



## Mineral dust and carbonaceous aerosols in West Africa: Source assessment and characterization

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### ABSTRACT

As part of the AMMA (African Monsoon Multidisciplinary Analysis) international research project, an intensive field campaign called “Special Observing Period” (SOP 0) was carried out in West Africa during the dry season (February 2006), near M’Bour, Senegal. The aim of the ground-based sampling experiment was to determine the chemical composition of dust and carbonaceous aerosols in the surface layer, then to investigate the main source areas influencing the chemical composition of the particles. Major elements (Al, Ca and Fe), total (TC) and black carbon (BC), and water soluble ion ( $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{NH}_4^+$ ,  $\text{Cl}^-$ ,  $\text{NO}_3^-$ ,  $\text{SO}_4^{2-}$  and  $\text{PO}_4^{3-}$ ) concentrations were measured. Total mass, number concentration and aethalometer measurements of PM-10 were also obtained. Mineral dust in the surface layer is principally present in the coarse fraction representing 75–90% of the collected mass (wt.%). Dust, suggested by backward trajectories of the air masses and supported by the variations of Ca/Al ratios, originates mainly from Northern Sahara. Particulate organic matter (POM) concentrations are more variable, but POM is mainly present in the fine fraction (up to 77 wt.%). Its presence is due to local sources such as domestic fire emissions rather than to remote sources as open-field vegetation fires in the Sahelian zone. Comparisons of Black Carbon (BC) concentrations measured with an aethalometer in the Ultra-violet and the Near-infrared wavelengths, show that POM originating from the adjacent Western African coast contains less aromatics than POM transported from the main biomass burning areas of the Sahelian zone. Thus, smouldering, the main combustion process for locally emitted carbon aerosols appears to generate less aromatic compounds than burning of vegetation.

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### 1. Introduction

The radiative impact of carbonaceous aerosols in the global climate system is now clearly established (Pinker et al., 2010). The vertical distribution of such particles, as well as their external mixing with other aerosols having critical absorbing properties (e.g. mineral dust) is addressed in many recent studies (Kandler et al., 2007; Haywood et al., 2008). In addition, mineral dust acts as a vector for micronutrients, such as iron, a key element in marine biogeochemistry (Paris et al., 2010). Based on advanced

microanalysis techniques, very recent studies have tackled the issue of the carbonaceous coating of amorphous and crystallised carbon on African dust (internal mixing), by the combined use of elemental and molecular semi-quantitative analyses at the particle scale (Hand et al., 2010). Such investigations highlight the heterogeneous structure of aerosols and the need for field campaigns to better assess the variability of the chemical nature of atmospheric particulate matter.

The main purpose of the present study is to provide evidence of mixing between carbonaceous aerosols and mineral dust on a regional level, as well as to assess the main source areas, by investigating the variability of the chemical composition of tropospheric aerosols.

The sampling location was situated in the coastal Sahelian zone, West Africa, an area that is strongly influenced by dust storms and biomass burning (Johnson et al., 2008; Osborne et al., 2008). In

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wintertime, aerosol transport over West Africa frequently occurs in two or more layers (Capes et al., 2008; Johnson et al., 2008; Osborne et al., 2008), with a surface transport of Saharan dust due to Harmattan winds (Formenti et al., 2008). Similar structures were observed at M'Bour during our ground-based measurements (Derimian et al., 2008). Considering LIDAR profiles, two layers were regularly observed: the lower one (called the surface layer) occurring at altitudes <2 km, while the higher layer was located between 2 and 4 km height. Considering the aerosol single scattering albedo during some characteristic events, Derimian et al. have shown that in each layer the aerosol phase was a mixture essentially constituted by dust and carbonaceous aerosols. This was confirmed by individual particle analysis by Hand et al. (2010) for the elevated layer and by Deboudt et al. (2010) for the surface layer, but the origin of carbonaceous aerosols and, to a certain extent, that of dust remain unclear. Do aged Saharan aerosols constitute the main component of the surface layer, even in the absence of significant Saharan dust storms? Does long-range transport of biomass burning aerosols affect surface carbonaceous particle concentrations? In the present study, based on ground measurements, we document chemical key parameters of atmospheric particulate matter in order to investigate the key source regions involved in the aerosol composition variability in wintertime over coastal Sahel, viewed as a receptor zone for Saharan dust outbreaks and biomass burning long-range transport episodes.

## 2. Materials and methods

### 2.1. Sampling site location and climatology

The ground-based sampling experiment (from February 2nd to February 15th 2006) was performed at an environmental research station (Institut de Recherche pour le Développement - IRD) located near M'Bour, Senegal and 90 km South of Dakar. The site (14°23'38"N, 16°57'32"W) is located precisely 3 km south of the City of M'Bour (180,000 inhabitants), along the coastline.

