AIRBORNE MEASUREMENTS OF BIOMASS BURNING PRODUCTS OVER AFRICA

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SUMMARY

Ozone has been observed in elevated concentrations by satellites over hitherto believed "background" areas. There is meteorological evidence, that these ozone "plumes" found over the Atlantic ocean originate from biomass fires on the African continent. Therefore we have investigated ozone and assumed precursor compounds over African regions. The measurements revealed large photosmog layers in altitudes between 1.5 and 4 km. Here we will focus on some results of ozone mixing ratios obtained during the DECAFE 91/FOS experiment and estimate the relevance of biomass burning as a source by comparing the strength of this source to stratospheric input.

Key words: Ozone, biomass burning, Africa

INTRODUCTION

It was already realized in the late 70's, that biomass fires emit the same ingredients that can form photosmog as urban pollution does (Evans et al., 1974; Evans et al, 1977). This was deduced from prescribed fires, which were set to reduce the density of flammable undergrowth. The technique is practiced in many regions of the world (Goldammer, 1990). Together with incidental fires and those induced by lightning, they influence ecosystems in several ways. They reduce vegetation, change patterns of succession and biodiversity, and have a global impact on climate and soil. In respect to the last issue, changes in soil hydrology and atmospheric moisture are anticipated as well as alteration of the budgets of atmospheric trace gases on a global scale. For the present approximately 40% of global CO_2-emissions are estimated to be due to biomass burning (Crutzen and Andreae, 1990). The production of ozone in the emission plumes of vegetation fires follows the same rules as the wellknown formation of photosmog in cities as the ingredients are the same. Biomass fires produce nitrogen oxides and unsaturated hydrocarbons, which, with sunlight yield ozone. Mixing ratios of up to 100 ppbv ozone frequently are encountered (Delany et al., 1985; Browell et al., 1988; Helas et al., 1989; Andreae et al., 1992). Not only that these elevated mixing ratios can be harmful, a main concern is that ozone acts as a powerful greenhouse gas, especially in the upper troposphere.

As the results of DECAFE 88 (Dynamique et Chimie de l'Atmosphère en Forêt Equatoriale), which took place over forested areas of central Africa, pointed to the fact that most of the assessed airmasses originated from savanna areas, we surveyed in a second experiment DECAFE 91/FOS (Fire of Savannas) savanna areas of western Africa.

EXPERIMENTAL

We have measured ozone with an UV-absorption instrument, e.g. a Thermo Electron 49. For other compounds which were measured in parallel, IR-absorption (CO_2), wet chemiluminescence (NO_2), and gas chromatographic techniques have been applied (CO, CO_2, CH_4). Measurements were made from a Beechcraft Bonanza. Flight patterns were chosen to probe air ranging from local background to directly contaminated by the flames of the vegetation fires. The field campaign was carried out in the Ivory coast between Bouaké and Lamto in January 1991 during the local dry season.

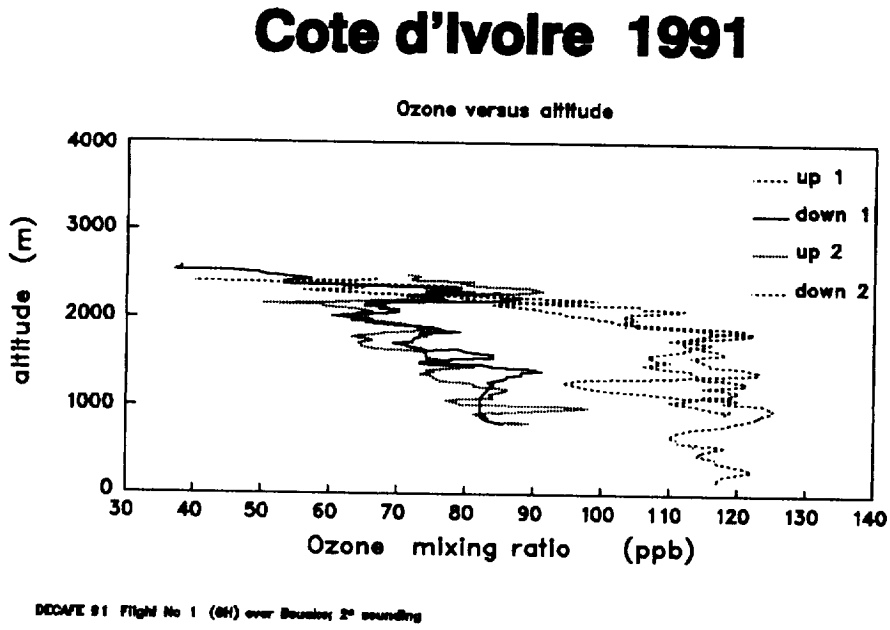

Figure 1:
Mixing ratios of ozone measured over the savanna between Bouaké and Lamto, Ivory Coast on Jan. 10th, 1991.

