

Raman LIDAR measurements at Roque de los Muchachos Observatory.

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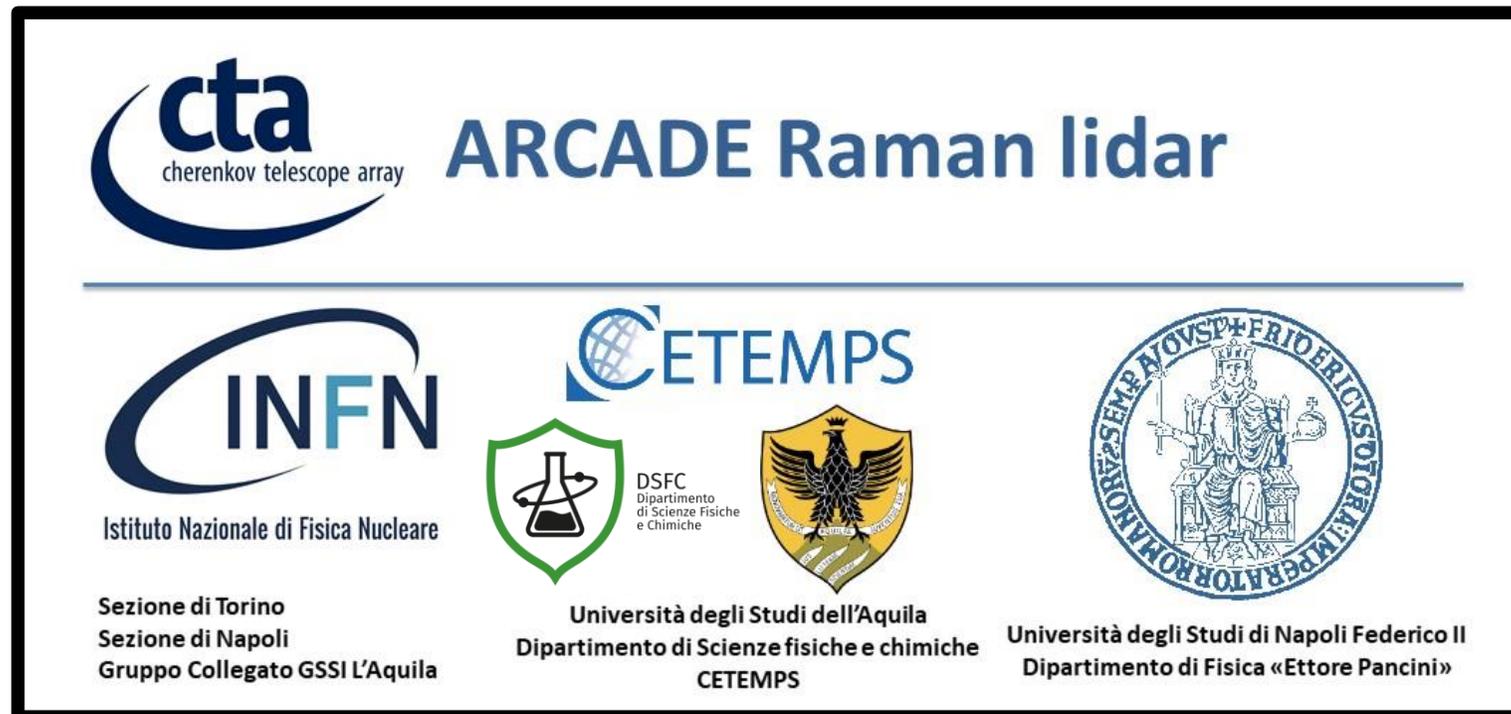
CETEMPS/DSFC and INFN, Università Degli Studi dell'Aquila, L'Aquila, Italy.

Ermanno Pietropaolo, Vincenzo Rizi, Carla Aramo for CTA Collaboration.

Alberto Cirella, Stefano Galli, Emanuele Avocone.

