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OBSERVATION OF ARABIAN AND SAHARAN DUST IN CYPRUS WITH A NEW GENERATION OF THE SMART RAMAN LIDAR POLLY

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ABSTRACT

The atmospheric science community demands for autonomous and quality-assured vertically resolved measurements of aerosol and cloud properties. Aiming this goal, TROPOS developed the fully automated multiwavelength polarization Raman lidar Polly since over 10 years [1, 2]. In cooperation with different partner research institutes the system was improved continuously. Our latest lidar developments include aside the “3+2” measurements also a near-range receiver to measure aerosol extinction and backscatter down to 120 m above the lidar, a water-vapor channel, and measurements of the linear depolarization at two wavelengths.

The latest system was built in cooperation with the National Observatory of Athens (NOA). Its first campaign however was performed at the Cyprus Institute of Nicosia from March to April 2015, aiming specifically at the observation of ice nuclei with in-situ and lidar remote sensing techniques in the framework of BACCHUS [3, 4].

1. INTRODUCTION

Lidar profiling of atmospheric aerosol and cloud layers have become important for climate research during the last decades. More recently, the volcanic eruption hazards of Eyjafjallajökull and Grimsvötn for aircraft safety have shown the need for a height–resolved monitoring of the aerosol concentration on continental scales. Aside from spaceborne observations (e.g. CALIPSO, ATLID, EARTHCare) continental networks of lidars such as EARLINET, MPLNET, AD-Net, LALINET, and CORALNET are a great tool for such observations. Nowadays, and with the technical and methodological developments of the recent years it is possible not only to observe aerosol layers in terms of an optical characterizations but also to infer on many microphysical aerosol properties such as the type, the shape, the concentration, and even to separate aerosol mixtures in terms of smoke and dust concentration as well as fine and coarse mode fractions of dust [5, 6].

Such observations require fully automated and advanced lidar systems because manpower for the continuous operation is sparse. At TROPOS meanwhile we developed nine of our automated lidars in the framework of the Polly (POrtabLe Lidar sYstem) idea. Advanced Raman and depolarization lidar techniques combined in a cabinet for the installation basically anywhere around the globe. The requirements for the operation are power, an internet connection, and occasional maintenance (e.g. window cleaning, flash lamp replacement in the laser, and replacement of neutral density filters if required).

We follow the idea of a PollyNET [7], where all users have a platform to upload the data, receive immediate quicklooks, and exchange ideas, or solve technical problems. Many technical details of the different systems are similar and allow network observations in such a harmonized way (laser system, signal acquisition, data structure), whereas constant improvement is possible when needed (automated calibration routines, higher photon count rates, additional near-range capabilities, aircraft-safety radar). However, becoming part of PollyNET and sharing data and knowledge is a mandatory prerequisite in our “philosophy”.

Our latest systems include a full set of measurement channels always guided by the needs, recommendations, and techniques that have been developed within the community of the European Aerosol Research Lidar Network (EARLINET). Nowadays, a Polly can measure the aerosol backscatter and extinction coefficients at 3 and 2 wavelengths, respectively. Also the linear depolarization is measured at two wavelengths. Measurements of the water-vapor mixing ratio and near-range capabilities are another new feature.

In the framework of the BACCHUS campaign in March 2015 we installed the new NOA system on the roof of the Cyprus Institute in Nicosia, Cyprus. In this contribution we will summarize the latest technical developments of our smart Polly systems (section 2) and give an overview about the scientifically unique location of Cyprus (section 3). We applied the automated system over four weeks continuously in Cyprus and present first results in section 4.

2. THE LIDAR POLLY

Figure 1 shows the setup of the Polly-XT NOA at the Cyprus Institute. The typical cabinet-like shape together with a water chiller for the laser cooling shows the apparent simplicity of the system. Equipped with a precipitation sensor an automated roof shuts down the measurements if required by the meteorological conditions. It has a weight of 500 kg but can be easily maneuvered on four wheels.

