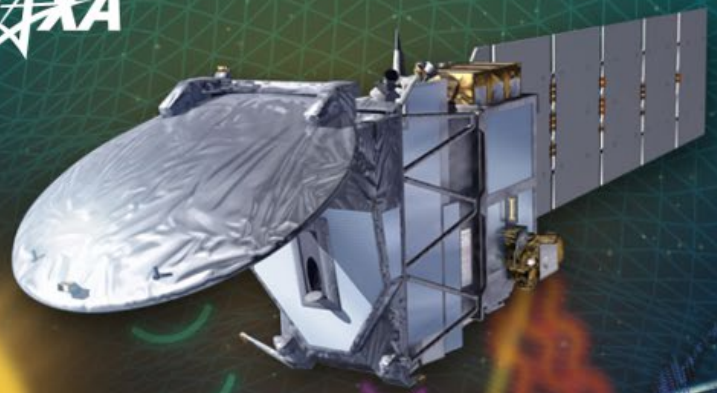


ESA-JAXA Pre-Launch EarthCARE Science and Validation Workshop

13 – 17 November 2023 | ESA-ESRIN, Frascati (Rome), Italy

EMORAL lidar observations for EarthCARE Cal/Val Activities and beyond

Iwona Stachlewska, G.Georgoussis, V.Freudenthaler, P.Poczta, V.Amiridis, D.Nicolae

University of Warsaw, Faculty of Physics (UW), Warsaw, Poland

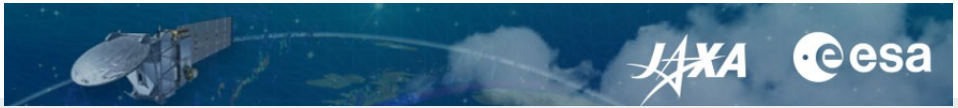
Raymetrics – Lidar Systems S.A., Athens, Greece

Ludwig Maximilian University of Munich (LMU), Munich, Germany

Poznan University of Life Sciences (PULS), Poznan, Poland

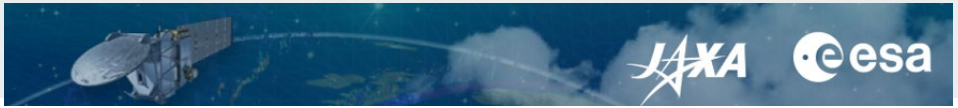
National Observatory of Athens (NOA), Athens, Greece

National Institute of Research and Development for Optoelectronics (INOE), Măgurele, Romania



Outline

- The current configuration of the ESA MObile RAman Lidar (EMORAL)
- New functionalities: wavelength-dependent polarization, Raman water vapor, broadband fluorescence.
- Examples of measurements in different environments.
- Recommendations for the smooth operation



Motivation and objectives

The EMORAL lidar development started in 2007 with objectives to:

- take part in campaigns all over Europe in order to enhance European competence in the domain of Cal-Val campaigns for EOP mission
- build and maintain in ESA a key competence, such as the lidar knowhow
- test atmospheric lidar concepts and technologies
- provide datasheets for scientific research and other ESA activities

Since then, several instrument upgrades!

Here we talk only upgrades in last ~5 years …

EMORAL UPGRADES I

September 2017 till March 2018

- **mobile platform upgrade:**

new IVECO van nad its modifications,
e.g.: additional air-con, manual hatch in the roof
(***ESA – NOA collaborative effort***)

- **lidar system upgrade:**

re-design of transceiver with new laser, new telescope
new design of polychromator,
new/upgraded transient recorders
(***ESA – UW, LMU, Raymetric collaborative effort***)

DATA QUALITY ASSESSMENT: UW & INOE

EMORAL UPGRADES I

Main goals:

- **Redesign of transceiver** to assure decreased overlap down to ~250-350m and increased height resolution to 3.75m
- **Extend the number of measured signals** to assure more data products of higher quality (data products cross-validation)

COMPROMISE: *use of the existing parts in the re-designed version as long as they do not decrease significantly the overall lidar performance!*

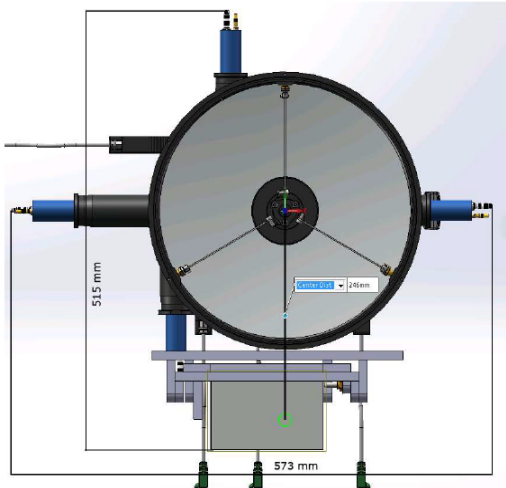
EMORAL UPGRADES I

New, custom designed transciver (Raymetrics, Greece) comprising:

- **More powerful Nd-YAG laser**, (SpitLight 400, InnoLas, Germany) operating at 1064 nm (112 mJ), 532 nm (103 mJ) and 355 nm (128 mJ), with a repetition rate of 10Hz and pulse length 5-7 ns.
- **Smaller size Cassegrain telescope** primary mirror of 300 mm and adjustable FOV 2-3.6 mrad

New design of detection channels (Raymetrics, Greece) comprising:

- Signals simultaneously recorded (analogue + photon-counting mode) by PMTs (except 1064 nm (analogue only, APD) with **new 16 bits transient recorders** (TR40-160, Licel, Germany)