For AERONET: Africa Barreto Velasco, State Meteorological Agency of Spain (AEMET)

For ORM: responsables of ORM-IAC services





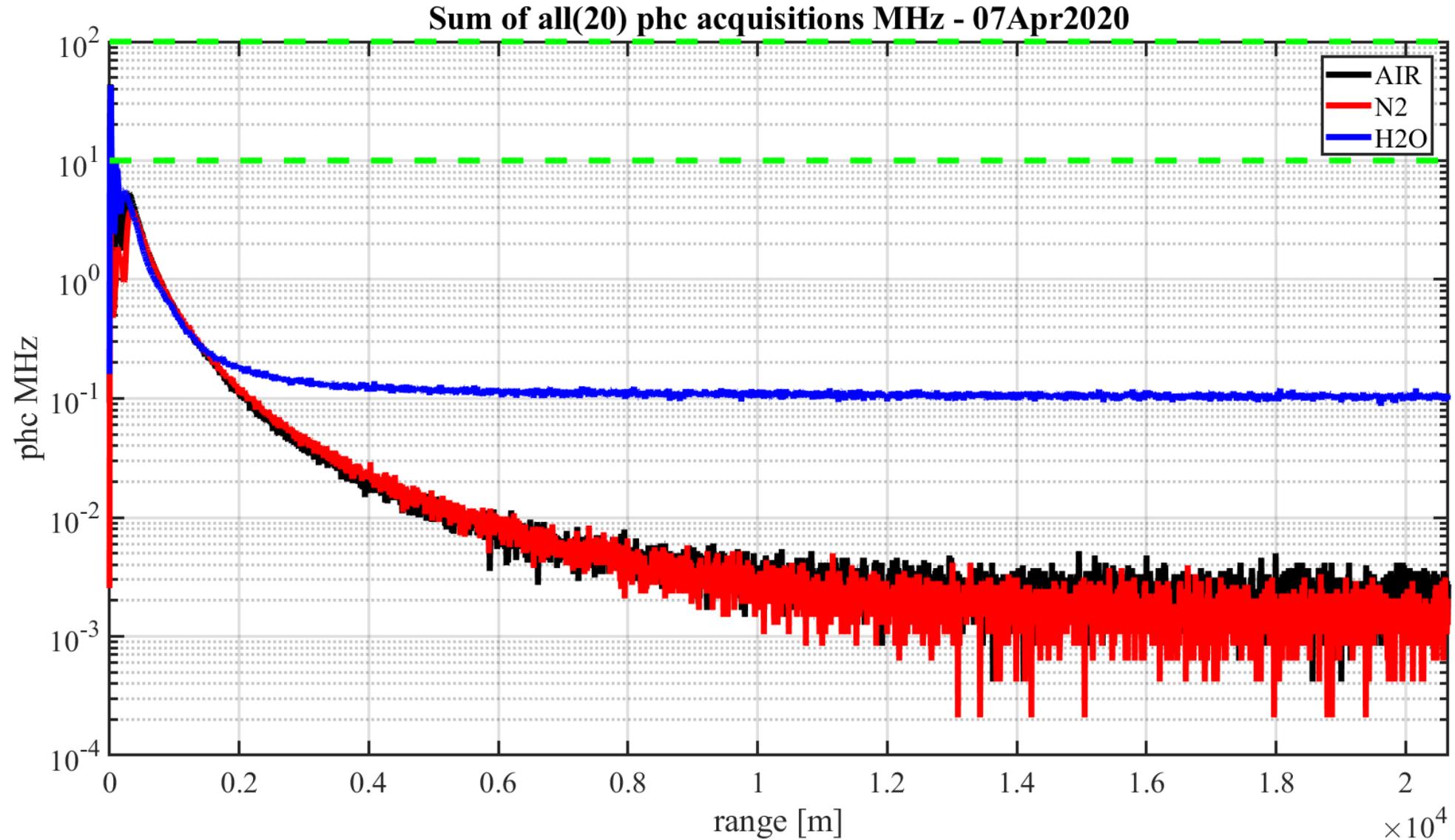
AtmoHEAD 2022, 13 - 15 July (Capri, Italy)

• Performances & Measurements status

One year of measurements summary (automated & unattended):

