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CENTRAL ASIAN DUST EXPERIMENT (CADEX): MULTIWAVELENGTH POLARIZATION RAMAN LIDAR OBSERVATIONS IN TAJIKISTAN

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ABSTRACT

For the first time lidar measurements of vertical aerosol profiles are conducted in Tajikistan/ Central Asia. These measurements just started on March 17th, 2015. They are performed within the Central Asian Dust Experiment (CADEX) in Dushanbe and they will last at least one year. The deployed system for these observations is an updated version of the multiwavelength polarization Raman lidar Polly^{XT}. Vertical profiles of the backscatter coefficient, the extinction coefficient, and the particle depolarization ratio are measured by this instrument. A first and preliminary measurement example of an aerosol layer over Dushanbe is shown.

1. INTRODUCTION

Tajikistan (Fig. 1) lies in the global dust belt in close proximity of some major dust sources like the Taklimakan desert, the Aralkum desert of the desiccating Aral Sea, the Kyzylkum and Karakum deserts east of the Caspian Sea, and the Iranian Dasht-e-Kavir and Dasht-e-Lut deserts. Therefore Tajikistan is frequently affected by severe dust events. Furthermore, Central Asia and especially Tajikistan are highly affected by climate change. For example, dramatic glacier shrinking took place in the last decades [1], which has also an effect on the water resources of Tajikistan and the whole Central Asian area, since trans-regionally important rivers as Amu Darya and Syr Darya are fed by glacier meltwater.

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.

Up to now, only few experiments were performed to characterize the aerosol over Central Asia. So, a joint Soviet-American research group did dust research in Tajikistan in 1989 [2]. They characterized the chemical and physical properties of mineral dust collected in 2 dust storms [3, 4]. During these dust storms in 1989 optical depths of up to 3.5 (at 550 nm) were measured. Furthermore a few vertical profiles of the dust distribution were measured by aircraft [5]. They found well mixed dust aerosols up to a height of 3 km.

Nevertheless, the knowledge of the vertical aerosol distribution over Tajikistan and especially the transport of mineral dust over Central Asia is still insufficient. Therefore CADEX aims to provide long-term data on vertical profiles of the backscatter coefficient, the extinction coefficient, and the particle depolarization ratio.

2. FIELD SITE AND INSTRUMENTATION

The measurement site is located in an urban area on a slightly elevated hill near the Physical Technical Institute of the Academy of Science of Tajikistan in Dushanbe. Its coordinates are 38°33'34" N, 68°51'22" E, and its altitude is 864 m a.s.l..

Fig. 1: Physical map of Central Asia with Dushanbe/Tajikistan (red circle). (The World Factbook 2013-14. Washington, DC: Central Intelligence Agency, 2013)

The updated version of the multiwavelength polarization Raman lidar Polly^{XT} [6, original design] is used for the lidar measurements. The

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last improvements were the installation of an additional depolarization channel at 355 nm for this campaign (Fig. 2) and the change of most of the electronic components to the current Polly^{XT} systems standard parts to ensure higher counting rates (see contribution Engelmann et al. [7] at this conference). All Polly^{XT} systems contain a laser that emits light at 355 nm, 532 nm, and 1064 nm. The receiver of the used system has 8 channels. With this system, vertical profiles of the backscatter coefficient are determined for all three emitted wavelengths. The channels at 387 nm, 607 nm, and 407 nm allow to detect Raman scattering at night time to determine extinction coefficient and water vapor profiles. Another two channels are installed to detect cross-polarized light at 355 nm and 532 nm. This allows to measure the particle depolarization ratio at these wavelengths. The system has a vertical resolution of 7.5 m and temporal resolution of 30 s.

