Eleventh International Conference on Remote Sensing and Geoinformation of Environment / 17-19 March 2025 / Paphos

HETEAC-Flex Model: Comparative Evaluation of 6 Forward model configurations for Dust Cases using Ground-based Lidar Observations in Limassol

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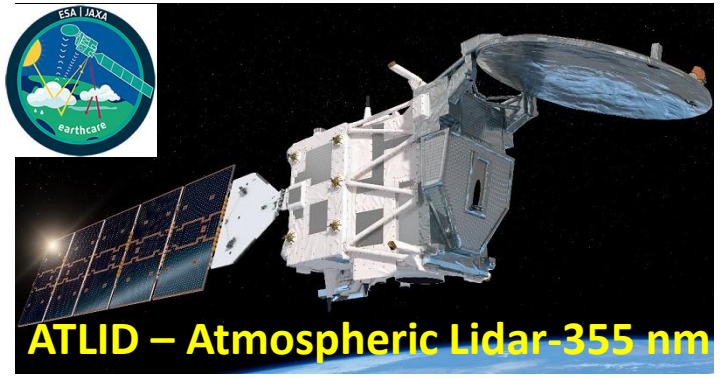
a. Eratosthenes Centre of Excellence / b. Cyprus University of Technology / Leibniz Institute for Tropospheric Research

Athina Savva, PhD student / Assistant researcher A'

Satellite image of Limassol, Sentinel -2 Copernicus EU

Introduction

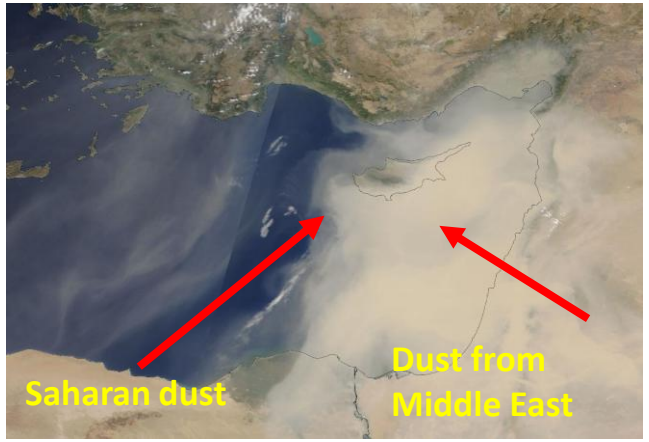
EarthCARE Satellite



HETEAC - Flex model

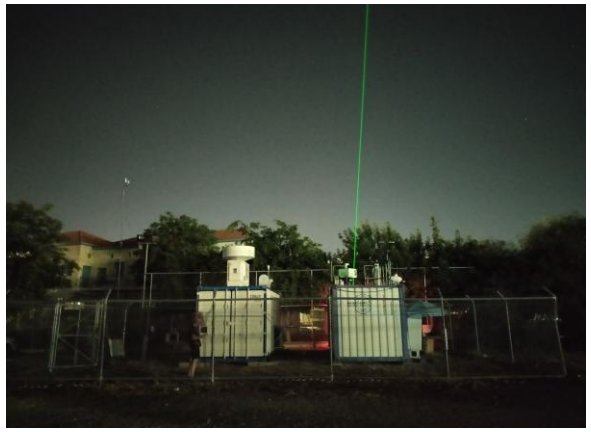
Aerosol types in the area

29/07/2021
Satellite image (MODIS)
Smoke from fires in Turkey



08/09/2015
Satellite image (MODIS)
Dust from Sahara & Middle East

Key facility for study of aerosols



Polly XT Raman LIDAR depolarization system, CARO NF of Eratosthenes Centre of Excellence

Sun/sky photometer of AERONET network,
CUT-TEPAK site

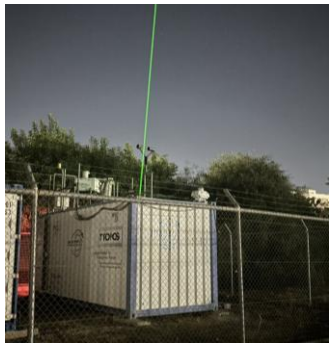
HETEAC-Flex model

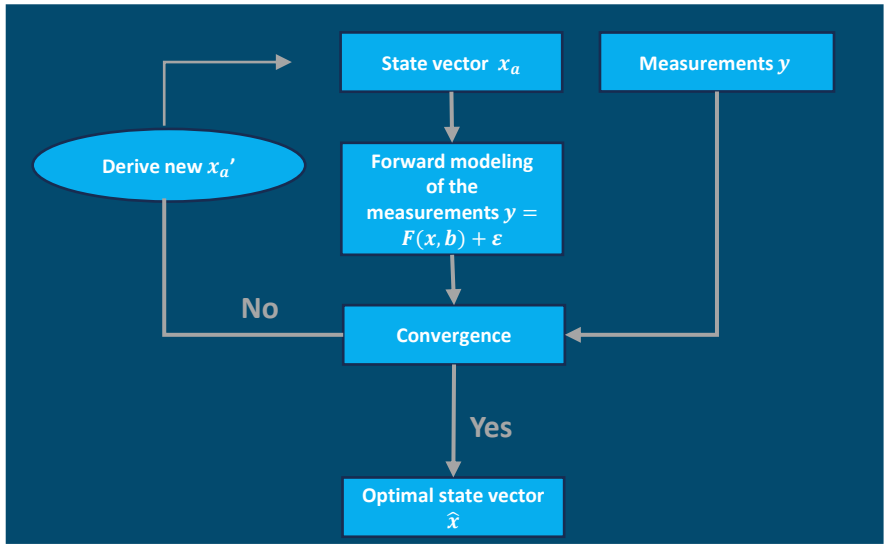
A. A. Floutsi et al., 2024

HETEAC-Flex is an advanced aerosol-typing scheme that utilizes lidar-derived optical properties to classify and quantify aerosol components.