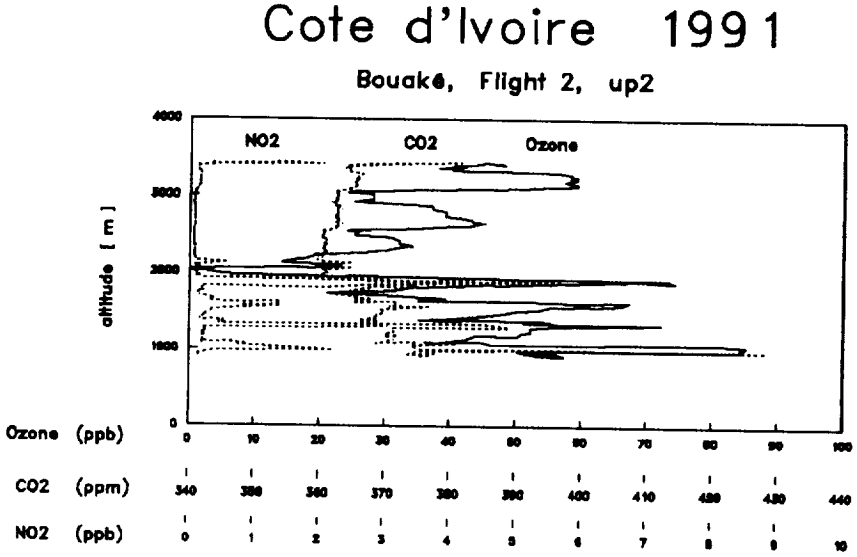

Figure 2:
Mixing ratios of O_3, CO_2 and NO_2 measured over the savanna between Bouaké and Lamto, Ivory Coast on Jan. 11th, 1991.

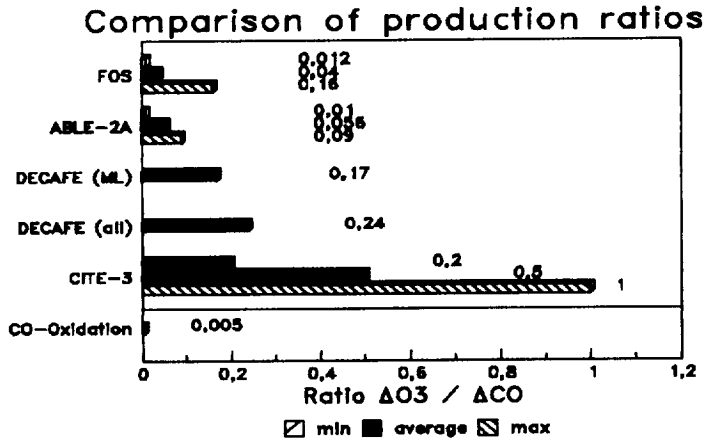

Figure 3:
Comparison of production ratios of delta O_3 to delta CO as determined during different field assessments of biomass burning. The ratios are ordered in an approximate plume age with FOS ca. hours to CITE-3 ca. 1 week. Details see text.

TABLE 1:
Comparison of biomass burning as a source for tropospheric ozone to input from the stratosphere.

Biomass burning	CO ---> O_3	
	Tmol / year	Tmol / year
Logan et al. (1981)	23	8.1
Seiler and Conrad (1987)	36	12.6
Crutzen and Andreae (1990)	26	9.1

Stratospheric input-- data taken from Warneck (1988) in Tmol / year	Hemisphere North	South
Fabian and Pruchniewics	8.9	5.7
Mohnen	8.2	-
Nastrom	5.2	-
Gidel and Shapiro	6.5	3.3
Warneck I	8.1	-
Warneck II	10	-

RESULTS AND DISCUSSION

We found elevated mixing ratios of ozone in air masses above the savanna area of western Africa. As is shown in Figure 1 the mixing ratios extended up to 100 ppbv. The most striking feature, however, is the distinct layering of the atmosphere as is visible in the concentrations. This behavior is also reflected in the concentrations of the concurrent measured CO_2 and NO_2, which we show here in Figure 2 for a single ascent. Obviously the individual plume air parcels are not as well mixed as was observed during DECAFE 88 (Helas et al., 1989; Andreae et al., 1992), though

convective mixing in the area clearly was visible from the cloud formation during the sampling.

In order to assess the importance of vegetation fires as a source for tropospherical ozone we determined the production ratio of delta O_3 to delta CO. The delta indicates enhancement of trace components above background. This value ranged from 0.012 to 0.16 with an average of 0.04. When comparing this ratio to those determined during other field assessments on biomass burning as is shown in Figure 3, we find a distinct increase with plume age. While the air masses probed during DECAFE 91/FOS were approximately 1 hour old, meteorological evidence shows that the plumes of ABLE-2A (Andreae et al., 1988) and DECAFE 88 in the monsoon layer were in the order of a day, while the average of all data of DECAFE 88 together were derived from ages of several days (Andreae et al., 1992). Finally the plume surveyed during CITE-3 was estimated to be a week old (Andreae et al., 1990). In this latter plume the production ratio ranged from 0.2 to 0.5 with excursions up to 1. This development of delta O_3 to delta CO is also expected from the model calculations of Chatfield and Delany (1990), who showed that the concentration rise of ozone produced by the ingredients of vegetation fires develops particularly rapid in the first few days after dilution of the initial plumes. Based on the comparison shown in Figure 3 we predict that the delta O_3 to delta CO determined during DECAFE91/FOS of 0.04 will increase by a factor of ten during the transport from the source region to the remote troposphere.

As we find that the biomass burning plumes can survive over an extended period of time, we have chosen for further calculation as a conservative value an average production ratio of O_3 to CO of 0.35 and multiplied this value with estimates of CO production due to biomass burning found in the literature (Logan et al., 1981; Seiler and Conrad, 1987; Crutzen and Andreae, 1990). The data used are compiled in Table 1. With these data we calculate a production rate of approximately 10 Tmol ozone per year. We compare this source strength to the yearly input of ozone from the stratosphere downward. This is shown in the lower part of Table 1, which is taken from Warneck (1988). Several estimates are compiled from literature together with two assessments, which are denoted as Warneck I and Warneck II. We find both sources for ozone, biomass burning and stratospheric input, to be similar in strength. Thus the input of ozone from biomass burning on a global scale cannot be neglected.

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