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TRANSTEC EDITORIAL

A Technique for Validating Emission Production Models Test Results for the Central Region of Brazil

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INTRODUCTION

Fires in biomass fuels emit a complex mixture of particulate matter and gases into the atmosphere. Globally, the diversity of combustion products results from wide ranges in fuel types and fire behavior induced by the large variations in ecological types and weather phenomena. Fires in tropical ecosystems consume at least 80% of the biomass burned globally. For these fires, satellites have proven to be a valuable tool in studying their occurrence. One objective for this experiment was to provide basic data needed to calibrate differential irradiance measurements to estimate the proportion of flaming and smoldering combustion. Here, we explore a technique of measuring the flux of emissions from a large area of cerrado northwest of Porto Nationale in Brazil (the method was described by Malingreau et al., [1993]). This research was part of the SCAR-B Experiment carried out during August and September of 1995.

METHODS

A rectangular area was selected to the northwest of Porto Nationale of about 125 x 150 km. The coordinates of the rectangle in Figure 1 are: B) 9° 30'S, 49° 00'W; C) 8° 10'S, 49° 00'W; D) 8° 10'S, 50° 25'W; and E) 9° 30'S, 50° 25'W). The ER-2 NASA research aircraft was flown around the perimeter of the box making one revolution per hour. On board the ER-2 were several remote sensing instruments including the AVERIS and MODIS multi-channel remote sensing instruments. In addition, the GOES and NOAA AVHRR satellite imagery were collected for the period of the experiment (11 September 1995, 9:00 to 17:00 hours), however, we have not completed the analysis of the satellite imagery.

Detailed chemical profiling was done from the INPE Bandeirante research aircraft using a package of sensors from the US Forest Service and the University of Sao Paulo. The package included a system for collecting grab samples of trace gases in stainless steel canisters and samples of particulate matter less than 3 μm diameter on filters of teflon material. Three profiles were flown from near the surface (300 m above ground level (a.g.l.) on the east side and 400 m on the west side) to the top of the mixing layer from 2700 m to 3300 m above m.s.l. Measurements of CO_2 and CO were made with instruments with overall measurement accuracy of ±2 ppm and 20 ppb, respectively [Babbitt et al., this proceedings]. Absolute pressure was maintained along with a constant flow through the real time instruments. Canister samples were analyzed using gas chromatography equipped with an f.i.d. with absolute accuracy of ±2 ppm and 20 ppb, respectively, for CO_2 and CO. Vertical profiles were flown in a north/south line along the east edge of the rectangle of approximately 100 km in length then along the west edge over the same length. The profiles took about one hour each to complete (See Figure 1).

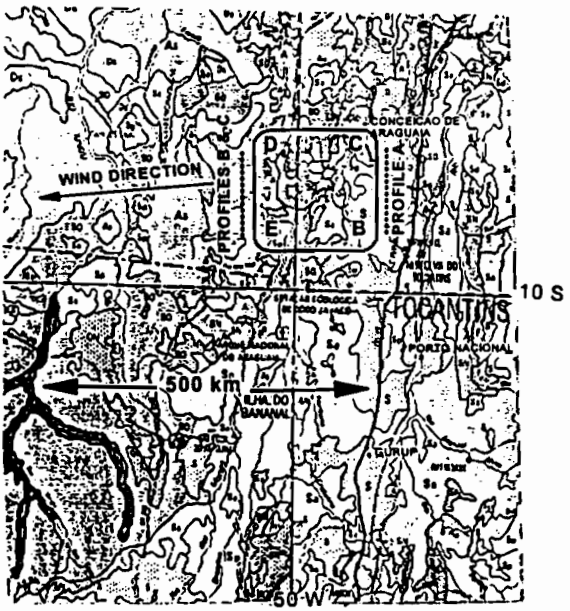

Figure 1. Area of cerrado to the east and forest to the west used for flux measurements discussed in this paper.

The upwind background concentration was determined by plotting the concentrations at the four different altitudes and a best fit linear line passed through these measurements. Constant values of 362 ppm CO_2 and 200 ppb CO were used in developing the delta concentrations for the individual heights and locations along each profile. Concentrations of CO_2 and CO were measured both in real time and from canister samples at 600 m differences in elevation at each of the 3 transects. Two canister samples were collected at each altitude and these intercompared with the integrated real time data for CO_2 and CO. Differences between the downwind profiles and upwind profile were calculated for each altitude.