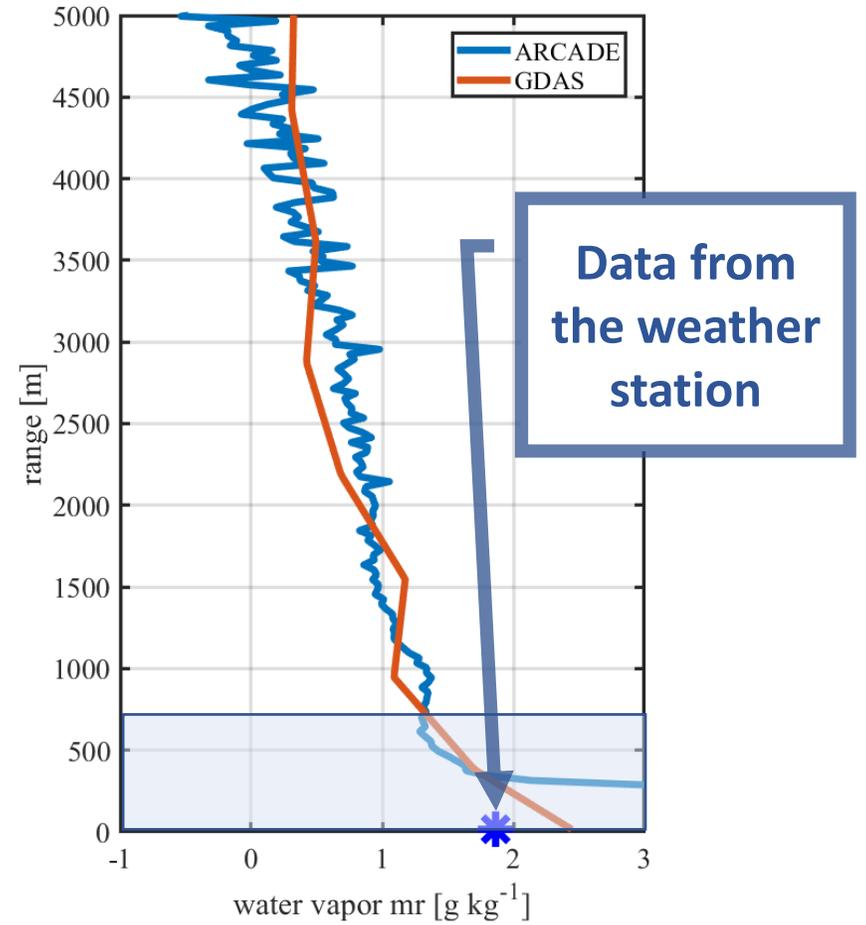
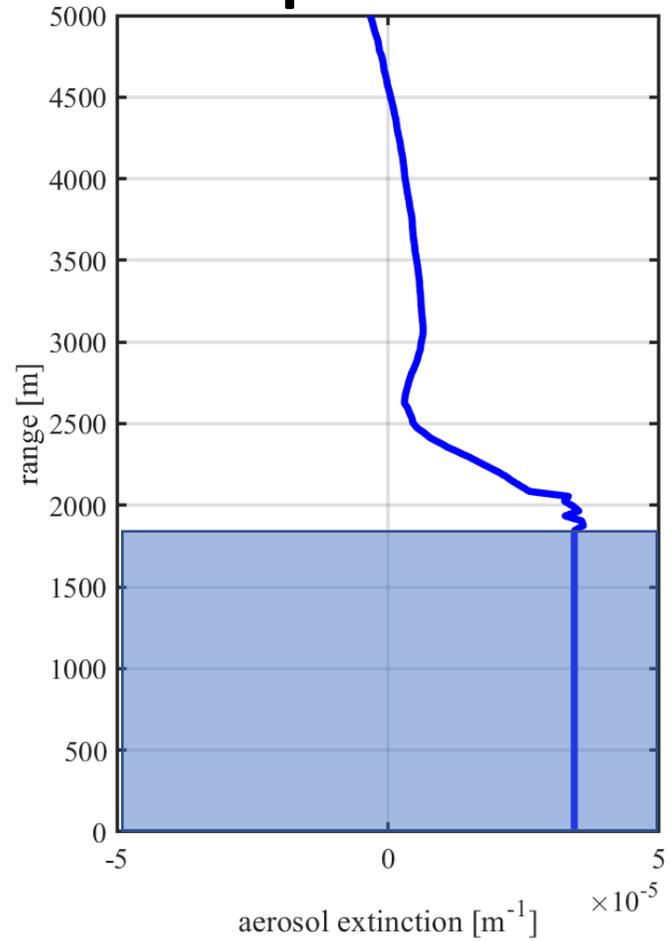
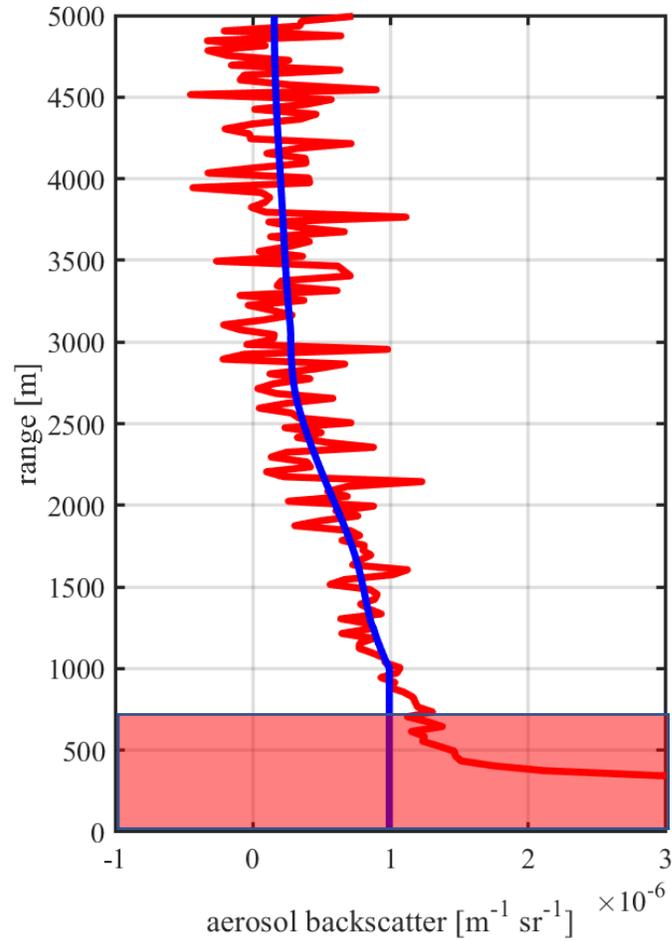
- Schedule: two 15min measurements per day (before dawn and after sunset)
- 1189/1313 days covered with at least one measurement session (17may22)
 - (1048/1318 2x meas., 141 1x meas., no meas. 129/1318)
- 129 days of no measurements. Causes:
 - Mainly bad weather (heavy LLC/fog/rain: automatic no measurements)
 - Computer malfunctions.
 - We had some network problem: no harm to measurements, only delays on data transfer
- Measurement done does not means "good" data (ex. Because dirty exit window, Low level clouds, other hardware problems etc...).
- Required "on site" services not done (last dec 2019) because COVID:
 - Raman channels off since 2021
 - Elastic channel (mainly) ok but SNR no more ideal
 - Other adjustment to be fixed only "on site".

