Desert dust microphysical properties utilizing GRASP algorithm from synergy of PollyXT Lidar & sun/sky photometer in Limassol, Cyprus

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Terra/MODIS Satellite image, 03/04/2026

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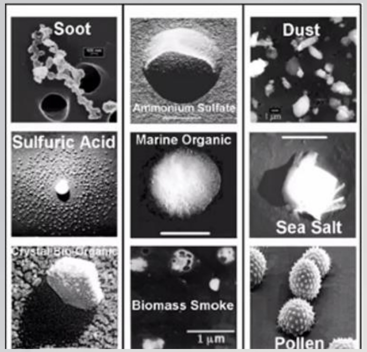
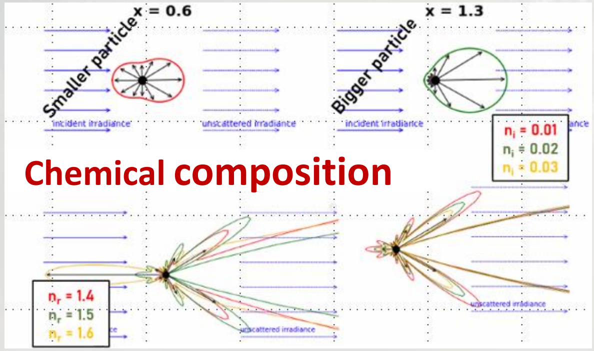
Introduction & Objectives

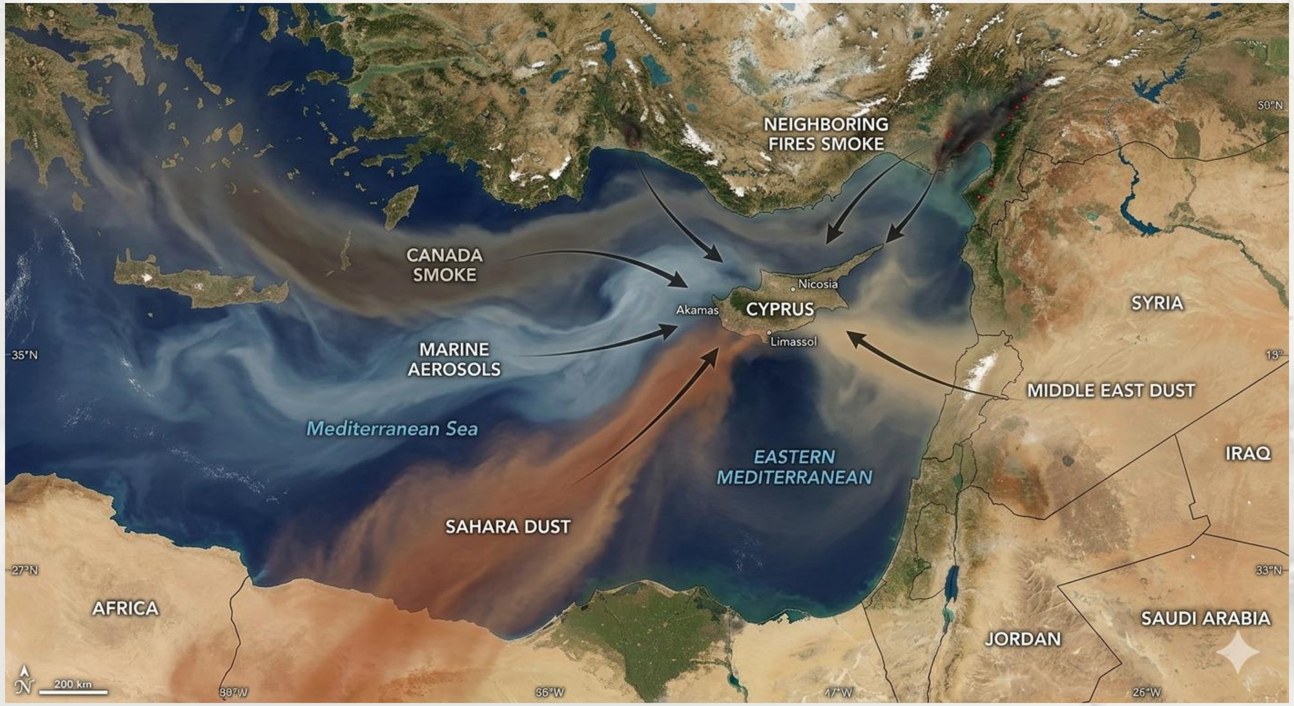
- **Context: <u>Cyprus</u>** is frequently impacted by mineral dust from the ***Sahara and Arabian*** Peninsula due to synoptic-scale meteorological systems.
- **Objective:** To derive vertical and column-integrated ***optical and microphysical*** parameters of desert dust layers over Limassol using the ***GRASP inversion*** algorithm

Shape



Size





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Synergy - Instrumentation

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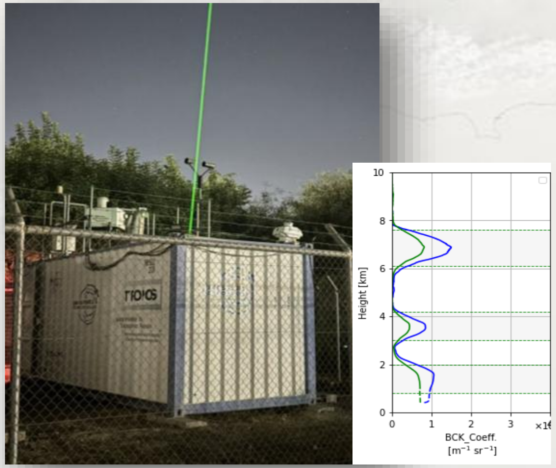
CARO by ERATOSTHENES Centre of Excellence

