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V.W.J.H. Kirchhoff

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V.W.J.H. Kirchhoff
E.V.A. Marinho

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We describe the first carbon monoxide (CO) measurements performed directly in the Amazonian rainforest from air samples collected near the surface. CO mixing ratios from air grab samples were measured several times a day, at several sites, during 36 consecutive days in the Amazonian wet season. A sensitive instrument using chromatographic separation followed by mercury vapor detection was installed in the middle of the Amazonian rainforest, at Ducke forest preserve, 30 km north of Manaus ($3^{o}S$, $60^{o}W$). The average background concentration of surface CO was about 100 ppbv. This is three to four times smaller than values measured by other groups during the dry season, implying a large seasonal (dry x wet) variation. During the first half of the experiment there was considerable variability in the CO data with daily averages showing large error bars. Only small variability was observed during the last half of the experiment, probably owing to local meteorological conditions. Comparisons of samples from the clearing, representing air masses from above the canopy, with samples taken inside the forest, under the canopy, gave consistently larger concentrations within the forest.

OBSERVAÇÕES / REMARKS

This work was partially supported by the "Fundo Nacional de Desenvolvimento Científico e Tecnológico" under contract FINEP-537/CT. This work will be presented at the Spring AGU Meeting, Baltimore, May 16-20, 1988.

SURFACE CO RESULTS FROM THE ABLE-2B EXPEDITION TO AMAZONIA

V.W.J.H. KIRCHHOFF

and

E.V.A. MARINHO

Instituto de Pesquisas Espaciais - INPE/MCT
C.P. 515, 12201 - São José dos Campos, S.P.
Brazil

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E.V.A. MARINHO

Instituto de Pesquisas Espaciais - INPE/MCT

C.P. 515, 12201, São José dos Campos, S.P.

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ABSTRACT

We describe the first carbon monoxide (CO) measurements performed directly in the Amazonian rainforest from air samples collected near the surface. CO mixing ratios from air grab samples were measured several times a day, at several sites, during 36 consecutive days in the Amazonian wet season. A sensitive instrument using chromatographic separation followed by mercury vapor detection was installed in the middle of the Amazonian rainforest, at Ducke forest preserve, 30 km north of Manaus (3^{o}S, 60^{o}W). The average background concentration of surface CO was about 100 ppbv. This is three to four times smaller than values measured by other groups during the dry season, implying a large seasonal (dry x wet) variation. During the first half of the experiment there was considerable variability in the CO data with daily averages showing large error bars. Only small variability was observed during the last half of the experiment, probably owing to local meteorological conditions. Comparisons of samples from the clearing, representing air masses from above the canopy, with samples taken inside the forest, under the canopy, gave consistently larger concentrations within the forest.

1.0.- INTRODUCTION

Carbon monoxide concentrations have been measured, near the surface, for a continuous period of 36 days in the Amazonian rainforest. The measurements were performed as part of the INPE-NASA GTE ABLE-2B expedition to Amazonia in April-May, 1987, in the local wet season. Instrumentation for measuring CO was set up at Ducke forest preserve, some 30 km north of Manaus (3^{o}S, 60^{o}W). Previous measurements of CO concentrations have been made in the Manaus region from airplanes (Sachse et al, 1988; Crutzen et al, 1985). We describe the first surface CO results measured directly in the forest over a relatively long period.

It should be noted that we have not yet exhausted the analysis of all aspects of the data set. A much more detailed discussion of the data will be presented elsewhere.

1.1.- MEASUREMENT TECHNIQUE

The basic CO measurement technique used is chromatographic separation followed by mercury vapor detection (Seiler, 1974). This technique has much better chromatographic resolution and measurement precision, as well as linearity of response, as compared, for example with the FID technique, for low concentrations in the ppbv (parts per billion by volume) range. The carrier gas is dried and filtered to eliminate interference from reducing gases. Sulphur dioxide and hydrocarbons, which could react with mercuric oxide at the reaction chamber temperatures are eliminated on a routine basis since the instrument is dedicated to the measurement of CO only.

