CADEX and beyond: Installation of a new Polly^{XT} site in Dushanbe

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Abstract. During the 18-month Central Asian Dust Experiment we conducted continuous lidar measurements at the Physical Technical Institute of the Academy of Sciences of Tajikistan in Dushanbe between 2015 and 2016. Mineral dust plumes from various source regions have been observed and characterized in terms of their occurrence, and their optical and microphysical properties with the Raman lidar Polly^{XT}. Currently a new container-based lidar system is constructed which will be installed for continuous long-term measurements in Dushanbe.

1 Introduction

Mineral dust from Central Asia is one of several major contributors to global aerosol. However, profiling observations of dust occurrence, mobilization, transport, of its mixing with anthropogenic pollution, and also of its interaction with clouds are rare in these regions although such measurements are strongly needed to correctly address the dust effects in regional and global dust models. Therefore, the Central Asian Dust EXperiment (CADEX) was initiated in which in-situ and remote lidar measurements of dust over Dushanbe were performed from 2015 to 2016 in a statistical manner [1, 2]. The portable Raman lidar Polly^{XT} [3] used for the campaign is part of Polly-NET [4]. At the same time, the idea of two new permanent Polly-NET stations in the eastern Mediterranean and Central Asian dust regions was born, which led into the project to install two Polly^{XT} lidar systems in Cyprus and Tajikistan (PoLiCyTa). In this presentation we want to summarize some results from the CADEX campaign and present the current status of the new permanent lidar system in Dushanbe.

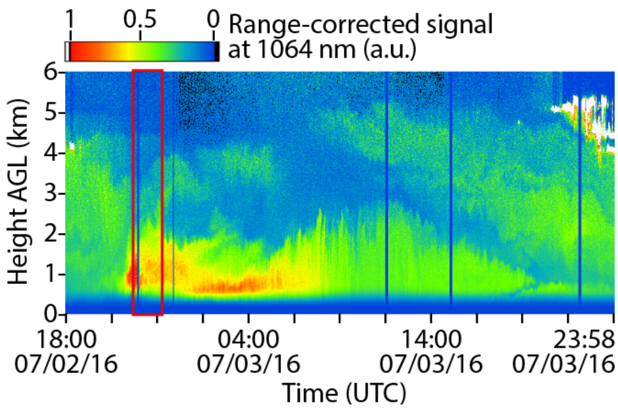

Figure 1. Measurement of a near-ground dust layer on 2 – 3 July 2016 in Dushanbe. Temporal development of the range-corrected signal at 1064 nm wavelength from 2 July 2016, 18:00 UTC to 3 July 2016, 23:58 UTC. Blue bars: no measurements, due to automatic depolarization calibration. Red box: averaging period for calculation of the profiles in Fig. 2 (2 July 2016, 21:40 – 23:19 UTC).

2 Measurements

During CADEX near-ground and lofted dust layers have been observed frequently above the measurement location in Dushanbe, Tajikistan [2]. An example of such a near-ground dust layer is shown in Fig. 1. On 2 July 2016 after 20:30 UTC until about 3 July 2016 08:00 UTC the lidar signal in the lowest 2 km was strongly enhanced. Thereafter, most likely a dilution process by the developing convective layer took place and the signal intensity decreased.

Figure 2 shows the vertical profiles of the optical properties measured on 2 July 2016 21:40 – 23:19 UTC. Dust was present up to 4.5 km height which can be seen from the particle backscatter and extinction coefficients and the elevated particle linear depolarization ratio (PLDR) values. Above 3 km height the depolarization ratios decreased only slightly down to 25% which indicates a non-dust fraction of the aerosol composition.

