CHARACTERISATION OF BIOMASS BURNING AEROSOL FROM MICROLIDAR AND CO-LOCATED OBSERVATIONS AT DJOUGOU (BENIN) DURING AMMA/SOP 0

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ABSTRACT

A new microlidar system has been developed by Cimel Electronics to operate automatically during field experiments. Two identical systems have been installed in western Africa for the AMMA dry season experiment which was held from mid-January to mid-February 2006. We report here on the results obtained in the Djougou site (9.7 N, 1.6 W) located in northern Benin, in the region of fires, which allowed to profile the biomass burning aerosol load on the vertical. Once corrected from signal saturation and geometrical factor, the attenuated profiles are inverted to retrieve extinction profiles using sun photometer measurements of the AOD obtained on the same site. Measurements are combined to sun-photometer data obtained over the same site to characterise mixing of biomass burning and mineral particles. Results are compared to ceilometer data and airborne observations.

1. AMMA DRY SEASON EXPERIMENT

Source regions for dust and biomass burning particles are very important in western Africa. Fires and horizontal transport processes near fire and dust sources

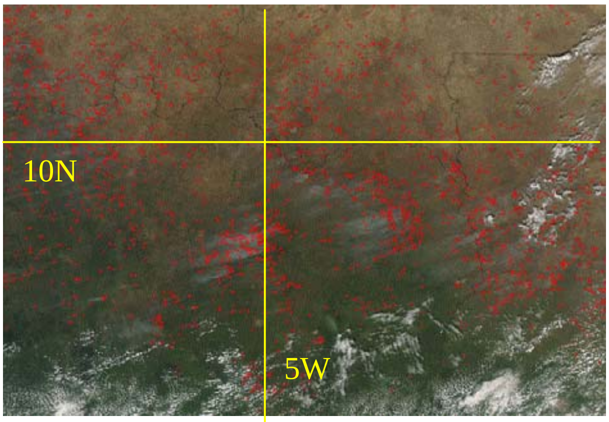

Figure 1: Fire sources and plumes identified by MODIS in northern Sahel. The area shown is about 5° in latitude and 7° in longitude.

can be identified by radiometry from satellite, as shown in Figure 1, showing MODIS observations on January 2006. Dust and biomass burning aerosol particles have different microphysical and radiative properties (size, shape, absorption) and their mixing is leading to complex modifications. Mixing and, further on, aging, sedimentation and cloud processing occurring over land and ocean will then result in a variable forcing which needs to be better understood. This is the purpose of the AMMA SOP0-A field experiment [1].

One of the main difficulties remains to precisely identify the vertical extension of the transported particles, which is critical to the radiative impact due to their significant absorption. Far from the sources, dust or biomass burning aerosols can be frequently observed in elevated layers [2]. Combination of in situ, passive and active remote sensing during the SHADE campaign have recently allowed a better characterization of their radiative impact [3]. Biomass burning aerosols have been extensively characterized during the SAFARI campaign [4], but no characterization has been done over western Africa.

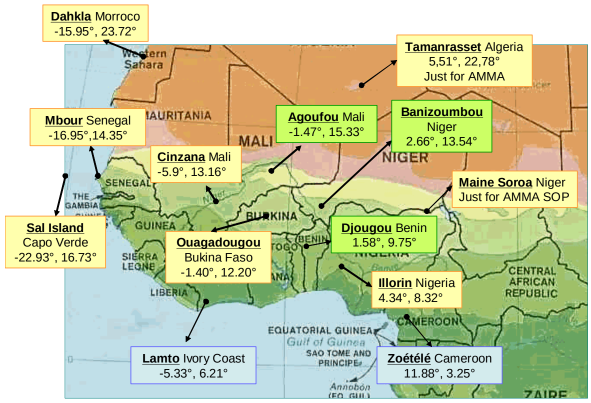

Figure 2. AERONET (yellow), IDAF (blue) and both AERONET/IDAF (green) ground-based stations.

During AMMA-DABEX/SOP0 several sites were equipped with in situ (counters, nephelometers, aethalometers, impacters, …) and remote sensing instruments (sun-photometer, lidar and radiometers) in

Djougou (Benin), Niamey (Niger) -where the US Atmospheric Radiation Measurement Mobile Facility is implemented-, Banizoumbou (Niger) and M'Bour (Senegal) to characterize dust and biomass burning particles, study their mixing and transport and radiative impact. Fig. 2 gives a map of the locations of the main observation sites including AERONET (http://aeronet.gsfc.nasa.gov/) and IDAF (http://medias.obs-mip.fr/idaf/) sites. This equipment was complemented by aircraft (BAe146 from UKMO/NERC) and Ultra-light (LSCE/CNRS-CEA), as well as satellite observations, as described in the SOP 0 document [1]. The AMMA-SOP 0/DABEX started on 13 January and lasted until 16 February. The Bae146 was based in Niamey (Niger) from January 13 to February 2nd, and then operated from Dakar Senegal).

