Particulate Content of Savanna Fire Emissions

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Abstract. As part of the FOS-DECAFE experiment at Lamto (Ivory Coast) in January 1991, various aerosol samples were collected at ground level near prescribed fires or under local background conditions, to characterize the emissions of particulate matter from the burning of savanna vegetation. This paper deals with total aerosol (TPM) and carbon measurements. Detailed trace element and polycyclic hydrocarbon data are discussed in other papers presented in this issue.

Near the fire plumes, the aerosols from biomass burning are primarily of a carbonaceous nature (C% ~ 70% of the aerosol mass) and consist predominantly of submicron particles (more than 90% in mass.) They are characterized by their organic nature (black to total carbon ratio Cb/Ct in the range 3–20%) and their high potassium content (K/Cb ~ 0.6). These aerosols undergo aging during their first minutes in the atmosphere causing slight alterations in their size distribution and chemical composition. However, they remain enriched in potassium (K/Cb ~ 0.21) and pyrene, a polycyclic aromatic hydrocarbon, such that both of these species may be used as tracers of savanna burning aerosols. We show that during this period of the year, the background atmosphere experiences severe pollution from both terrigenous sources and regional biomass burning (44% of the aerosol). Day-night variations of the background carbon concentrations suggest that fire ignition and spreading occur primarily during the day. Simultaneous TPM and CO2 real-time measurements point to a temporal and spatial heterogeneity of the burning so that the ratio of the above background concentrations (ΔTPM/ΔCO2) varies from 2 to 400 g/kg C. Smoldering processes are intense sources of particles but particulate emissions may also be important during the rapidly spreading heading fires in connection with the generation of heavy brown smoke. We propose emission factor values (EF) for aerosols from the savanna biomass burning aerosols: EF (TPM) = 11.4 ± 4.6 and 69 ± 25 g/kg C dry plant and EF(Ct) = 7.4 ± 3.4 and 56 ± 16 g C/kg C dry plant for flaming and smoldering processes respectively. In these estimates, the range of uncertainty is mostly due to the intra-fire variability. These values are significantly lower than those reported in the literature for the combustion of other types of vegetation. But due to the large amounts of vegetation biomass being burnt in African savannas, the annual flux of particulate carbon into the atmosphere is estimated to be of the order of 8 Tg C, which rivals particulate carbon emissions from anthropogenic activities in temperate regions.

Key words: particulate carbon, total particulate matter, savanna burning, tropical aerosols, emission factors.
1. Introduction

The growing concern about the potential effects on the radiative balance of the atmosphere by tropospheric aerosols has increased interest in their natural and anthropogenic source strengths and the factors governing their variability. Up to now, the focus has been placed on the important atmospheric loading of sulphate aerosols (Charlson et al., 1987, 1992) with controversial theses on the origin of these particles and their role in climate control (Schwartz, 1988). But in spite of our patchy knowledge of their spatial and temporal distributions, aerosols emitted by combustion processes are also likely to contribute to the global burden of tropospheric fine aerosols (Heintzenberg, 1989; Cachier et al., 1990) and they have recently been proposed to counteract the anthropogenic greenhouse warming, either by a direct reflection of incoming solar radiation or a modification of the cloud cover (Ghan and Penner, 1992).

A comparison of estimates of worldwide fuel consumption shows that the burning of fossil fuels (Boden et al., 1990) and that of vegetation fuels (Levine, 1990; Houghton, 1991) roughly consume the same amount of material annually, about $5 \times 10^{15}$ g C each. Both types of combustion produce primary and secondary fine aerosols that are potentially radiatively effective. It might be assumed here that due to the less favorable physical conditions of the combustions, biomass burnings are more effective producers of particles, on average, than industrial combustion processes.

More than 80% of the biomass burning occurs in the tropics where among the various type of burns, the savanna and bushfires are really the most important. Due to the importance of savanna areas in Africa and the increasing occurrence of the burns (Cahoon et al., 1992), it appears that now more than 30% of the tropical biomass is burned during savanna fires on this continent alone (Andreae, 1991). Thus, the large-scale issue of an influence of particulate emissions by African savanna fires on the regional and global atmospheric environment has to be addressed.

In light of few previous data and in an effort to improve our knowledge on particulate emissions by savanna biomass burning, we set up ground experiments at Lamto, a savanna site in the Ivory Coast, as part of the FOS-DECAFE/91 campaign during which various prescribed savanna fires were explored. For the first time, qualitative and quantitative data were obtained in the field that document the physico-chemical aspects of the aerosol phase, in order to provide tracers of this type of biomass combustion and to propose emission factors for the main elements found in the particles. The various ground-based measurements which were performed with regard to the aerosol phase are listed in Table I, with references to the main papers appearing in this issue. The present study focusses on the bulk aerosol (TPM: total suspended matter) and its main component, the carbonaceous fraction.