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POLLY^{NET} - AN EMERGING NETWORK OF AUTOMATED RAMAN-POLARIZARION LIDARS FOR CONTINUOUS AEROSOLPROFILING

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ABSTRACT

Polly^{NET} is a network of portable, automated, and continuously measuring Raman-polarization lidars of type Polly operated by several institutes worldwide. The data from permanent and temporary measurement sites are automatically processed in terms of optical aerosol profiles and displayed in near-real time at *polly.tropos.de*. According to current schedules, the network will grow by 3-4 systems during the upcoming 2-3 years and will then comprise 11 permanent stations and 2 mobile platforms.

1 INTRODUCTION

Motivated by the urgent need for robust Raman-polarization lidars that are easy to operate and allow aerosol typing, an automated portable lidar system, called Polly^{XT}, has been developed at the Leibniz Institute for Tropospheric Research (TROPOS) with international partners during the last decade [1, 2]. The aim was to develop a sophisticated automated Raman-polarization lidar for scientific purpose, but with the advantages of an easy-to-use and well-characterized instrument with same design, same automated operation, and same centralized data processing delivering near-real-time data products. By the end of the year 2016, ten Polly systems have been constructed and are employed worldwide. As the number of Polly lidars and measurement sites has increased, an independent, voluntary, international network of cooperating institutes, the so-called Polly^{NET} [3], has evolved as an additional contribution to the worldwide aerosol observational efforts like for example the European Aerosol Research Lidar Network (EARLINET) and the Asian Dust Network (AD-NET). In this contribution, we present the basic idea behind Polly^{NET}, its stations, the automated data analysis efforts and future plans.

2 POLLY LIDAR SYSTEMS

All Polly lidar systems are designed for automatic and unattended operation in 24/7 mode (continuously 24 h a day, 7 days per week). As the capabilities have continuously expanded, all lidars differ slightly from each other. Nevertheless, they feature a similar design, the same data format, and benefit from unified calibration and quality assurance routines. An overview of the different systems including their capabilities and different characteristics can be found in [2]. The latest developed Polly^{XT} (with extended capabilities) is a so-called $3+2+2+1+2+2$ multiwavelengths lidar with near-range capabilities (3 elastic, 2 Raman, 2 depolarization, 1 water-vapor, 2 near-range elastic, and 2 near-range Raman channels). The lidar emits light at 1064, 532, and 355 nm at an energy of 180, 110, 60 mJ per pulse. The primary mirror of the receiver unit has a diameter of 30 cm. The data of all channels is acquired with a vertical resolution of 7.5 m in temporal steps of 30 s (laser repetition rate 20 Hz). Below about 600–800 m above the lidar, the overlap of the laser beam and the receiver field of view is incomplete and needs to be corrected. As a consequence, a second detection unit together with a near-range telescope was added to the system to detect the elastic and inelastic backscatter in the UV and VIS in the lowermost height range above the system. As a result, the determined overlap function of the far-range channels can be verified and backscatter and extinction profiles can be obtained down to about 100 m a.g.l. Further system details are given by [1] and [2].

3 POLLY$^{\text{NET}}$

Until now, the Leibniz Institute for Tropospheric Research (TROPOS), the Finnish Meteorological Institute (FMI), the National Institute of Environmental Research in Korea (NIER), the Évora University in Portugal (CGE), the University of Warsaw in Poland (UW), the German Meteorological Service (DWD) and the National Observatory of Athens in Greece (NOA) contribute actively to Polly$^{\text{NET}}$ by operating Polly systems. Each group contributes with its expertise and knowledge to the network and to joint scientific projects.
Within Polly$^{\text{NET}}$, Polly lidar measurements have been performed at 30 locations in Europe, the Amazon rain forest, Southern Chile, South Africa, India, China, Korea, Tajikistan, Israel and over the Atlantic Ocean. Very different aerosol types and aerosol mixtures have been observed. An overview of findings from these observations is given in [3].
Figure 1 shows the current and planned

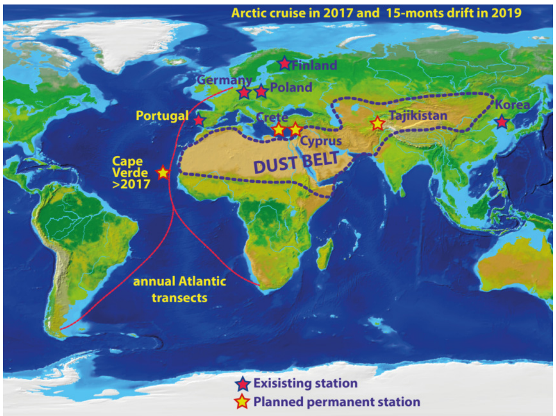

Figure 1: Map of current and planned Polly$^{\text{NET}}$ stations.

measurement sites within Polly$^{\text{NET}}$. Currently, measurements are performed at Kuopio, Finland (FMI); Leipzig, Germany; Limassol, Cyprus; Haifa, Israel (TROPOS); Warsaw, Poland (UW), Hohenpeißenberg, Germany (DWD); Evora, Portugal (CGE); and Banegnyeong Island, Korea (NIER). Most of these stations operate the lidar continuously. Additionally, regular shipborne observations are performed twice a year by TROPOS onboard the German research vessel Polarstern crossing the Atlantic Ocean latitudinal.
Data from the permanent locations as well as from measurement campaigns are centrally collected via internet, processed, and displayed in near-real time at *polly.tropos.de*.
In future, new permanent stations are scheduled for Cape Verde (TROPOS), Finokalia, Crete, Greece (NOA), Cyprus (TROPOS), Tel Aviv, Israel (TAU) and Dushanbe, Tajikistan (TROPOS).