Key Features

- Applicable to **ground-based & spaceborne lidars**
- Uses **lidar-derived intensive optical properties**
- Based on the **Optimal Estimation Method (OEM) - (Rodgers, 2000),**
- Identifies **up to four aerosol components**
- Provides **six forward retrieval modes** - different sets of optical properties
- Determines **relative volume contributions of aerosol mixtures**





Aerosol components

CNS

Desert dust

CS

Sea salt

FSNA

Pollution

FSA

Smoke

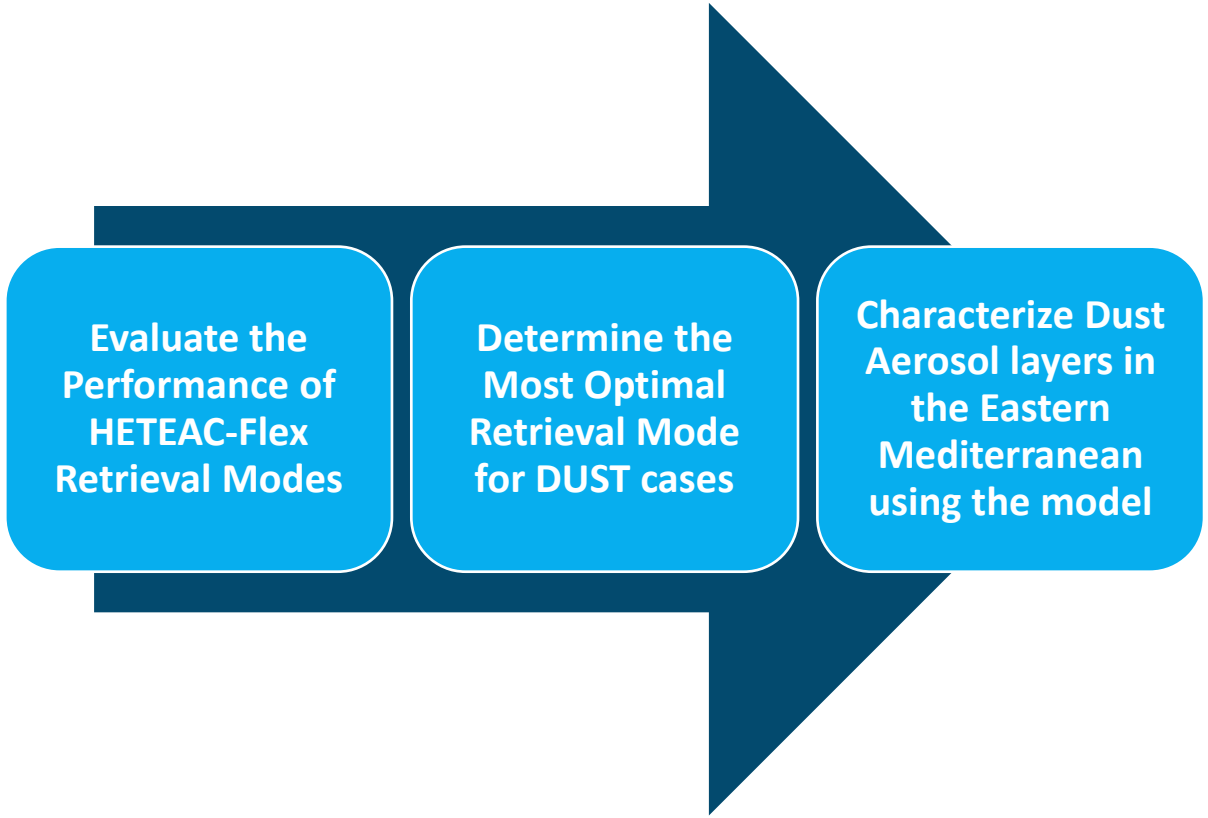
CNS: Coarse non-Spherical
CS: Coarse Spherical
FSNA: Fine Spherical non-Absorbing
FSA: Fine Spherical Absorbing

- Particle linear depolarization ratio at 355, 532 nm **(δ355, δ532)**,
- Lidar ratio at 355, 532 nm **(S355,S532)**,
- Extinction-related Ångström exponent at 355/532 nm **(AE(355/532))**,
- Backscatter-related color ratio for 532/1064 nm **(Cβ(532/1064))**.

Size, Shape
Quantity, Absorption
Type / source

Retrieval modes	Parameters
1	δ_{355}, S_{355}
2	δ_{532}, S_{532}
3	$\delta_{355}, S_{355}, Å_{355/532}$
4	$\delta_{532}, S_{532}, C_{\beta 532/1064}$
5	$\delta_{355}, S_{355}, \delta_{532}, S_{532}$
6	$\delta_{355}, S_{355}, Å_{355/532}, \delta_{532}, S_{532}, C_{\beta 532/1064}$

Objectives & Research Question



?

Which of the configurations of the HETEAC-Flex model most accurately retrieves the relative volume contribution for dust cases in Limassol?