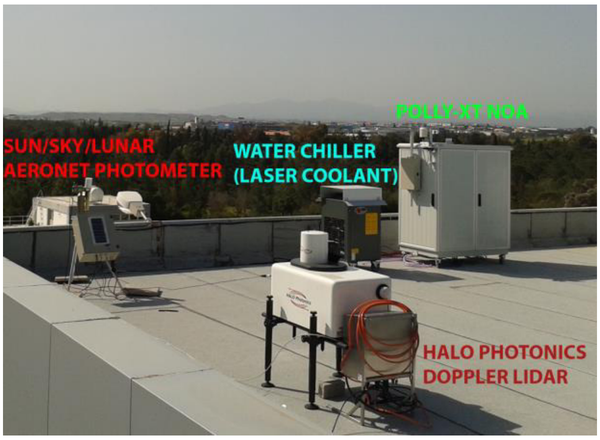

***Figure 1:** The Polly lidar on the roof of the Cyprus Institute, Nicosia, together with an AERONET photometer and a Doppler lidar.*

In terms of the optical setup the lidar is completely build on a carbon fiber board which gives a light-weight but sturdy framework for the components. In case of major maintenance requirements the board can even be removed from the system and realigned in an optical laboratory. Figure 2 shows the schematically setup of the optical parts. The flash-lamp pumped Nd:YAG laser (E1) emits radiation of 500 mJ, 20 Hz at 1064 nm wavelength which is then frequency doubled and tripled at (E2) and "post"-polarized (E3). After two beam steering mirrors an external safety shutter (E4) is implemented before the beam is expanded 8X (E5) and transmitted into the atmosphere. The receiving telescopes are R1 (50-mm near-range telescope) and R2 (300-mm main telescope). An automated depolarization calibration unit (R3) is placed in front of the field stop. By use of the Δ90° method [8] absolute calibration is possible on a regular basis. Various beam splitters are then used to separate all paths for the detection channels seen in Fig. 2.

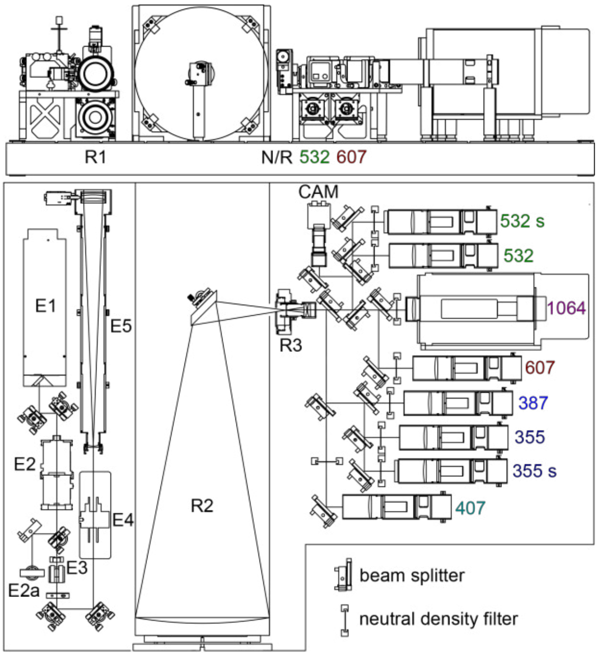

***Figure 2:** The optical setup of Polly-XT NOA. The upper part displays a top view and the lower part the front view of the system.*

For simplicity (e.g., statistical error calculation) and stability (no induced signal noise, no interference with laser discharges …) all detectors operate in photon counting mode. We employ a data acquisition that has been developed by Holger Linné of the Max-Planck Institute, Hamburg, Germany. With this acquisition system we obtain dead-times of approximately 2.3 ns. Furthermore in order to better correct for dead-time effects we measure this effect with a defined ramping light source for each photomultiplier separately in a special laboratory setup and store the correction coefficients in the final data files.

3. THE CYPRUS SITE

The island of Cyprus is a unique spot in the Eastern Mediterranean Sea where different and very complex aerosol mixtures occur [9]. One the one hand, Saharan dust and marine aerosol reach the island quite frequently. One the other hand, Arabian dust mixed with anthropogenic pollution from the Middle East or Europe can be observed, too, as well as clean maritime conditions with Aerosol optical depth <0.05 at 500 nm.