4 AUTOMATED DATA ANALYSIS

Polly systems are designed to operate continuously, i.e., accumulate up to 2880 raw files per day. Naturally, a robust automatic data analysis algorithm is necessary to make use of such an amount of data. Thanks to equal system

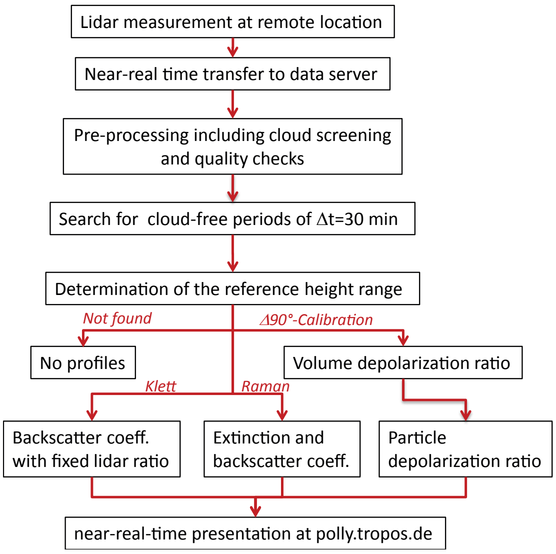

Figure 2: Schematic description of the steps for the automatic data analysis chain.

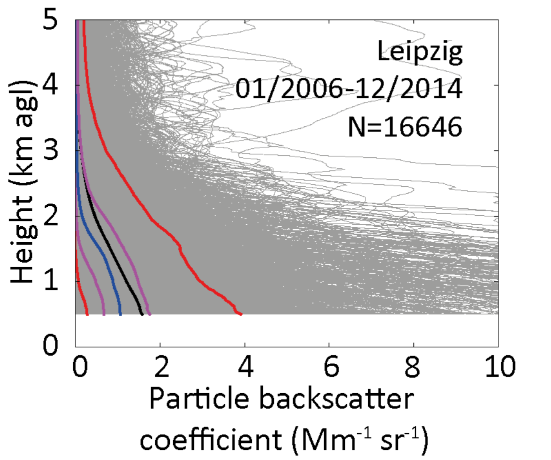

Figure 3: Particle backscatter coefficients profiles at 532 nm at Leipzig from 2006 to 2014. 16646 individual 30-min profiles were used to compute the median (blue), mean (black), 25 and 75 % percentile (purple), and 5 and 95 % percentile (red) profiles.

setup and data format this could be achieved within Polly^{NET}. The complete procedure for the automatic determination of aerosol optical profiles is illustrated in Fig. 2 and in detail described in [3].

After pre-processing including cloud-screening, optical profiles at 355, 532, and 1064 nm are calculated using the well-known retrieval algorithms with the help of an automated Rayleigh fit procedure for reference height finding. The choice between the preferred Raman method and the Klett method is based on the signal-to-noise ratio (SNR) in the channels detecting the Raman scattered light (387 and 607 nm). Then, either profiles of the backscatter and extinction coefficient (Raman method) or the backscatter coefficient only (Klett method) are determined. From the profile of the volume linear depolarization ratio and the backscatter coefficient profile, the particle linear depolarization ratio is calculated. For high quality in the depolarization measurements, the Δ90° calibration [4] is automatically performed three times a day since 2012 [2].

Finally, the vertical aerosol profiles (backscatter, extinction, and depolarization) are stored centrally and displayed at *polly.tropos.de* in near-real time without any manual intervention. For research on aerosols only, a post-processing is applied, e.g., screening for cirrus clouds and discarding contaminated measurements. From those screened profiles, further studies like, e.g., a statistical analysis of the vertical aerosol distribution at the Polly^{NET} stations can be performed. Such an analysis based on the backscatter coefficient profiles at 532 nm is shown for a nine-year data set of Leipzig in Fig. 3. In addition to the 16646 individual 30-min profiles, the mean (black), the median (blue), the 25- and 75 %-percentile (purple), and the 5- and 95 %-percentile (red) profiles are plotted. The median and extreme profiles may be of particular interest, if representative aerosol profiles at specific locations are needed as a priori input for models or data retrieval algorithms.

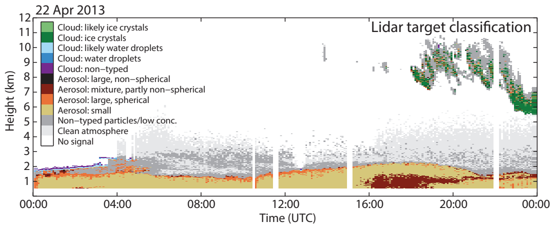

Figure 4: Example of target classification from Polly lidar observations near Jülich, Germany on 22 April 2013.

5 CONCLUSIONS AND OUTLOOK

A powerful global network of automated and continuous measuring Raman-polarization lidar systems has been established with Polly^{NET}. Permanent as well as temporary sites form a network of Polly instruments.

The lidar data collected within Polly^{NET} since 2006 is analyzed with an automated data processing procedure. All analyzed data are shown online at *polly.tropos.de* and are available on demand for further use in agreement with the respective station representatives.

In future, Polly^{NET} will expand. New stations with new systems in Cape Verde, Cyprus, and Tajikistan are planned by TROPOS. NOA plans to install a permanent site in Crete. Also the data processing chain will be further developed and merged with ACTRIS (The European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gases, *www.actris.eu*). E.g., the combination with Cloudnet (continuous measurements with cloud radar, microwave radiometer, and ceilometer, *www.cloud-net.org*) might be a powerful tool to investigate aerosol-cloud-interaction. A high-resolution target categorization based on absolute calibrated lidar signals as exemplary shown in Fig. 4 have been developed for such purposes [5].

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