LIDAR DERIVED FINE SCALE RESOLUTION PROPERTIES OF TROPOSPHERIC AEROSOL MIXTURES

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ABSTRACT

Fine scale resolution analysis was applied to the complicated aerosol structures observed with the PollyXT-UW lidar over Warsaw during the night of 9/10 August 2015. The full sets of the particle optical properties profiles, so called 3β+2α+2δ+wv (3 backscattering, 2 extinction coefficients, 2 depolarization ratios and water vapour mixing ratio), were obtained to discriminate multiple aerosol height sectors, which were then used for the microphysical properties inversion. The statistical characterization of the main aerosol/mixture types was obtained.

1. INTRODUCTION

For studies on influence of atmospheric aerosol on the earth radiative budget it is crucial to know the optical and microphysical properties of aerosol particles related to particular aerosol type, the altitude of aerosol layers suspension, and the type of ground surface over which the layers are present. Additional challenge arises, when suspended aerosol does not represent pure aerosol type, but composes a mixture of different ones. Exploration of the aerosol mixtures properties is a difficult task and requires detailed analysis in the fine scale.

The presented study concerns multiple aerosol layers detected over Warsaw during a heat wave event over Poland, known as favoring the long-range transport of biomass burning aerosol [1]. Biomass burning particles advection (2-3 days old) from over France, Germany, and Czech Republic, was observed in majority of the layers over Warsaw, being sometimes mixed in with an anthropogenic pollution from sources in Poland [2].

2. METHODOLOGY

In the current study, the data from the 8-channel PollyXT-UW lidar [3], installed at the Remote Sensing Laboratory (RS-Lab) of the Institute of Geophysics, Faculty of Physics, University of Warsaw (52.21ºN, 20.98ºE, 112 m a.s.l) were analyzed. The RS-Lab operates within the European Aerosol Lidar Network EARLINET [4]. The quasi-continuous vertical lidar measurements with the 355, 532, 1064 nm laser light, provide the elastic backscattering signals at all three emitted wavelengths, the elastic depolarized signals at 355 and 532 nm, the non-elastic Raman signals on N_2 molecules at 387 and 607 nm and on H_2O at 407 nm. The raw signal resolution is 30 s and 7.5 m.

The sets of the particle optical properties profiles (3β+2α+2δ+wv) are derived using the classical Raman approach, according to the evaluation scheme given in [5], and then smoothed using a customized algorithm detailed in [2]. The profiles of linear particle depolarization ratio were derived with the ±45° calibration method [3]. The relative humidity profiles were derived as in [6].

The microphysical properties (complex refractive index (m), particle size distribution, effective radius (R_{eff}), surface (S) and volume (V) concentrations) were obtained using the inversion algorithm developed at University of Potsdam; details are given in [7],[8],[9]. For all calculations the spherical model was used, as the mineral dust contribution was not expected. The regularization method based on the truncated singular value decomposition (TSVD) was applied.

The optical properties were calculated for each consecutive 30 minutes from 19-02 UTC on the night of 9/10 August 2015. In total 9 sets of 3α+2β+2δ+wv profiles were obtained. In each set, multiple height sectors were discerned; based mainly on the extinction and relative humidity profiles. The mean values of optical properties were obtained in each height sector, and based on those the intensive aerosol properties calculation and microphysical inversion followed. Finally, the height sectors were grouped in the main aerosol/mixture layers and the optical properties within them were obtained in a statistical way. Extensive analysis of the results is given in [2].

3. RESULTS

3.1 Optical properties

Fine scale analysis of optical properties derived in all height sectors (for brevity only some are indicated in Fig.1) allows for discrimination of the same aerosol type layers in statistical way. In lowermost Layer 1 (Fig.1, in black), anthropogenic industry-driven pollution uplifted from boundary layer was likely mixed with biomass burning. Here the lidar ratios are being relatively low: LR_{355} of 55±6 sr and LR_{532} of 43±4 sr with Ångström exponent AE_{α} of 1.48±0.10. Above it, Layer 2 contained moderately-fresh biomass burning aerosol. Here the lidar ratios were significantly higher with the mean values of 76±7 sr for LR_{355} and 62±4 sr for LR_{532}. The AE_{α} of 1.35±0.18 was only slightly lower. For both layers, the particle depolarization ratios were similar at each wavelength: δ_{355} of 1.5-1.6 % and δ_{532} of 3.5-3.6 %.

