

Introduction

The coastal city, Limassol, located in Cyprus (34.7°N, 33°E) is strongly influenced by the aerosol transport from neighboring regions. Saharan and Arabian desert dust, marine aerosols, fresh smoke from nearby areas and aged smoke from distant regions are the common aerosols observed over the area. Studying aerosol particles is crucial due to their impact on air quality, cloud formation, radiative forcing, health and climate.

In this study 3 cases of different atmospheric conditions are used to characterize **dust**, **smoke** and **marine** aerosol layers in Limassol by retrieving optical and microphysical properties. The Generalized Retrieval of Atmosphere and Surface Properties (GRASP) algorithm (Dubovik *et al* (2014, 2022)) is used for the retrieval of particles' size distribution, complex refractive index, AOD and the aerosol vertical distribution. The synergy of Lidar and radiometer enables the characterization of fine and coarse mode aerosols.

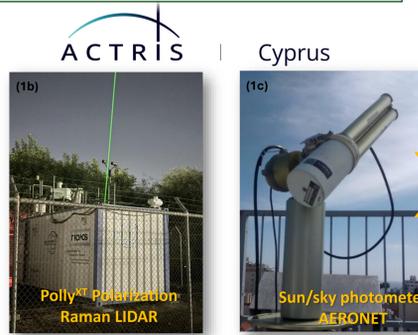


Figure 1: (a) Map of Cyprus and Cyprus Atmospheric Remote Sensing Observatory location (ARO-LIM ACTRIOS National Facility). It is often influenced by different type aerosol transportation from distant and neighboring regions. (b) Polly^{XT} Polarization Raman Lidar of ERATOSTHENES Centre of Excellence and (c) CUT-TEPAK AERONET sun/sky photometer of Cyprus University of Technology in Cyprus.

Methodology & Data

Aerosol observations from the Polly^{XT} Polarization Raman Lidar of the Cyprus Atmospheric Remote Sensing Observatory National facility (CARO NF) of ERATOSTHENES Centre of Excellence provide the vertical aerosol characteristics to the algorithm, while the CUT-TEPAK AERONET (Aerosol Robotic NETwork) sun/sky photometer provides columnar information and constraints on the quantity and type of aerosol.

Dust-dominated, **Smoke-dominated**, and **Marine-dominated** cases were analyzed and compared with measurements from the instruments.

INPUT

- Polly^{XT} Raman Lidar**
 - (a) Elastic backscatter signals at 355, 532, 1064 nm,
 - (b) Volume Depolarization Ratio at 355, 532 nm.
- Sun Photometer**
 - (a) Total optical depths
 - (b) Total scatter radiances at 340, 380, 440, 500, 675, 870, 1020 & 1064 nm.

GRASP

OUTPUT

- Aerosol properties (Fine & Coarse modes):**
 - (a) Columnar properties: Size distribution, complex refractive index, single scattering albedo,
 - (b) Backscatter and extinction profiles.

Figure 2: Input and output of the GRASP algorithm.

Results

DUST Case 20 May 2024

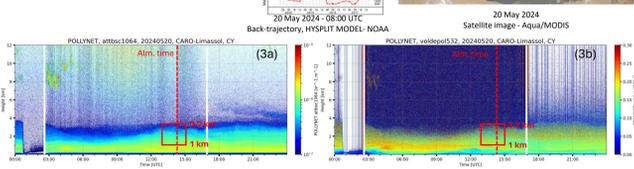


Figure 3: PollyXT lidar (a) Attenuated backscatter at 1064 nm (b) Volume linear depolarization ratio at 532 nm over Limassol, Cyprus, on 20 May 2024. Red boards indicate the region of the studied aerosol layer.

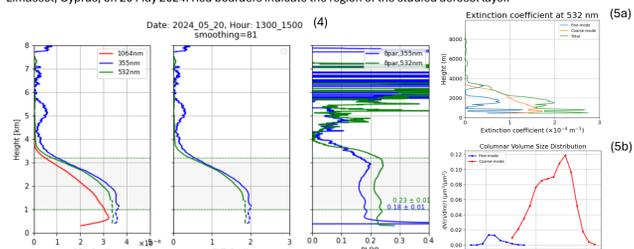


Figure 4: Vertical profiles of the backscatter coefficient, extinction coefficient, particle depolarization ratio measured in Limassol, Cyprus on 20 May 2024 from 13:00-15:00 UTC.

