AEROSOL ABSORPTION MEASUREMENTS AND RETRIEVALS IN SHADOW2 CAMPAIGN

Qiaoyun HU[1], Philippe GOLOUB[1], Thierry PODVIN[1], Igor VESELOVSKIY[2,3], Anton LOPATIN[1], Oleg DUBOVIK[1], Benjamin TORRES[4], Laura REVILINI[1], Suzanne CRUMEYROLLE[1], Tatsiana LAPIONAK[1], Christine DEROO[1]*

[1] Laboratoire d'Optique Atmosphérique, Université de Lille 1, Villeneuve d'Ascq, France
[2]Physics Instrumentation Center of GPI, Troitsk, Moscow, Russia
[3]Joint Center for Earth Systems Technology, UMBC, Baltimore, MD, USA
[4]GRASP-SAS-SME, Lille, France
**Email: qiaoyun.hu@ed.univ-lille1.fr*

ABSTRACT

Dust, maritime and dust-smoke mixture events observed during SHADOW2 (**Sa**ha**HA**ran **D**ust **O**ver **W**est Africa) field campaign are selected and analyzed by using Raman and GARRLiC retrievals.

The derived aerosol optical and microphysical properties will be shown. Dust absorption profile and on ground level are derived from GARRLiC retrievals and Aethalometer measurements, respectively. Our results provide a closer insight about dust absorbing properties.

1 INTRODUCTION

Mineral dust is the most abundant constitute in the atmosphere. Originated mostly from the arid and half-arid areas, every year large amounts of mineral dust are emitted into the atmosphere. Mineral dust plays a crucial role in the radiative forcing because it absorbs and scatters the solar radiation thus directly influencing the radiation budget. Additionally, mineral dust may change the cloud condensation nuclei process, thus affecting indirectly the radiation arriving to the ground [1].

Plenty of researches have focused on the quantification of the absorption of mineral dust, which is a key factor for estimating its radiative forcing effect. Generally, aerosol absorption is obtained from laboratory measurements or retrievals of remote sensing measurements in ambient air. Both techniques have their limitations. The widely used Aethalometer for measuring absorption coefficient has drying effects on the particles that are taken into the chamber. And the high irregularity of the shape of mineral dust poses challenges to the modeling [2], thus resulting in uncertainties for the retrieval.

To investigate the mineral dust properties near the main source, the SHADOW2 campaign was conducted at M'bour, Senegal, in March, April, December 2015 and January of 2016. Both in-situ and remote sensing instruments are deployed in the campaign; airborne measurements were performed as well, so that intensive parameter sets were achieved.

In this paper, we select two typical and representative cases; analyze the measurements from Multi-wavelength Raman Lidar (LILAS) and Aethalometer. Optical properties from Raman retrievals, absorption coefficients (ABS) and SSA (**S**ingle **S**cattering **A**lbedo) derived from Aethalometer (ABS) and GRASP/GARRLiC (ABS and SSA) retrieval are shown and analyzed. The results show the potentials and our first try to quantify the absorption of mineral dusts.

2 INSTRUMENT&METHODOLOGY

M'bour site is affiliated to the AERONET network so the standard AERONET protocol is performed regularly. Apart from the sun photometer, multiple instruments were deployed in the campaign. Nephelometer and Aethalometer measured the scattering coefficient and absorption coefficient, respectively. It should be noted that, in the campaign, the Aethalometer was equipped with a sampling head that took only particles with diameter of 1 μm or smaller. The OPC (**O**ptical **P**article **C**ounter) and GRIMM measured the particle size distribution on the ground level and also aloft when airborne measurements were conducted. Two Lidars: LILAS and a single wavelength CIMEL Lidar were in operation to monitor the aerosol temporal and vertical variations. Other instruments, such as wind Lidar, Fluxmeter, Radiometer, etc. were also operating

simultaneously. And here we emphasize the measurements from Aethalometer and LILAS.

The Aethalometer measures the absorption at 7 wavelengths: 370, 470, 520, 590, 660, 880 and 950 nm. LILAS has three emitting wavelengths: 355, 532 and 1064 nm. The receiving wavelengths consist of three elastic channels that are the same as the emission and three Raman channels: 387, 530 and 408 nm. In addition, 355 nm and 532 nm channels are operated with both parallel and perpendicular channels, which enable to measure the linear depolarization ratio of aerosols at both wavelengths.