Excellent **durable mechanics** design and manufacturing by Raymetrics

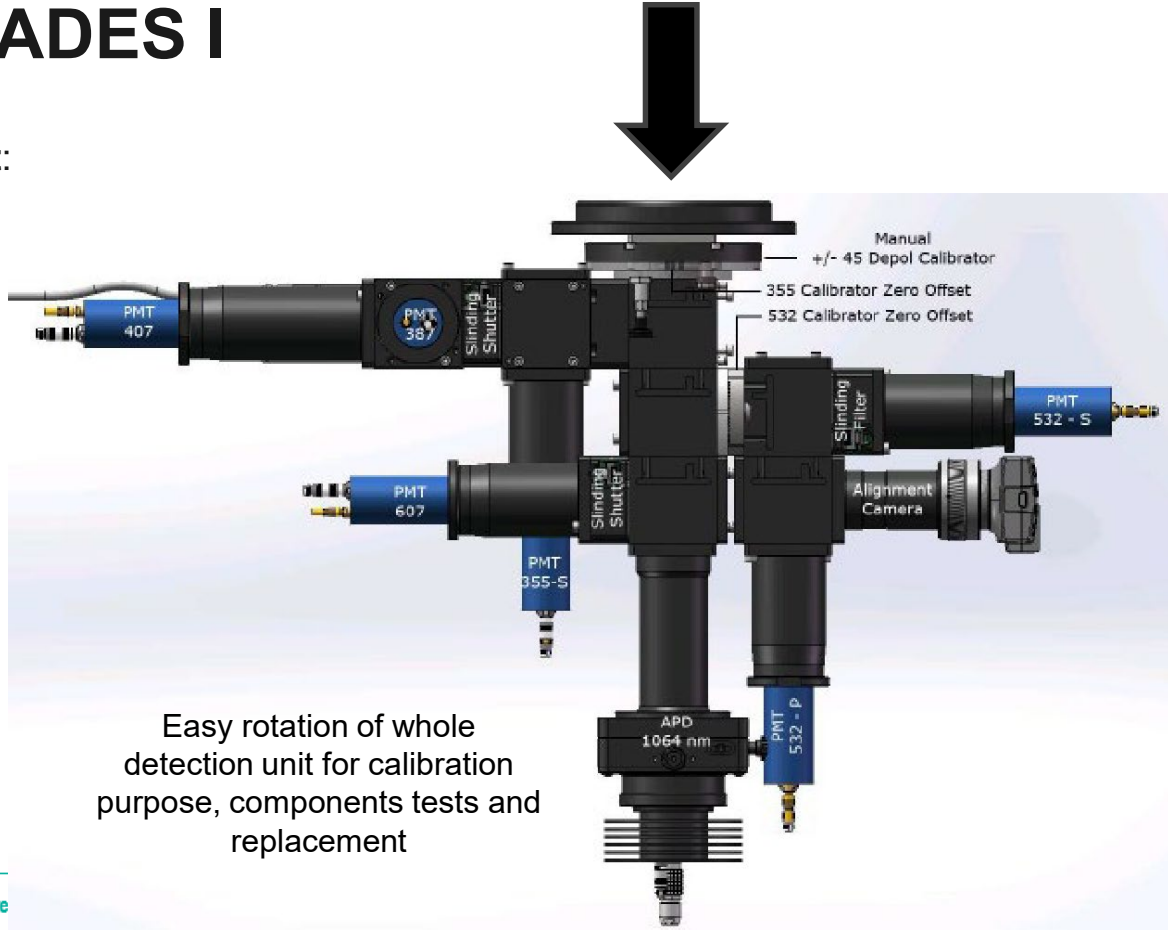
EMORAL UPGRADES I

Compact wavelength separation unit:

3 elastic Mie channels
1064 nm, 532 nm, and 355 nm

3 vibrational Raman channels
nitrogen at 387 nm and 607 nm
water vapor at 407 nm

2 depolarization Mie channels
532 nm and 355 nm

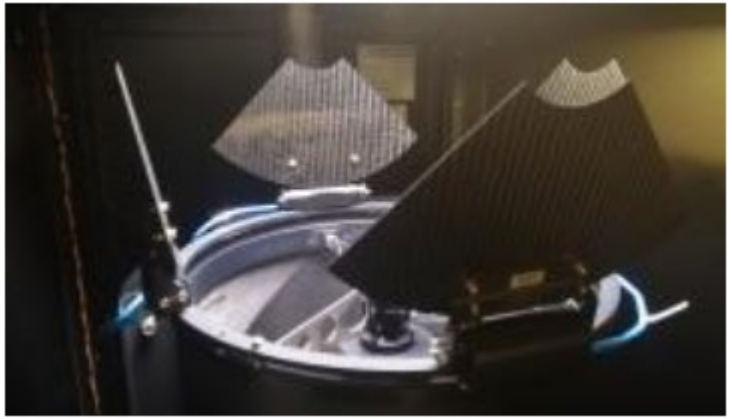


Easy rotation of whole detection unit for calibration purpose, components tests and replacement

EMORAL UPGRADES I

Developments increasing measurement quality:

- automated telecover mechanism
- calibration system for polarization measurements
- sliding filters for Raman and polarization channels
- possible rotation of whole detection unit
- CCD camera for monitoring the outgoing laser beam
- several laser interlocks for safe lidar operation



Additional needs of operation in extreme conditions (winter/summer, peatland):

- two oil heaters for winter operation
- insolation chimney
- external UPS for system stabilization
- camera for sky-monitoring

EMORAL UPGRADES II

September 2019 till October 2020

Purpose:

- **additional purely technical upgrades conducted at Raymetrics**
- **campaigns related to ESA missions at NOA**

Recommendation for changes was prepared by POLIMOS Team and provided to ESA (G.Tzeremes) and Raymetrics (G.Georgoussis).