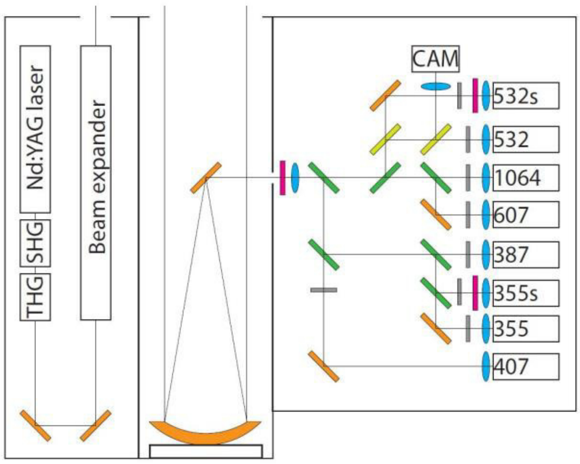

Fig. 2: Scheme of Polly^{XT}. 1064 nm Nd:YAG laser with second (SHG) and third harmonic generation (THG). Orange: Mirrors, including parabolic 30 cm main mirror. Blue: Lenses. Green: Dichroic beam splitters. Yellow: Non-polarizing 50% beam splitters. Magenta: Polarizers. Grey: Neutral density filters. Numbers: Photomultiplier tubes for the different wavelengths. CAM: Camera.

Additionally, a CIMEL sun photometer from the AERONET station in Dushanbe is collocated with the Polly^{XT} lidar to measure the aerosol optical depth and retrieve further particle properties, like size distribution, fine and coarse mode fraction.

There are also devices measuring ground level aerosols at the measurement site in Dushanbe. A Digitel DHA-80 High Volume Sampler is collecting PM10 particulates on quartz fiber filters for subsequent chemical analysis. A Grimm Environmental Dust Monitor EDM-180 is measuring particle size distribution of ground level aerosols without any initial cut off size.

Later, simulations with the regional dust model COSMO-MUSCAT [8] will be performed to access the transport and radiative effects of the dust during the time of the field campaign. The properties measured with the Polly^{XT} serve as input parameters for the model.

3. FIRST MEASUREMENTS

An example of one of the first measurements during CADEX is shown in Fig. 3. The temporal evolution of the range-corrected signal at 1064 nm on March 19th, 2015 reveals a lofted aerosol layer, located between the planetary boundary layer and the high-level cirrus clouds. The layer is settling down from about 6 km to about 4.5 km from 00:04 to 06:00 UTC. Between 03:00 and 04:00 UTC a cirrus cloud has formed in the altitude of about 6 km where the layer was located before.

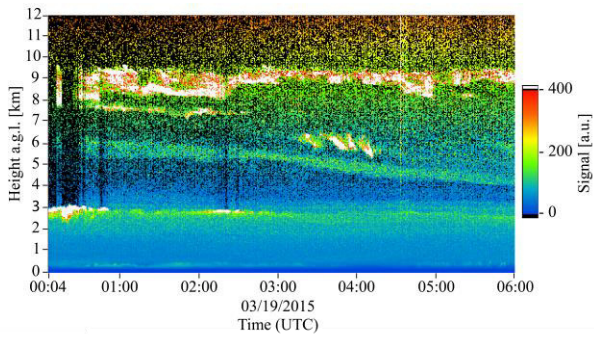

Fig. 3: Temporal evolution of the range-corrected signal at 1064 nm on March 19th, 2015.

HYSPLIT [9, 10] back trajectories indicate that the air, carrying this aerosol layer at 6 km height, was transported over the Middle East to Tajikistan (Fig. 4). Despite being transported along the global dust belt the air did not reach into the planetary boundary layer.

Fig. 5 shows vertical profiles of the backscatter coefficient (a), the extinction coefficient (b), the depolarization ratio (c) and the lidar ratio (d) averaged between 00:50 and 01:05 UTC on

March 19th, 2015. The analysis was conducted with the Raman method [11]. The depolarization ratio was calculated based on the internal depolarization calibration which is automatically