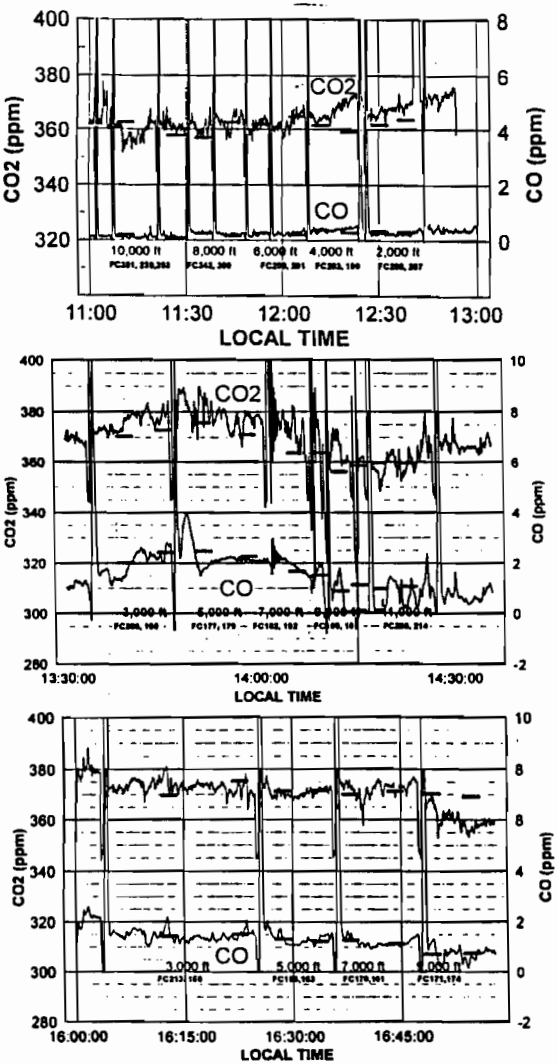

Figure 2. Top panel shows the upwind CO_2 and CO profiles by altitude, the middle panel is for the morning profiles, and the bottom panel is for the late afternoon period of time. The canister concentrations are superimposed on the trace for CO_2 and CO.

RESULTS AND DISCUSSION

Measured Concentrations--The real time instruments yielded a range of concentrations of 357 to 383 and 0.1 to 2.3 ppm for CO_2 and CO, respectively. Figure 2 shows the variable concentrations of CO_2 and CO for each of the three profiles made on 11 September. The variability in concentration between the upwind background samples and the downwind high-concentration plume samples by elevation is plotted in Figure 3. The two canister sample concentrations for each height and each profile transect line were averaged and these values subtracted from the background concentrations. The delta concentration of CO_2 and CO ranged to 16.4 ppm and 1.92 ppm, respectively, for the canister samples. Agreement between methods was excellent for CO with a coefficient of determination (CD) of 0.914, whereas, for CO_2 the

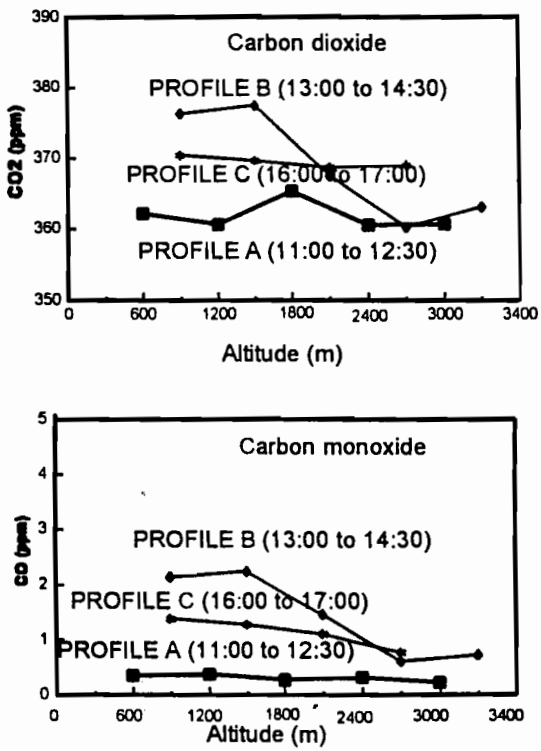

Figure 3. CO_2 and CO concentrations for two profiles downwind of major burn area (B and C).