Samples are individually injected and the concentration is determined by comparison with calibration

gases. Injection into the flow system is accomplished by initial transference to a 2 ml sample loop which is, after extensive flushing with sample air, introduced into the main flow using a six-port valve. The operation is very simple and fast and has excellent resolution and precision. Around 100 ppbv, typical precision is 0.2%. Each sample is analysed in about 5 minutes.

The samples are collected by a small portable air pump that pressurizes stainless steel cans of 800 ml volume, electropolished internally and especially manufactured for air sampling purposes, developed by R. Rasmussen, Oregon Graduate Center.

2.0.- RESULTS

Table 1 summarizes the data obtained between April 6 and May 11, 1987. During the first three days air samples were taken using glass syringes, but for the rest of the period special stainless steel cans (courtesy of Rei Rasmussen) were used.

Our basic sampling strategy was to take samples in the forest, that is, under the forest canopy, and in the clearing. Sampling sites were defined close to the improvised laboratory and samples were taken systematically. At each site at least three samples were taken daily, one in the morning (8 A.M.), one at noon, and another at 4 P.M. After April 26 we took hourly samples during the daytime. We also took hourly samples during continuous periods of 24 hours on 4 occasions, starting April 20, 26, and May 1 and 6. Besides the sampling at Ducke we also tried to obtain an idea about surface distributions, and took sporadic samples at several other sites of interest, some as far as 160 km eastward from Ducke.

The sampling sites at Ducke are shown in Fig. 1.

Four sampling sites are defined by M1 to M4. M1 and M3 are in the clearing, and M2 and M4 are within the forest. M2 is on the natural forest side whereas M4 was chosen within cultivated trees. From a small iron tower at M3 one could take samples from several heights above ground.

Our results did not show differences between M1 and M3 samples, or between M2 and M4 samples. There was a significant difference, however, between the clearing and forest samples, as will be shown later.

Daily average surface CO concentrations are shown in Fig. 2. The values shown are the average for three daily samples: one at 8 A.M., one at noon, and one at 4 P.M. All samples are collected at about 1.5 m above ground. The period average is about 100 ppbv (Rasmussen absolute scale). It is apparent that in April, between about day 13 and 26, the variability is much larger than in May. The large April error bars reflect large CO concentrations that occurred sporadically, and believed to be due to air masses that were brought from the city limits of Manaus. The winds in this period had the right direction, that is, instead of blowing from the east, as usual, the air was coming from the southwest-southeast direction.

In an attempt to find a diurnal trend we have plotted in Fig. 3 the averages of all morning, noon, and afternoon samples for sites M1, M2, and M4. The record for M3 is incomplete for this analysis and is not included here. There seems to be a slight noon maximum in the Ducke CO data, with the afternoon values being smallest. Note also that the concentrations in the forest (M2, M4) are larger than in the clearing (M1). We have performed a special additional comparison campaign between CO concentrations in the clearing and the forest, and the concentration in the forest seems to be consistently higher than in the clearing, by about 5 ppbv.

While we took regular samples at the Ducke sites we also wanted to have an idea on CO concentrations at other locations, especially when the winds were bringing air from Manaus to Ducke. Fig. 4 shows a simplified map of the Manaus region and its main road system. The state road AM 010 to Itacoatiara, to the east, was chosen for taking a few samples, especially during the Manaus airmasses episodes, when the winds were blowing from the south. Samples were taken at the sites Rio Preto (R.P.), Embratel Tower (E.), and Rio Urubu (R.U.), about 160 km away from Ducke.

Fig. 5 shows the result of our samplings along the road on April 19, 1987, when the winds were blowing from the south. The concentration at Ducke was 20% larger than the period average. But along the road, to the east of Ducke, the concentrations were smaller, being only 80 ppbv at R.U. This result seems to be consistent with the interpretation that the Ducke concentration was at least in part contaminated by Manaus air. It is interesting to note that on later days the CO concentration at R.U. was always larger than at Ducke, as shown in Fig. 6.