When the Lidar is in a good shape...



... nevertheless we should face the limitation caused by overlap function...

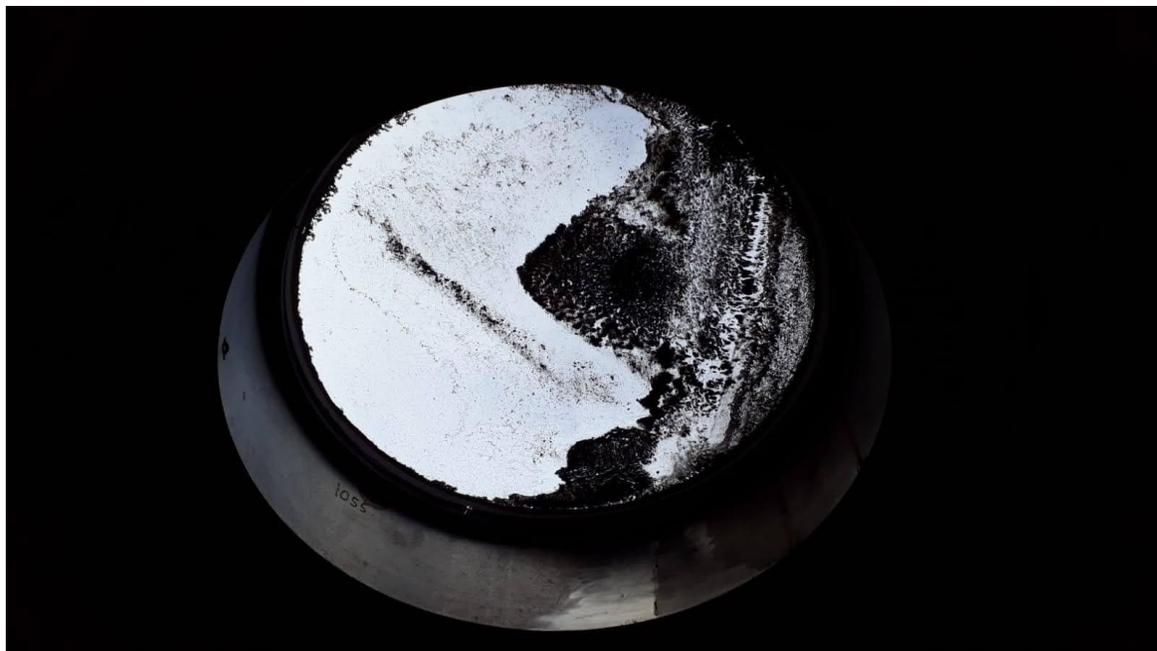
7 April 2020



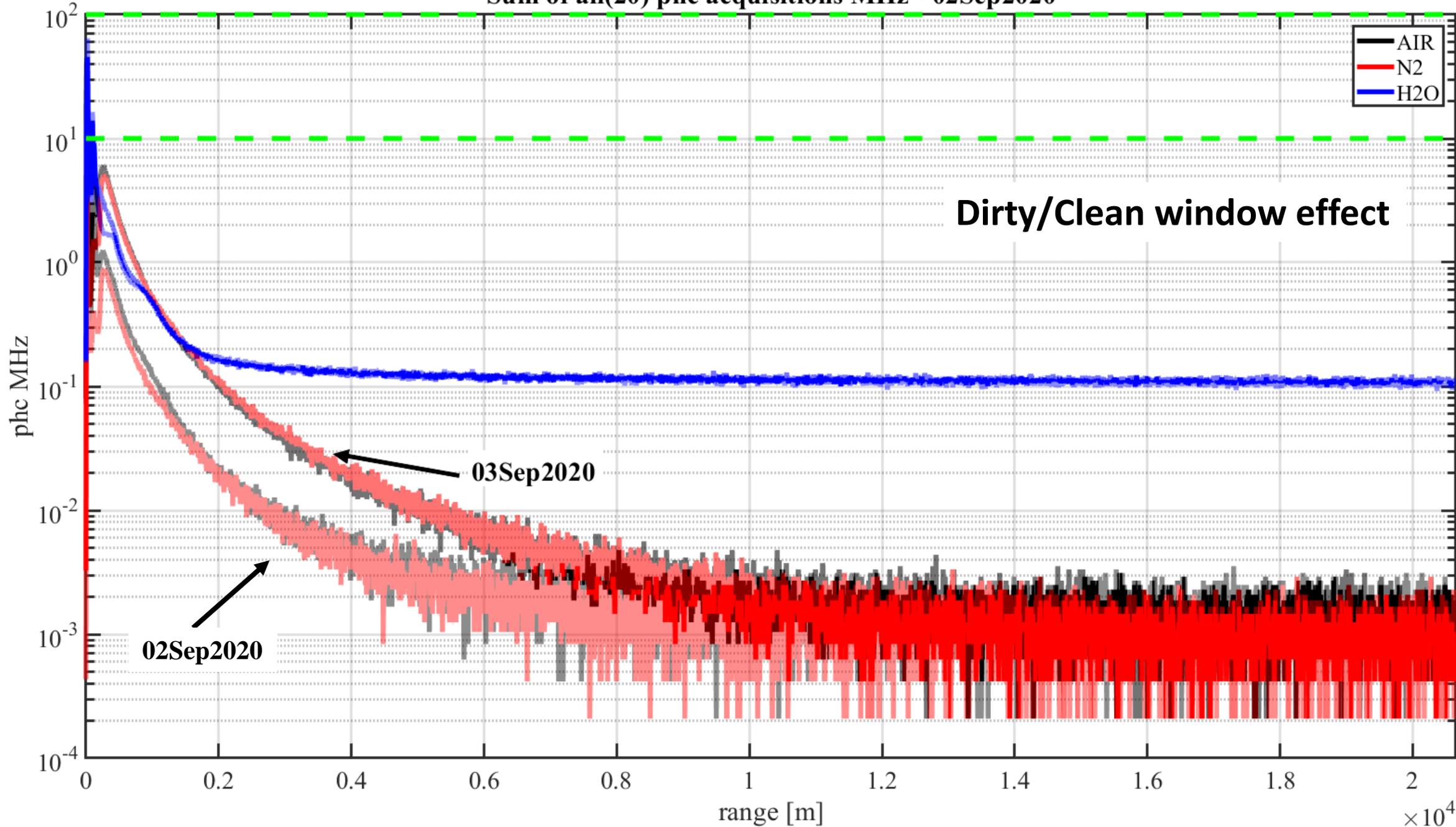


Other problems...
Saharan Dust/Volcano
effect on the exit window.
...before and after...

