourth International Polar Year, and when measurements of CO₂ levels in the atmosphere are commonplace, it is appropriate to draw attention to the series made by P. Hyades at Bahia Orange, Hardy Peninsula, Hoste Island, Tierra del Fuego (70°20' 47"W, 55°31'26"S) in 1882–1883 (Fig. 1). As early as 1869, several French scientists had put forward the idea that the effects of the industrial revolution might be increasing the concentration of CO₂ in the atmosphere. For example Bolin and others (1986) indicated that in 1896 the famous Swedish chemist Svante August Arrhenius had pointed out that the burning of fossil fuels might cause an increase in atmospheric CO₂.

Several attempts were made to develop a method to measure the concentrations of this gas in a reproducible manner, until one was developed in 1881. Using this method A. Muntz and E. Aubin (1881a) measured the concentrations of CO₂ in Paris and in the countryside near the city. After improvements had been made in the technique, J.B. Dumas (1882) suggested to the organisers of the French first IPY expedition to Bahia Orange that a series of measurements be made of the CO₂ concentrations at that locality. The suggestion was adopted and the French expedition made a series of 39 measurements at Bahia Orange with a mean result of 256 ppm and 6 measurements with a mean result of 268 ppm during their return journey to Cherbourg.

Measurements during the 19th century

The method used for measuring the concentrations of CO₂ in the atmosphere at Bahia Orange is given in detail in articles by A. Muntz and E. Aubin (1882b, 1884c) and by Dumas (1882). The description of the method is as follows:

A measured volume of air, of about 160 litres, was drawn at Bahia Orange from an inlet tube at a height of 4 meters above ground and at an altitude of 29 meters and away from possible sources of contamination, into a glass tube with pointed ends containing pumice stone impregnated with a measured solution of potassium hydroxide, free of carbon dioxide. The ends of the tube are cut immediately before the sample is taken and after the sample has been taken the ends of the tube are resealed. The tubes can then either be transported to the laboratory where the carbon dioxide is extracted and the concentration is measured or, since the tubes are enclosed in metal boxes, the tubes and their contents can be kept more or less indefinitely and the concentrations of carbon dioxide measured later. For each measurement two samples are taken.

The 160 litres of air contained some 90 ml of CO₂. Two samples were taken each day and because of the time taken to carry out the sampling, there was an interval between the taking of the two samples, as indicated in the tables of results. The question naturally arises concerning where the analyses were performed. It is certain that those taken on board the vessel were taken to Paris for analysis as were all the samples taken at the stations participating in the transit of Venus observations. It is evident from some of the descriptions of earlier sampling by Muntz

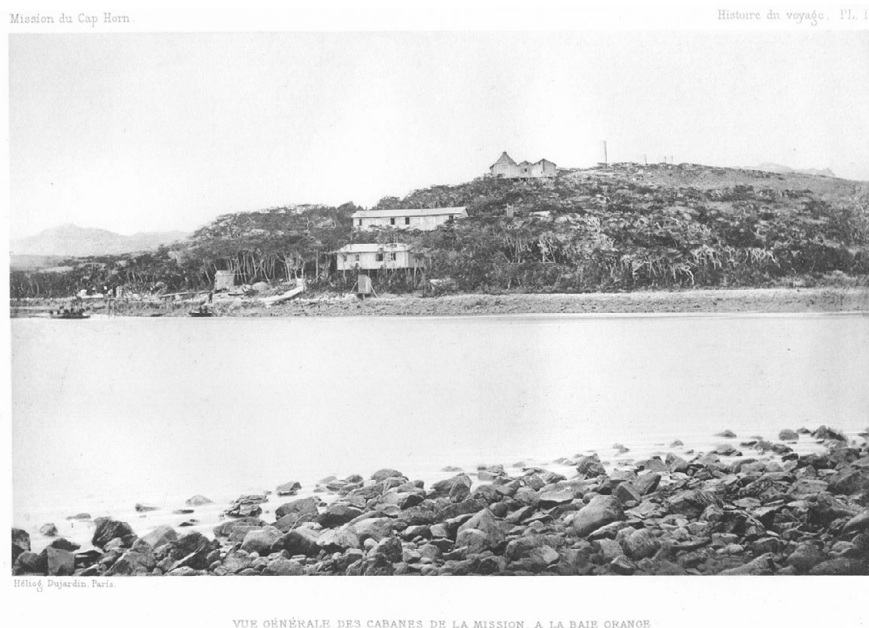


Fig. 1. A photograph showing the French Mission at Bahia Orange. The hut for CO₂ observations is that on the left of the group of three on the skyline. Courtesy of Archives de l'Académie des Sciences, Institut de France, Paris

and Aubin that those samples were also taken to Paris for analysis. The glass tubes containing the samples were put in metal cases and the samples once introduced and sealed into the tubes could be analysed at any time. It is certain that some of the samples were analysed at the Conservatoire des Arts et Métiers, Paris and there may be some samples that were never analysed.