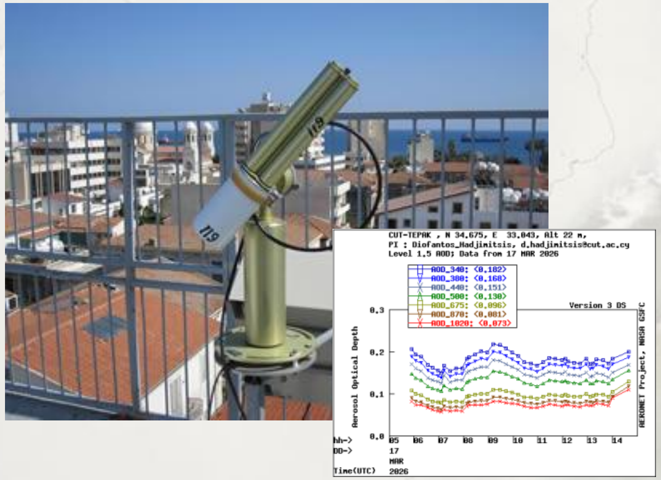
ACTRIS | Cyprus

- **Station:** Cyprus Atmospheric Remote Sensing Observatory **(CARO),** an ACTRIS National Facility.
- **Instruments:**
  - **PollyXT Lidar:** Provide vertical profiles of Backscatter at 355, 532, 1064 nm and Volume depolarization ratios at 355 and 532 nm.
  - **Cimel Sun-Photometer** (AERONET): Provides columnar optical and microphysical properties.

CARO: Cyprus Atmospheric Remote Sensing Observatory



Polly XT Raman LIDAR depolarization system



Sun/sky photometer

CUT-TEPAK site

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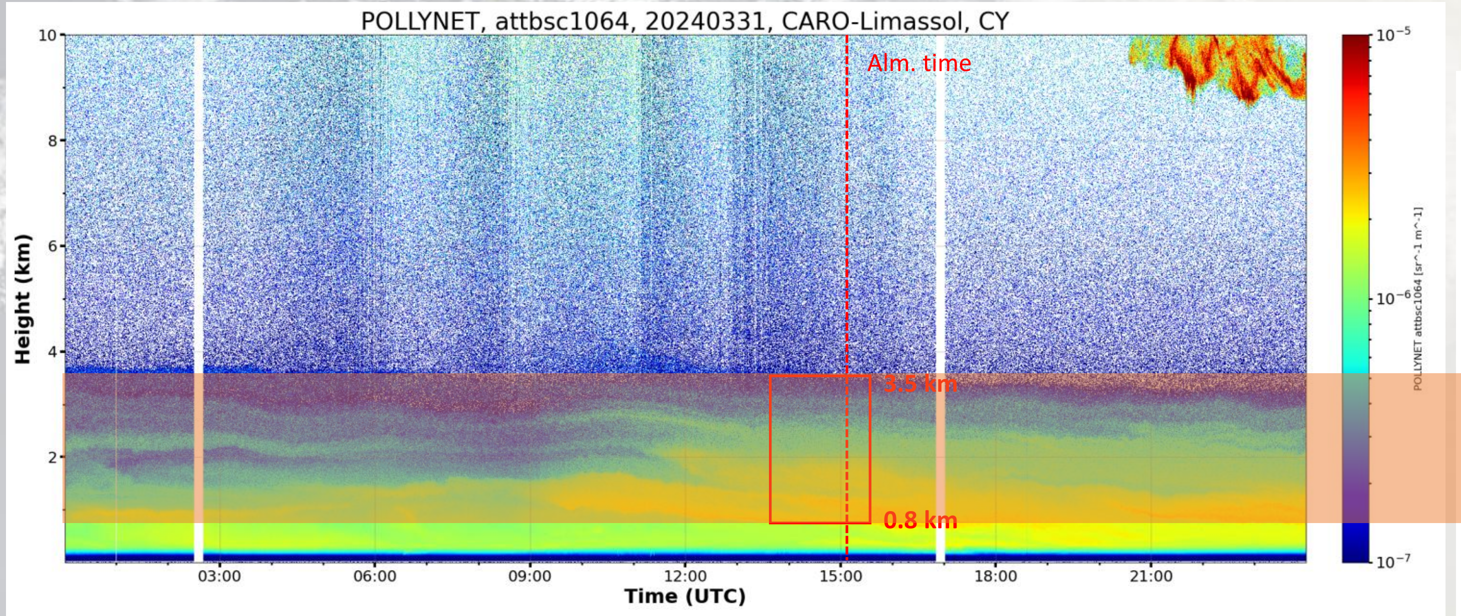
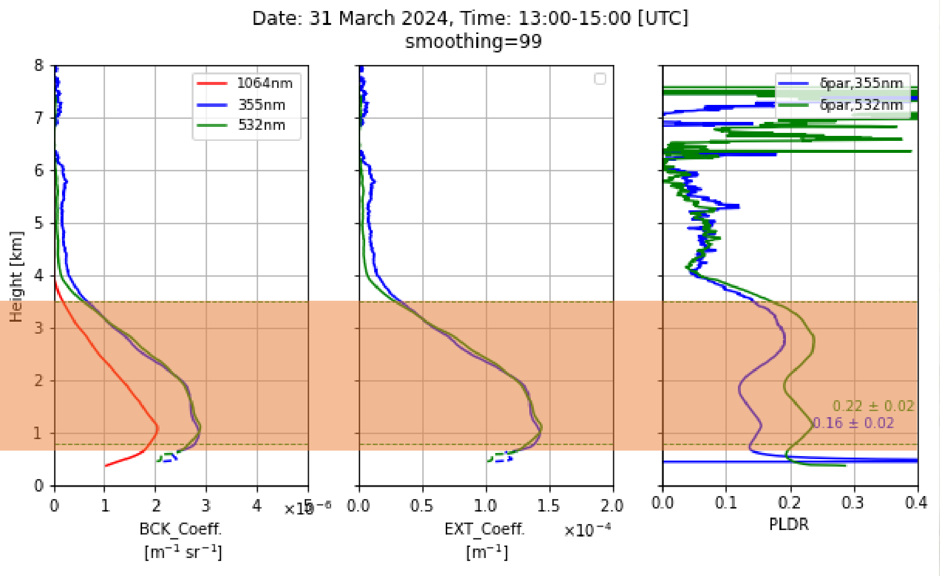
The new information

Retrieval of aerosol microphysical properties within aerosol layers

EXCELSIOR

Example case: Arabian dust Case, 31 March 2024





Load

Shape

What about the Microphysical properties of the aerosols in the layers?