A few comparisons have also been made between Ducke samples and Met Tower samples. The concentrations for M1 are smaller (this is again consistent with our earlier result showing larger CO values in the forest than in the clearing). Also, the canopy results at the tower are smaller than the surface concentrations at the tower (Fig. 7).

3.0.- DISCUSSION

During April high concentrations of CO were observed at times. The presence of these peaks reflected in the much larger variability shown in Fig. 2 for April, with much larger error bars. During this time period the wind regime was unusual on some days bringing air that came from the Manaus area, when the normal wind direction is from the east. It appears that the normal behavior is better shown by the results in May when the variability is much smaller. The average concentration was about 100 ppbv. No concentrations below 80 ppbv were observed.

The average of 100 ppbv for the wet season may be considered high when compared to averages from marine sites at which concentrations of 40-50 ppbv are reported. On the other hand it is much lower than concentrations observed in the dry season when typical values of 300, 400, and up to 700 ppbv can be observed (Crutzen, 1985; Kirchhoff, in preparation, 1988).

CO concentrations below the canopy have been found slightly larger than in the clearing. This can be seen from the Ducke data and comparing the Ducke clearing data with the Micro Met Tower data. In addition we have performed 5 special hourly comparison campaigns and these also show about 5 ppbv more CO in the forest than in the clearing.

4.0.- CONCLUSIONS

Surface carbon monoxide concentrations were measured in the Amazonian rainforest. Our data represent the first results obtained during the wet season.

In order to minimize adverse effects of sample storage and transportation we have performed the sample analysis directly in the forest. Daily samples were analysed for a continuous period of 36 days. Major results are:

1 - The average CO concentration was about 100 ppbv. This is much larger than background values observed at Pacific or Atlantic sites.

2 - Sharp concentration increases were noticed at times, especially during April, peaking at about 200 to 300 ppbv, but lasting for only a few hours. It appears that the reason for such increases was air transported from the Manaus area, and possibly small regional fires.

3 - A diurnal variation can be seen with maximum in the daytime (noon) and minimum in the afternoon. The amplitude is small and more data will be necessary to confirm this diurnal trend.

4 - Our data show larger concentrations in the forest (below the canopy) than above it (in the clearing). The difference is only about 5 ppbv but was consistently observed..

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Seiler, W., The cycle of atmospheric CO, Tellus, 2, 116-135, 1974.

LIST OF FIGURES

TABLE 1 - Summary of surface CO data obtained between April 6 and May 11

SAMPLE TYPE	SITE	DATES
1 - Morning, noon, alfternoon	Ducke	April 6 to April 25
2 - Hourly samples	Ducke	April 26 to May 11
3 - Day-night sequences	Ducke	April 20, 26 and May 01, 06
4 - Surface distributions	Manaus	April 7, 13, 15
	Emater	April 10, 18, 19
	Airport	April 11, 22
	Tropical Hotel	April 11
	ZF1 Tower	April 12, 16
	Met Tower	April 13, 18, 24 and May 5
	INPA	April 22
	Careiro	April 25
	Rio Preto	April 19, 20, 28, 29 and May 04
	Embratel	April 19, 20, 28, 29 and May 04
	Rio Urubu	April 19, 20, 28, 29 and May 04

