MEASUREMENT OF THE LINEAR DEPOLARIZATION RATIO OF AGED DUST AT THREE WAVELENGTHS (355, 532 AND 1064 nm) SIMULTANEOUSLY OVER BARBADOS
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ABSTRACT
A ground-based polarization Raman lidar is presented, that is able to measure the depolarization ratio at three wavelengths (355, 532 and 1064 nm) simultaneously. This new feature is implemented for the first time in a Raman lidar. It provides a full dataset of 3 backscatter coefficients, two extinction coefficients and 3 depolarization ratios (3+2+3 lidar system). To ensure the data quality, it has been compared to the well characterized two-wavelength polarization lidar POLIS. Measurements of long-range transported dust have been performed in the framework of the Saharan Aerosol Long-Range Transport and Aerosol-Cloud-Interaction Experiment (SALTRACE) in the Caribbean.

1. INTRODUCTION
Aerosols affect the radiative budget of the Earth. Mineral dust is one major component of the global aerosol load. It demonstrates a high temporally and spatially variability and furthermore the dust may change its properties and size distribution during transport or gets mixed with other species of aerosols. So observation and modelling of the properties and distribution of dust is a challenging task.

Lidar measurements provide vertically resolved profiles of the optical properties of the aerosols, such as the particle backscatter and extinction coefficient and the depolarization ratio. In order to get most detailed information about the dust particles, several wavelengths are used. With this additional spectral information, it will be easier for inversion algorithms to retrieve microphysical properties from the measured optical properties. Especially for dust investigations the aerosol linear depolarization ratio at 1064 nm is of great benefit (Gasteiger and Freudenthaler, 2014).

In order to provide such an extensive data set, the lidar system BERTHA of the TROPOS has been newly set up. Additionally to the backscatter at three wavelengths and the extinction at two wavelengths, the simultaneously measurement of the linear depolarization ratio at three wavelengths is now implemented.

Long-range transported dust has been observed the this improved lidar system in the Saharan Aerosol Long-Range Transport and Aerosol-Cloud-Interaction Experiment (SALTRACE) on Barbados (13°N, 59°W) in 2013 (summer) and in 2014 (winter and summer). The campaigns aim to analyze the properties of long-range transported Saharan dust, taking advantage of the fact, that the dust is transported about 5000 km only over the ocean without pollution or continental influence. In line with the previous campaigns SAMUM-1 (Heintzenberg, 2008) in southern Morocco (2006) and SAMUM-2 (Ansmann et al., 2011) at the Cape Verde (2008), the SALTRACE campaign completes the investigation of the transport way of the dust from the source region in the Sahara to the Caribbean. A measurement example of a dust outbreak will be shown.

2. LIDAR SYSTEM
The multi-wavelength polarization Raman lidar BERTHA (Backscatter Extinction lidar-Ratio Temperature Humidity profiling Apparatus) of the Leibniz Institute of Tropospheric Research (TROPOS) is a container-based mobile lidar system. It has been renewed after the SAMUM campaigns and contains a new receiver unit enabling the measurement of the depolarization at three wavelengths simultaneously. Furthermore a
high spectral resolution channel (HSRL) at 532 nm was added.

A second lidar system POLIS (Portable Lidar System, contribution of V. Freudenthaler at the 27th ILRC) from the Ludwig-Maximilians-University, Munich, was deployed in the same campaign. It is a small portable 6-channel Raman and depolarization lidar system measuring the co- and cross-polarized backscattered light at 355 nm and 532 nm (day- and night-time) and the N2-Raman shifted backscattered light at 387 nm and 607 nm (night-time only).

### 3. MEASUREMENT EXAMPLE

To give an example for the measurements of the depolarization ratio at three wavelengths the dust case of June 30, 2013 will be shown. It is a typical example for a strong dust event over the Western Caribbean. The Saharan dust plume was measured in parallel with the lidar systems BERTHA and POLIS, placed 30 m apart from each other, on Barbados during the SALTRACE campaign.

Figure 2 shows the range-corrected signal for the total and the cross polarized 1064 nm channel measured by the BERTHA system. The aerosol layer reaches up to 4.1 km about ground level. Combining the information of both channels the dust layer can be determined between about 1.8 km and 4.1 km. It is characterized by a relative humidity of around 30%. The layers beneath the dust layer are significantly more humid (around 80%). The relative humidity is obtained by a radiosonde launched at 0000 UTC at the measurement site.
The atmospheric conditions remained almost constant over more than two hours (as it can be seen in Fig. 2). The retrieved profiles are averaged over this measurement period and shown in Fig. 3 for both lidar systems. The particle backscatter at 355 and 532 nm from BERTHA can be compared to the measurements obtained by POLIS and they agree very well. BERTHA measured additionally the particle backscatter at 1064 nm, which reaches in the dust layer only about 70% of the particle backscatter at the other wavelengths. The particle extinction coefficient for BERTHA is determined via the Raman method (Raman channels at 387 and 607 nm), for POLIS via the Fernald/Klett inversion with a fixed lidar ratio within the dust layer.

The measured lidar ratio within the transported dust layer (1.8 to 4.1 km) is approximately 61 sr and 71 sr for the 355 nm and 532 nm, respectively. For the Fernald/Klett algorithm a typical lidar ratio for dust of 55 sr is taken.

The Ångström exponent yields to different values for backscatter and extinction, caused by different influence of the particle size distribution on these quantities. A lesser amount of large particles could be responsible for the lower backscatter at 1064 nm.
Depolarization ratio agrees very well between BERTHA (0.27±0.07) and POLIS (0.27±0.02). For 1064 nm a particle linear depolarization ratio of 0.24±0.1 can be reported.

4. CONCLUSIONS AND OUTLOOK

A method to measure the depolarization at three wavelengths simultaneously has been implemented and a unique data set of long-range transported Saharan dust has been recorded in two periods in summer 2013 and summer 2014 within the SALTRACE campaign. Furthermore pure marine conditions and dust, that had been mixed with biomass burning smoke over Western Africa and transported over the Atlantic Ocean, was measured in winter 2014 at Barbados. Dust-smoke mixtures will be shown at the conference as well.

The information, that can be obtained from the lidar ratio at two wavelengths (355 and 532 nm), the Ångström exponent for extinction and two backscatter ratios as well as the linear depolarization ratio at three wavelengths (355, 532 and 1064 nm), consists of 8 vertically resolved parameters, which may serve as an input for more sophisticated aerosol classification schemes (Burton et al., 2012; Groß et al., 2013) and furthermore for the retrieval of microphysical properties of the aerosol particles. It will be also used to improve the modelling of dust particles (Gasteiger et al., 2011) and the separation of non-dust, fine mode and coarse mode dust (Mamouri and Ansmann, 2014).

The measurement of the depolarization ratio at three wavelengths combined with Raman lidar measurements reveals a deeper look into the aerosol properties by means of remote sensing.

REFERENCES