GRASP/GARRLiC retrieval uses the AOD/TOD and Almucantar measurements from sun photometer (at 440, 670, 870 and 1020 nm) and 3 Lidar profiles (elastic channels) from LILAS. The retrieved parameter sets are aerosol size distribution, aerosol vertical concentration, and complex refractive indices (called CRI hereafter) of both fine and coarse mode aerosols. The vertical absorption profile can be calculated from the aforementioned parameters. To show the comparison between the Aethalometer measurements, the absorption of fine mode particles is specifically calculated in the case studies.

3 CASE STUDY

In March and April 2015, dust was the most frequently observed aerosol type, and maritime aerosols and smoke occurred from time to time. Whereas, mixture of dust and smoke occurred relatively more frequent in December 2015 and January 2016.

3.1 11 April, 2015

Figure 1 shows the extinction, backscattering (Figure 1(a)) and particle linear depolarization ratio (called PDR hereafter) profiles retrieved from Lidar measurements for the time interval of 00:00-01:30 UTC, 11 April 2016. The AOD during this period is around 1.0 at 532 nm. The extinction profile does not show obvious spectral dependence. Whilst, the backscatter coefficient at 532 nm is obviously stronger in amplitude compared with 355 nm. The PDR is of values between 30% and 35%, which indicates the presence of irregular particles. Additionally, the Ångström Exponent is -0.2 ~ 0 (not shown in the figure), from which we can tell there are bigger particles in the atmosphere. Relative humidity (RH) profile increases slightly with height. An insignificant peak is observed at 2.0 km. It needs to be mentioned that, the RH is calibrated by radio sounding measurements in Dakar, which is not collocated with Lidar, so that the absolute values of RH may not be accurate, but the variation of the its amplitude represent qualitatively the vertical and temporal variations of RH. The back trajectory (Figure 2(a)) shows the air mass at 2 km and 3 km comes from Mauritania and Mali. Around 0.8 km, the air mass originated from the North Atlantic Ocean, and the air mass crossed Western Sahara and Mauritania before reaching the site.

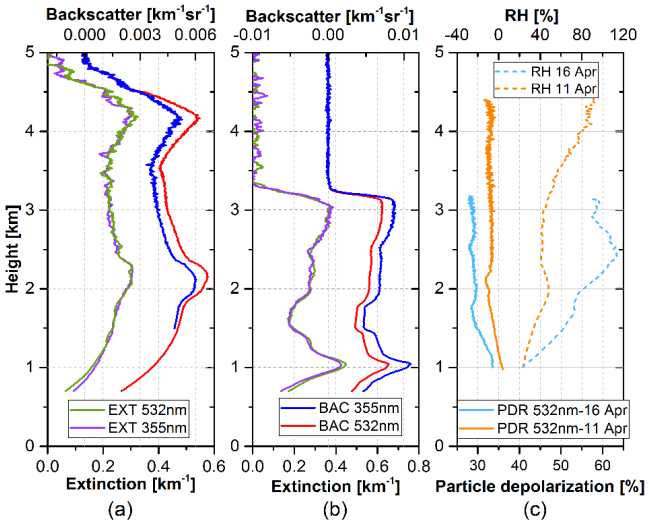

Figure 1. (a) Extinction and backscatter profiles retrieved from LILAS. Profiles are averaged between 00:00-01:30 UTC, 11 April 2015. (b) Similar plots to (a), but profiles are averaged between 05:00-06:00 UTC, 16 April 2015. (c) PDR and RH profiles corresponding to the time intervals in (a) (orange) and (b) (cerulean).

3.2 16 April, 2015

Maritime aerosols mixed with dust were observed on 16 April 2016. For the time interval of 05:00-06:00, the AOD at 532nm is around 0.9. The extinction profiles show very weak spectral dependence, like in the previous case. However, the backscatter coefficient at 355 nm is augmented and stronger than that at 532 nm. The PDR at 532 nm is ~ 27% and Ångström Exponent varies from 0 to 0.1, between 1.2 km and 3.2 km.