2. CIMEL LIDAR SYSTEM DESCRIPTION

The Cloud and Aerosol Micro-Lidar (CAML)CE 370-2 developed by CIMEL is a micropulse system operating at 532 nm. Its main characteristics are given in Table 1.

Table 1 : Main CAML system characteristics

Emitted energy Pulse Repetition Rate	8 µJ	4.7 kHz
Telescope size focal length	20 cm	0.90 m
Field of view Complete overlap range	100 µrd	2.4 km
Range resolution	15 m	
Time resolution		1 s

Figure 3 : view of the CAML emission-reception telescope, acquisition rack and 12" portable computer used for acquisition and control.

The rack shown in Fig. 3 contains the laser source and the detection optics and electronics. It also includes the photon counting system (2048 bins) and summation processor [6]. Files are transferred every second to the external command and control computer. The IPSL/SA system was installed in Djougou on January 20 and continuously operated till the beginning of February for the SOP0.

3. CIMEL LIDAR OBSERVATIONS

Measurements are taken according to a standard sequence of 10 minutes acquisition every half an hour. During this sequence, 600 individual profiles are acquired, which allows to perform calculation of statistical fluctuations. Mean and standard deviation profiles are obtained over the 10 minutes sequence.
One minute profiles are normalized to clear air at altitudes estimated from minimal signal and variance analysis, so to derive vertical profiles of the attenuated backscattering coefficient.

3.1 Derivation of structural parameters

As given in Table 1, the system is designed to have a small field of view to increase signal-to-noise ratio of measurements during daytime. This implies that the overlap altitude is rather high and prevents measurements close to the surface.

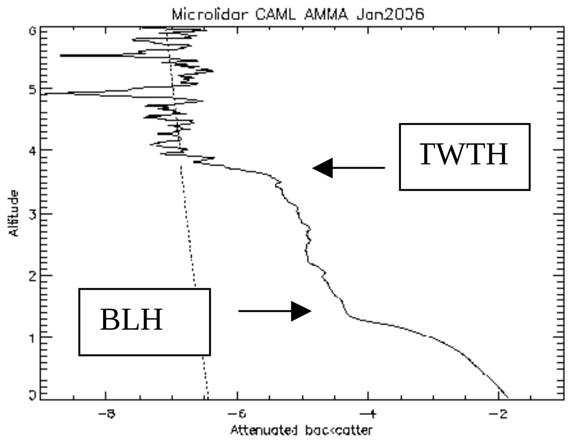

Figure 4 : Example of retrieved attenuated backscattering coefficient (ABC, solid line) in decimal logarithmic scale (x is 10^x $m^{-1}sr^{-1}$) as a function of altitude (1 mn and 75m resolution). Dotted line is molecular backscattering from the seasonal model used for normalization. The boundary layer height (BLH) and the trade wind layer top height (TWTH) can be obtained from the analysis of the ABC.

To correct for such effect measurements were performed with the system pointing horizontally so that the overlap function can be estimated assuming horizontal homogeneity. This allows to derive the height of the boundary layer (level 2 a data) using a gradient analysis down to about 350m in altitude, using a zenith pointing as in Djougou. A better performance can be obtained using slant observations. This configuration was not installed in Djougou. Figure 5 shows an example of 1 minute level 1b attenuated backscattering coefficient (ABC) profile obtained at 12:15 UTC over Djougou after processing.

The boundary layer height derived from a gradient analysis [6] is 1.3 km AGL. It is a layer where winds are usually coming from the south. Retrieval of the boundary layer height can also be done using the standard deviation analysis either on raw signals (level 0) or level 1a profiles. Figure 4 shows examples of a 1 minute standard profile obtained near 12:30 UTC. The height derived from a threshold analysis (materialized by the dotted line) is very close to the one obtained from the gradient analysis.

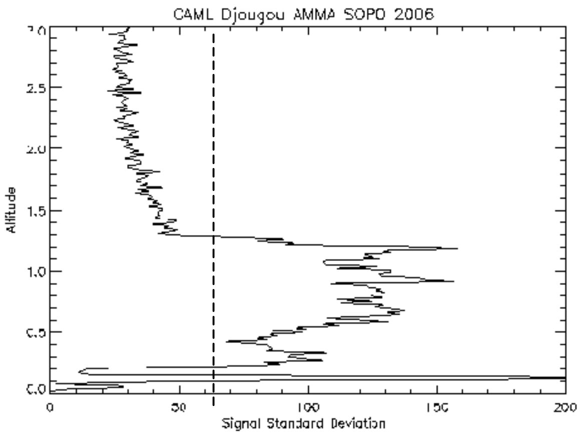

Figure 5 : Standard deviation profile of the raw signal (arbitrary units) over a 1 mn acquisition time near 12:15 UTC used to derive boundary layer height.

This altitude is similar to the one obtained from the CT25K ceilometer installed by University of Münich, and was close from day to the other at the end of January.

