

## SAHARAN AND ARABIAN DUST AEROSOLS: A COMPARATIVE CASE STUDY OF LIDAR RATIO

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### ABSTRACT

This work presents a first comparative study of the Lidar Ratio (LR) values obtained for dust particles in two singular dust-influenced regions: the Canary Islands (Spain, close to the African coast in the North Atlantic Ocean), frequently affected by Saharan dust intrusions, and the Kuwait area (Arabian Peninsula) as usually influenced by Arabian dust storms. Synergetic lidar and sun-photometry measurements are carried out in two stations located in these particular regions for that purpose. Several dusty cases were observed during 2014 in both stations and, just for illustration, two specific dusty case studies have been selected and analyzed to be shown in this work. In general, mean LR values of 54 sr and 40 sr were obtained in these studies cases for Saharan and Arabian dust particles, respectively. Indeed, these results are in agreement with other studies performed for dust particles arriving from similar desert areas. In particular, the disparity found in Saharan and Arabian dust LR values can be based on the singular composition of the suspended dust aerosols over each station. These results can be useful for CALIPSO extinction retrievals, where a single LR value (40 sr) is assumed for pure dust particles independently on the dust source region.

### 1. INTRODUCTION

The extinction-to-backscattering coefficient ratio (Lidar Ratio, LR) is an aerosol-type dependent parameter associated to the chemical composition, particle shape and aerosol size distribution. Hence, the LR estimation from lidar measurements is a crucial task in aerosol research, since this parameter can provide valuable information on optical/microphysical properties of aerosols. A special emphasis is devoted to dust, as shown by diverse published works [i.e., 1-11, among others]. Moreover, data from diverse observational platforms and techniques, as space-borne instrumentation (CALIPSO/CALIOP and Aqua/MODIS) as ground-based aerosol networks (EARLINET and AERONET), and analysis from several models (BSC-DREAM, NAAPS, ...) have been used for assessment of the Aerosol Optical Depth (AOD), mainly, regarding the LR value used for dust aerosols. Hence, the single LR value assumed by CALIOP/CALIPSO ([www-calipso.larc.nasa.gov](http://www-calipso.larc.nasa.gov)) for pure dust (40 sr) is under discussion. Instead, a higher value (58 sr) is proposed by EARLINET (European Aerosol Lidar NETwork, [www.earlinet.org](http://www.earlinet.org)) based on multi-year lidar measurements of Saharan dust intrusions over Europe [7, and references herein]. However, lower LR values are reported for Arabian dust by only a few works [i.e., 6; 8]. Currently, lidar measurements carried out in the Arabian Peninsula and surroundings are still scarce.

The aim of this work is to show a first comparative analysis on LR values retrieved for dust particles present over two different dust-influenced regions: the Canary Islands (Spain, close to the African coast in the North Atlantic Ocean), frequently affected by the arrival of Saharan dust intrusions, and the Kuwait area (Arabian Peninsula) as usually influenced by Arabian dust storms. Hence, dust observations were performed in particularly located lidar stations under both Saharan and Arabian dust influence in order to establish a long-term dust aerosol monitoring over these stations in the future. In this first step, two case studies of these dust observations are presented. Results can be useful for retrieving AOD from CALIPSO observations, despite a single LR value (40 sr) is assumed for pure dust particles independently on the dust source region.

## 2. METHODOLOGY

Lidar measurements in synergy with sun-photometry data are performed in two aerosol stations:

- 1) the Izaña observatory (IZO, 28.3°N, 16.5°W, 2400 m a.s.l.), belonging to the Spanish Meteorological Agency (AEMET), is located at the Tenerife Island, in a pristine environment and representative of the Free Troposphere (FT) stations; hence, only pure dust particles are present under Saharan dust intrusion occurrence; and
- 2) the Kuwait station (KW, 29.3°N, 47.9°E, 40 m a.s.l.), belonging to the College of Health Sciences of Kuwait, is located in the Arabian Peninsula and usually influenced by dust storms. Their impact is particularly relevant in the Boundary Layer (BL) since they are transported by surface level northwesterly “Shamal” winds to Kuwait from Syria, Iraq and Jordan areas [12].

Synergetic measurements of both height-resolved lidar and columnar-integrated sun-photometry observations were performed in both areas. LR values are retrieved by using an elastic inversion procedure based on the AOD constraint and

assuming the presence of pure dust particles. Details of this method are reported in [11].

### 2.1. Tenerife instrumentation

Lidar measurements for IZO site were carried out by a Micropulse Lidar v. 3 (MPL-3), within NASA/MPLNET (Micro Pulse Lidar NETWORK, [mplnet.gsfc.nasa.gov](http://mplnet.gsfc.nasa.gov)), located in the AEMET/Santa Cruz de Tenerife observatory (SCO, 40 km far from IZO, at 52 m a.s.l.). The MPL-3 is an elastic lidar, operated by the Instituto Nacional de Técnica Aeroespacial (INTA), with the following main features: highly-pulsed (2500 Hz) and low-energy (10  $\mu$ J, max.) laser at 523 nm, and Cassegrain-type telescope receiving system. It is a small, easy-handle system with coaxial configuration, high autonomy and low attendance, operational in full-time continuous mode (24 h day<sup>-1</sup>/365 days year<sup>-1</sup>). Routine measurements (MPLNET settings) are 75-m vertical resolution and 1-minute integrating time.