Below 1.2 km, the PDR is between 30% and 35% and Ångström Exponent between -0.1 and 0. This difference suggests different aerosol types in the two layers. The RH of 16 April is much higher compared with 11 April and increases with height.

Referring to the back trajectories, in the upper layer air mass came originally from the surface of North Atlantic Ocean and then landed from Western Sahara. In the lower layer, air mass came from the continent, which is usually transported dust.

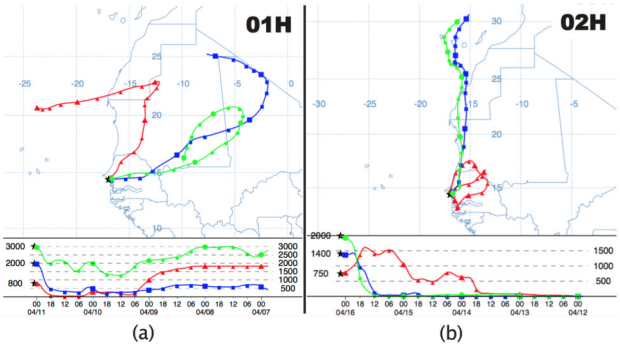

Figure 2. 100-hour back trajectories at (a) 01:00 UTC, 11 April 2015 and (b) 02:00 UTC, 16 April 2015.

4 GRASP/GARRLiC RETRIEVAL

GRASP/GARRLiC retrievals are performed around 09:30, 11 April 2015 and 08:02, 16 April 2015, and about half an hour Lidar profiles are averaged as the input of GRASP/GARRLiC.

4.1 Size distribution and concentration

Figure 3(a) shows a bimodal size distribution with a pronounced coarse mode in both cases. For 16 April, the median sizes of coarse and fine mode are 1.93 μm and 0.11 μm. The ratio of concentration is: $C_{vc}/C_{vf} \approx 8.74$. For 11 April, the median sizes of coarse and fine mode are 2.44 μm and 0.12 μm, respectively. The ratio of concentration: $C_{vc}/C_{vf} \approx 12.59$. It is noteworthy that, from 04:00 UTC, 16 April, the wind direction changed from northerly to northeasterly, thus bringing more dust aerosols, which may, to a certain extent, dilute the marine aerosols. The insert of Figure 3 shows the vertical concentration of fine and coarse mode aerosols. On 11 April, the aerosol layer is up to 4.5 km and most aerosols concentrated below 3 km on 16 April. As we have mentioned that, on 16 April, the aerosol type below 1.2 km differs from the upper layer, since continental wind injected to the lower layer may bring more dust particles. The retrieval shows a sharp peak of the concentration of coarse mode at ~0.9 km, this could qualitatively support our inference.

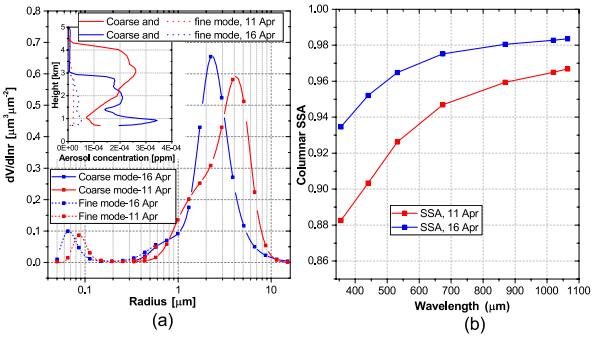

Figure 3. (a) Size distribution and aerosol vertical concentration (insert) retrieved from GRASP/GARRLiC and (b) Columnar SSA from GRASP/GARRLiC for 16 April (blue) and 11 April retrieved (red).

4.2 Single Scattering Albedo and absorption

In Figure 3(b), the columnar SSA increases with wavelength in both cases, and on 16 April, aerosols are apparently less absorbing than on 11 April. Studies have revealed that clean maritime aerosols have much lower absorption than mineral dust [3]. When mixed with each other, the optical properties of the mixture depend on the fraction of each component and the mixing mode as well. Previous researchers also obtained a lifted SSA of mineral dust when mixed with maritime aerosols [4]. The profile of SSA (Figure 4(a)) has no obvious vertical variation for both cases. A minor increase of SSA at 355 nm and 532 nm on 11 April is due to the change of the proportion of fine and coarse mode.