Method

Dust cases selection

Study of the layer
(mean values of optical properties, back-trajectory, satellite image, POLIPHON Bsc profile)

Prepare the input data for the HETEAC-Flex model

Processing Step
(HETEAC-Flex algorithm)

Aerosol Typing
Optimal solution &
Relative volume contribution determination

Comparison of study of layer with relative volume contribution of each mode

Method

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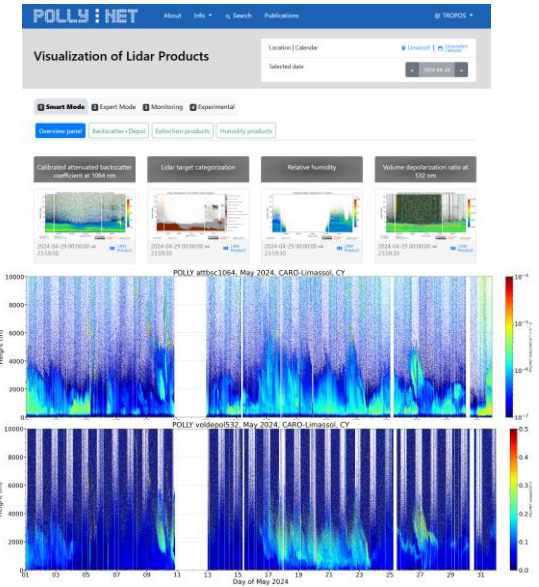

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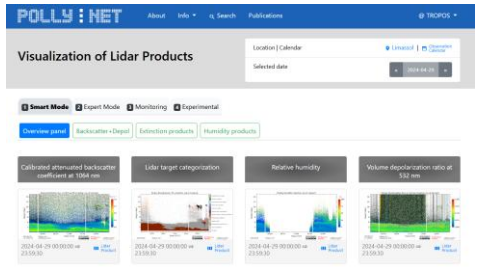
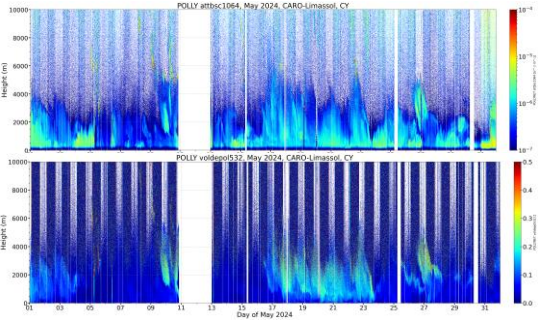
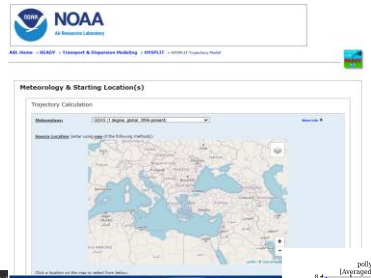
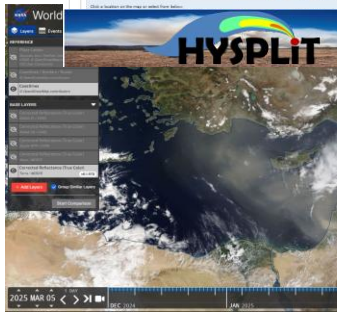
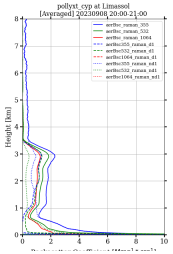










POLIPHON

Method

Dust cases selection

→

Study of the layer

(mean values of optical properties, back-trajectory, satellite image, POLIPHON Bsc profile)

→

Prepare the input data for the HETEAC-Flex model- mean values of optical properties- in txt format

→

Processing Step

(HETEAC-Flex algorithm)

→

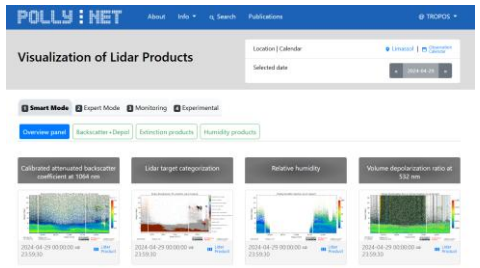
Aerosol Typing

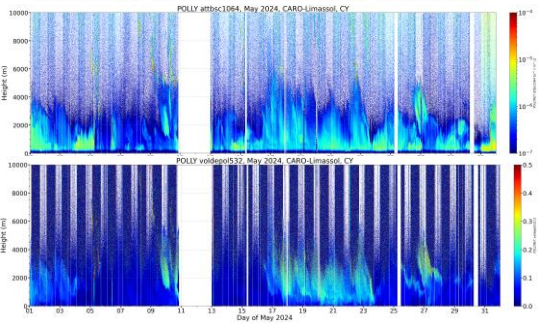
Optimal solution &

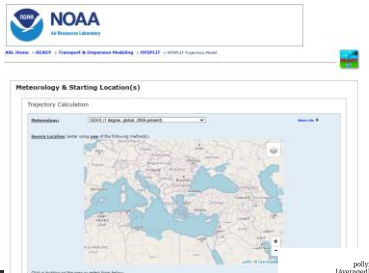
Relative volume contribution determination

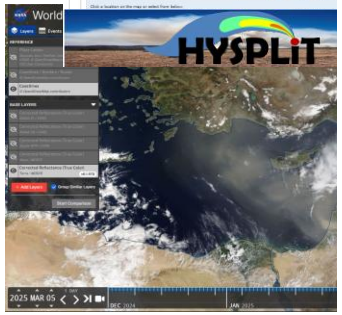
→

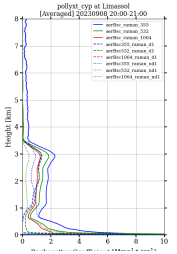
Comparison of study of layer with relative volume contribution of each mode



