Profiling aerosol optical properties at the Central Asian site of Dushanbe, Tajikistan: pure dust cases

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ABSTRACT

Tajikistan is often affected by atmospheric mineral dust originating from various surrounding deserts. The direct and indirect radiative effects of that dust play a sensitive role in the Central Asian climate system and therefore need to be quantified. The Central Asian Dust Experiment (CADEX) provides for the first time an aerosol climatology for Central Asia based long-term aerosol profiling by ground-based lidar (PollyXT type) in Dushanbe, Tajikistan. For pure dust cases, mean depolarization(lidar) ratios of 0.23±0.03(44±3 sr) at 355 nm and 0.32±0.02(38±3 sr) at 532 nm wavelength have been measured. The mean extinction-related Ångström exponent was 0.18±0.15.

1 INTRODUCTION

The Central Asian country Tajikistan and its neighboring countries contain vast arid regions and are located within the global dust belt reaching from the Sahara to the Gobi desert. Thus, the occurrence of dust events with a broad range of intensities is frequent in Tajikistan and whole Central Asia [1]. In this region, which is highly affected by climate change [2, 3], this dust has impacts ranging from radiative effects to health hazards [4, 5]. Aerosol observations in Tajikistan are therefore highly important to understand regional and global transport of mineral dust and its effects on radiation budget, cloud formation etc. Therefore, long-term data on vertical profiles of aerosol optical properties are provided by the Central Asian Dust Experiment (CADEX).

2 INSTRUMENTS AND METHODS

The CADEX campaign was conducted at a field site of the Physical Technical Institute of the Academy of Sciences of Tajikistan in Dushanbe (38°33′34″ N, 68°51′22″ E, 864 m ASL) [6]. During the 18-month campaign (March 2015 to August 2016), a multiwavelength polarization Raman lidar PollyXT [7] was operated continuously for the lidar measurements. During the measurement period, strong dust events occurred several times and lofted dust layers at various altitudes were frequent, as well as dusty mixtures and pollution aerosol, especially in winter and spring [6, 8, 9].

This contribution, however, provides a closer look at the aerosol optical properties during periods when purest dust was observed. Such periods were identified by the layer-mean particle linear depolarization ratio at 532 nm wavelength plus one standard deviation (of the mean within the averaging height range) being larger than 0.31. The basis of this analysis are profiles of the optical properties retrieved at each possible night during the observation period. The profiles were manually evaluated with the Raman method [10, 11, 12]. 22 profiles fulfill the aforementioned criterion, but one case of a thin lofted layer was excluded, due to a small averaging height range and noisy extinction profiles. The mean averaging height range for the remaining 21 profiles was 1.6±0.5 to 2.7±0.7 km AGL. For comparison of the layer-mean extinction-related Ångström exponent, AERONET (Aerosol Robotic Network [13]) data of the collocated AERONET CIMEL sun photometer [14] was used. The FLEXible

PARTicle dispersion model FLEXPART [15] was used for the backward trajectory calculations.

3 RESULTS

The layer-mean particle linear depolarization ratio of the 21 pure dust cases ranged from 0.18±0.01 to 0.29±0.01 at 355 nm and from 0.30±0.02 (determined by the applied selection criterion) to 0.36±0.01 at 532 nm wavelength. The layer-mean lidar ratio ranged from 39±2 sr to 49±9 sr at 355 nm and from 32±2 sr to 43±3 sr at 532 nm wavelength. The layer-mean extinction-related Ångström exponent ranged from -0.12±0.05 to 0.46±0.14. The means of all the values are listed in Tab. 1.

Table 1: Mean and standard deviation of layer-mean intensive parameters (particle linear depolarization ratio, lidar ratio and extinction-related Ångström exponent) of 21 dust events during the CADEX campaign.

wavelength	355 nm	532 nm
depol. ratio	0.23±0.03	0.32±0.02
lidar ratio	44±3 sr	38±3 sr
Ångstr. exp.	0.18±0.15	

Figure 1 shows a comparison of layer-mean Ångström exponents from lidar with column Ångström exponents from AERONET as scatter plots. The 21 cases have a smaller range in the AERONET Ångström exponent of the 440-870 nm range (Fig. 1a) than the ones of the 380-500 nm range (Fig. 1b). The correlation is similar in both cases, but the AERONET Ångström exponents of the 380-500 nm range (more comparable to the lidar wavelengths) are obviously distributed closer along the identity line (Fig. 1b).

Figure 2 shows examples of 7-day FLEXPART backward trajectories, which were calculated for all averaged layers. Exemplary lofted layers (Figs. 2a,b) had high accumulated residence times over the Arabian Peninsula, Iran and partly Afghanistan and Uzbekistan. Exemplary lower level layers had high accumulated residence times mainly in Uzbekistan and Kazakhstan towards the Caspian and Aral Sea (Figs. 2b,c).