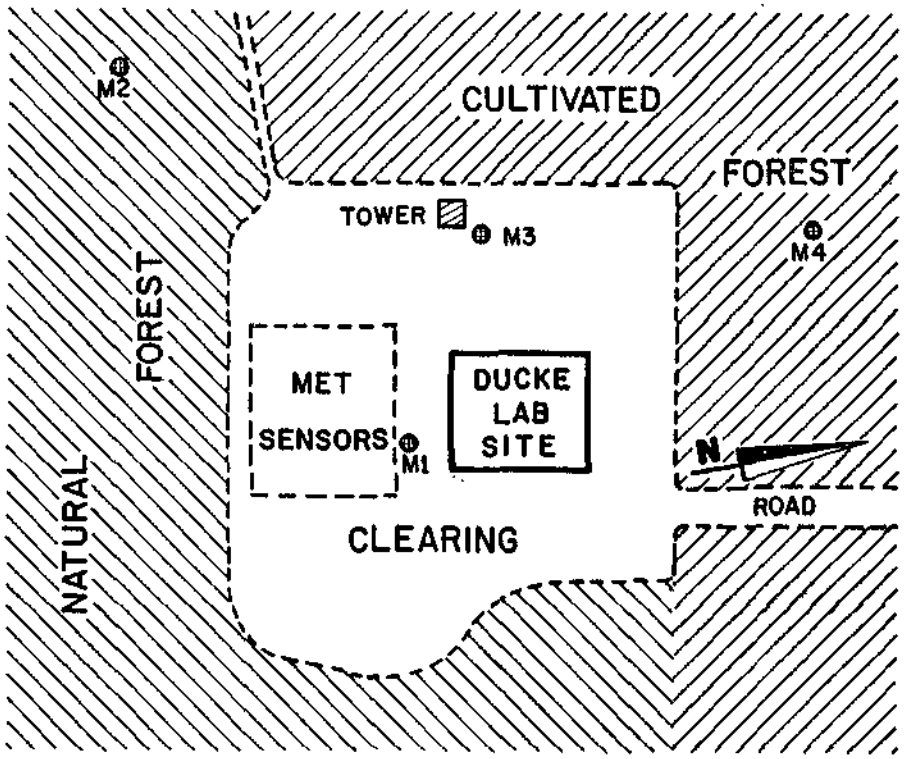

Fig. 1.- Sketch of sampling sites at Ducke forest preserve, 30 km north of Manaus (3^{o}S, 60^{o}W).