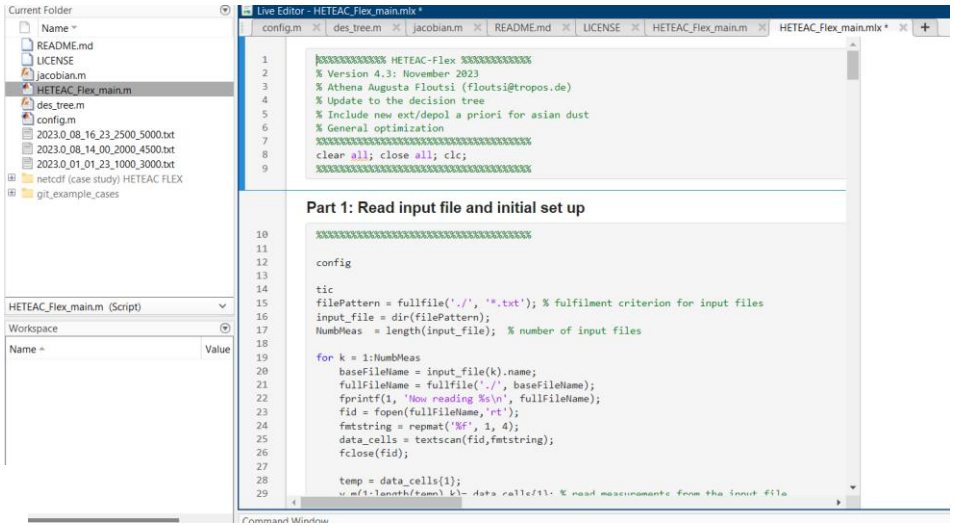








POLIPHON



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Dust cases selection

Study of the layer

(mean values of optical properties, back-trajectory, satellite image, POLIPHON Bsc profile)

Prepare the input data for the HETEAC-Flex model- mean values of optical properties- in the format needed

Processing Step

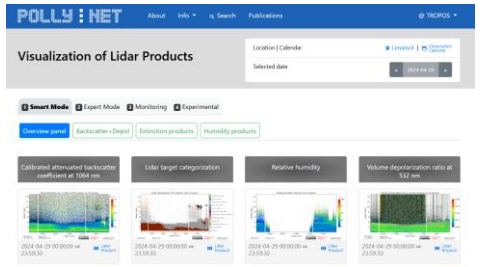
(HETEAC-Flex algorithm)

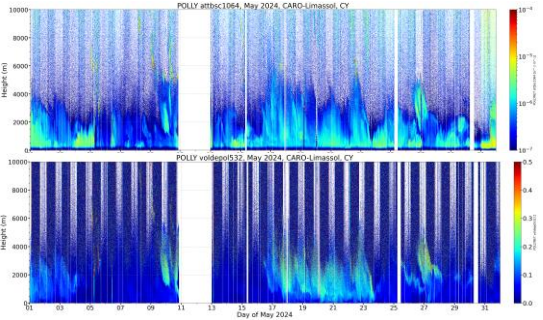
Aerosol Typing

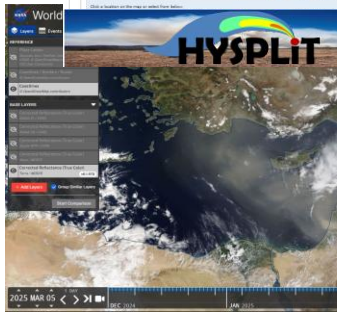
Optimal solution &

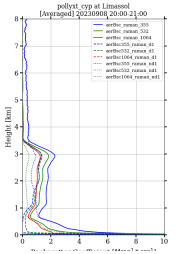
Relative volume contribution determination

Comparison of study of layer with relative volume contribution of each mode









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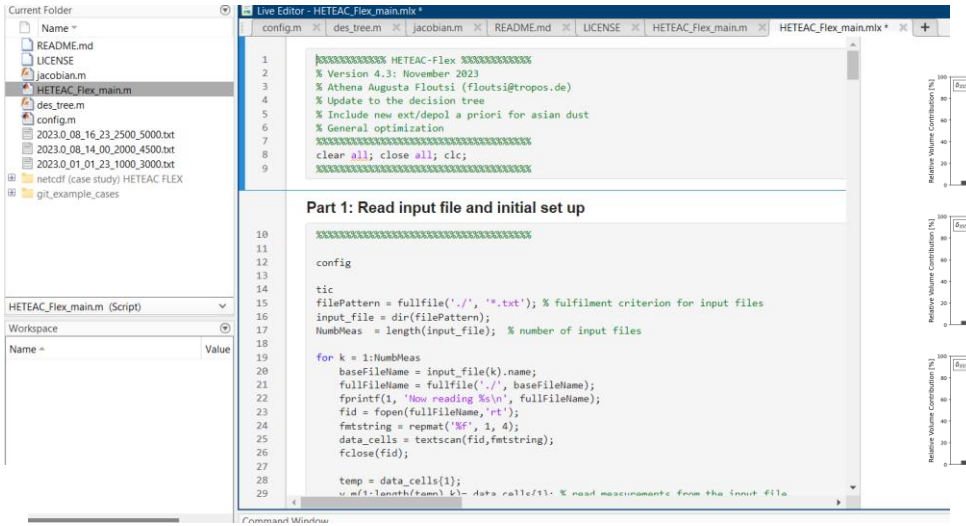