Motorized Hatch mechanism

PDU and Automation

UPS

Power Generator

Rain Sensor

EMORAL UPGRADES III

September 2022

Essential upgrades conducted at Raymetrics:

- **fluorescence channel**
- **Replacement of oldest PMTs**
- **aircraft radar for safety**
- **more powerful air-conditioning**
- **van: roof painting and door insulation**

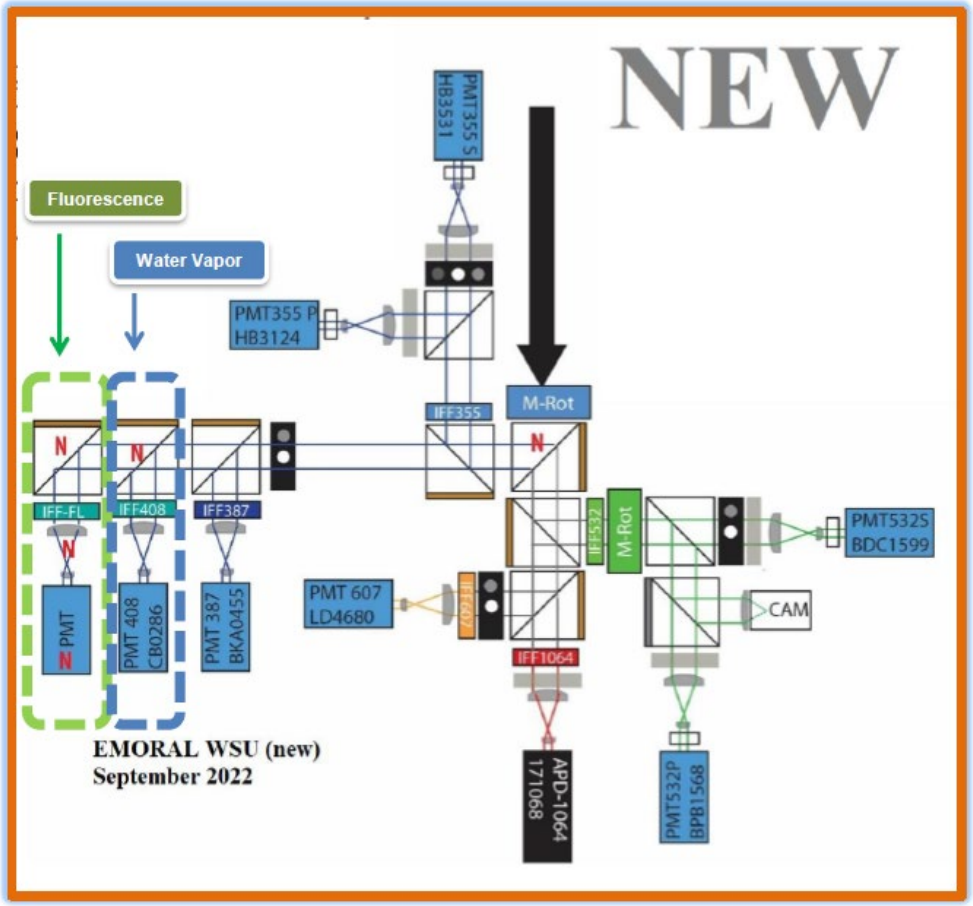
Recommendation for changes was prepared by POLIMOS Team and provided to ESA (P.Ribes) and Raymetrics (G.Georgoussis).

EMORAL UPGRADES III

Major upgrade: fluorescence channel

a) new broad band interference filer 420-500 nm
b) new Dichroic Mirror at the entrance of the WSU
c) new Long Pass Beam Splitter separate 407 and 420-500 nn
d) new Eyepiece and PMT for fluorescence detection
e) new Transient Recorder for fluorescence channel (an, pc)

NOTE: additionally PMTs replaced at 407 and 607 nm



Van to be visited outside the Conference hall ☺

Recent EMORAL intercomparisons

- 2018 against POLIS (LMU-MIM) & PollyXT (TROPOS) lidars
- 2019 against RALi (INOE) & PollyXT (TROPOS) lidars
- Several tests but ***no direct intercomparison*** after the EMORAL upgrade in 2020

