# Study of Aerosol Cloud Interaction in the Eastern Mediterranean: Long-term lidar Observations over Cyprus

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## Introduction

Cyprus, situated in the eastern Mediterranean, offers an exceptional natural laboratory for investigating aerosol–cloud interactions and cloud microphysical processes, owing to its frequent encounters with both natural aerosol events (e.g., desert dust intrusions, marine aerosols) and anthropogenic pollution layers (urban haze, biomass burning plumes). The Cyprus Atmospheric Remote Sensing Observatory (CARO), operated by the ERATOSTHENES Centre of Excellence, has conducted continuous multi-year observations using advanced remote sensing instrumentation to monitor air quality, dust transport, and cloud properties over the region.

Building on this, the novel **Dual-Field-of-View (DFOV) Polarization Lidar technique** exploits measurements of lidar backscatter signals at two different receiver fields of view to infer *key liquid-water cloud microphysical properties* such as the:
- Light-extinction coefficient of the cloud ($\alpha$),
- Droplet Effective Radius ($R_e$),
- Liquid Water Content (LWC), and
- Droplet Number Concentration ($N_d$)

by leveraging the differing contributions of multiple scatterings in each FOV channel.

By taking advantage of the DFOV capabilities of the Polly[XT] Raman lidar system, CARO offers coherent means to extend aerosol–cloud interaction studies by providing vertically resolved, continuous profiles of cloud microphysical parameters in conjunction with the average aerosol concentration below the cloud base.

## Methodology
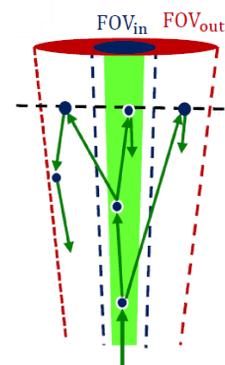
The PollyXT Raman Lidar is a multi-wavelength lidar system that operates at **355**, **532** and **1064** nm, capable of measuring the **Raman-shifted molecular signals** at **387**, **407**, **607** nm.

The Dual-Field-of-View technique was implemented on the PollyXT lidar at CARO to retrieve cloud microphysical properties near the cloud base. This approach makes use of lidar return signals at 532 nm from both the total and cross-polarized channels, recorded through two receiver fields of view (FOVs):

- **Narrow FOV (1 mrad):** captures primarily single-scattering signals
- **Wide FOV (2 mrad):** includes more multiple-scattering contributions

By analyzing the differences between these FOVs in both polarization channels, and by calculating the DFOV ratio up until 100 m above the cloud base, the degree of multiple scattering can be assessed and microphysical cloud parameters can be extracted as follows:

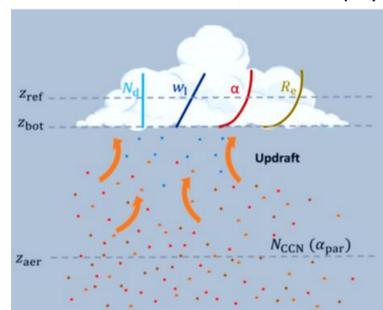$$\overline{\delta}_{rat} = \frac{\delta_{in}}{\delta_{out}}$$

$$R_e(z_{ref}) = R_0 + R_1 \times \overline{\delta}_{rat} + R_2 \times \overline{\delta}_{rat}^2 + R_3 \times \overline{\delta}_{rat}^3$$

$$\alpha(z_{ref}) = \alpha_0(R_e, z_{bot}) + \alpha_1(R_e, z_{bot}) \times \overline{\delta}_{in} + \alpha_2(R_e, z_{bot}) \times \overline{\delta}_{in}^2$$

$$w_l(z_{ref}) = \frac{2}{3} \rho_w \alpha R_e$$

$$N_d(z_{ref}) = \frac{1}{2\pi k} \alpha R_e^{-2}$$

$R_0, R_1, R_2, R_3$: Polynomial coefficients
$\alpha_0, \alpha_1, \alpha_2$: coefficients derived from polynomial regression analysis
$\rho_w$: density of water
k: droplet shape factor

*Images adopted from Jimenez, C. et al. (2020), ACP

→ By using Quasi Backscatter Coefficient products ($\beta_{par}^{quasi}$) and the Polarization Lidar Photometer Networking (POLIPHON) method, the average Particle Extinction Coefficient **($\alpha_{par}$)** as well as the average Cloud Condensation Nuclei Concentration **($N_{CCN}$)** between 600 to 375 meters below the cloud base can be estimated, resulting in detailed aerosol-cloud interaction studies.