LIDAR

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Methodology

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GRASP algorithm: Generalized Retrieval of Aerosol and Surface Properties.

GRASP

- **GRASP is a numerical inversion algorithm** that follows a statistically optimized **multi-term least squared method (LSM)** and **atmospheric radiation modelling.**
- **The GRASP Advantage:** Combines active and passive remote sensing to characterize fine and coarse mode aerosols.
- Synergistic use of **Lidar & sun-photometer.**
- **Analysis Modes:** Fine (F), Coarse non-spherical (CNS), and Coarse spherical (CS).

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 **(F, CNS, CS)**):

(a) Columnar properties

Size distribution, complex refractive index, single scattering albedo

(b) Vertical properties

Aerosol optical depth, single scattering albedo - (fine, coarse)

(c) Backscatter and extinction profiles.

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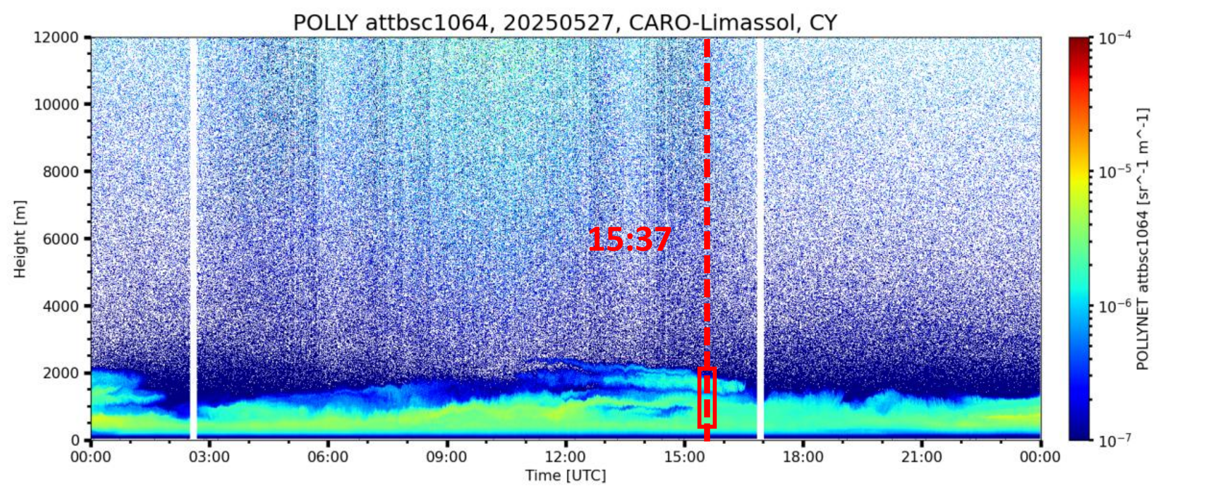
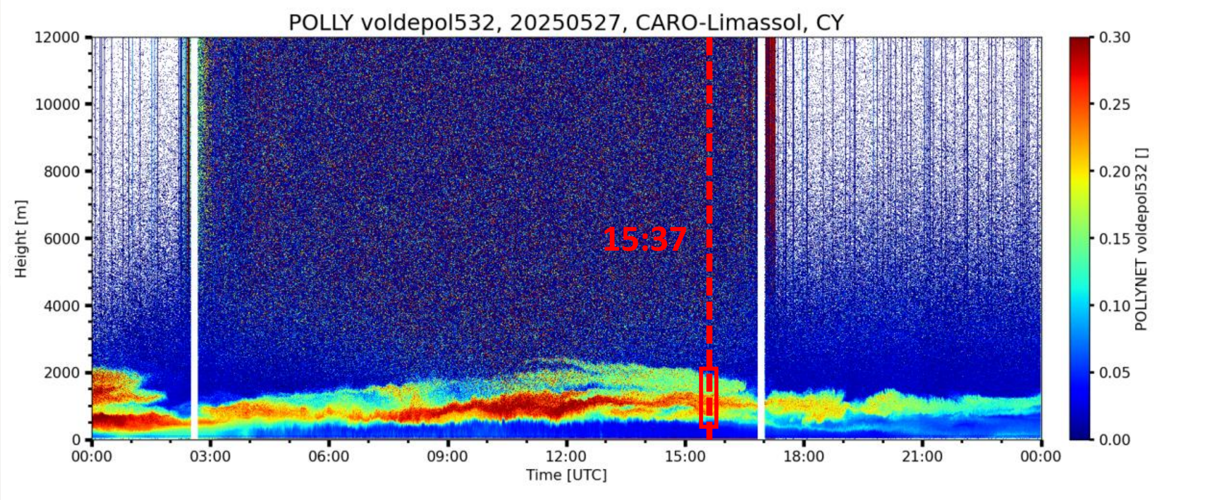
Case Study 1 – Saharan Dust (May 27, 2025)

- **Event Profile:** Air mass originating from the **Sahara desert in Africa**, confirmed by HYSPLIT back-trajectory at 1500m.
- **Layer Analysis:** Detailed analysis of the layer between **450 m and 2014 m**.