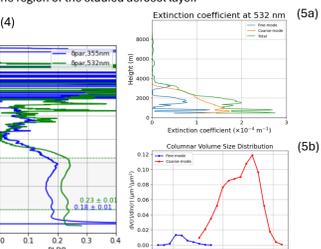


Figure 5: (a) Vertical profile of the extinction coefficient at 532 nm, (b) Columnar Volume Size distribution of fine and coarse mode particles at the altimetric time 14:13:34, retrieved using GRASP algorithm.

SMOKE Case 13 July 2023

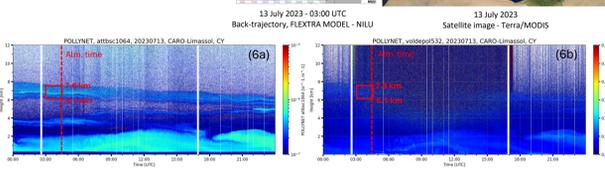


Figure 6: PollyXT lidar (a) Attenuated backscatter at 1064 nm (b) Volume linear depolarization ratio at 532 nm over Limassol, Cyprus, on 13 July 2023. Red boards indicate the region of the studied aerosol layer.

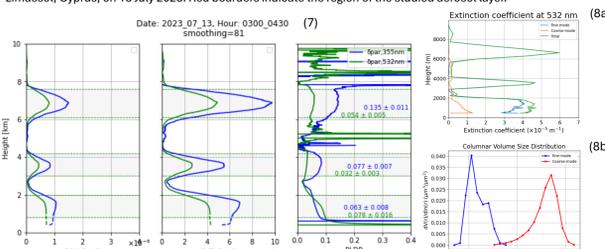


Figure 7: Vertical profiles of the backscatter coefficient, extinction coefficient, particle depolarization ratio measured in Limassol, Cyprus on 13 July 2023 from 03:00-04:30 UTC.

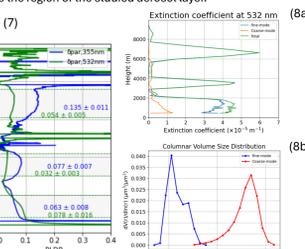


Figure 8: (a) Vertical profile of the extinction coefficient at 532 nm, (b) Columnar Volume Size distribution of fine and coarse mode particles at the altimetric time 04:31:34, retrieved using GRASP algorithm.

MARINE Case 3 February 2023

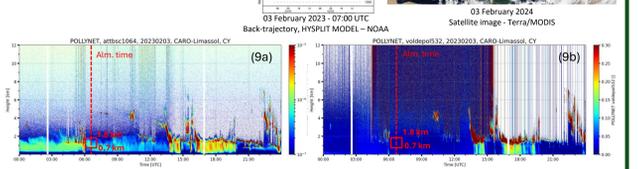


Figure 9: PollyXT lidar (a) Attenuated backscatter at 1064 nm (b) Volume linear depolarization ratio at 532 nm over Limassol, Cyprus, on 3 February 2023. Red boards indicate the region of the studied aerosol layer.

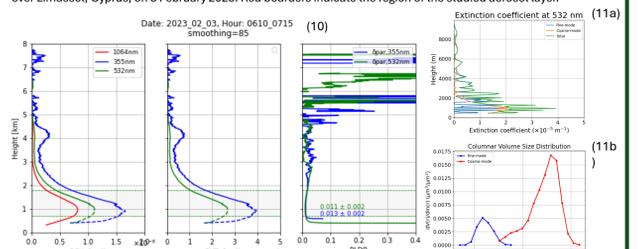


Figure 10: Vertical profiles of the backscatter coefficient, extinction coefficient, particle depolarization ratio measured in Limassol, Cyprus on 03 February 2023 from 06:10-07:15 UTC.