IZO is also a NASA/AERONET (AErosol RObotic NETwork, [aeronet.gsfc.nasa.gov](http://aeronet.gsfc.nasa.gov)) site. Retrieved inversion products level 1.5 (Cloud Screened) and 2.0 (Quality-assured) used are the spectrally resolved Aerosol Optical Depth (AOD) and Ångström Exponent (AEx). In particular, the Cimel-318 500-nm channel data are used in correspondence to the closer wavelength to that of the MPL-3 laser (523 nm).

### 2.2. Kuwait instrumentation

A polarized Micropulse Lidar (P-MPL) has been recently installed in the Kuwait station, and routine measurements are performed from November 2013 to date for dust research. This system is similar to that MPL-3 together to polarization capabilities included. The main features are the same as those for the MPL-3 system, but the laser is at 532 nm, and the receiving system is composed by a Matsukov-Cassegrain telescope with two polarization channels. Routine measurements are 30-m vertical resolution and 30-second integrating time.

Sun-photometer data, mainly AOD values, are obtained with a portable sun-photometer (Microtops II).

## 3. RESULTS

Several dusty cases were observed during 2014 in both stations. In particular, one case study for each station was selected: 29 June for IZO site and 09 August for KW station, reporting AOD values of 0.35 and 0.46, respectively (Note that IZO is placed at around 2400 m a.s.l.). LR values were retrieved for these dusty days, and preliminary results were analyzed.

Extinction profiles for Saharan and Arabian dust retrieved, respectively, from IZO MPL-3 and KW P-MPL measurements are shown in Figures 1 and 2, respectively.

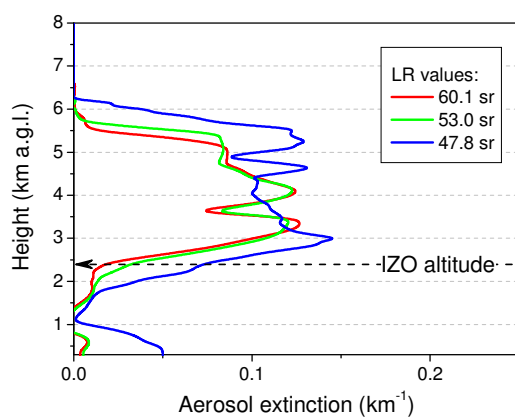


Figure 1. Saharan dust observed at IZO station: Aerosol extinction profiles derived from MPL-3 measurements performed on 29 June 2014 at several times (color lines).

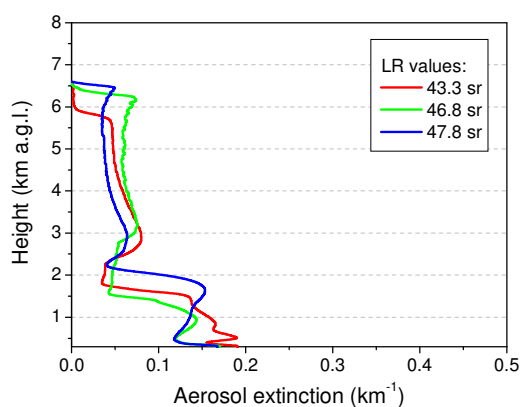


Figure 2. Arabian dust observed at KW station: Aerosol extinction profiles derived from P-MPL measurements performed on 09 August 2014 at several times (color lines).

Mean LR values of  $54 \pm 5$  sr and  $46 \pm 2$  sr are obtained for Saharan and Arabian dust particles, respectively, for these days (see Figs. 1 and 2). These preliminary results are in agreement with other LR values reported for dust in previous works [i.e., 6-8; 11] dependent on the desert dust source region. In addition, that observed disparity can be based on the singular composition of the suspended dust aerosols arriving from different desert areas, as reported in [6]. In that work an inverse relationship was found between LR and real refractive index, based on AERONET LR retrievals; in particular, Saharan dust presented a lower value of the real refractive index than that found for dust from the Arabian Middle East area; correspondingly, they obtained a higher LR (55 sr) for the Saharan dust than for Arabian dust (43 sr) [6]. Similar LR values were also derived by lidar measurements performed in Cyprus region for Arabian dust particles [8]. In general, it should be noted that results obtained in this work are specific for those particular cases analyzed.

#### 4. CONCLUSIONS

A novel comparative analysis has been performed between LR values retrieved from MPL measurements carried out in two different dust-influenced stations: SCO and KW sites, as affected, respectively, by Saharan and Arabian dust intrusions.

In this first study, one dusty case was selected for each station. Their derived LR values are in agreement with those obtained in other regions affected by both Saharan and Arabian dust arrivals, highlighting this way the diversity found in LR for dust particles arriving from different dust source regions. In particular, the LR assumed by CALIPSO for pure dust (40 sr) could be a correct value for dust over regions as Arabian Peninsula and surroundings. In addition, results can be relevant, indeed, for extinction retrievals from observations performed by future spaceborne elastic lidar instrumentation, as that aboard next ESA Sentinel and EarthCARE satellites.

Finally, a more extended dataset is to be analyzed in order to establish a long-term dust aerosol monitoring over these stations in the future.

Hence, similarities and differences might be plausibly obtained in LR retrievals for dust by using a larger dataset for each station.

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