3.2 Optical properties

The retrieval of optical properties of aerosols from CAML measurements are first made using the optical depth derived from the co-located CIMEL sun-photometer data to determine the lidar ratio S. An analysis similar to the one done from aircraft [8] can be performed, but it can be noticed that assuming a constant S value as a function of height, an analytical expression can be derived from the integrated attenuated backscattering coefficient γ as

$$S = \frac{1}{2T^2\gamma}(1 - T^2) \qquad (1)$$

where T is the transmission corresponding to the vertically integrated extinction by aerosols. This expression is corresponding to previous analyses [9] but using an upper altitude level normalisation. It allows to further obtain the extinction profile, applying a standard Klett inversion.

4. DISCUSSION

Long series of observations are made at Djougou site using the U. Münich ceilometer. Comparisons of observations on several diurnal cycles are being done. First comparisons show a good agreement between the two BLHs obtained by the ceilometer and the microlidar. Integrated backscattering obtained from the ceilometer is different as the microlidar is operating at a much smaller wavelength and also because the range of the ceilometer is smaller than the one of the microlidar.

A much smaller amount of mineral dust has been observed during 2006 as compared to the previous years, but the region of fires was rather turbid, with aerosol optical depths (AOD) exceeding 0.5 on average at 675 nm after mid-January, as given by the measurements taken with the sun-photometer in Djougou. Values of the AOD has been linearly interpolated between the AOD values obtained in the two channels at 440 and 675nm.

Sun-photometer AODs have been used to derive S values for different days. For the 21 January, we have obtained an AOD decreasing from 0.95 and 0.84, between 10 and 14 UTC. The corresponding integrated backscatter coefficient was varying from 0.12 to 0.14, which lead to values of S in the range of 15 to 20. These values are lower than expected as compared to values obtained in the literature for small biomass burning particles.

Two flights of the Bae146 have allowed to make measurements near Djougou and compare aerosol properties measured above the site with those of ground-based measurements as well as radiative measurements with ground-based ones. Results will be also used for comparisons.

The progression of the southerly flow is limited to the north by the available energy from the regional circulation patterns linked to the Saharan heat low and ITCZ systems. It is marked near the surface by a frontal transition, also called inter-tropical discontinuity (ITD), with the north-easterly flow (Harmattan). It is about 10°N in January. Above the ITD, the wind is blowing from the east or northeast, in the so-called trade wind layer, and then turns to the west at high altitude. This wind pattern gives a very specific vertical structure, which is marked by aerosol occurrence, as seen from lidar observations shown in Fig. 4. Using the Hysplit model (http://www.arl.noaa.gov), we have looked at forward trajectories of particles emitted close to the observation site from a point located at 8°N, 0°W, in the boundary layer at 500 m altitude, for different days at the end of January.

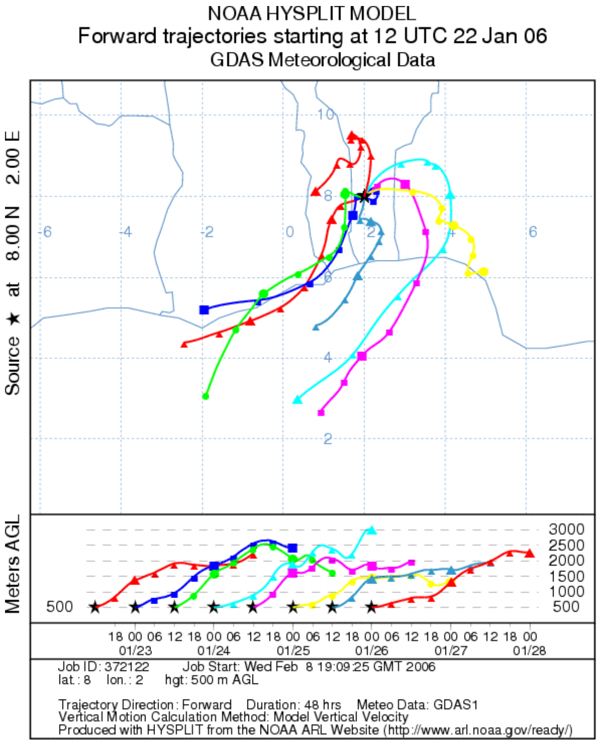

Figure 8 : Forward trajectories of biomass burning particles emitted at 8N, 0W (500m altitude).

It is interesting to note that the particles are all transported to upper levels above the BLH in about two days and then are transported to the south, leading to an accumulation of particles over the ocean as seen from space observations. The MODIS and PARASOL polar orbiting satellites as well as the geostationary Meteosat satellite, making recurrent observations over the area, will be used to characterise the evolution of the aerosol spatial distribution.

5. CONCLUSION

Lidar measurements have been performed in northern Benin during the first SOP of AMMA. Although the operation of the system was controlled by an operator, no alignment nor temperature control was required, and a first set of data has been obtained which will be used along with other observations to characterize biomass burning aerosol properties as well as their radiative impact.

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