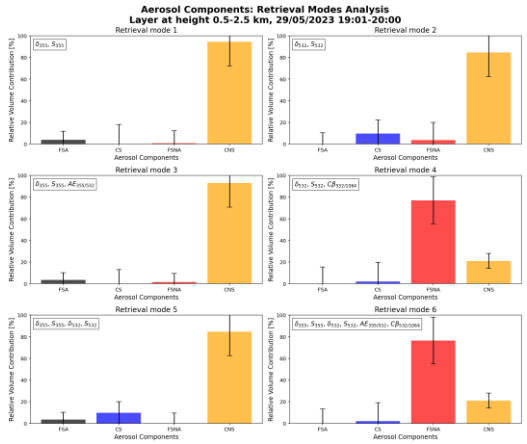

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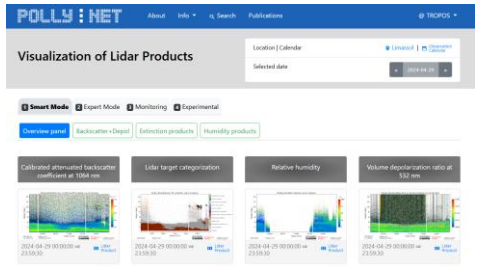

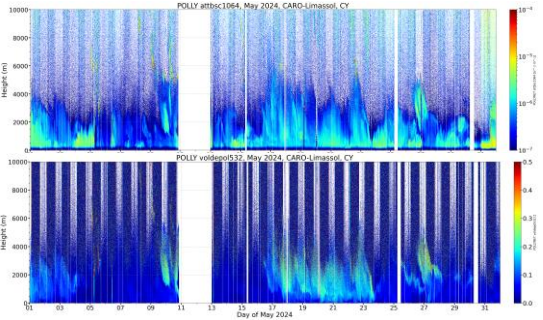

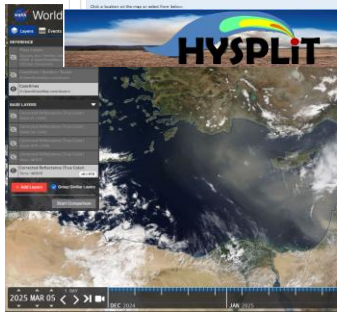

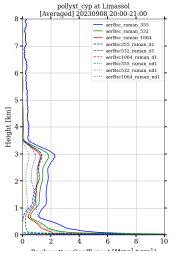

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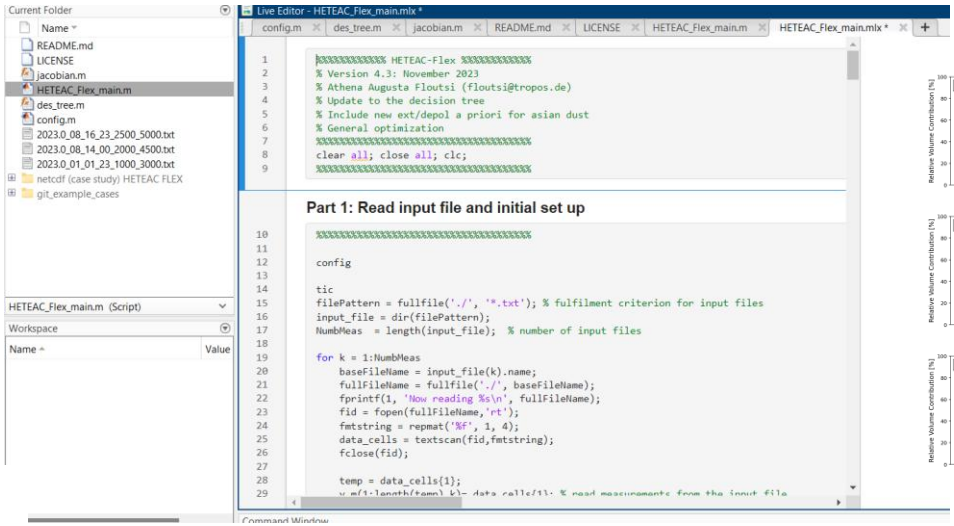
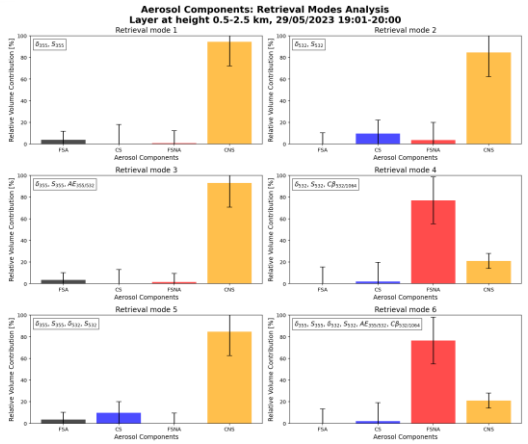
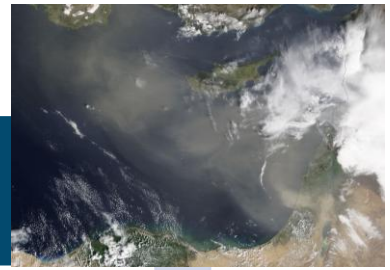




Selection of Dust Cases & Limitations

Main Selection Criteria



- Dust events
- Filtering by cloud-free conditions
- Select nighttime measurements
- Checking backscatter & depolarization ratio
- Availability of analysis data

Limitations & Challenges

- Errors in retrieval modes 4, 5, 6
- Model failure to converge in some cases within 30 iterations, not estimate optimal solution
- Dependence on automated analysis data availability.