The climatic conditions encountered during the experiment are described in Derimian et al. (2008). Local winds were blowing from North to Northeast, passing over the City of M'Bour in the evening. Wind speed values range from 2.5 to 4.0 km h<sup>-1</sup> and the mean

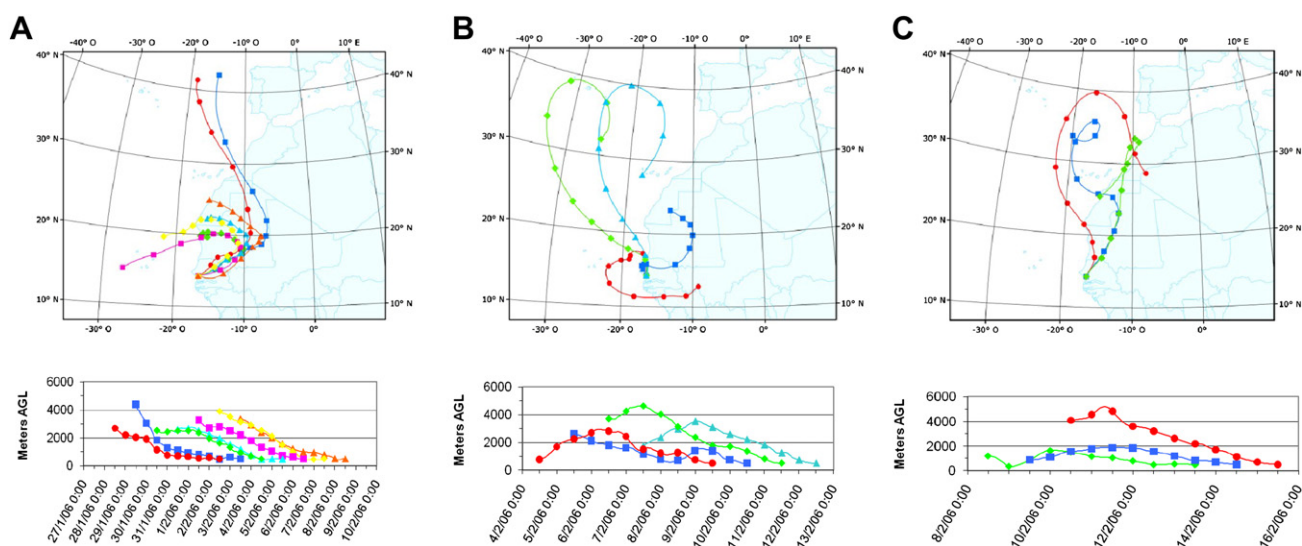
temperature and relative humidity were +23 °C and 40%, respectively.

Air mass back trajectories ending at 950 hPa (approx. 500 m above ground level) have been computed using the NOAA Hysplit model (Draxler and Rolph, 2003; Rolph, 2003). They are reported in Fig. 1. On the basis of this analysis, three time-periods may be distinguish: from February 2nd to February 8th 2006, air masses originate predominantly from continental Africa (West-Sahara and Mauritania); then from February 9th to February 12th, they are essentially oceanic with the last hours along the Senegalese seashore; finally during the last part of the campaign (13th–15th Feb), air masses are mainly coastal, with a continental final run in the low troposphere.

### 2.2. Aerosol sampling and analysis

Aerosols were collected using two isokinetic samplers, operating simultaneously 7 m above ground level, for 24 h sampling, during 14 days. The sampler specially designed to collect particles with an aerodynamic diameter <10 μm (PM-10 sampler) is fully described in Alfaro et al. (2003). This sampler was running at 12 L min<sup>-1</sup> and related to three different sampling lines working in parallel:

- two were mounted with 47 mm–0.5 μm Nuclepore® polycarbonate membranes, the first one to determine major ion concentrations by Ion Chromatography and the second one for major metal (Al, Ca, Fe,...) concentrations obtained by Graphite Furnace Atomic Absorption Spectrophotometry (GFAAS).
- the third line was equipped with 47 mm precleaned Whatman® QMA quartz fibre filters to determine the total (TC) and the elemental carbon (EC) concentrations using a two-step procedure set-up by in Cachier et al. (1989). Prior to analysis, aerosols are submitted to HCl fumes in order to eliminate carbonates, which for African aerosols is mandatory. This method yields the TC and EC contents of aerosol and the organic carbon (OC) content is calculated as the difference TC–EC. In addition, a quartz filter sample aliquot is used for additional analyses of water soluble organic acids by Ion Chromatography (Sciare et al., 2008). Here, "EC" refers to the



**Fig. 1.** 120-h backward trajectories of air masses sampled (A) from February 2nd to February 8th 2006, (B) from February 9th to February 12th 2006, and (C) from February 13th to February 15th 2006.

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