Klett analysis of **lidar signal** ±30 m **(15:00-16:00)**
GRASP analysis at almucantar time **15:37**

PDR layer (355 nm) %	PDR layer (532 nm) %
19.3 ± 1.9	**23.1** ± 2.3

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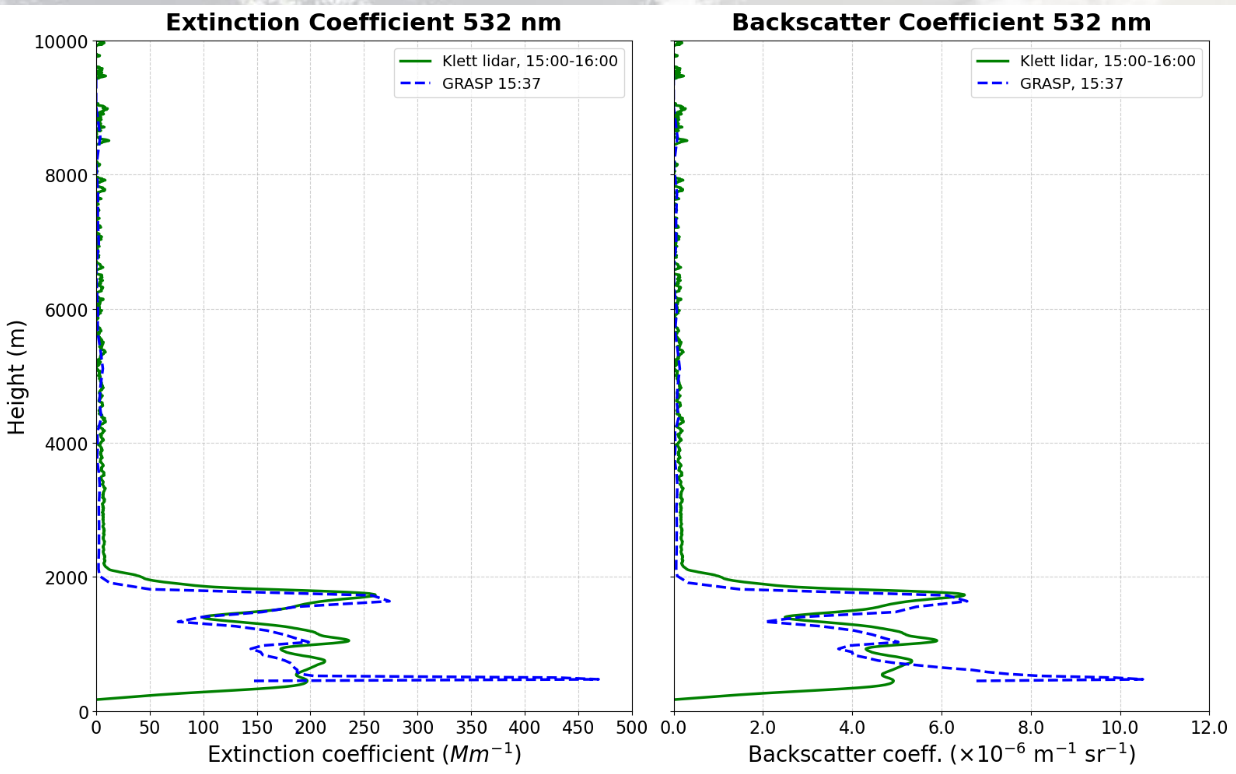
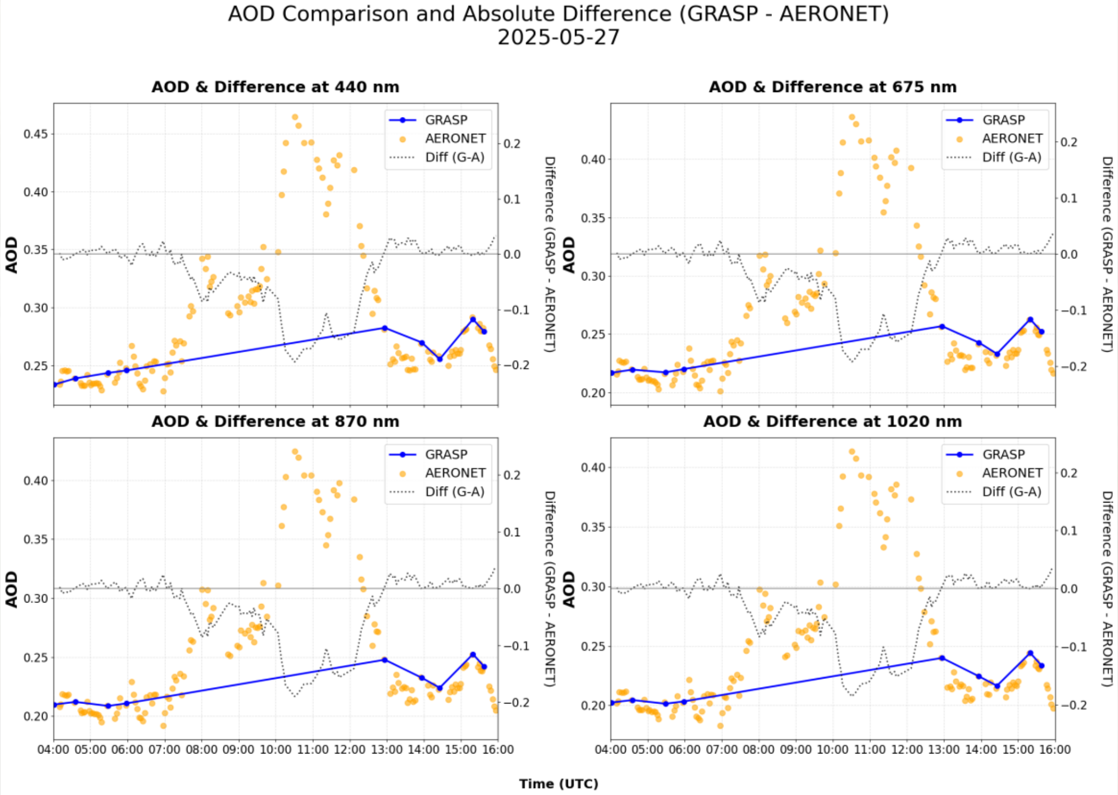
Validation GRASP – Lidar/Sun-photometer

Profile of Extinction coefficient & Aerosol optical depth

Validation: "Very good convergence" between Lidar (9 smoothing)/Sun-photometer measurements and GRASP simulations (Ext, Bsc & AOD).