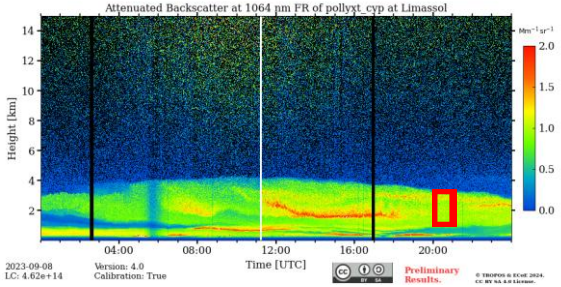
Results

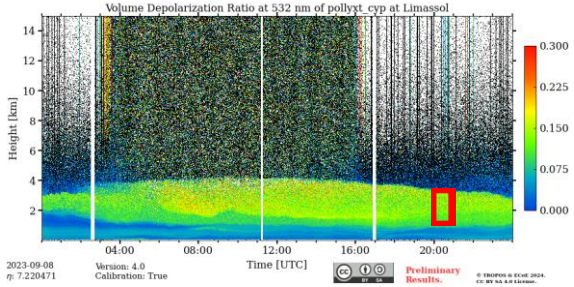
Case 1: 08/09/2023 – Saharan dust

08/09/2023
20:00 – 21:00
Layer height: 1-3 km

Properties from LIDAR	Mean values layer
δ_{355}	0.204 ± 0.017
S_{355}	57.869 ± 5.037
$Å_{355/532}$	0.342 ± 0.388
δ_{532}	**0.239 ± 0.012**
S_{532}	**43.731 ± 7.332**
$C_{\beta 532/1064}$	1.359 ± 0.073