The polarization-lidar photometer networking (POLIPHON) method [5–7] further allowed us to separate the dust and non-dust fractions in terms of mass concentrations by help of the measured PLDR. In order to apply POLIPHON we assumed the PLDR and lidar ratio of 31% and 40 sr, respectively, for mineral dust and 5% and 50 sr, respectively, for non-dust particles. Furthermore, an extinction-to-mass conversion factor of 2.08 μg m^{-3} Mm

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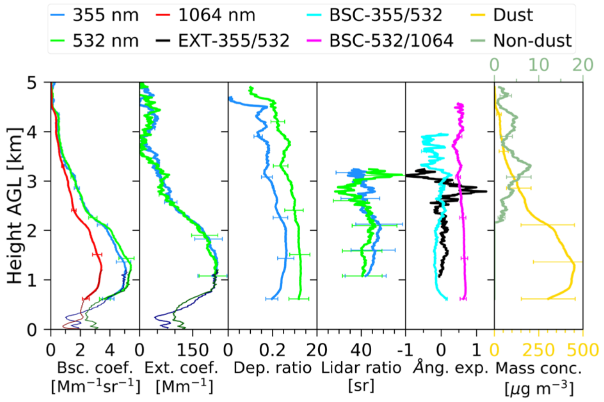

Figure 2. Vertical profiles of the optical properties on 2 July 2016, 21:40 – 23:19 UTC. a) Particle backscatter coefficient at 355, 532 and 1064 nm wavelength (188 m vertical smoothing, bold, light colors and 23 m vertical smoothing, thin, dark colors). b) Raman retrieved particle extinction coefficient at 355 and 532 nm wavelength (743 m smoothing, bold, light colors) and calculated from the backscatter coefficient with the constant lidar ratio at 1.1 km height (23 m smoothing, thin, dark colors). c) PLDR at 355 and 532 nm wavelength (188 m smoothing). d) Lidar ratio at 355, 532 nm wavelength (743 m smoothing). e) Extinction- and backscatter-related Ångström exponents. f) Dust and non-dust mass concentrations calculated with POLIPHON.

was applied for dust and of 0.56 μg m^{-3} Mm for non-dust to derive the separated mass concentrations.

Fig. 2f shows almost pure dust except between 3 and 4.5 km height where a minimal non-dust fraction below 10 μg m^{-3} was present. A maximum dust mass concentration of 450 μg m^{-3} at 1.5 km height was calculated. The calculation of the integrated dust mass yielded 1.3 g m^{-2}.

A summary of the mean optical properties measured by lidar and the AOTs and Ångström exponent from AERONET are presented in Tab. 1. The lidar-derived AOT was derived from integration of the profiles of the extinction coefficient from 0 – 5 km height. Because of the overlap effect these profiles were extended towards the ground by means of the backscatter coefficient times the lidar ratios of S_{355}(1.1 km) = 42.8 sr and S_{532}(1.1 km) = 40.6 sr below a height of 1.1 km (c.f. Fig. 2b). The two AERONET measurements temporally closest to this lidar measurement indicate that the dust arrived during night time in between the two data points. The AOT at 500 nm wavelength increased and the Ångström exponent from the 440 – 840 nm wavelength range decreased drastically overnight. Therefore, comparison with the lidar measurements at night-time are difficult. Nevertheless the AOT calculated from the lidar profiles are in reasonable agreement with the AERONET measurement about 2 h after the lidar observation.

Based on the 18-month data set during CADEX, we retrieved 268 profiles of optical properties during nighttime when it was possible to apply the Raman lidar method. Sixty-eight of these profiles were classified as dusty using a criterion of a PLDR larger

Table 1. Averaged optical properties for the dust case in Fig. 1 and 2 derived from lidar and sun photometer. Top: Mean values of PLDR (δ) and lidar ratio (S) at 355 and 532 nm wavelength, AOT (τ), and Ångström exponent (Å) . Bottom: AOT at 340, 380 and 500 nm wavelength and Ångström exponent from the 440 – 870 nm wavelength range from AERONET Level 2 from before and during the dust event.