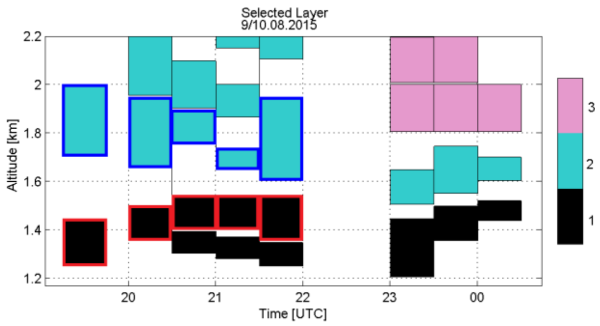

Figure 1: Schematic plot of aerosol layers derived on the night of 9/10 August 2016 from PollyXT-UW at the EARLINET-ACTRIS lidar site in Warsaw. Each color depicts different aerosol type. Blue and red rectangles mark layers for which microphysical inversion results are shown in Fig 2.

3.2 Microphysical properties

The microphysical properties derived in height sectors marked by red and blue rectangles in Fig.1, reveal very good agreement of the obtained results. The particle size distributions (Fig.2) have a fine mode dominating (~0.12 µm) and much smaller modes at larger radii (~0.75 and ~1.5µm). This consistency is clear in reference to individual height sectors and the mean values of each layer type, whereby the mean distributions for the biomass burning aerosol (Layer 2) and the anthropogenic pollution (Layer 1) differ only in terms of the 0.75 µm mode existing in the latter.

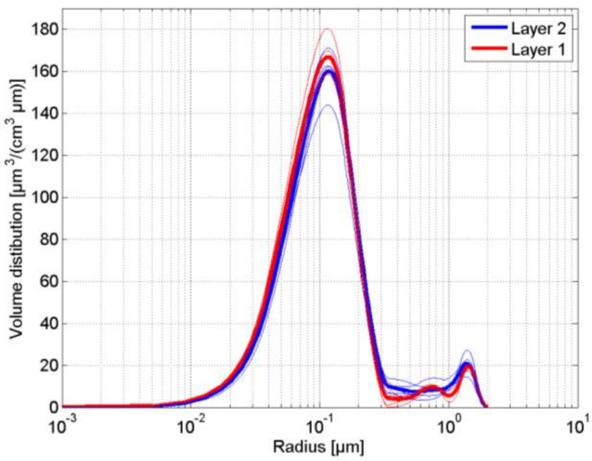

Figure 2: Particle size distributions obtained by the microphysical inversion of the PollyXT-UW lidar data at the night of 9/10 August 2016 at in Warsaw. Thin lines denote individual distributions for each height sector and the thick lines the mean distributions for each aerosol-type layer .

Table 1: Mean microphysical properties for aerosol layers derived in height sectors, depicted in rectangles in Fig. 1, with the standard deviation.

R_{eff} [µm]	*Re* m	*Im* m	S [µm²/cm³]	V [µm²/cm³]	SSA_{355}	SSA_{532}
Layer 1 mixed BB & AP						
0.15 ± 0.01	1.54 ± 0.01	0.013 ± 0.002	783 ± 34	40 ± 2	0.92 ± 0.01	0.90 ± 0.01
Layer 2 long-range transported BB						
0.17 ± 0.02	1.55 ± 0.02	0.028 ± 0.003	757 ± 52	43 ± 5	0.85 ± 0.02	0.83 ± 0.02

In Table 1, the mean microphysical properties for each aerosol layer are listed. The effective radius R_{eff}, the volume V and surface S concentrations are the same in the standard deviation limit. The real part of refractive index is also similar for both aerosol types. However, the imaginary part of 0.013±0.01 (Layer 1) and 0.028±0.02 (Layer 2) differ distinctly, indicating higher absorption for the biomass burning layer. The single scattering albedo (SSA) for this layer is very low ~0.84, as expected. In the anthropogenic pollution layer the SSA is of ~0.91, which is still indicating possible absorption, thus pollution mixed with biomass burning is confirmed.

4. CONCLUSIONS

In presented study, optical and microphysical properties of aerosol over Warsaw during a heat wave event were derived and analyzed in fine temporal and spatial scales. The analysis allowed for discrimination of aerosol layers dominated by the long-range transported biomass burning (lidar ratios higher than ~20 sr, twice higher imaginary part of the refractive index) and those being mixed with the anthropogenic pollution (additional mode at radius of ~0.75, higher SSA). This case study has a great potential for further use in aerosol type separation algorithms.

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The RS-Lab site provides the data products to the PolandAOD-NET (*http://www.polandaod.pl*), the EARLINET (*https://www.earlinet.org*), and the Polly.NET (*http://polly.tropos.de*) networks.

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