- **Recent: September 2022 against POLIS (LMU-MIM), RALi (INOE), ALPHA (INOE)**

ACTRIS-CARS site at INOE

LIDARS

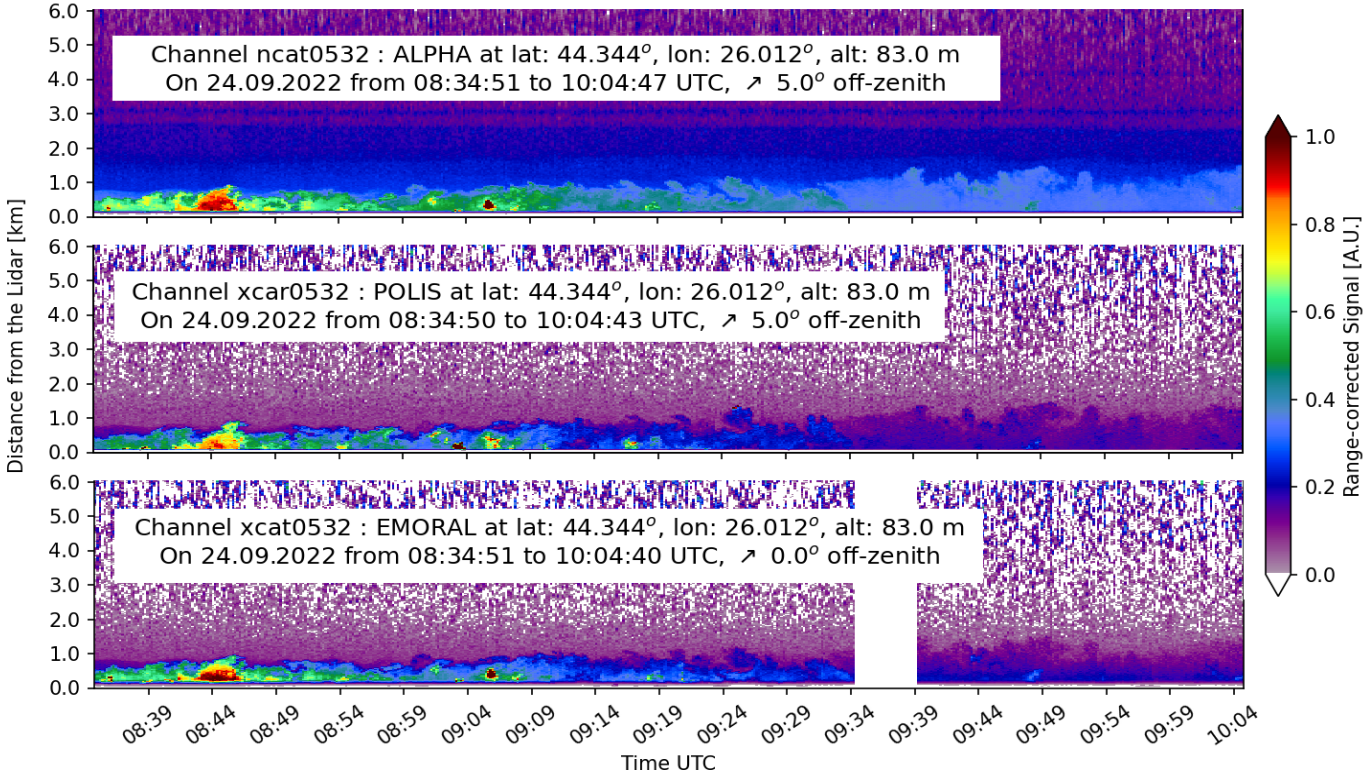
Intercomparison

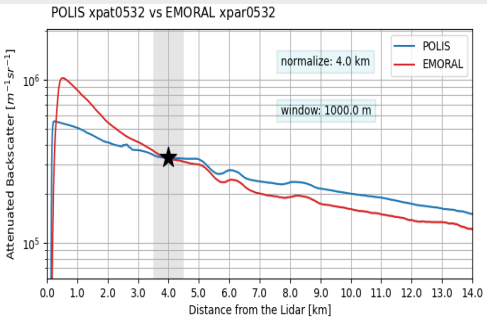
ALPHA INOE (reference)

POLIS LMU (reference)

EMORAL ESA/UW

Lidar comparison at single location at ACTRIS CARS (INOE, Magurele, Romania)

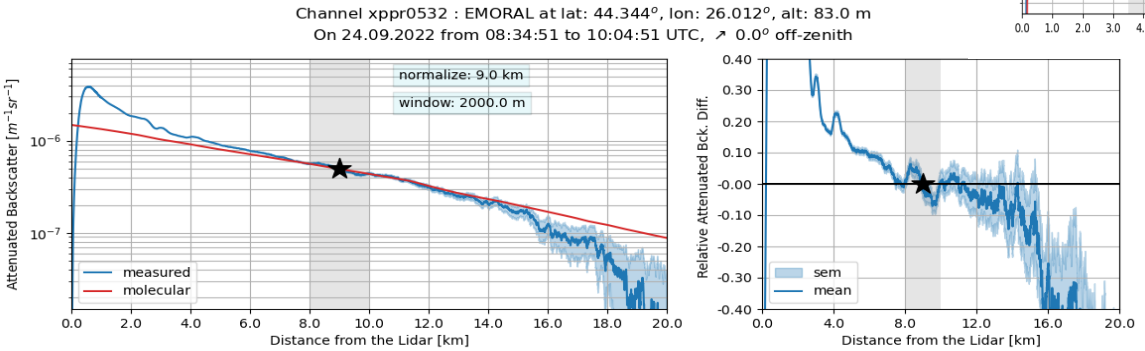




EMORAL QA tests and optimization

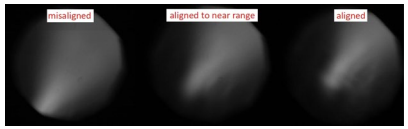
Rayleigh fit

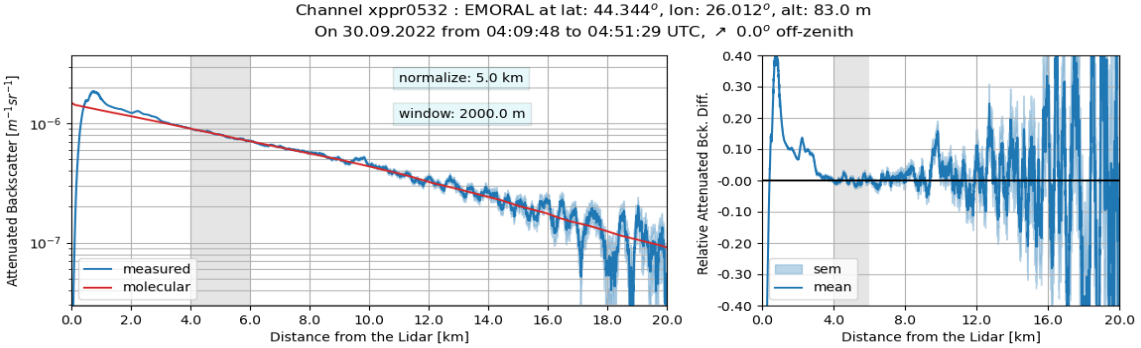
Lidar misaligned too much signal in the near-range



Issues at far-field (loosing signal)

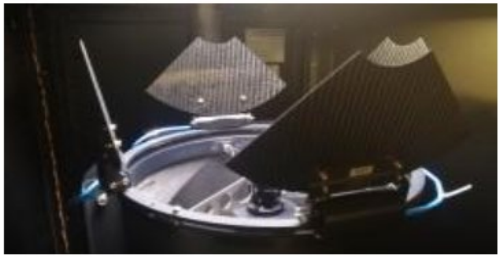
Lidar aligned properly thanks to beam-camera