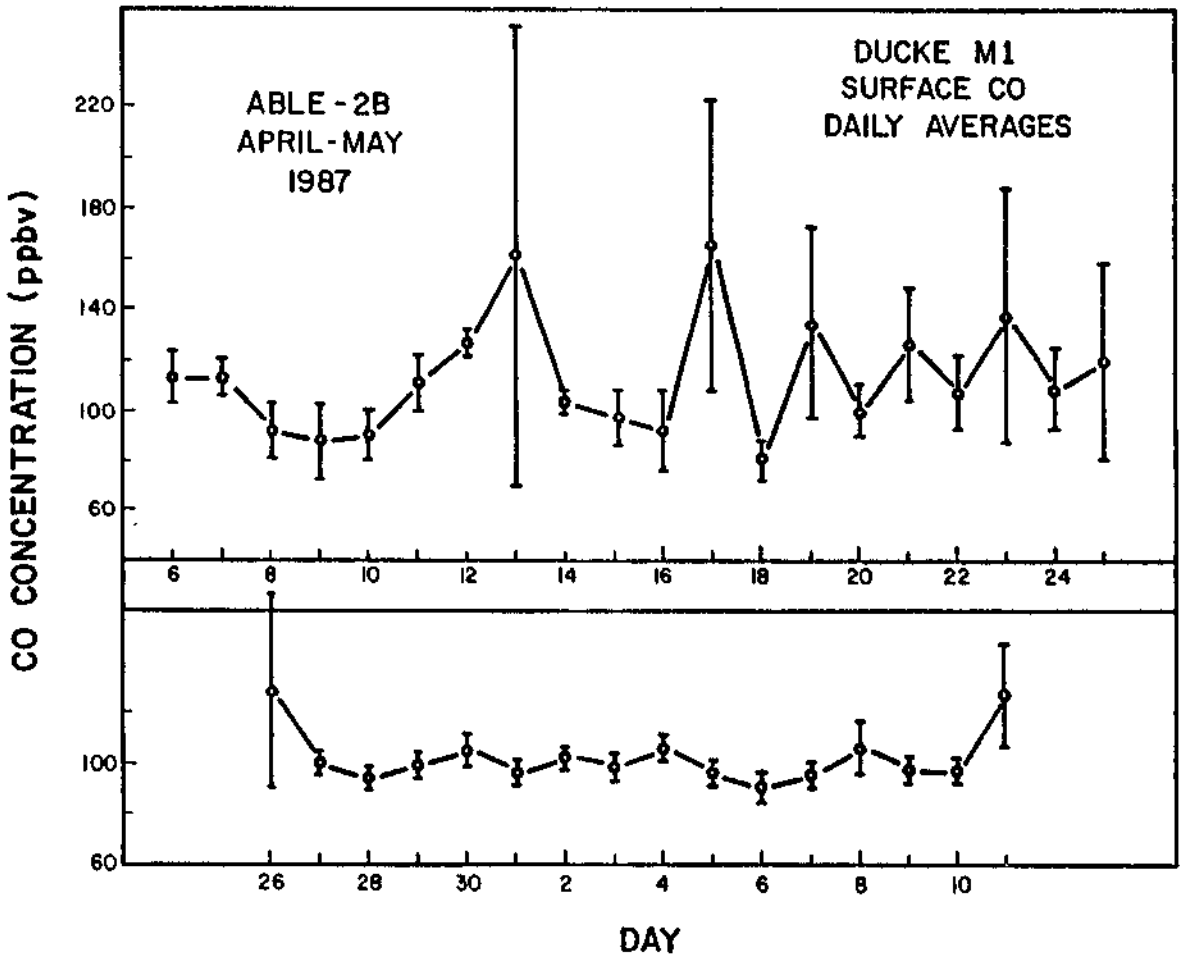

Fig. 2.- Daily (morning, noon, afternoon) average CO concentrations samples at site M1 during the experiment.

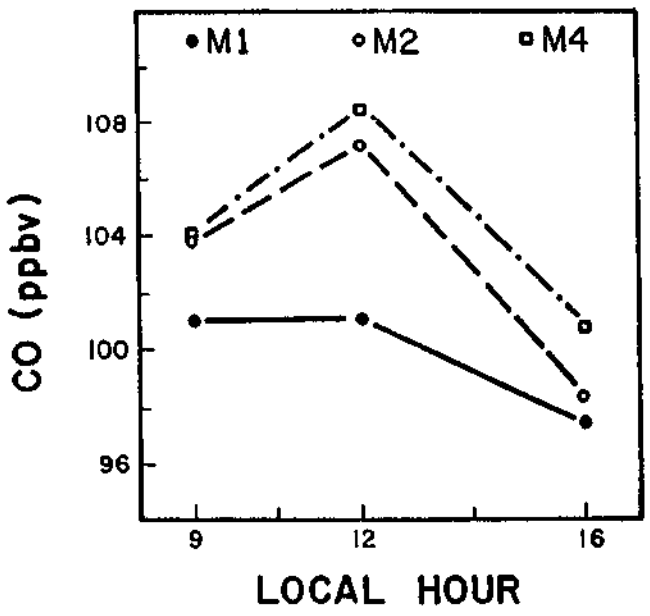

Fig. 3.- Diurnal variation at sites M1, M2, and M4 showing the morning, noon, and afternoon (8 A.M., noon, 4 P.M.) averages. Note also M2 and M4 are larger than M1.