Klett analysis of lidar signal ±30 m (15:00-16:00)
GRASP analysis at almucantar time 15:37





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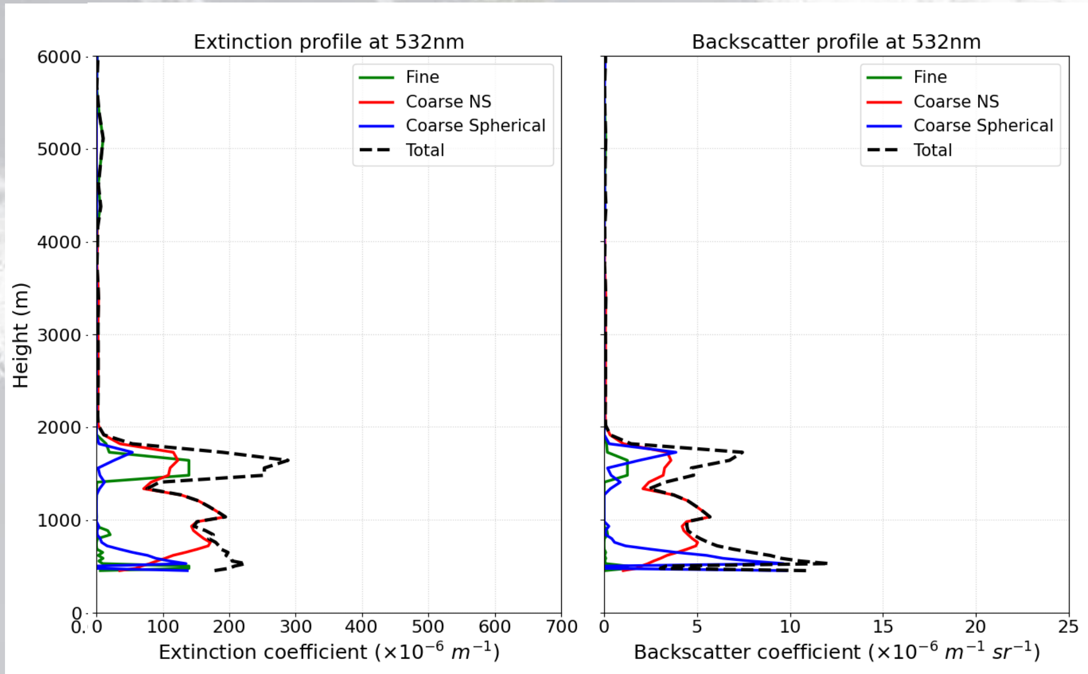
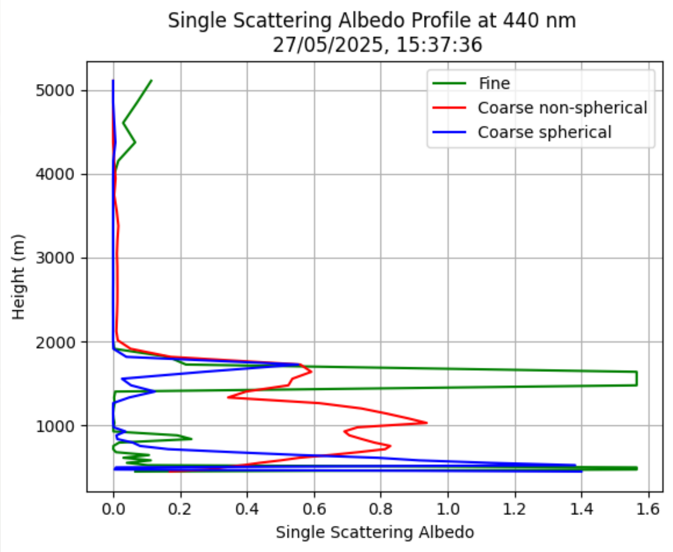
Case Study 1 – Saharan Dust (May 27, 2025)



MODE	**AOD** (440 nm)	**AAOD** (440 nm)	**SSA** (440 nm)
Fine	0.0607	0.0181	0.703
Coarse non-spherical	0.1472	0.0046	0.969
Coarse spherical	0.0078	0.0000	1.000
Total	**0.2157**	**0.0226**	**0.895**

Highly scattering

Optical Properties (at 440 nm) of the **layer (450 - 2014 m):**
Total **AOD: 0.216**.
Total **AAOD: 0.023**.
Single Scattering Albedo **(SSA): 0.895**→ typical for SH dust.



$$SSA(\lambda) = \frac{AOD_{scattering}}{AOD_{total}} = \frac{AOD(\lambda) - AAOD(\lambda)}{AOD(\lambda)}$$

Dubovik et al. (2002)