Correct signal at near and far-field

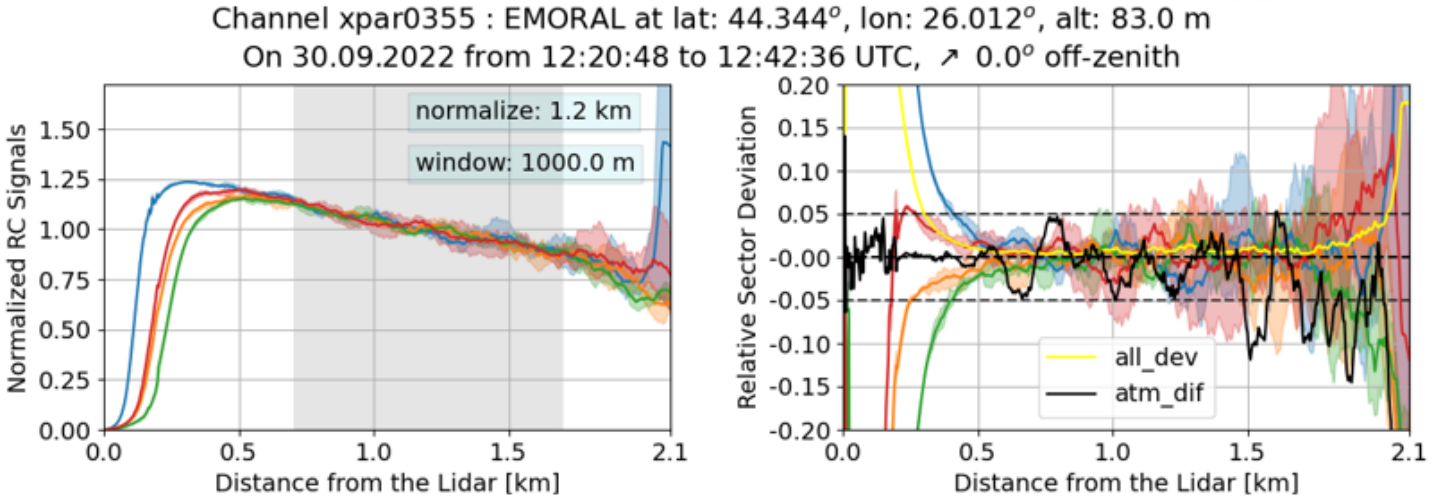
EMORAL QA tests and optimization



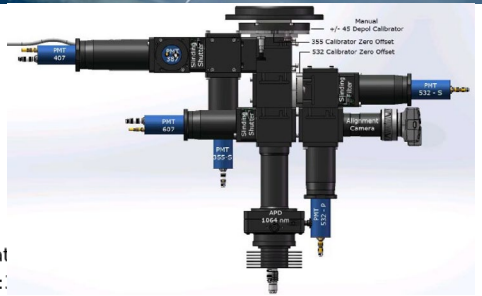
Telecover test

Lidar aligned properly thanks to the automated telecover mechanism.

Low overlap achieved.

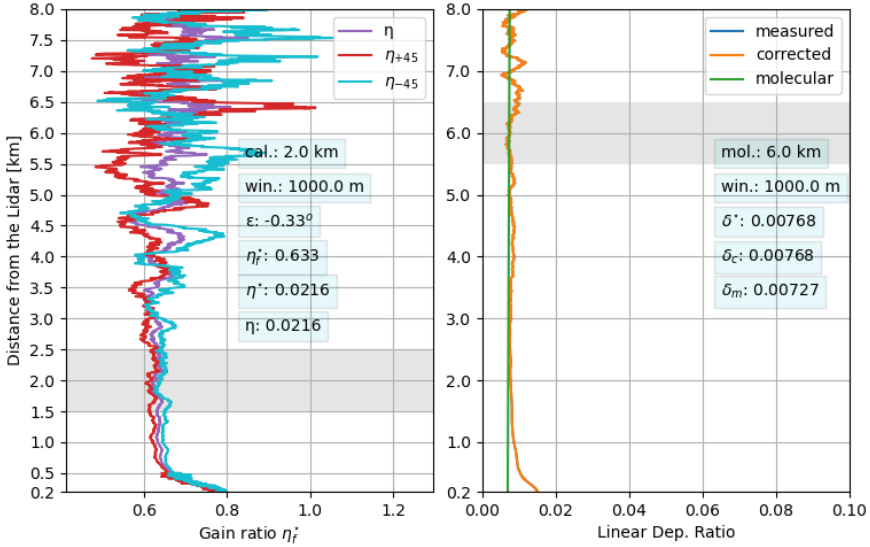


EMORAL QA tests and optimization

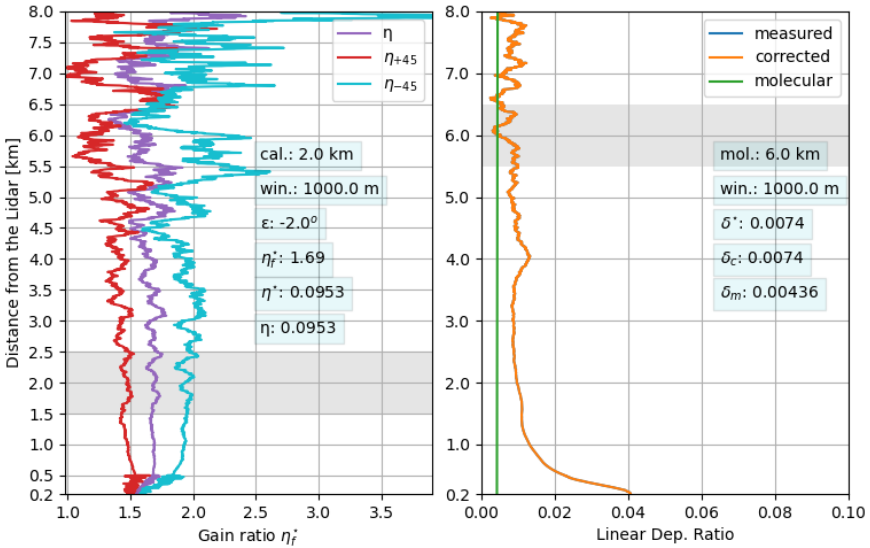


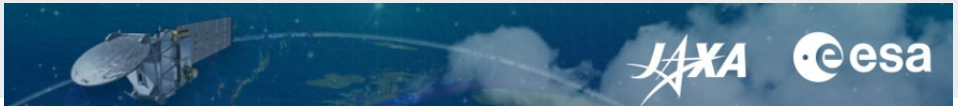
Depolarization Calibration at 355 and 532 nm thanks to easy +/- 45 deg rotation