From literature *Saharan dust* mean values
Floutsi et al., 2023

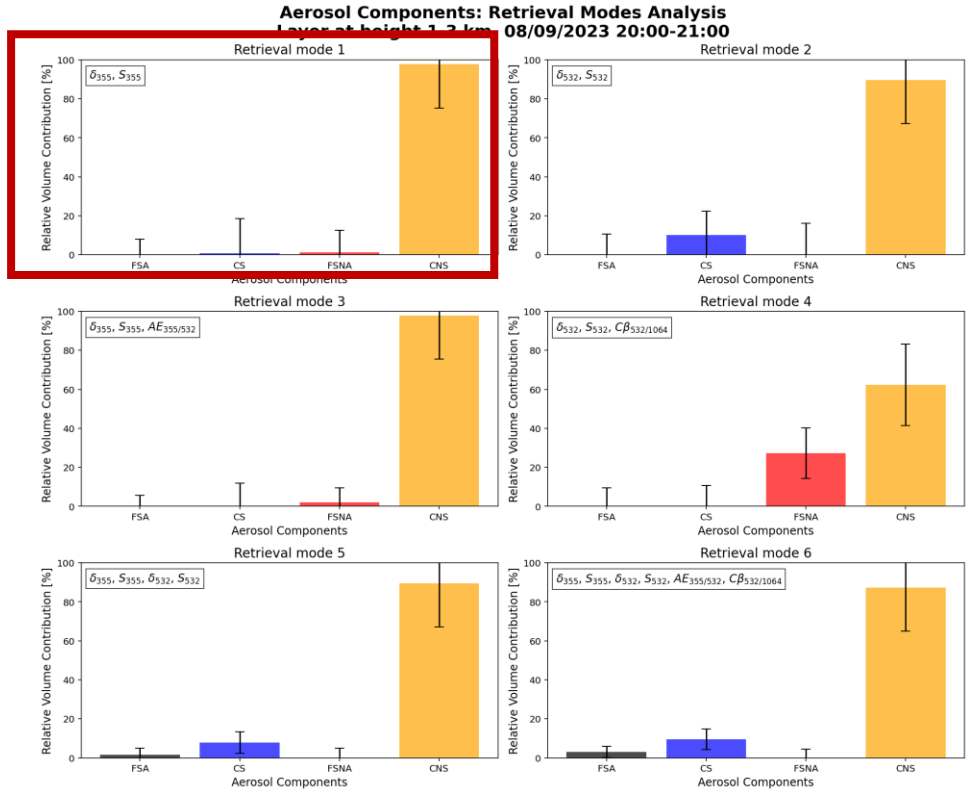


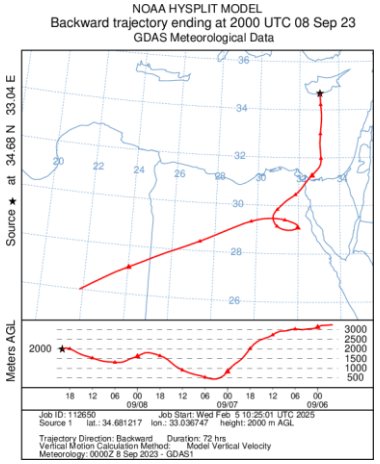


Initial guess - state vector based on decision tree of input data

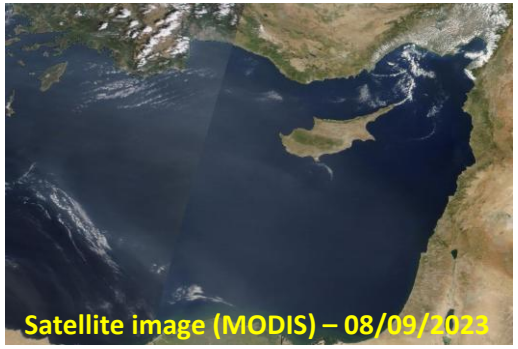
(CNS*)DESERT DUST dominated mix

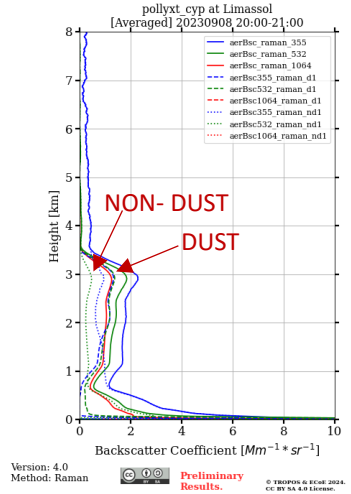
S.S.





72h back-trajectory HYSPLIT model
08/09/2023 20:00





Backscatter profiles POLIPHON
29/04/2024 00:00-00:59

Most trusted retrieval modes 1!

HETEAC-FLEX

Results

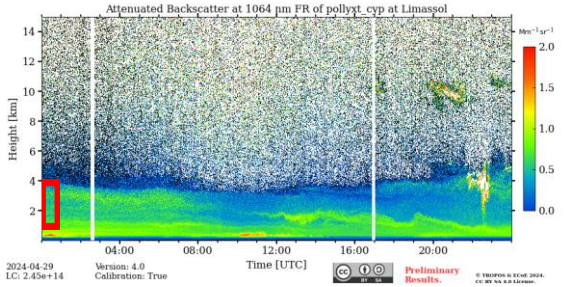
Case 2: 29/04/2024 – Middle East dust

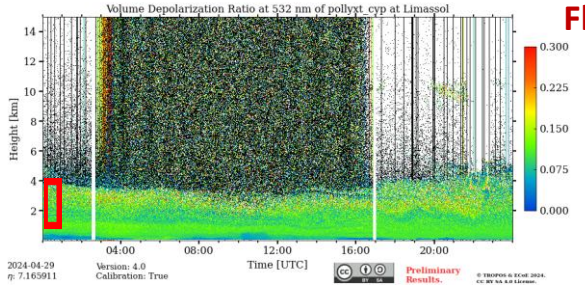
29/04/2023
00:00 – 00:59
Layer height: 1-4 km

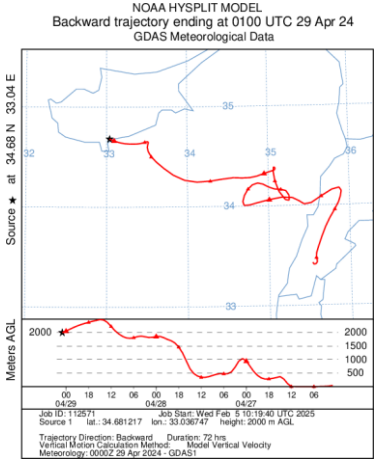
Properties from LIDAR	Mean values layer
δ_{355}	0.202 ± 0.045
S_{355}	56.2 ± 13
$Å_{355/532}$	0.355 ± 1.21
δ_{532}	**0.219 ± 0.019**
S_{532}	**45.5 ± 17**
$C_{\beta 532/1064}$	1.82 ± 0.12

From literature *Middle East dust* mean values
Floutsi et al., 2023

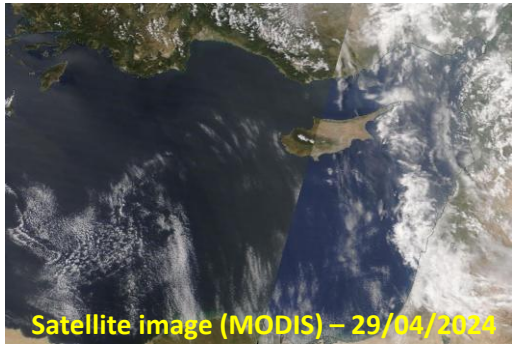
Initial guess - state vector based on decision tree of input data
(CNS*)DESERT DUST dominated mix