Muntz and Aubin published (1881b) an article entitled 'Sur la proportion d'acide carbonique contenu dans l'air' (On the concentrations of carbon dioxide in the atmosphere) in which they presented the results of three measurements made on 1 April 1881 which gave 273 ppm, 290 ppm, and 299 ppm. They indicated that the increase was associated with a darkening of the sky.

The concentrations of CO₂ in the atmosphere made in 1869, 1870 and 1871 at Rostock, northern Germany, by F. Schultze (Dumas 1882) gave 287 ppm, 290 ppm, and 301 ppm while the 193 measurements made by J. Reiset in 1872, 1873 and 1879 on the sea shore, in the countryside, at ground level, in crops, in woods and in Paris varied from 294 ppm to 310 ppm. Following these measurements, J.B. Dumas (1882) put forward the idea that the industrial revolution might be increasing the concentrations of CO₂ in the atmosphere and several attempts were made to verify this. For example, Muntz and Aubin (1881c) made observations in the 'high' atmosphere (although measurements with similar results had already been made from a balloon in 1875) at 2877 m at the top of the Pic du Midi from 9 to 14 August 1881 with concentrations in the range 276 ppm to 301 ppm and at lower levels on 5 to 7 August at Pierrefitte (507 m) where the results were 279 ppm to 300 ppm, and at Luz (730 m) with a result of 269 ppm. From these,

they deduced that CO₂ is uniformly distributed in the atmosphere.

First IPY measurements

J.B. Dumas (1882) suggested to a meeting of the French academy on 6 March 1882 that: i) advantage be taken of the French first IPY expedition to Bahia Orange and of other expeditions making observations of the transit of Venus to take place on 6 December 1882, to make measurements of CO₂ concentrations in the atmosphere; and ii) if the measurements proved effective to organise annual observations at well selected stations in different parts of the globe. Fortunately the first suggestion was adopted but unfortunately the second was not.

Almost at the last minute, the organisers of the French IPY expedition being transported in the vessel *Romanche* agreed to carry out such measurements in the more pristine environment of Bahia Orange so that these could be compared with the measurements made earlier in France, where it was thought the effects of pollution would be more apparent. Muntz and Aubin (1882b) prepared the necessary equipment and instructed P. Hyades, the ship's medical doctor, concerning how to use it. *Romanche* left Cherbourg on 17 July 1882 and arrived at Bahia Orange on 6 September 1882.

The measurements began on 31 October 1882 and would seem to be the first long series of measurements of concentrations of CO₂ to be made in the southern hemisphere. The 39 measurements made at the Bahia Orange station covered the period up to 1 July 1883. In addition six measurements were made between 20 September and 21 October 1883 on board *Romanche* during the return

Table 1. Observations of Carbon Dioxide Concentrations at Bahia Orange, French IPY Station (70°20' 47"W, 55°31'26" S).