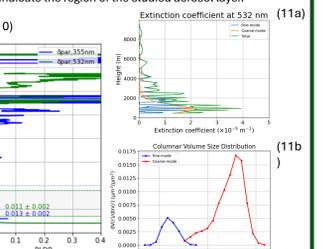


Figure 11: (a) Vertical profile of the extinction coefficient at 532 nm, (b) Columnar Volume Size distribution of fine and coarse mode particles at the altimetric time 06:41:36, retrieved using GRASP algorithm.

Layer information

Case	Time (UTC)	Almucantar time	Layer height (km)	Geo info		Optic info				Micro info		
				$\delta_{355 \text{ nm}}$ [%] (LIDAR)	$\delta_{532 \text{ nm}}$ [%] (LIDAR)	$S_{355 \text{ nm}}$ (sr)*	$S_{532 \text{ nm}}$ (sr)*	AOD _{532 nm} (LIDAR)	AOD _{532 nm} (GRASP)	SSA _F 440 nm (GRASP)	SSA _C 440 nm (GRASP)	SSA 440 nm (GRASP)
DUST	13:00 - 15:00	14:13:34	1 - 3.2	18 ± 1	23 ± 1	55	55	0.314	0.273	0.703	0.984	0.894
SMOKE	03:00 - 04:30	04:31:34	6.1 - 7.6	13.5 ± 1.1	5.4 ± 0.5	65	60	0.052	0.029	0.823	0.972	0.824
MARINE	06:10 - 07:15	06:40:36	0.7 - 1.8	1.3 ± 0.2	1.1 ± 0.2	24	24	0.0237	0.022	0.998	0.974	0.984

Columnar information

Case	Almucantar time	Height	Geo info		Optic info				Micro info		
			AOD _{440 nm} (GRASP)	AOD _{440 nm} (AERONET)	$\eta_{R,F440nm}$ (GRASP)	$\eta_{I,F440nm}$ (GRASP)	$\eta_{R,C440nm}$ (GRASP)	$\eta_{I,C440nm}$ (GRASP)	Reff _F (μm) (GRASP)	Reff _C (μm) (GRASP)	SSA _{440 nm} (GRASP)
DUST	14:13:34	Columnar	0.448	0.446 ± 0.014	1.52	0.08	1.45	0.0001	0.105	1.176	0.88
SMOKE	04:31:34	Columnar	0.238	0.234 ± 0.004	1.44	0.028	1.41	0.00002	0.092	2.362	0.83
MARINE	06:40:36	Columnar	0.059	0.061 ± 0.006	1.47	0.0001	1.54	0.0005	0.119	1.614	0.99

* Best estimation for of the Lidar ratio used in Klett Analysis. The selection based on the closed Raman analysis.

** δ : Particle linear depolarization ratio; S (sr): Lidar ratio; AOD: Aerosol optical depth; AE: Angstrom Exponent; η_R : Real part of the refractive index; η_I : Imaginary part of the refractive index; Reff: Effective radius; SSA: Single Scattering Albedo; F: Fine-mode aerosols; C: Coarse-mode aerosols.

Conclusions

Dust, **Smoke**, and **Marine** dominated cases were analyzed and characterized, utilizing Polly^{XT} Raman Lidar, sun-photometer and GRASP algorithm retrievals.

- The properties of size, sphericity, absorption and quantity of the cases for the three aerosol types are given within selected layers as well as in the atmospheric column.
- Additional information from GRASP algorithm
 - Marine layer showed high SSA values (≈ 1) indicating their strong scattering property. Dust case is mostly scattering, and Smoke layer is mainly absorbing.
 - The columnar $\eta_{I,C}$ indicated non-absorbing particles for all the three studied cases.
 - The columnar $\eta_{I,F}$ indicated strongly absorbing for Dust, absorbing for Smoke and non-absorbing for Marine cases. This is consistent with the SSA for coarse particles.
 - The vertical profile of extinction coefficients for the fine and coarse mode particles revealed distinct particle mode dominance by aerosol type, characterizing the studied layers as follows: Dust - Coarse mode, Smoke - Fine mode and Marine - Coarse mode. This highlights the importance on accurate layer aerosol classification.