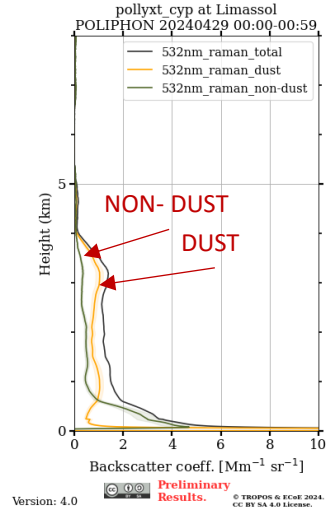






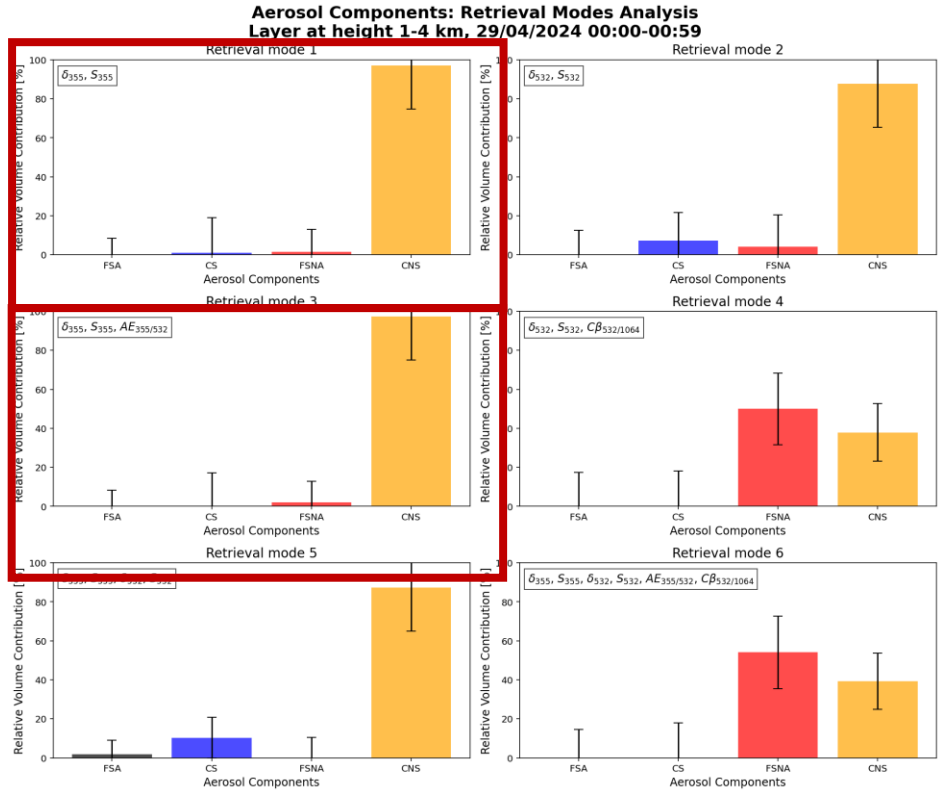
72h back-trajectory HYSPLIT model
29/04/2024 01:00





Backscatter profiles, POLIPHON method, 29/04/2024 00:00-00:59

S.S.



Most trusted retrieval modes 1, 3!

HETEAC-FLEX

Conclusions

Retrieval modes	Parameters
1	δ_{355}, S_{355}
2	δ_{532}, S_{532}
3	$\delta_{355}, S_{355}, Å_{355/532}$

❖ The most effective **HETEAC-Flex retrieval modes** for dust aerosol classification were **1, 2, 3 modes** for the cases selected for this study.

- Particle linear depolarization ratio at 355, 532 nm **(δ355, δ532)**,
- Lidar ratio at 355, 532 nm **(S355, S532)**,
- Extinction-related Ångström exponent at 355/532 nm **(AE(355/532))**

❖ Since Mode 1 is reliable, it can be effectively used for validating aerosol classification of EarthCARE for dust cases.

EarthCARE Satellite

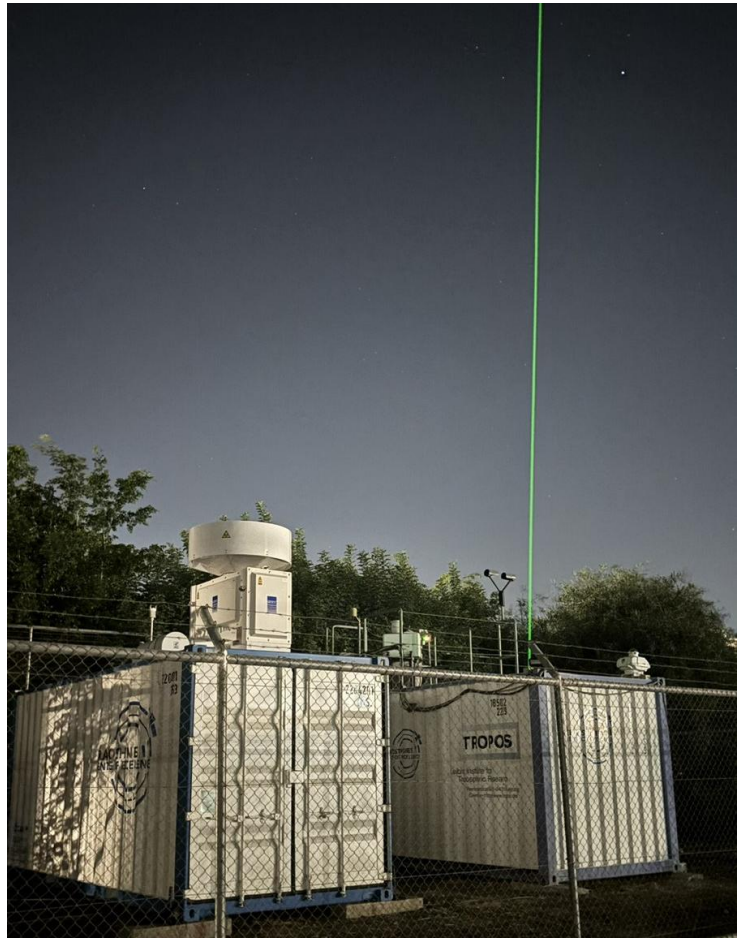
Discussion - Future Work:

TASK	Why?	Expected outcome
Better signal analysis 🔍	More reliable inputs	Larger dataset for retrievals
Study more aerosol types 🌍	Expand knowledge beyond dust	Better classification
Statistical analysis 📊	Validate results	Improve accuracy

Thank you!

Questions?

EarthCARE satellite



CARO station - Limassol

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