Dates	Time	Air Temperature °C	Barometric Pressure mm	Concentrations of carbon dioxide ppm
1882				
31 Oct.	13.40 & 18.10	+4.2	737.0	250
10 Nov.	15.11 & 18.20	9.0	740.5	252
20 Nov.	10.02 & 12.53	6.5	742.4	268
01 Dec.	19.20 & 22.47	9.3	752.5	251
14 Dec.	16.37 & 20.07	8.8	750.0	251
20/21 Dec.	22.50 & 02.55	6.0	743.7	257
1883				
01 Jan.	05.11 & 08.00	9.6	749.6	257
10 Jan.	13.52 & 16.20	6.0	750.5	265
20 Jan.	23.10 & 01.43	6.0	728.2	243
01 Feb.	06.03 & 08.23	6.8	754.0	266
10 Feb.	14.22 & 16.33	3.0	737.3	276
20 Feb.	22.45 & 01.36	8.0	741.4	272
01 Mar.	07.32 & 10.03	9.0	735.0	261
06 Mar	00.45 & 03.08	2.0	729.6	261
10 Mar	01.43 & 04.33	8.5	751.8	254
20 Mar	22.33 & 01.12	6.0	735.6	247
31 Mar	06.40 & 09.25	3.5	752.9	254
01 Apr	06.27 & 08.50	5.5	745.7	250
10 Apr	22.35 & 01.05	11.0	739.8	260
20 Apr	22.05 & 00.35	4.0	741.2	252
10 May	15.04 & 17.35	5.0	752.0	262
10 May	20.21 & 23.04	3.0	749.3	265
20 May	23.31 & 03.18	6.0	751.2	285
01 June	09.00 & 11.54	6.2	746.2	263
09 June	21.33 & 01.03	0.0	738.9	255
10 June	11.57 & 15.10	1.0	740.0	247
10 June	21.29 & 00.10	2.0	738.0	238
16 June	10.23 & 13.55	1.5	752.7	231
16 June	20.03 & 23.31	2.6	753.9	232
17 June	20.19 & 23.59	3.0	753.5	259
18 June	20.09 & 23.35	0.0	761.6	255
21 June	10.34 & 13.39	4.0	758.9	251
27 June	11.52 & 15.27	2.4	750.9	258
27 June	20.25 & 23.40	2.0	750.2	260
28 June	20.18 & 23.59	4.5	752.8	260
29 June	20.26 & 00.05	2.0	753.9	250
30 June	20.04 & 23.33	3.8	741.4	244
01 July	04.27 & 07.42	2.0	737.5	275

voyage to Cherbourg. The individual measurements are set out in Tables 1 and 2. The average of the readings at Bahia Orange was 256 ppm and for the observations made on board *Romanche* the average was 268 ppm which the authors indicate as being approximately the mean of the observation made in France and those made at Bahia Orange. The maximum and minimum concentrations recorded at Bahia Orange were 285 ppm and 231 ppm and on *Romanche* 277 ppm and 247 ppm. The official report (Martial 1885–1891) giving all the observations was published between 1885 and 1891. The CO₂ measurements made at Bahia Orange were published by Muntz and Aubin in 1886 but this is essentially a copy of the paper they presented earlier to the French academy of sciences (Muntz and Aubin 1884c).

Muntz and Auban (1884a) also made a preliminary presentation to the French academy of the results of the measurements made at stations participating in observations of the transit of Venus in Chile, Haiti, Florida, Martinique, Mexico: and in Patagonia at Chubut and Santa Cruz.

Conclusion

In view of the interest of several eminent French scientists in the concentrations of CO₂ in the atmosphere and of the proposal of J.B. Dumas (1882) to continue annual observations at a number of stations throughout the world if those made at Bahia Orange were successful, it seems strange that neither French nor other scientists, seem to have been very interested in the results obtained

Table 2. Observations made on board *Romanche*.

Dates	Time	Air temperature °C	Barometric Pressure mm	Concentrations of carbon dioxide ppm
1883				
20 Sept.	14.35 & 17.15	10,0	765.2	274
28 Sept.	14.04 & 16.30	20,5	766.5	277
01 Oct.	09.30 & 11.35	21,0	766.1	272
04 Oct	14.34 & 17.04	21,0	765.7	270
16 Oct	12.36 & 14.48	26,0	761.1	249
21 Oct	12.27 & 14.46	27,0	761.3	270

Notes to the tables.

1. The tables given in Muntz and Aubin (1884b, 1884c and 1886) also include weather, wind speed and direction, hygrometry, volume of air analysed and the concentration of CO₂ calculated for 0°C and 760 mm pressure. Since these do not modify the concentrations of CO₂ they have been omitted for simplicity's sake.
2. The coordinates are as stated by Muntz and Aubin in the final report. However, several sets of coordinates for the station (possibly for different buildings) are given in different sources. That used for taking the CO₂ samples was 35 m from the nearest inhabited building on the base.

by the French first IPY expedition nor of those made by the transit of Venus stations. The existence of the former has already been noted in *Polar Record* (Baker 1982). It would be interesting today to repeat some of the measurements using the same technique in order to compare the measurements made at the end of the 19th century with those of today. In any case, if one plots the 19th century measurements on the curve given by Duplessy and Morel (1990) we see that they are slightly below those obtained from the analysis of the gas contained in bubbles of air from Arctic ice cores. This may be due to the difference in measuring techniques or because of the increase in CO₂ concentrations caused by northern hemisphere industries, as they suggest.

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