19th International Conference on Environmental Science and Technology

Kos, Greece, 3 to 6 September 2025

Optical and microphysical properties of Saharan and Saudi Arabian desert based on AERONET data products

GIANNAKAKI E.*, KOUTOUNIDIS I.

Department of Environmental Physics and Meteorology, Faculty of Physics, University of Athens, 15784 Athens, Greece

*corresponding author: Giannakaki Elina
e-mail: elina@phys.uoa.gr

Abstract The study investigates possible differences between the Saharan and Saudi Arabian deserts' dust particles based on AERONET network. Our results shows that while particle depolarization ratio values at 440 nm were similar for both regions, the Saudi Arabian lidar ratio (at 440 nm) was determined to be 53 ± 7 sr, much lower than the Saharan lidar ratio at the same wavelength that was found equal to 66 ± 10 sr. Our findings are in consistent with earlier studies based on AERONET products but they do not agree with lidar observations. We found significantly larger lidar ratios at 440 nm both for Arabian dust (difference of 15 sr) and Saharan dust (difference of 13 sr) compared to lidar observations. These differences are smaller for 532 nm. Reliable conversion factors between aerosol optical thickness and column-integrated particle size distribution based on AERONET photometer observations are also for Saharan and Saudi Arabian dust particles.

Keywords: AERONET, dust, Saharan, Saudi Arabian

1. Introduction

Atmospheric particles play a crucial role in global climate variability through both direct and indirect mechanisms. They influence the Earth's radiation balance by scattering and absorbing sunlight and by affecting cloud formation and atmospheric processes, thereby introducing uncertainties in weather and climate projections. Among these particles, mineral dust represents one of the most significant aerosol types, contributing approximately one-third of the global aerosol burden and aerosol optical depth (AOD). In addition to its climatic impact, mineral dust affects atmospheric chemistry, air quality, human health, and visibility.

Mineral dust exhibits substantial variability in its size distribution, optical properties, and microphysical characteristics. These features are critical in determining its environmental and climatic effects, and therefore must be studied on a regional basis rather than relying on global averages. Northern Africa is the dominant source of mineral dust worldwide, and previous studies have noted compositional differences between dust originating from various deserts within this region (Shin et al., 2018). Accordingly, this study focuses on a detailed regional comparison between mineral dust from the Sahara Desert and the Arabian Peninsula.

Aerosol classification can be performed using parameters derived from remote sensing techniques. Active remote sensing, particularly lidar, enables the classification of mineral dust through two key parameters: the extinction-to-backscatter ratio (lidar ratio) and the particle linear depolarization ratio. These are obtained from polarization-sensitive Raman or high spectral resolution lidar systems. The lidar ratio provides information on aerosol size and absorption properties, while the depolarization ratio indicates particle shape, with higher values typically associated with more non-spherical particles.

2. Methodology

2.1. Theoretical background

The retrieved aerosol products used in this study are available from the AERONET database (last accessed: April 2025; https://aeronet.gsfc.nasa.gov/). For each observation, the elements $F_{11,\lambda}(r, n)$ and $F_{22,\lambda}(r, n)$ of the Müller scattering matrix (Bohren and Huffman, 1983) are calculated using the particle size distribution and complex refractive index $n=n_r+i\cdot n_i$, both retrieved from the AERONET inversion product (Dubovik et al., 2006). The lidar ratio can be derived from the element $F_{11,\lambda}(r,n)$ evaluated at the scattering angle of 180° and the concurrently retrieved single-scattering albedo ω_λ, as follows:

$$S_\lambda^p = \frac{4\pi}{\omega_\lambda F_{11},\lambda(r,n,180^0)}$$

The particle linear depolarization ratio is calculated by the elements $F_{11,\lambda}$ (r, n) and $F_{22,\lambda}$ (r, n) at a scattering angle of 180° as:

$$\delta_\lambda^p = \frac{1-\frac{F_{22,\lambda}(r,n,180^0)}{F_{11,\lambda}(r,n,180^0)}}{1+\frac{F_{22,\lambda}(r,n,180^0)}{F_{11,\lambda}(r,n,180^0)}}$$

2.2. Data selection

The AERONET sites used for this study are located in the Saharan and Saudi Arabian deserts. In order to achieve the most accurate results, the sites were selected depending on their location and time availability. Six stations are representative for the Arabian desert and ten for the Saharan desert. To ensure that the resulting values are an accurate representation of pure dust conditions (i.e., undiluted dust plumes), the AERONET inversion products have been filtered. In this study we set as thresholds an Aerosol Optical Depth greater than or equal to 0.4 at 440 nm and a 440/870 nm Ångström exponent value less than 0.2 to retain high accuracy and minimize interference of non-dust aerosols despite the fact that fine mode dust might also be eliminated.