Ratio xppr0355 to xcpt0355: EMORAL at lat: 44.344°, lon: 26.012°, alt: 83.0 m
Calibration on 28.09.2022 from 11:28:32 to 11:39:59 UTC, ↗ 0.0° off-zenith
Rayleigh on 28.09.2022 from 07:55:43 to 11:20:53 UTC, ↗ 0.0° off-zenith



Ratio xppr0532 to xcpt0532: EMORAL at
Calibration on 28.09.2022 from 11:28:
Rayleigh on 28.09.2022 from 07:55:43 to 11:20:53 UTC, ↗ 0.0° off-zenith





Research Campaigns

Goals:

Derivation of new data products in different environments:

- Direct data products (fluorescence backscatter coefficient)
- Fluorescence-Mie-Raman synergy products (fluorescence capacity)

New algorithms:

- Algorithm for synergic evaluation of lidar signals

Results:

- Successful retrieval of fluorescence data products.
- Aerosol typing using fluorescence capacity and depolarization ratio.

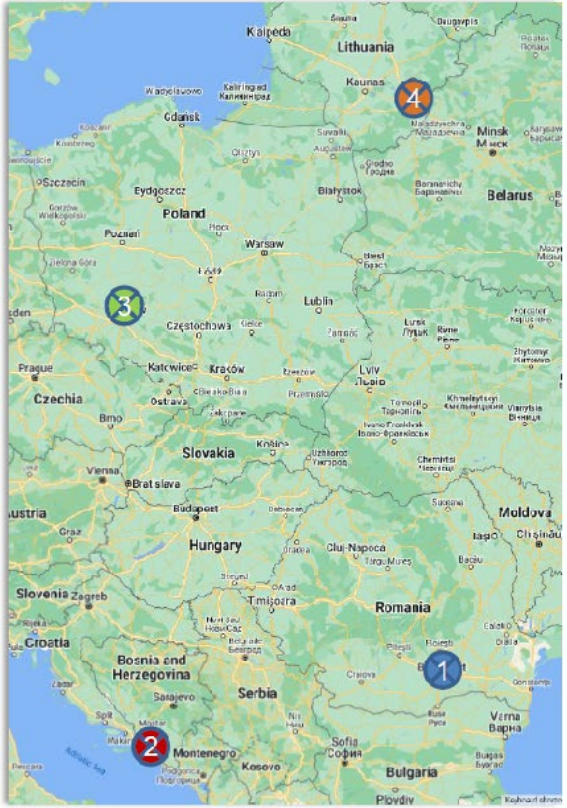
Campaigns

1. Măgurele (RO) - INOE
- ***Autumn:*** 23rd-30th of September 2022
- ***Suburban Area***
- 77 m a.s.l
- 43.3444 N, 21.0122 E

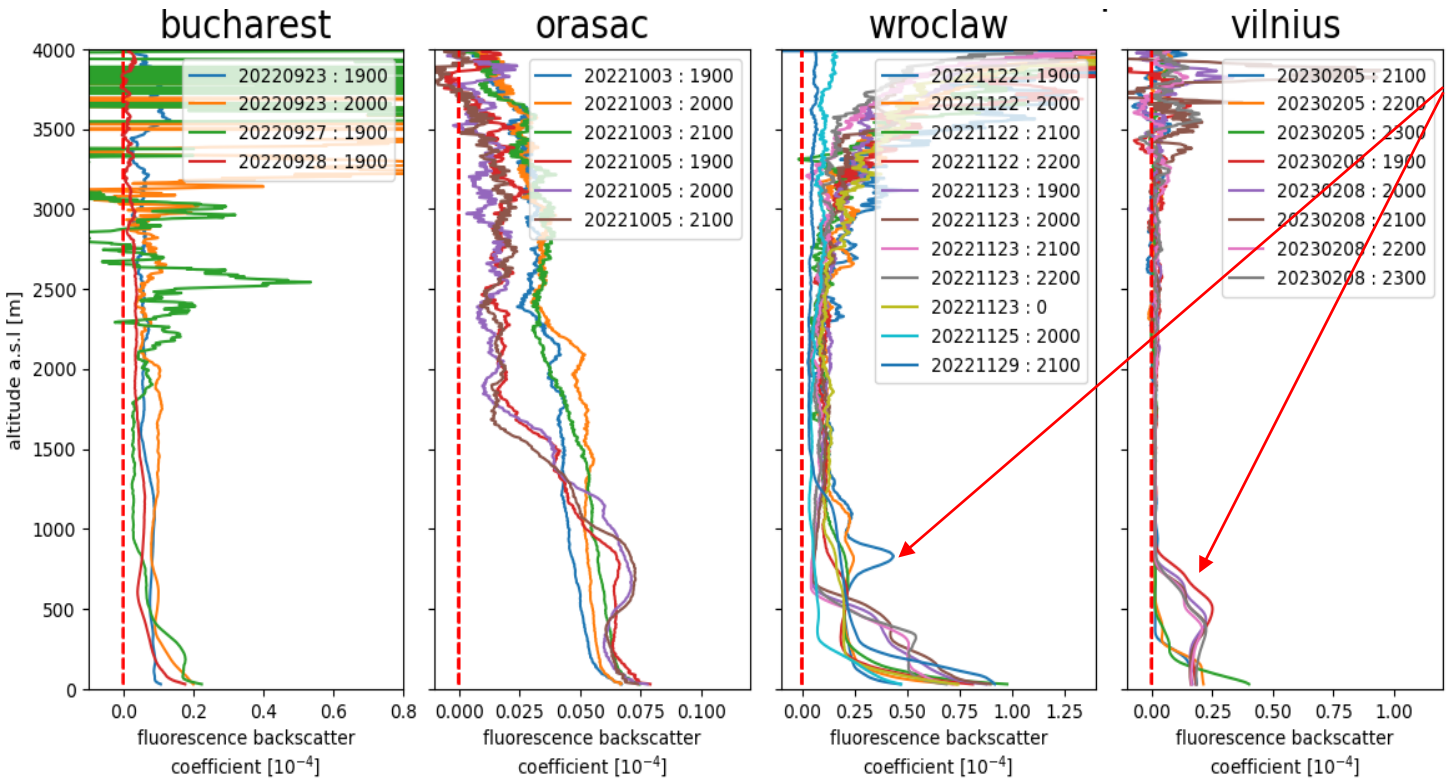
2. Orašac (CR)
- ***Autumn:*** 3rd-7th of October 2022
- ***Coastal rural area***
- 80 m.a.s.l
- 42.6955 N, 18.0146 E