## Results

**MARINE CASE**
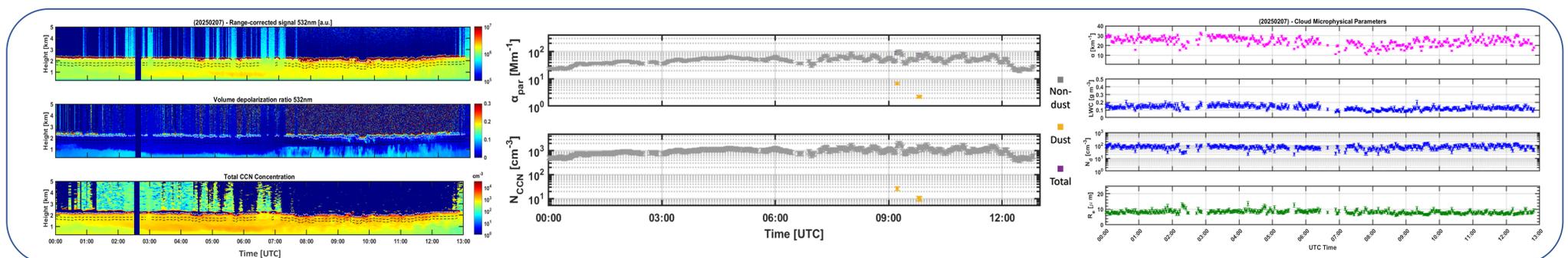


**SAHARAN DUST CASE**
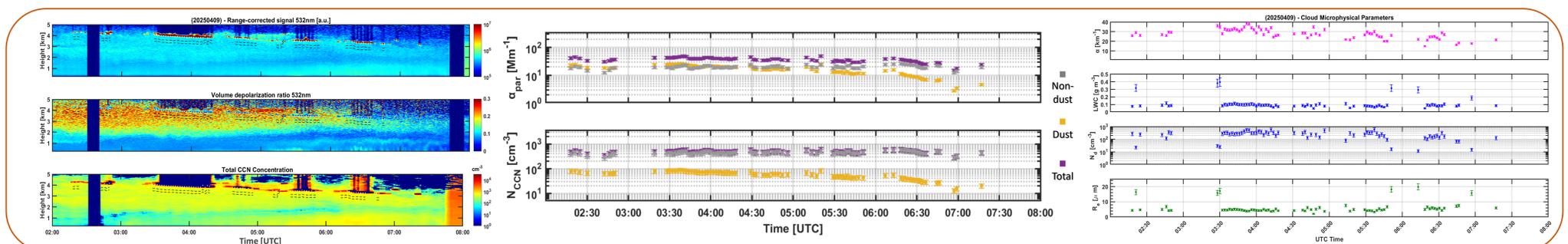


## Conclusions

→ In the **marine case**, as can be seen non-dust particles are detected with extinction values between 10 to 100 Mm[-1], and concentration values close to 1000 cm^{-3}, in contrast to the second case where **Saharan dust** is present and dust extinction coefficient is mostly above 10 Mm[-1] and dust concentration is close to 100 cm^{-3}.

→ Both cases recorded similar light-extinction coefficient inside the cloud (a little higher values even in the dust case).

→ The Liquid Water Content (LWC), as well as the Effective Radius ($R_e$) of the droplets are found to be higher in the marine case than in the dust one.

→ The Droplet Number Concentration ($N_d$) is found to be lower in marine cases in contrast to dust cases where droplet concentration is higher.

→ **Next steps:** the information of the **vertical wind** needs to be implemented to better examine how the **updrafts** or **downdrafts** and especially the uplifting of **different CCN types** affect cloud formation and their evolution processes.

| Cloud Microphysical Parameter | Marine Case | Dust case |
|---|---|---|
| $\alpha$ [km[-1]] | 20 – 30 | 20 – 40 |
| LWC [g/m^{3}] | 0.1 – 0.2 | < 0.1 |
| $N_d$ [cm[-3]] | ~ 100 | >> 100 |
| $R_e$ [μm] | ~ 10 | ~ 5 |