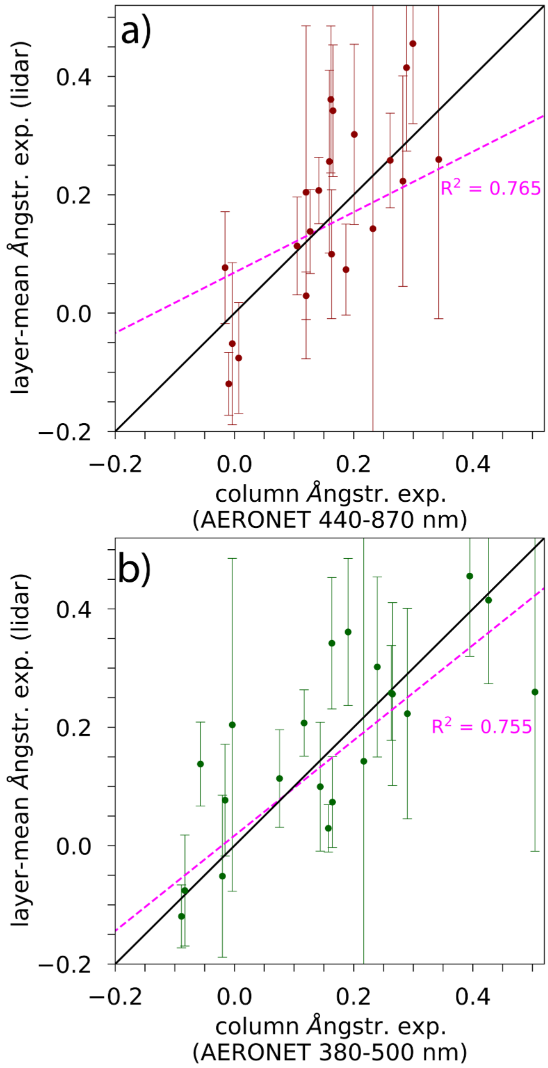

Figure 1: Comparison of layer-mean dust Ångström exponents from lidar with column Ångström exponents from AERONET from the 440-870 nm (a) and 380-500 nm (b) wavelength range. Errorbars indicate the standard deviation within the averaging height range.

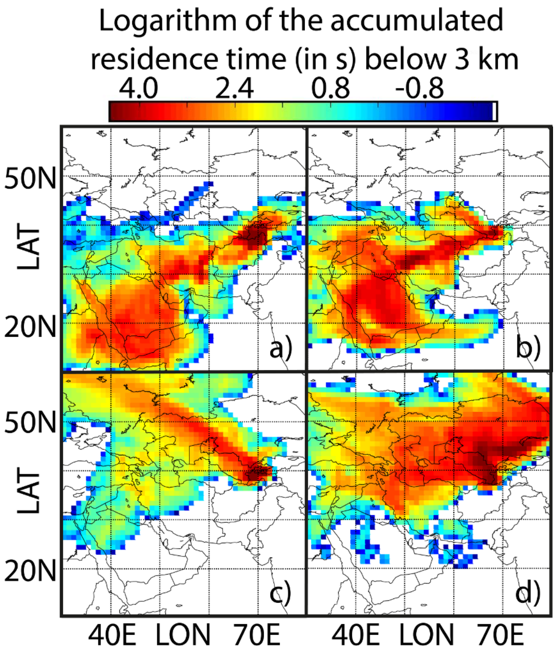

Figure 2: Accumulated residence times of 7-day FLEXPART backward trajectories arriving at Dushanbe at the following dates (UTC) and heights (AGL): a) 13 April 2015, 15:10-16:10, 2.8-3.8 km. b) 23 April 2015, 20:47-21:47, 3-5 km. c) 10 June 2015, 19:00-20:00, 1.4-2.5 km. d) 14 July 2016, 18:30-19:30, 1.4-1-8 km.

4 CONCLUSIONS AND OUTLOOK

The 18-month lidar observations in Dushanbe, Tajikistan, provided unprecedented data of vertical profiles of aerosol optical properties in Central Asia. The optical properties of pure dust cases observed during the CADEX campaign are presented in this study. Further analyses include the depolarization ratio, lidar ratio, Ångström exponent of all the different observed aerosol conditions as well as aerosol layer heights. The polarization-lidar photometer networking (POLIPHON) [16, 17, 18] method will be used to estimate dust and non-dust mass concentrations, as well as concentrations of cloud condensation nuclei and ice nucleating particles on a climatological basis. For further aerosol characterization, backward trajectory analyses and AERONET data will be used in addition to the lidar data. Furthermore, forward trajectory analysis can give insights on the transport of lofted dust layers further east.

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