3. Wroclaw (PL)
- ***Winter:*** November 23rd - December 1st 2022
- ***Highly urbanized site***
- 116 m a.s.l
- 51.1052 N 17.0888 E

4. Vilnius (LT)
- ***Winter:*** January 16th – March 12th 2023
- ***Background urban site***
- 103 m a.s.l
- 54.7239 N, 25.3262 E



Fluorescence Backscatter Coefficients



Remarks:

- High consistency results (similar time)
- Observable variability (at same day)
- Lowest aerosol load - Oracac
- Exotic conditions – Worcław: highly polluted urban atmosphere in wintertime

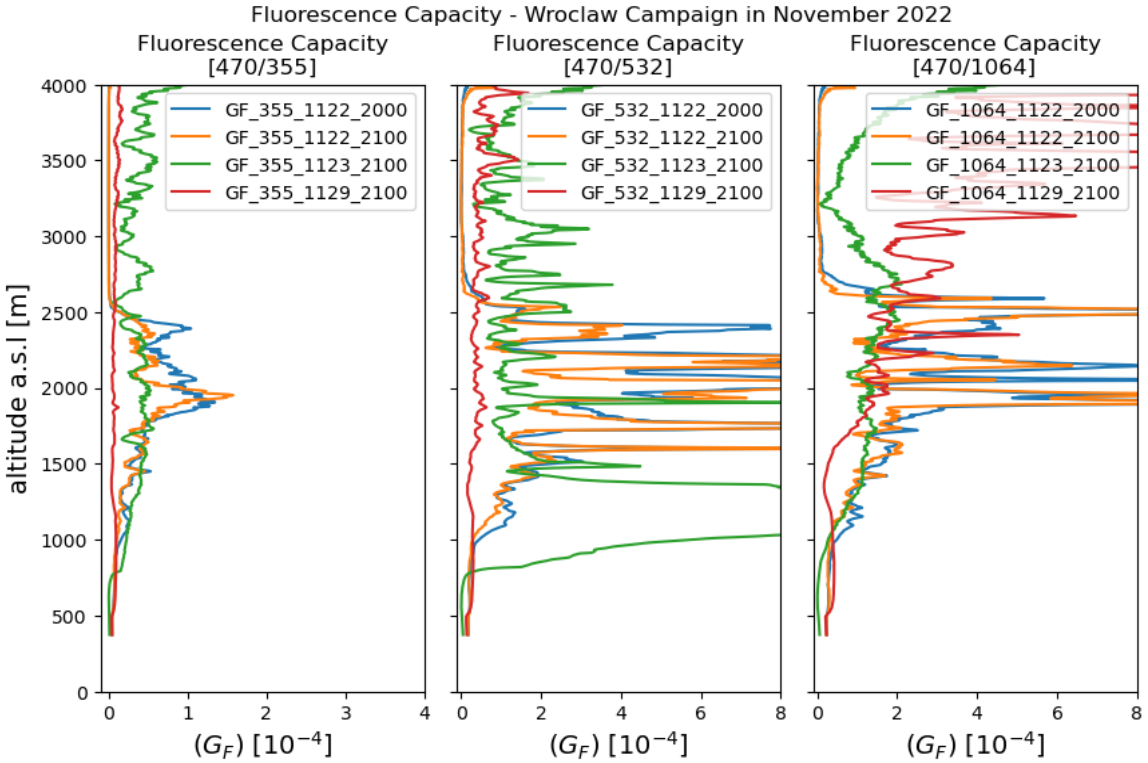
Cloud layers from ~ 3 km
Wroclaw 22 and 23 Nov

mind the scale

Fluorescence Capacity

Promising outcome:

- More stable GF obtained at 355 nm
- Obtainable until below 500 m
- Unique: combining input form WV to correct data
- No other lidar with such synergic observations in so many locations!



Aerosol properties

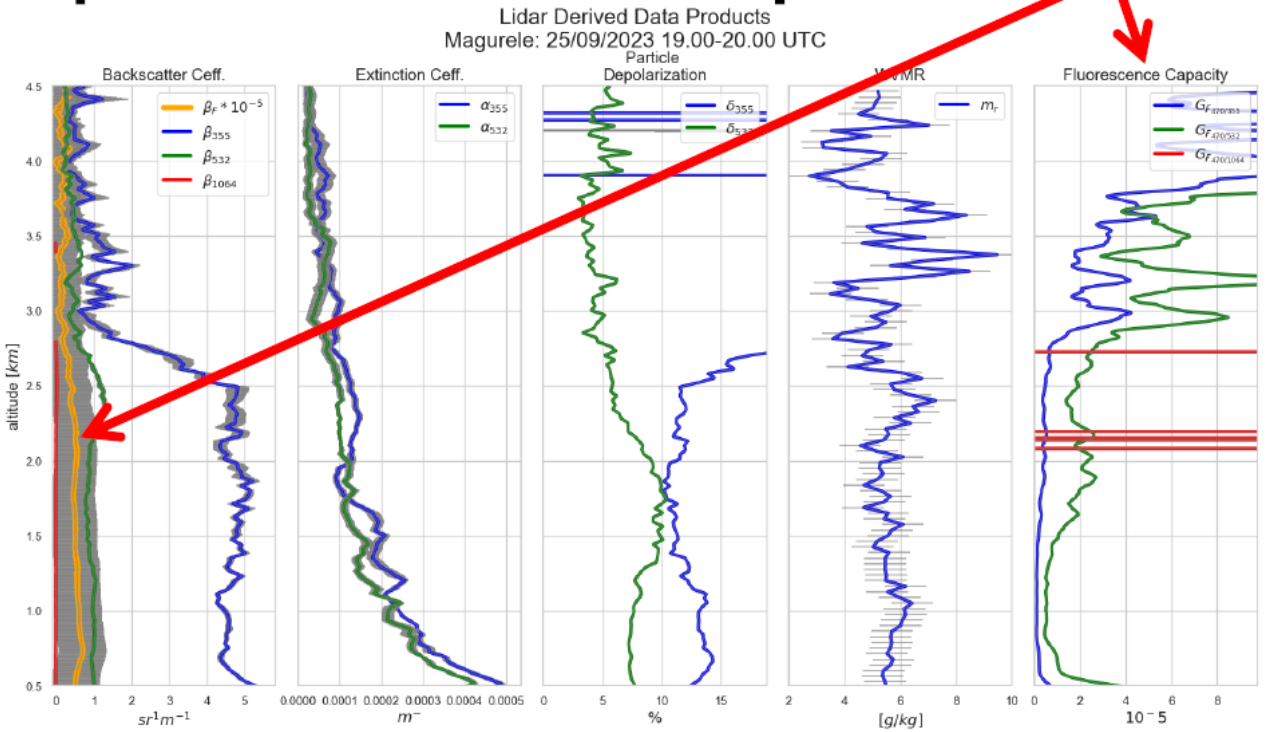
Optical Product (SCC)