In the framework of a BACCHUS campaign (Impact of Biogenic versus Anthropogenic emissions on Clouds and Climate: towards a Holistic UnderStanding) together with the Raman lidar Polly we installed a SUN/SKY/LUNAR AERONET photometer and a Doppler wind lidar (cf. Fig. 1) at Nicosia (35.14°N, 33.38°E). In this way we obtained an observational area spanning from the very south of Cyprus with the CUT lidar at Limassol to the northernmost area of the Republic of Cyprus also to observe the local island effects.

4. FIRST RESULTS

Figure 3 shows the measurements of the first week of the campaign. Except for a few power breaks during the start of the campaign the lidar and the photometer were operating continuously. During the first days from 4 - 6 March clean, almost maritime, conditions with aerosol optical thicknesses (AOT, 550 nm) of 0.05 - 0.1 and Angström exponents (AE, 380 - 870 nm) of 1.2 – 1.7 prevailed. Local dust (e.g. slightly increased volume depolarization) was detected during the diurnal boundary-layer development up to a height of 0.8 km. At midnight of 7 March a plume of Arabian dust arrived at Nicosia, as indicated by backward trajectories and different by dust models (DREAM8b v2.0, SKIRON). This dust layer extended from 0.8 – 2.8 km height above ground and the AOT increased towards 0.2 – 0.3 while the AE was observed to be around 0.4. At noon of 8 March the Arabian air layer was subsequently replaced by Saharan air and Saharan dust. This Saharan dust was observed to heights up to 5 km with a maximum AOT of 0.38. The AE values were around 0.5 indicating not pure Saharan dust conditions but moreover a mixture with pollution. In the upper part of the Saharan layer we already observed heterogeneous cloud formation in the first week of this BACCHUS campaign. Further and more detailed investigations will be performed after the end of the campaign.

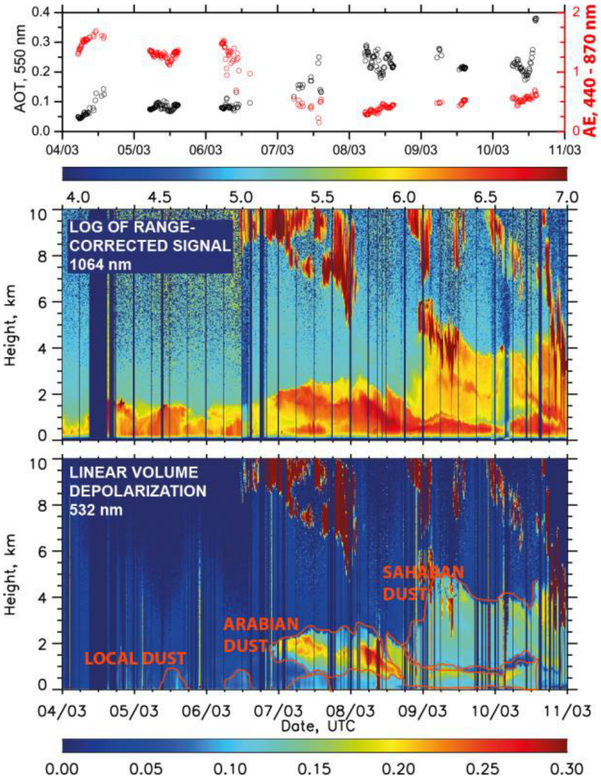

Figure 3: AERONET optical thickness and Angström exponent, Range-corrected lidar signal and volume linear depolarization ratio measured with Polly at Nicosia from 4-10 March 2015.

5. OUTLOOK

At the conference we will present more detailed case studies of profiles of backscatter and extinction, lidar ratio, and particle linear depolarization ratios contrasting Arabian and Saharan dust. We will also compare the profiles with the ones obtained from the Limassol lidar station located much closer to the sea. Additionally in-situ INC observations were performed during the campaign aboard Unmanned Aerial Vehicles (UAV) from the Cyprus institute. Our goal is to show first comparisons between in-situ and lidar derived ice nuclei concentrations.

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