CD was 0.60. The low CD was attributed to one pair of samples taken for the second downwind profile at the 2700 m level. When these are not considered in the regression model, the CD increases to 0.75. In general, the canister values were considered of a higher accuracy than the real time data and are used in all the analyses that follow.

Table 1. Delta concentrations of CO_2 and CO for Profile B minus A and for Profile C minus A. Elevations above ground level (e.a.g.l.) are in meters and represent the approximate e.a.g.l. of the transect.

e.a.g.l.	CO2 (B-A)	CO (B-A)	CO2 (C-A)	CO (C-A)
2700	0	0	7.977	0.442
2100	-0.822	0.282	7.977	0.442
1500	6.477	1.147	7.712	0.782
900	16.427	1.922	8.627	0.952
300	15.227	1.827	9.377	1.067

Table 2. Rate of emissions of CO_2, CO, and vegetation consumed by fires burning within the rectangular area shown in Figure 1.

	12:30-13:30			16:00-17:00		
WIND	TOTAL	Flame	SMOL	TOTAL	Flame	SMOLDG
	--(T/s)-	--(T/s)-	--(T/s)-	--(T/s)-	--(T/s)	(T/s)---
CARBON DIOXIDE RELEASED						
5 mps	13.9	3.0	10.9	18.7	13.6	5.0
10 mps	27.9	6.1	21.8	37.3	27.3	10.1
20 mps	55.8	12.1	43.7	74.7	54.5	20.1
CARBON MONOXIDE RELEASED						
5 mps	1.3	0.3	1.0	1.0	0.7	0.3
10 mps	2.6	0.6	2.0	2.0	1.4	0.5
20 mps	5.2	1.1	4.1	4.0	2.9	1.1
VEGETATION CONSUMED						
5 mps	8.7	1.9	6.8	11.0	8.1	3.0
10 mps	17.5	3.8	13.7	22.1	16.1	5.9
20 mps	34.9	7.6	27.3	44.1	32.2	11.9

Calculated Fluxes--Estimates of vertical profiles of windspeed are used for making carbon flux calculations. Three different windspeeds were used (5, 10, and 20 m/s). The lower 300 m windspeed was assumed to decrease linearly to zero at the surface. For the lower 300 m, the delta concentration of carbon was assumed to be constant and equal to that measured at 300 m a.g.l. An average windspeed of 2.5, 5, or 10 m/s was multiplied by the measured concentrations for the lower level. For all other heights, values of 5, 10, or 20 m/s were multiplied by the corresponding delta concentrations (Table 1). All flux calculations were first estimated on a per m length of traverse line and then multiplied by the length of the side of the rectangle sampled by the aircraft (approximately 100 km). The average calculated flux are listed in Table 2. The flux of CO_2 and CO ranged to 78.7 T/s for the highest windspeed profile (along the 100 km distance on the west side of the sample area).

Calculated Combustion Efficiency--The flux of compounds is used in calculating the total emissions of CO_2, CO and modified combustion efficiency (MCE_W). The MCE_W for Profile B is 0.88 and for Profile C is 0.92. MCE_W is calculated by dividing the total carbon released as CO_2 by the sum of the carbon released as CO_2 and CO.

From Ward et al. [1992, 1996] combustion efficiency values for flaming (MCE_F) and smoldering (MCE_S) combustion were determined to be 0.95 and 0.85, respectively. With this information, the ratio of vegetation consumed by smoldering combustion can be calculated as follows:

$$MCE_W = MCE_F(1 - S) + MCE_S(S) \quad (1)$$

Smoldering combustion can be calculated to have consumed 78% of the vegetation that burned for Profile B and 27% for Profile C with a corresponding shift in the amount of flaming combustion between the morning and afternoon.

Based on these calculations, the amount of flaming and smoldering consumption of vegetation is calculated and given in Table 2 along with the production of CO_2 and CO by phase of combustion. It is interesting to carry the analysis one step further and calculate the area of flaming combustion assuming that the fire in this vegetation type would have a residence time of about 15 seconds and a spread rate of 0.1 m/s for the fires contributing to the emissions sampled in profile B. In other words, the flames would reside in one spot on the average for about 15 seconds during which time the fire would have moved 1.5 m. Assuming that the fuel consumed for the cerrado ecosystem is 1.0