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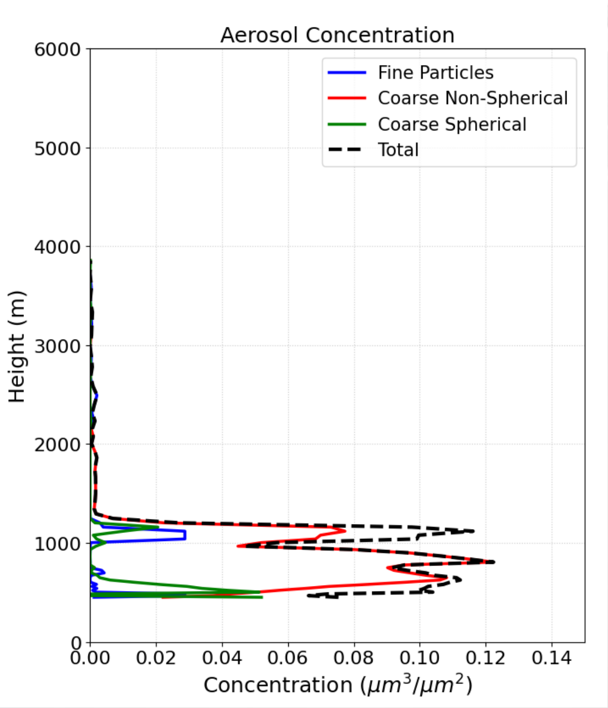
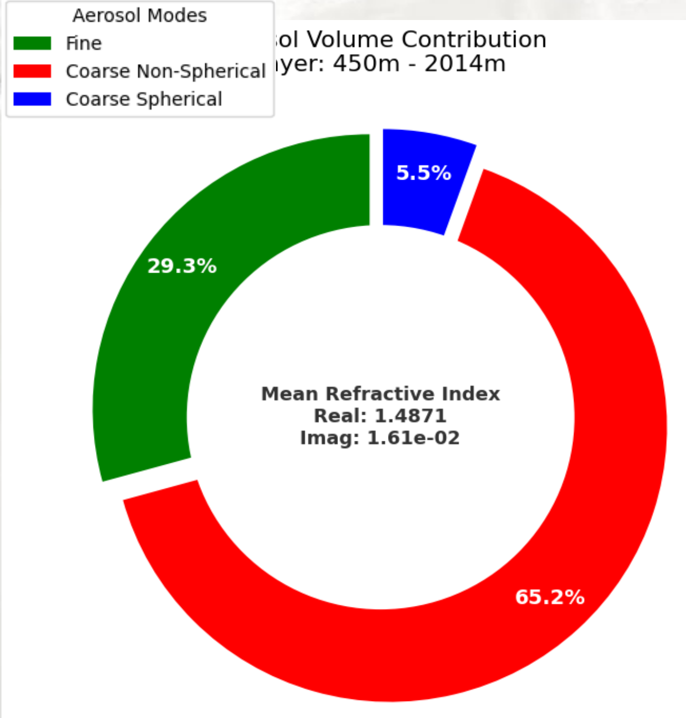
Case Study 1 – Saharan Dust (May 27, 2025)

Aerosol concentration: Coarse Non-Spherical **0.10 μm³/μm²**.
Layer Composition: Dominantly **Coarse Non-Spherical (65.2%)**, with 29.3% Fine mode and 5.5% Coarse spherical.





$$Modal\ Volume\ contribution_{mode} = \frac{Vol_{mode}}{Vol_{fine} + Vol_{cns} + Vol_{cs}}$$

Dubovik & King (2000)

MODE	Layer composition
Fine (columnar)	29.3%
Coarse non-spherical (columnar)	**65,2%**
Coarse spherical (columnar)	5.5%
Total	**100%**

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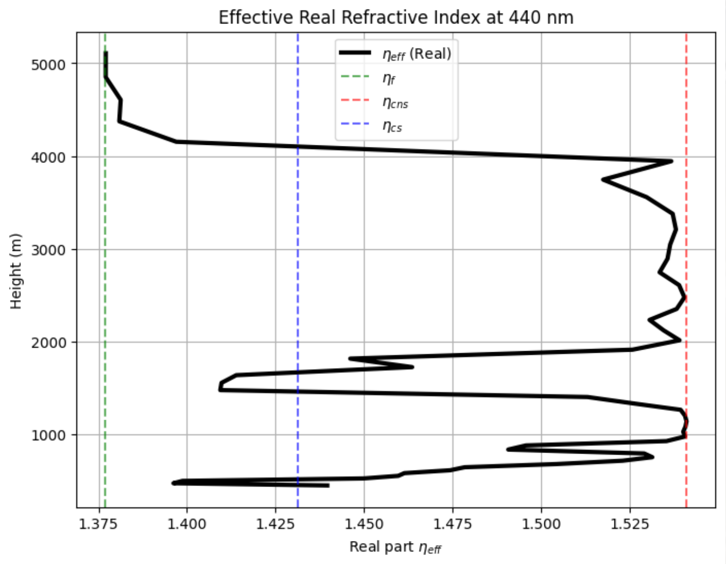
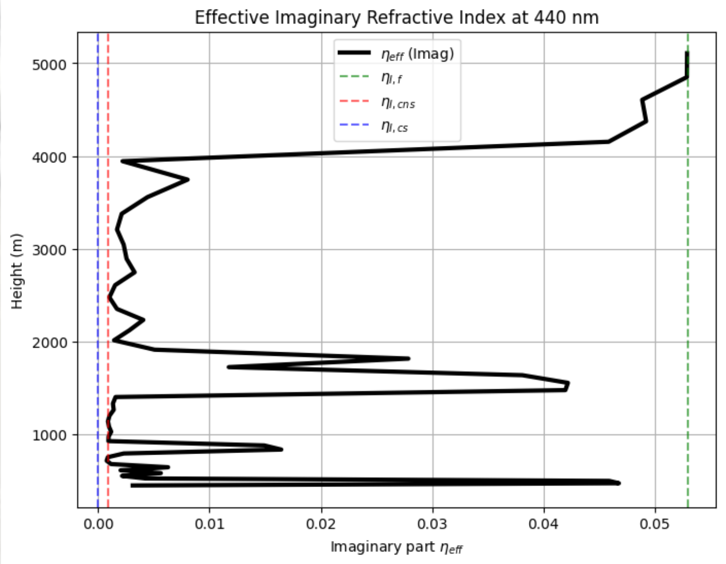
Case Study 1 – Saharan Dust (May 27, 2025)

Refractive Index (Total): 1.487 + 0.016i., **(Coarse Non-Spherical):** 1.54 +0.001i





$$\eta_{eff}(z) = \frac{\eta_f * V_f(z) + \eta_{cns} * V_{cns}(z) + \eta_{cs} * V_{cs}(z)}{V_{tot}}$$

Hess et al. (1998)

