THE MONTSOURIS SERIES OF CARBON DIOXIDE CONCENTRATION MEASUREMENTS, 1877–1910*

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Abstract. The longest continuous record of measurements of atmospheric CO2 concentration available to date, that was made between 1877 and 1910 at the Montsouris Observatory in the outskirts of Paris, is presented and the methods used and the site are described. Annual, seasonal and daily variations in the record were considerable, especially between 1877 and 1880 and possible reasons for this high variability are discussed. Although no direct proof of the reliability of the series is available an attempt has been made to estimate this by comparisons with contemporary series whose precision is better known and also through an analysis of the results from the point of view of the major sources of error. The results suggest a precision of measurement better than 2%; analysis of the daily and the mean seasonal variation shows no evidence of any significant urban contamination of the Montsouris record. Mean decadal values of the Montsouris series show a marked rise in concentration from 283 ppm in the first decade to 313 ppm in the second, with a small and nonsignificant drop to 309 ppm in the third decade of the series. The results of the measurements are thus compatible with the hypothesis that a major and variable non-fossil fuel source of atmospheric CO2 was active during the last quarter of the nineteenth century.

1. Introduction

The increase in atmospheric CO2 concentration caused by human activities is thought to have important implications for climatic change (for a recent bibliography see Olsen et al., 1980). Initially attention was focussed exclusively on the release by combustion of carbon stored in fossil fuels (Callendar, 1940); more recently the role of deforestation and other land use changes as a source of atmospheric CO2 has received considerable attention (Woodwell et al., 1978).

In evaluating the relative importance of these two sources, information on the CO2 concentration in the atmosphere prior to the period of massive fossil fuel use would be of considerable assistance, especially if an extended series of measurements were available which could provide information on the long-term rate of increase due to land use changes, as well as on the size of shorter term fluctuations due to other causes.

The purpose of this communication is to present the results of such an extended series of early CO2 measurements and to examine their reliability. The measurements were started at the Montsouris observatory in the outskirts of Paris in 1876 and were continued almost without interruption for one third of a century. A description of the methods used and of the site is presented and the results obtained analyzed in an attempt to

ascertain whether the variations observed were due to sampling and analysis deficiencies or airmass circulation and vegetation effects.

2. Details of Measurement Methods and Site

The brief account of the methods of measurement which follow was taken from the short descriptions accompanying the results of the measurements which appeared in the Annuaire de l’Observatoire de Montsouris for the years 1879, 1880 and 1881 and in the brief notes accompanying the results given in the Annuaire Statistique de la Ville de Paris for the years 1877–1910.

Measurements were started in 1876 by M. Albert Levy with the assistance of P. Allaire and were carried out almost continuously from October 1876 until November 1910; for this 34-year period only six monthly mean values are missing. Until 1885 the measurements were reported as mean daily values, after which they were published as mean monthly values. All CO$_2$ concentrations were presented to the nearest 100 cm$^3$ CO$_2$ per 100 m$^3$ of air sampled, i.e., to the nearest part per million (ppm).

The method of measurement used was to continuously draw air from an inlet near a closed window of the laboratory in the Parc de Montsouris using a calibrated wet gas meter to measure the volume of air sampled. The saturated air was passed as very fine jets through three absorption tubes arranged in series which contained strong KOH solution with a few drops of tournesol added to increase dispersion. Each day, at noon, the absorption tubes were changed and the amount of CO$_2$ absorbed in each of them was measured by titration with HCl.

Two thirds of the CO$_2$ measured was contained in the first tube, one third in the second and less than 1% in the third. Despite this, the brief notes accompanying the tabulated results report that a fourth absorption tube was added in 1885 to ensure that complete absorption occurred in the first three tubes. From 1892 H$_2$SO$_4$ was used as the titrating agent.

The volume of CO$_2$ released by titration was measured by displacement of water to which a layer of oil was added to reduce absorption of CO$_2$. Small differences between the temperature and pressure of the air at the time of analysis and during the preceding 24 hours of sampling were corrected on the basis of temperature and pressure measurements made at the time of analysis and at six hourly intervals during the day. It is not stated explicitly if the values of CO$_2$ concentration presented were fractions of the volume of dry air sampled, however, it is clear that the measurements needed to correct for the variable water content of the air were available in that the temperature of the air saturated in the wet gas meter was measured four times a day together with the atmospheric pressure, so that a correction could be made for the volume of water contained in the air analyzed.

A precision of a few parts per million were claimed for the Montsouris CO$_2$ measurements by Marie-Davy (1880b) in response to discussion of the results obtained during the first 44 months of measurement (Reiset, 1880). Marie-Davy did not present a quantitative analysis of the errors of measurement at Montsouris in support of his claim; he does,