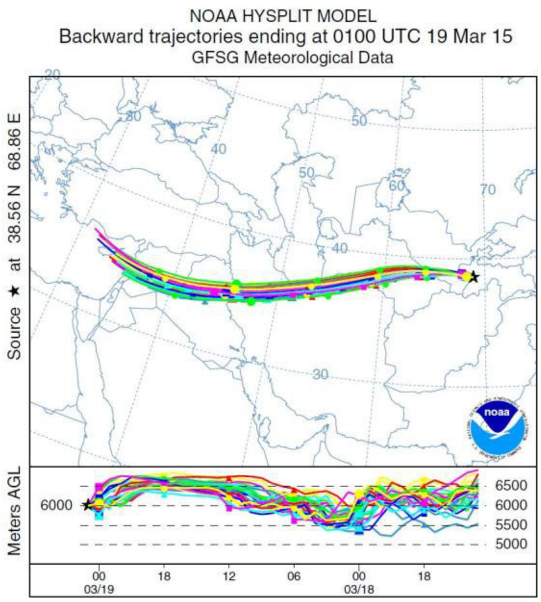

Fig. 4: HYSPLIT ensemble backward trajectories arriving on 6 km over Dushanbe at 01:00 UTC on March 19th, 2015.

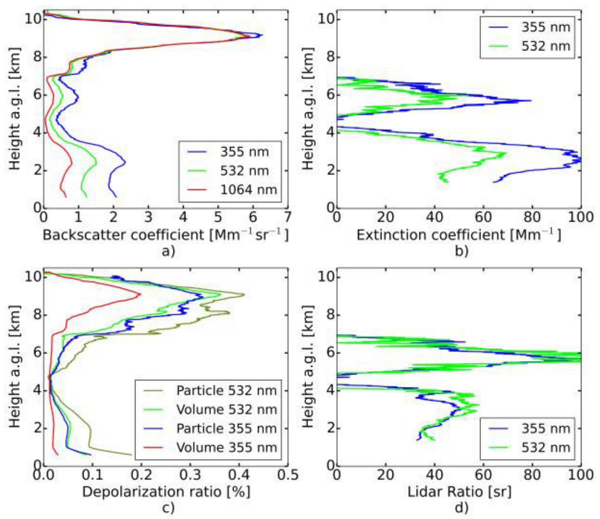

Fig. 5: Averaged profiles from 0050 to 0105 UTC on March 19th, 2015, of a) backscatter coefficients for 355 nm, 532 nm, and 1064 nm, b) extinction coefficients for 355 nm and 532 nm, c) volume and particle depolarization ratios for 355 nm and 532 nm, and d) lidar ratios for 355 nm and 532 nm. The backscatter coefficient and the depolarization ratio are smoothed over 161, the extinction coefficient and the lidar ratio over 231 vertical bins.

Performed by the system three times a day [12]. Low signal-to-noise ratios did not allow the calculation of extinction coefficients and lidar ratios above 7 km. The lofted aerosol layer between about 5 to 6 km depolarizes only weakly (Fig. 4c)) but has larger extinction values (Fig. 4b)). Also it shows rather large lidar ratios of > 60 sr. So, bringing this information together leads to the conclusion that this layer is a particle layer originating mainly from pollution and/or burning processes and it is most likely not mineral dust. However, the shown data have to be considered yet as very preliminary. Ongoing overviews of the measurements in Dushanbe are available under http:\\polly.rsd.tropos.de and www.tropos.de/en/research/projects-infrastructures-technology/research-projects/cadex-home/.

4. OUTLOOK

The Polly^{XT} lidar is measuring since March 17th, 2015 in Dushanbe, Tajikistan. It is planned to operate it continuously until at least April 2016. The obtained backscatter, extinction and depolarization profiles will be used to characterize the aerosol types [e.g. 13, 14]. Analyses of HYSPLIT back trajectory clusters have indicated that the air masses arriving in Tajikistan can carry desert dust from as far as the Sahara and the Middle East. Hence we will statistically analyze the aerosol characterization and especially the measured aerosol optical properties according to the air masses' origin. Also anthropogenic pollution from local and distant sources is likely to form a complex aerosol mixture together with desert dust over Tajikistan. This needs approaches to separate optical profiles of dust from non-dust like [15]. Furthermore a separation of coarse mode and fine mode dust like [16] will be done with the performed polarization measurements.

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