Aerosol layers characterization in the Eastern Mediterranean: Long-term lidar observations over Limassol, Cyprus

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Abstract: Long term continuous vertically resolved aerosol measurements were performed by lidar in Limassol, Cyprus. Observations with the multiwavelength polarization Raman lidar PollyXT were conducted during CyCARE (Cyprus Cloud Aerosol and Precipitation EXperiment) from October 2016 to March 2018 as well as permanently since October 2020 at the ERATOSTHENES Centre of Excellence in Limassol, Cyprus. Co-located with the lidar, a sun photometer was also operated. During the 18-month measurement campaign, and the 3 years of continuous measurements, aerosol layers originated by different aerosol sources were detected frequently from ground to the cirrus level height. In this study, an overview of the measurement period is given. A detailed statistical analysis of the defined aerosol layers was performed to give information about sources, frequency, seasonality, and geometrical properties of the aerosol layers advected Cyprus providing for the first time a complete picture of aerosol vertical distribution over Cyprus.

1. Introduction

Atmospheric aerosol is one of the key factors influencing the Earth's radiation budget and multiwavelength lidar systems provide unique opportunity to derive height-resolved particle intensive properties. An identified hot spot regarding climate change and aerosol load is Cyprus. As an island in the Eastern Mediterranean, Cyprus is defined by an intense Mediterranean climate with a typical seasonal rhythm of hot and dry summers, lasting from mid-May to mid-September, and rainy winters from November to March (Department of Meteorology, Republic of Cyprus, 2018). It is affected by several different types of aerosols, making it one of the most polluted areas of the world [1]. Mineral dust originating from the Sahara or Middle- Eastern deserts, marine aerosol, aged anthropogenic particles as well as smoke from the North can all be regularly found in the atmosphere above Cyprus.

2. Instrumentation

A multi-wavelength Raman lidar PollyXT (POrtabLe Lidar sYstem) [2] was operated at Limassol, Cyprus between October 2016 and March 2018 and a PollyXT 3rd generation lidar is operated since October 2020 at the Cyprus Atmospheric Remote Sensing Observatory (CARO) of the Eratosthenes Centre of Excellence at Limassol (34.677˚N, 33.0375˚E).

The Polly^{XT} system is housed in a container, and it is operated 24/7 with a diode-pumped laser that emits the first (1064nm), second (532 nm) and third (355 nm) harmonic frequency of linear polarization light with a pulse repetition rate of 100 Hz. It enables the retrieval of vertically-height resolved profiles of the particle backscatter coefficient β at 355, 532 and 1064 nm, the particle extinction coefficient α at 355 and 532 nm, the corresponding extinction-to-backscatter ratios (lidar ratios, L), and the volume and particle linear depolarization ratios δ at 355 and 532 nm. The system includes a second near-range receiver.

3. Data and Methodology

The climatological analysis of the lidar observations was based on the profiling of the optical properties and the aerosol type in the defined aerosol layers. In order to determine the optical profiles, two nighttime aerosol profiles were retrieved per day using the Raman method [3]. We considered as high-quality aerosol

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layers the ones which were not affected by clouds and exhibited lidar ratios between 10 and 120sr, linear particle depolarization ratio between 0 and 40% and Ångström exponents between -0.5 and 3.

The geometrical boundaries of the aerosol particle layers were retrieved from a less vertically smoothed lidar profile (less than 400m) as opposed to the optical properties which were retrieved by applying higher smoothing. The AERONET observations have been used in addition for the aerosol and atmospheric conditions characterization

The identification of the source of aerosol particles was possible with the synergetic use of in situ and satellite measurements, as well as utilizing model estimations. Four-day backward trajectories (HYSPLIT-4) were calculated for the centre of the layer observed and for the time of the lidar measurement. Each aerosol layer was classified into one of the four main aerosol types, i.e. marine, dust, continental (urban, european) and biomass burning, after thorough visual inspection of the backward trajectories, MODIS hotspot fire products and in situ aerosol observations. Furthermore, a distinguish between different desert sources from Africa (Saharan) and Middle East (Arabian) as well as mixed and polluted aerosol layers have been taken into consideration. All in all, 7 aerosol type categories (and 1 unclassified) have been used for characterization of the aerosol layers.

4. Results

For the present analysis the mean values of all the available optical properties, i.e backscatter (β) and extinction (α) coefficients, lidar ratios (LR), Ångström exponents, and linear particle depolarization ratios (δp) were calculated for each of the layers, along with their geometrical properties (depth and centre mass). Figure 1 summarizes the frequency distribution of the aerosol type identified in the analyzed layers. From the analysis one can conclude that the majority of the lofted observed aerosol layers (more than 70%) over Limassol are influenced by dust particles. The 30% of the dust related cases are referring to the cases of polluted dust or dust mixtures. The mixing of the dust aerosols with maritime or even urban background aerosols cannot be excluded as a possible reason for the variability in the optical properties of the layers such as the lidar ratio and depolarization ratio values. Figure 2 summarizes the mean lidar ratio at 532 nm, presented together with the associated standard deviations, ranges (minimum and maximum values) and medians.

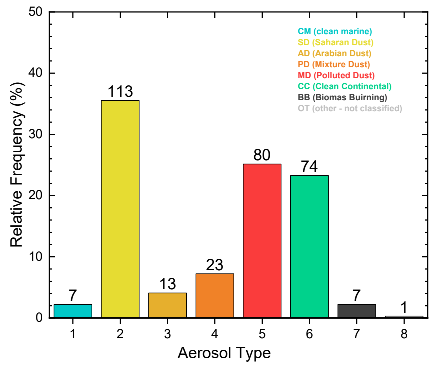

Figure 1. Frequency distribution of aerosol type.

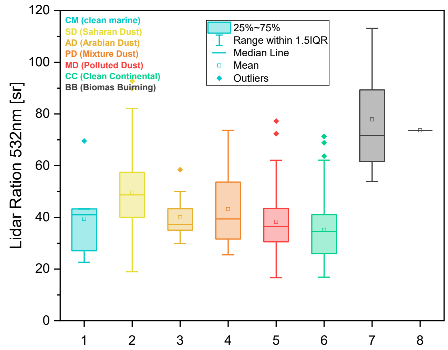

Figure 2: Box and whisker plots of the lidar ratio at 532nm for each of the seven aerosol types.

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5. References

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