MODE	Real part Refractive index (440 nm)	Imaginary part Refractive index (440nm)
Fine (columnar)	1.37	0.053
Coarse non-spherical (columnar)	1.54	0.001
Coarse spherical (columnar)	1.482	0.000
Total	**1.4871**	**0.0161**

CNS –
High scattering
Low absorption

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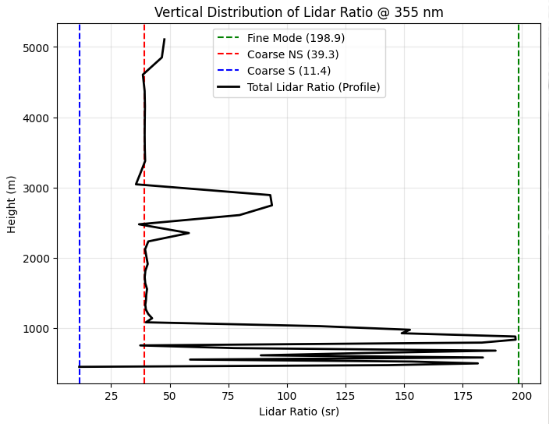
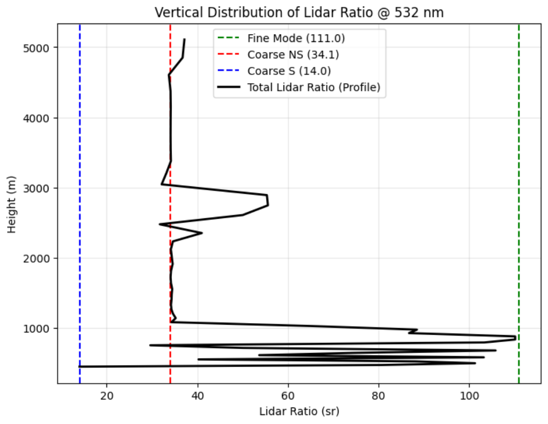
Case Study 1 – Saharan Dust (May 27, 2025)

Lidar Ratios (Coarse Non-Spherical): 40.54 sr at 355 nm and **34.29 sr at 532 nm.**
Volume Size distribution: Peak VSD (Coarse Non-Spherical): 0.076 μm³/μm² at 1.70 μm radius.

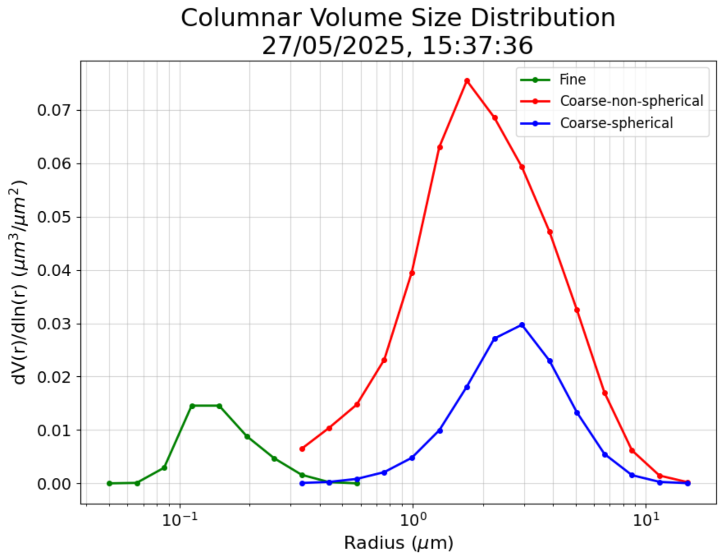




MODE	**LR** (355 nm), sr	**LR** (532 nm), sr
Fine (columnar)	190.08	106.17
Coarse non-spherical (columnar)	40.54	34.29
Coarse spherical (columnar)	13.79	14.14
Total (layer)	**90.14**	**54.40**

$$S_{total}(z) = \frac{a_f(z) + a_{cns}(z) + a_{cs}(z)}{\beta_f(z) + \beta_{cns}(z) + \beta_{cs}(z)}$$

Ansmann, A., & Müller, D. (2005)