Polly^{XT}	2 July 16, 21:40 – 23:19 UTC 355 nm	 532 nm
δ (1.2 – 2 km)	0.26 ± 0.01	0.32 ± 0.01
S (1.2 – 2 km)	46.0 ± 1.0 sr	42.0 ± 1.5 sr
τ (0 – 5 km)	0.528	0.502
Å (1.2 – 2 km)	0.08 ± 0.06	
AERONET	**2 July 16 13:43 UTC (before)**	**3 July 16 01:15 UTC (during dust event)**
τ (340 nm)	0.643	0.569
τ (380 nm)	0.568	0.556
τ (500 nm)	0.433	0.532
Å (440 – 870 nm)	0.812	0.187

than 0.25 at 532 nm wavelength. The resulting "averages over all averages" were (± 1 standard deviation): δ (355 nm) = 0.18 ± 0.04, δ (532 nm) = 0.29 ± 0.03, S (355 nm) = 41.5 ± 3.4 sr, S (532 nm) = 33.6 ± 4.4 sr, Å = 0.51 ± 0.35, τ (532 nm) = 0.475 ± 0.543, τ_{max} (532 nm) = 3.73, τ_{min} (532 nm) = 0.07.

3 New Polly^{XT} lidar in Dushanbe

Within the project PoLiCyTa a new version of Polly^{XT} is currently developed. Polly^{XT} are a series of automatic multiwavelength Raman polarization lidars developed by TROPOS over the last 15 years [3, 8]. Those systems are all part of Polly-NET [4]. The measured data are uploaded to a central server (http://polly.tropos.de) where they are all automatically processed and plotted by the same data routines. In this way data from different systems is comparable, quality assured, and in the future held available for a broader science community.

The new lidar system will be installed in a 20-ft sea container which is already constructed. Figure 3 shows a sketch of this container. An automatic hatch is foreseen with the ability to clean the roof window, a power generator will be applied to guarantee operation during power cuts, and a roof platform is integrated to give space for future instrumentation.

The main improvement for the new systems within PoLiCyTa is the application of a 100-Hz diode-pumped Nd:YAG laser system (Spitlight DPSS-250, InnoLas Laser GmbH, Krailling, Germany) in contrast to the 20-Hz flashlamp pumped system before which needed maintenance every two to three months. According to the specifications of this laser, maintenance is only required after two years of operation.

The lidar will have eight detection channels on a 30-cm far-range telescope and four channels on a near-range telescope. In this way it will be possible to measure profiles

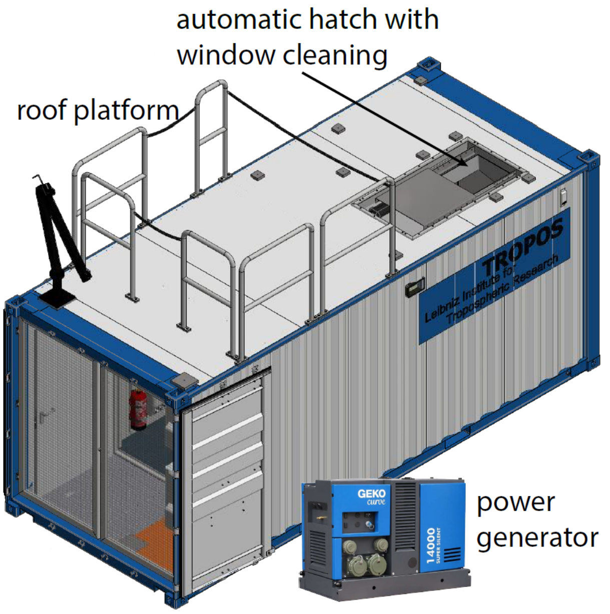

Figure 3. Current design of the new container housing the Polly^{XT}. The 20-ft container will house the lidar system, redundant air condition and power supply and a roof platform for further instruments.

of the backscatter coefficient at three wavelength (1064, 532, 355 nm), the extinction coefficient and the depolarization ratio at two wavelengths (532, 355 nm), and the water-vapor mixing ratio from 150 m to 15 km height.

4 Outlook

In 2019 a new automatic Polly^{XT} lidar system will be installed in Dushanbe as a collaboration between TROPOS and the Physical Technical Institute of the Academy of Sciences of Tajikistan to extend the measurements started during CADEX. With the operation of this system we will aim for the site of Dushanbe to be part of the European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gases (ACTRIS). Furthermore, we will support the satellite missions Aeolus and EarthCare of the European Space Agency with calibration and validation data by this new ground station.

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