3. Results

Our findings are consistent with previous studies utilizing AERONET data, such as Shin et al. (2018). Specifically, we observed differences in lidar ratio values of only 1 to 3 sr compared to those reported in S18, and the spectral dependence observed in our results aligns well with earlier analyses. Regarding the particle linear depolarization ratio, we found slightly higher values—by approximately 2%—for Arabian dust, whereas values for Saharan dust remained nearly identical to those previously reported.

These results support the hypothesis that, even when evaluated under less stringent constraints, Arabian dust exhibits a lower depolarization ratio in AERONET products, suggesting a tendency toward more spherical particle shapes. Conversely, Saharan dust shows higher lidar ratio values, indicative of greater light absorption.

However, discrepancies arise when comparing AERONET-derived lidar ratio and depolarization ratio values with those obtained from lidar-based measurements (Floutsi et al., 2023). Notably, we observed significantly higher lidar ratios at 440 nm in AERONET data for both Arabian dust (a difference of 15 sr) and Saharan dust (13 sr) relative to lidar observations. These differences were less pronounced at 532 nm. At both 440 nm and 532 nm, the deviation between AERONET and lidar-based measurements was approximately 5% for Arabian dust and even lower—around 2%—for Saharan dust.

At present, the source of these discrepancies between sun photometer (AERONET) and lidar-derived products, particularly regarding lidar ratio values, remains unclear and warrants further investigation.

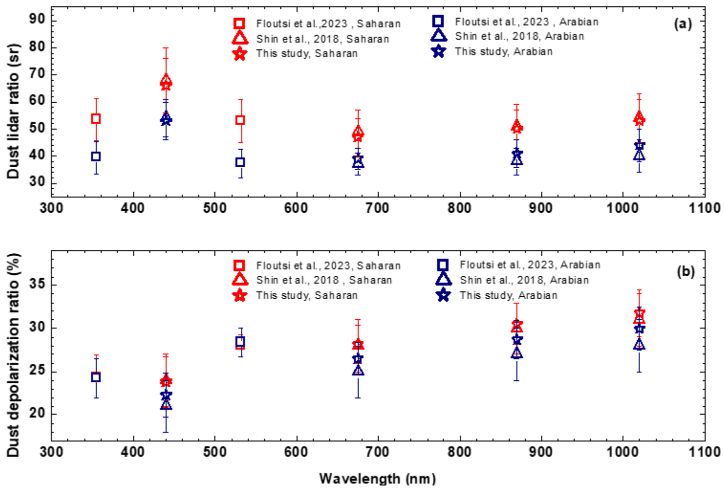

Figure 1. Lidar ratio (a) and depolarization ratio (b) for this study (asterisk) compared to an earlier lidar study (Floutsi et al., 2023; square) at 355 and 532 nm and sunphotometer AERONET study (Shin et al, 2018; triangle) both at Saharan (red) and Arabian (blue) region.

Acknowledgements

The research work was supported by the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the "Basic Research Financing (Horizontal support for all Sciences), National Recovery and Resilience Plan (Greece 2.0)" (Project Acronym: SCOPE, Project Number: 015144)

References

Bohren, C. and Huffman, D. (1983), Absorbing and scattering of light by small particles, *Wiley, Weinheim*.

Dubovik, O., Sinyuk, A., Lapyonok, T., Holben, B. N., Mishchenko, M., Yang, P., Eck, T. F., Volten, H., Muñoz, O., and Veihelmann, B. (2006). Application of spheroid models to account for aerosol particle nonsphericity in remote sensing of desert dust, *Journal of Geophysical Research*., **111**, D11208.

Floutsi, A. A., Baars, H., Engelmann, R., *et al.*. (2023) DeLiAn – a growing collection of depolarization ratio, lidar ratio and Ångström exponent for different aerosol types and mixtures from ground-based lidar observations, Atmospheric Measurements Techiques, **16**, 2353–2379..

Shin S., Tesche M., Kim K., Kezoudi M., Tatarov B., Müller D. and Noh Y (2018), On the spectral depolarisation and lidar ratio of mineral dust provided in the AERONET version 3 inversion product, *Atmospheric Chemistry and Physics*, **18**, 12735–12746.