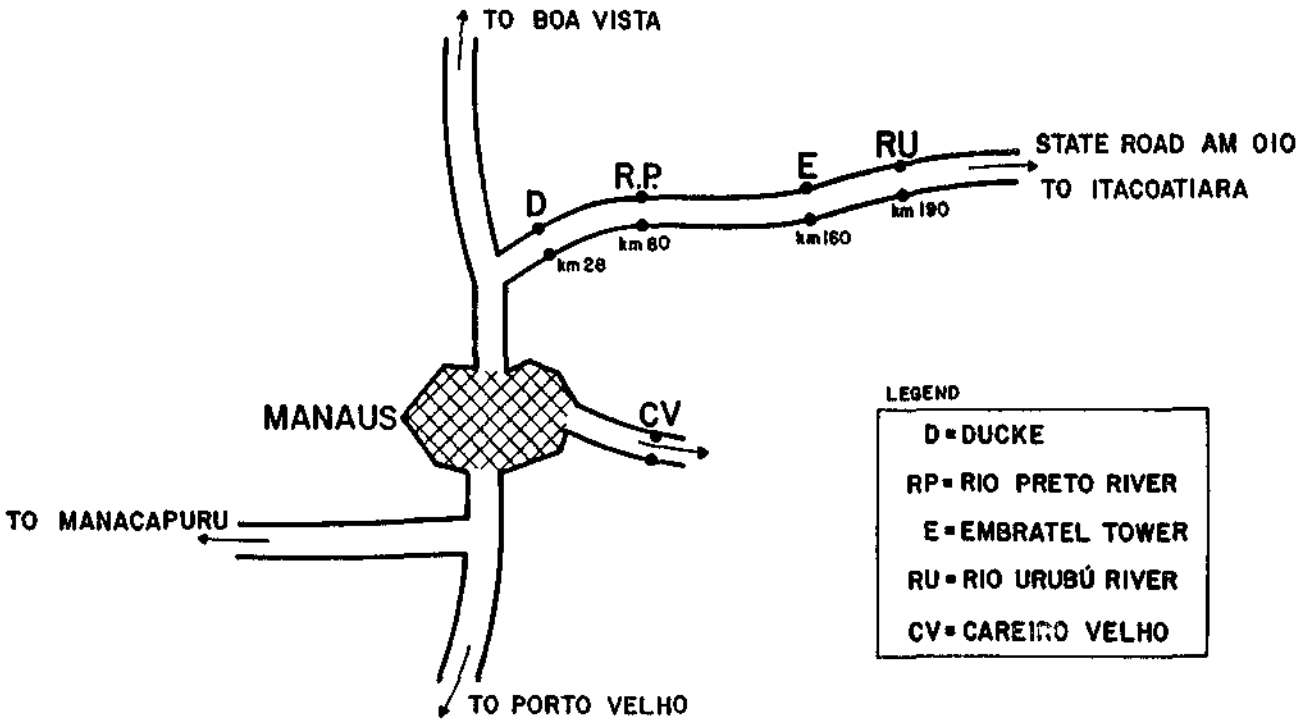

Fig. 4.- Simplified road map in the Manaus area, showing sampling sites eastward of Ducke forest.

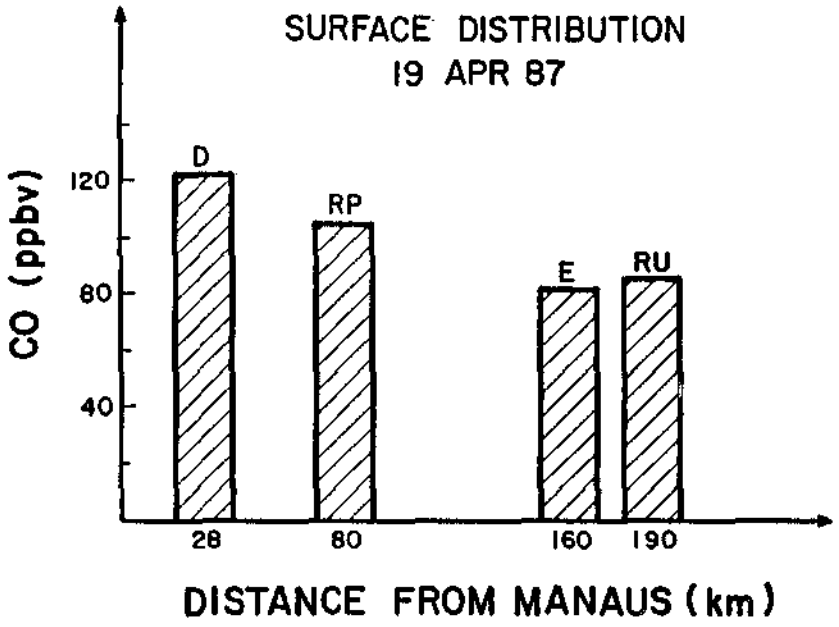

Fig. 5.- Surface distribution of CO concentrations along the AM 010 road on April 19, 1987.