The maximum absorption appears at ~0.8 km and ~3.0 km for 11 April and 16 April, respectively. Above 1 km, the absorption on 11 April is 1~2 times stronger than 16 April. Around 2 km, the particle concentration in the two cases is close, however, the absorption on 11 April is ~30% higher than that on 16 April. Below 1 km, the particle concentration of 16 April exceeds that on 11 April, and the absorption is superior.

The fine mode absorption profiles are plotted to compare with the in-situ absorption, since the

Aethalometer samples particles with diameter of 1 μm or smaller. On 11 April, the absorption of fine mode particles is very low and shows almost no spectral dependence, while the fine mode absorption on 16 April is 2-3 times stronger and has a more pronounced spectral dependence. Similar tendencies are also observed from the in-situ measurements.

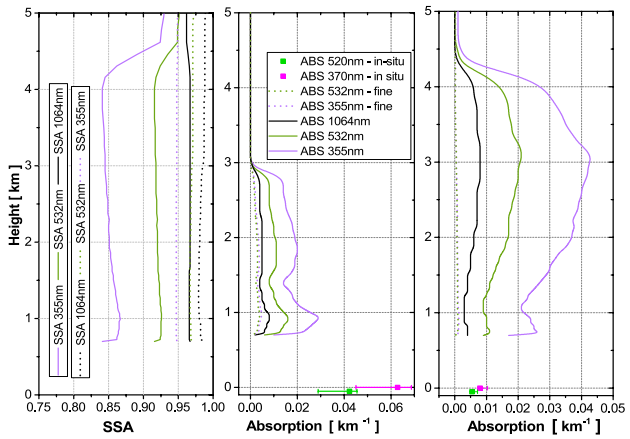

Figure 4. (a) SSA profile for 11 April (solid line) and 16 April (short dashed line). (b) Absorption coefficient profile for 16 April. (c) The same plot as (b), but for 11 April. In (b) and (c), the points on the ground level represent the in-situ Aethalometer measurements.

4.3 Complex Refractive Indices

The real parts of CRI on 11 April are higher than 16 April (Figure 5). The reported values of real part of CRI vary with the origins of mineral dust. For instance, 1.55 ± 0.03 is reported for Bahrain-Persian Gulf, 1.48 ± 0.05 for Cape Verde. Here, we retrieved:

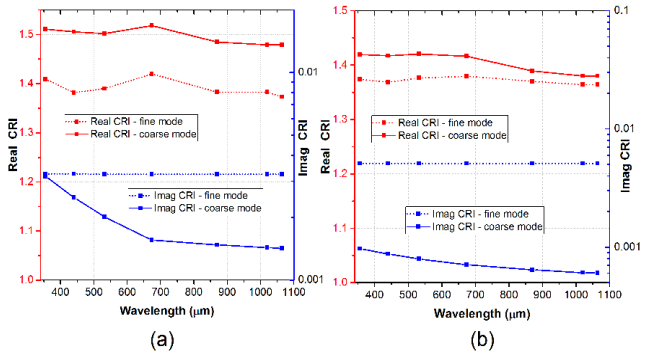

Figure 5. CRI from GRASP/GARRLiC for (a) 11 April and (b) 16 April.

$$m_r \approx 1.505, m_i \approx 0.0025, at\ 440nm, 11\ Apr$$

$$m_r \approx 1.417, m_i \approx 0.0008, at\ 440nm, 16\ Apr$$

On 16 April, aerosols are 'softer' and less absorbing, which is in agreement with our inference that dust and maritime aerosols are observed. Due to the low concentration of fine mode particles, the retrieved fine mode properties may have high uncertainties.

5 Conclusions

This study shows the absorption measurements and retrievals for selected two cases, derived columnar and vertical resolved SSA, absorption coefficients and ground-level absorption are shown and compared. The results are qualitatively in agreement with the expecting aerosol properties and suggest the potential of quantifying the vertical absorption. Uncertainties and validation still need to be studied carefully in future work.

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