Fluroescence Procucts

To be optimized:

- Reduction/filtering of the data noise
- Data products with us of the ACTRIS Single Calculus Chain Tool

Current:
Beta 355, 532, and 1064 obtained using SCC not optimal for high aerosol load.
Noise handling (current MA-smooted 5-10 points).

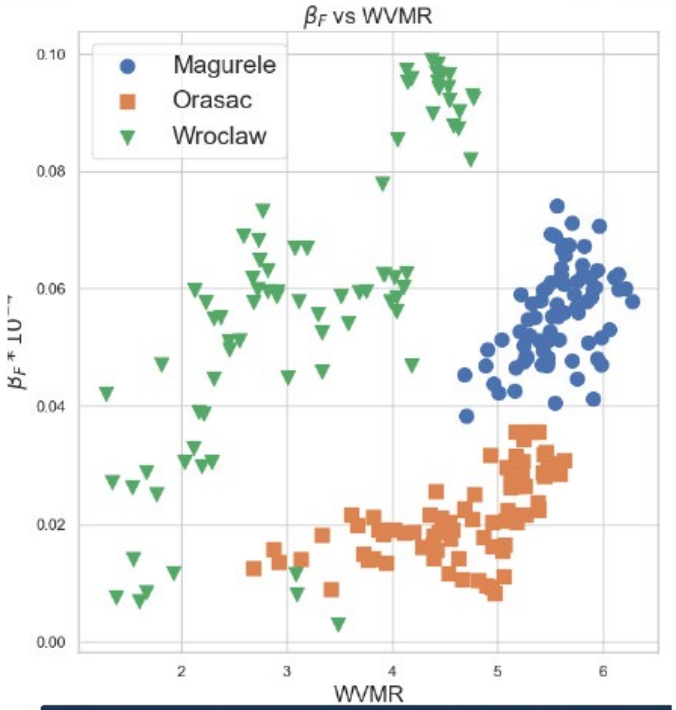


Potential for typing

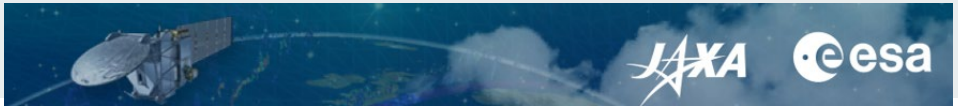
Clear separation of the properties depending on location of measurement and aerosol type / mixture

(only appetizer shown)

β_F within the atmospheric boundary layer



Magurele: 20220925 19.30-20.00 UTC
Orasac: 20221003 2230-2300 UTC
Wroclaw: 20221129 2130-2200
Vilnius: 20230210 1800-1830 UTC



Summary

Lessons learned:

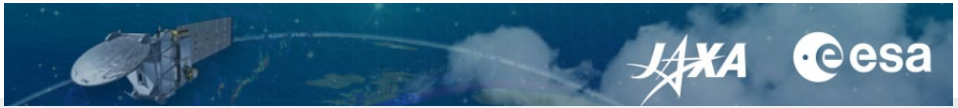
- Attention must be paid to transportation of lidar (proper packing, sensible driving and root planning)
- There is a need for 2 operators and 1 data evaluator during campaigns as NRT is required
- Isolating chimney is crucial for operation in wintertime and during hot summers
- Implemented ACTRIS QA tools help critically in lidar operation

Recommendations:

- Some analog signal disturbances mainly on 1064nm channel: further cooperation with InnoLAS for better electrical isolation of the laser power supply and with LICEL to optimize detection with APD.
- Exchange the oldest five Transient Recorders (1064, 532p,s, 355p,s)

Follow-up activities:

- Using the current lidar for ESA field campaigns is feasible even in tough conditions !



Thank you

"We would like to thank the Opto-Electronics section (TEC-MME) at the European Space Research and Technology (ESTEC) of the European Space Agency (ESA) for providing the ESA Mobile Raman Lidar EMORAL within Technical assistance for Polish Radar and Lidar Mobile Observation System (POLIMOS) funded by ESA-ESTEC Contract no. 4000119961/16/NL/FF/mg."

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PULS: B. Chojnicki, P. Poczta, K. Harenda; ***AGH****:* M. Zimnoch, J. Nęcki, J. Bartyzel; ***INOE:*** L. Belegante, J. Vasilescu, A. Nemuc, D. Nicolae; FTMC: S. Byčenkienė, S. Pauraitė-Dudek, D. Valiulis; ***UWR:*** A. Drzeniecka-Osiadacz, T. Sawiński; ***UŚ:*** M. Jabłońska; ***IPIŚ-PAN:*** K. Klejnowski, L. Jaworek; **NOA:** V. Amiridis, P. Kokkalis.