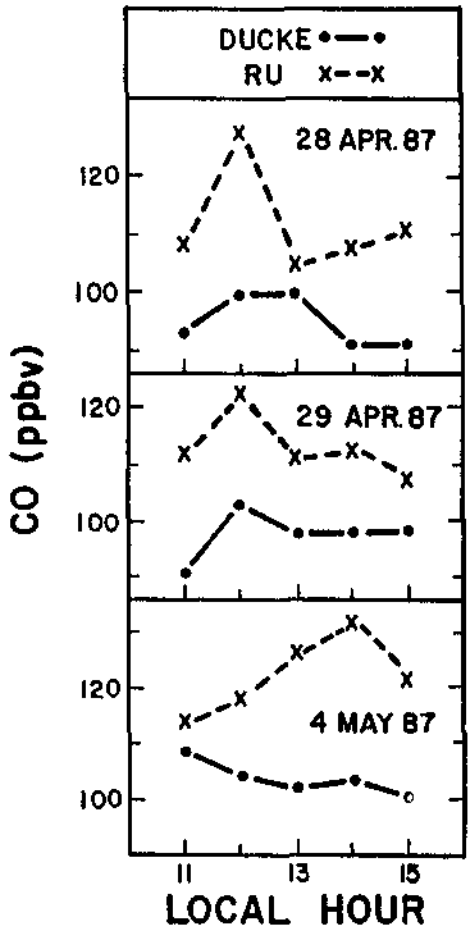

Fig. 6.- Comparison of CO concentrations at Ducke and at the R.U. site.

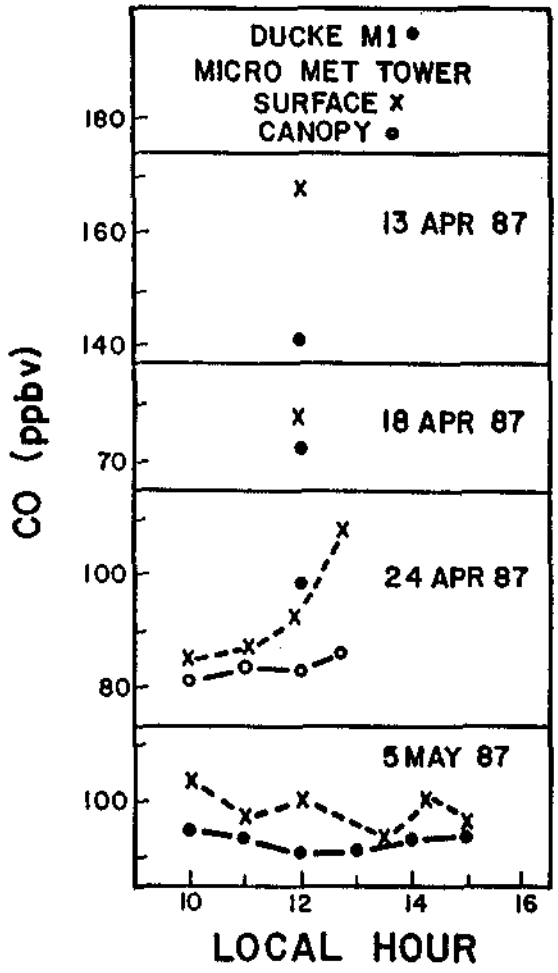

Fig. 7.- Comparison of CO concentrations at Ducke (M1 site) with canopy and surface concentrations at the Micro Met tower.

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E.V.A. Marinho

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JOSÉ MARQUES DA COSTA
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