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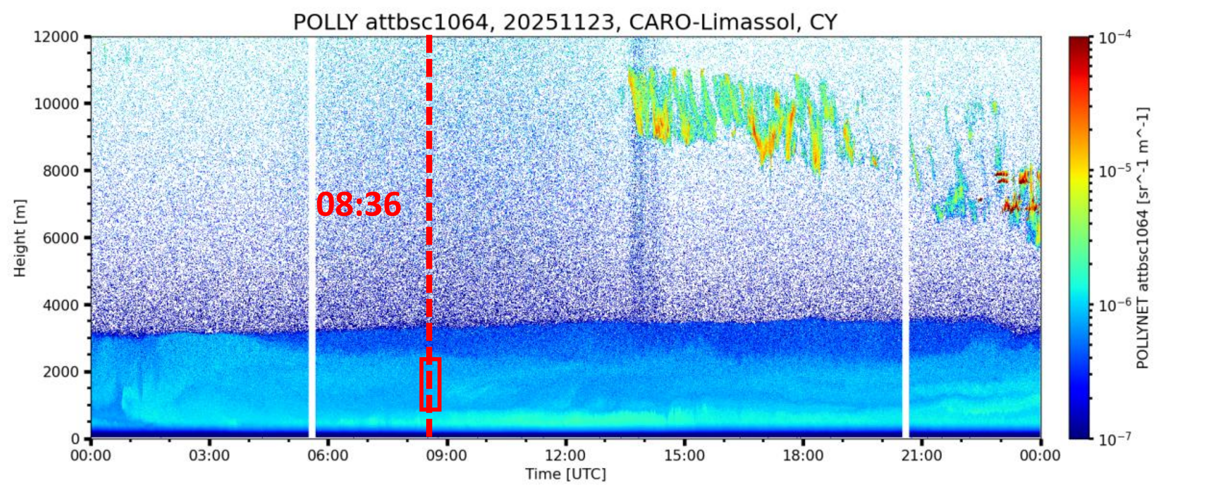
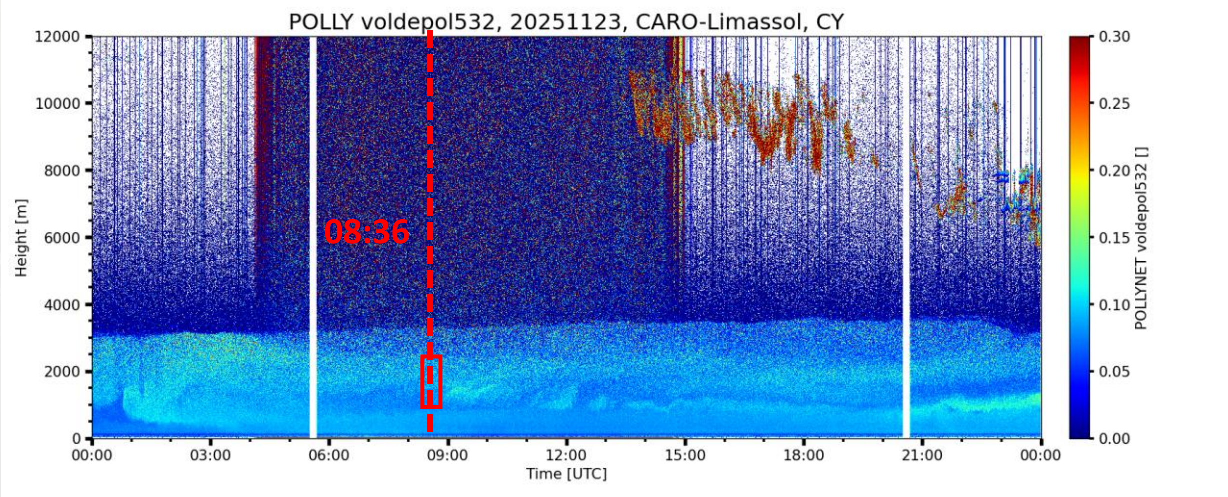
Case Study 2 – Middle East/Arabian Dust (Nov 23, 2025)

- **Event Profile:** Air mass originating from the **Middle East desert**, confirmed by HYSPLIT back-trajectory at 1000 and 2000 m.
- **Layer Analysis:** Focused on the layer from 450 m to 2352 m.





Klett analysis of **lidar signal** ±30 m **(08:00-09:00)**
GRASP analysis at almucantar time **08:36**

PDR layer (355 nm) %	PDR layer (532 nm) %
16.6 ± 1.7	**20.3** ± 2

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Comparative Microphysical Analysis

Parameter	Saharan Case (May 27)	Middle East Case (Nov 23)
AOD 440 nm (Total) L	**0.2157**	**0.2434** (slightly denser)
SSA 440 nm (Absorption) L	**0.895** (slightly more scattering)	**0.867**
Refractive Index (Real) 440 nm C	**1.4871**	**1.5395** (similar optical density)
Refractive Index (Imag) 440 nm C	**0.0161i** (significant absorption)	**0.0005i** (very low absorption)
Lidar ratio (sr) 532 nm L	**54.40** (typical for SHD)	**44.42** (typical for MED)
CNS % (Coarse Non-Spherical) L	**65.2%**	**87.9%** (Highly dominant)
Particle Depolarization ratio 532 nm (L)	**23.1** ± 2.3	**20.3** ± 2

L: layer
C: Column

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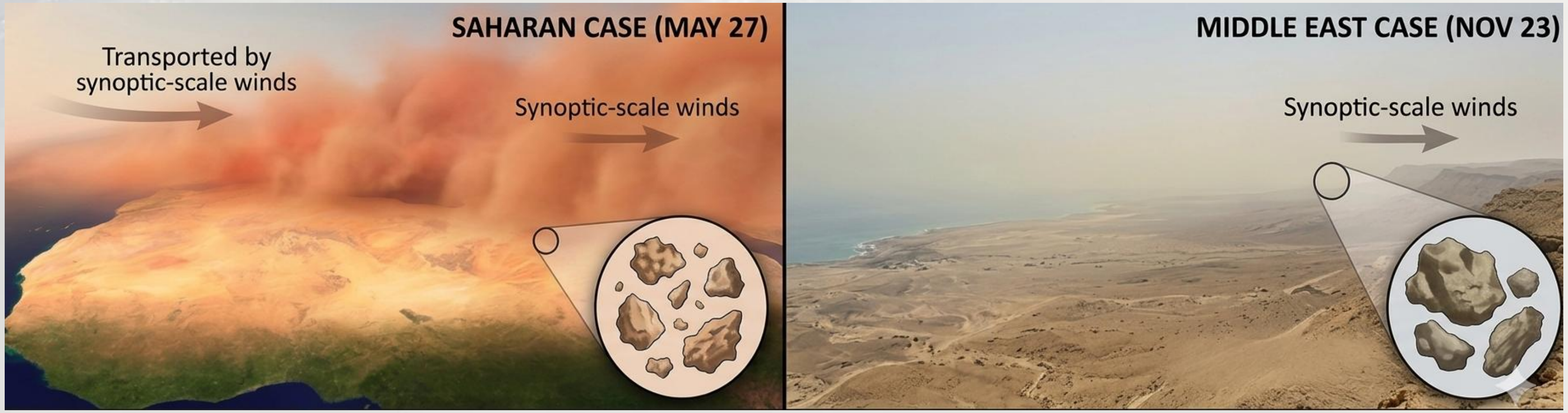
Conclusion

- **Source Differentiation:** Clear **differences** in **composition** (65.2% vs 87.9% CNS) and **refractive index** between Saharan and Middle Eastern dust.

- **Saharan dust exhibited slightly higher scattering properties (SSA = 0.895) compared to Middle Eastern dust (SSA= .867)**

- **The higher imaginary part of the refractive index for the Saharan dust case (0.016i vs. 0.0005i) suggests a different mineralogical composition.**



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Thank you!

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