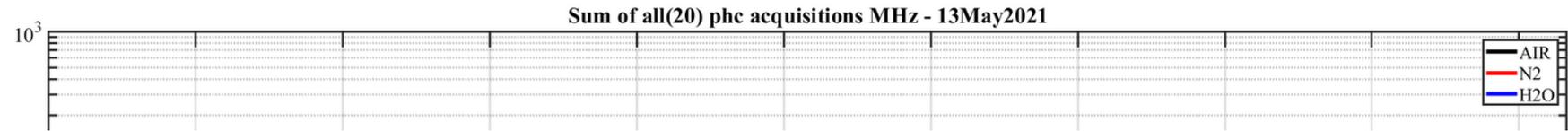
Thanks!



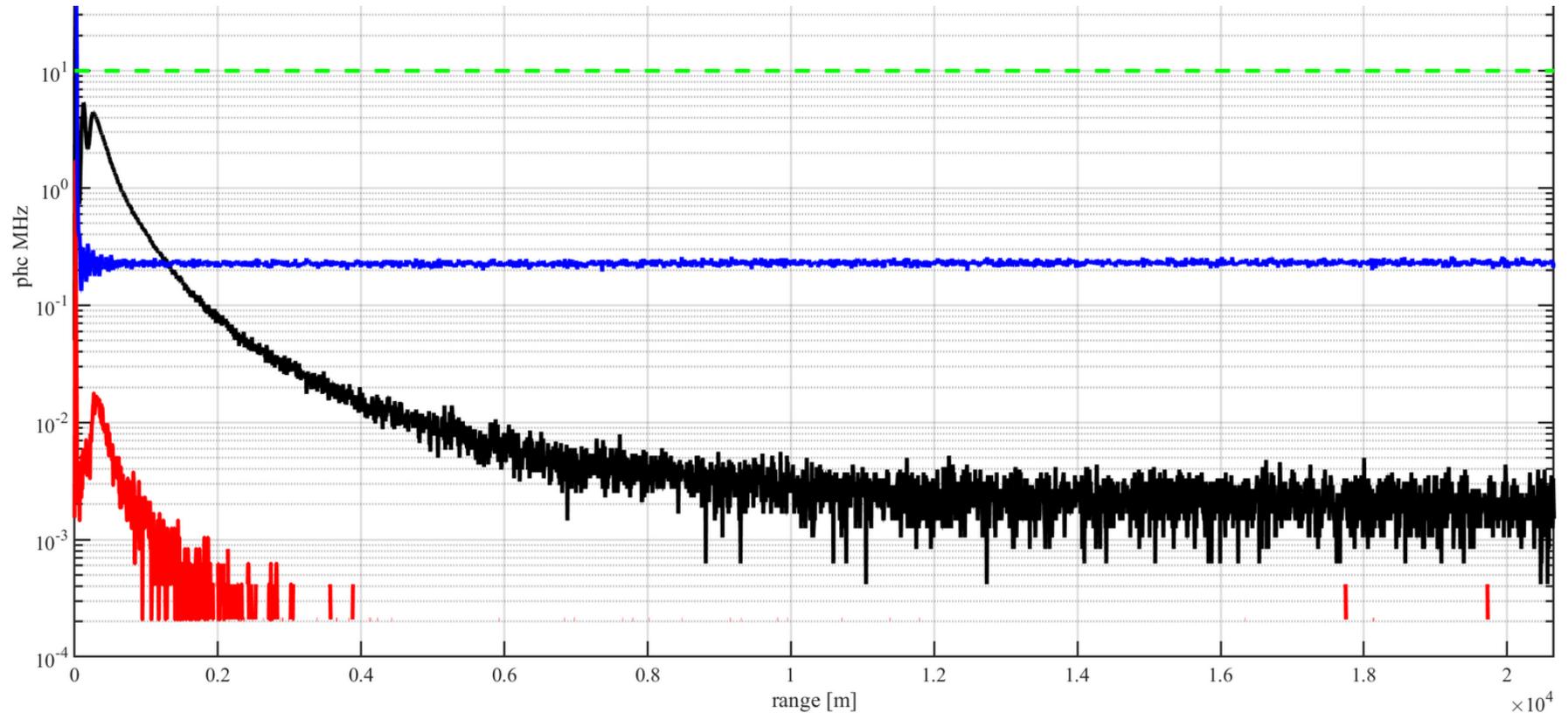
Sum of all(20) phc acquisitions MHz - 02Sep2020

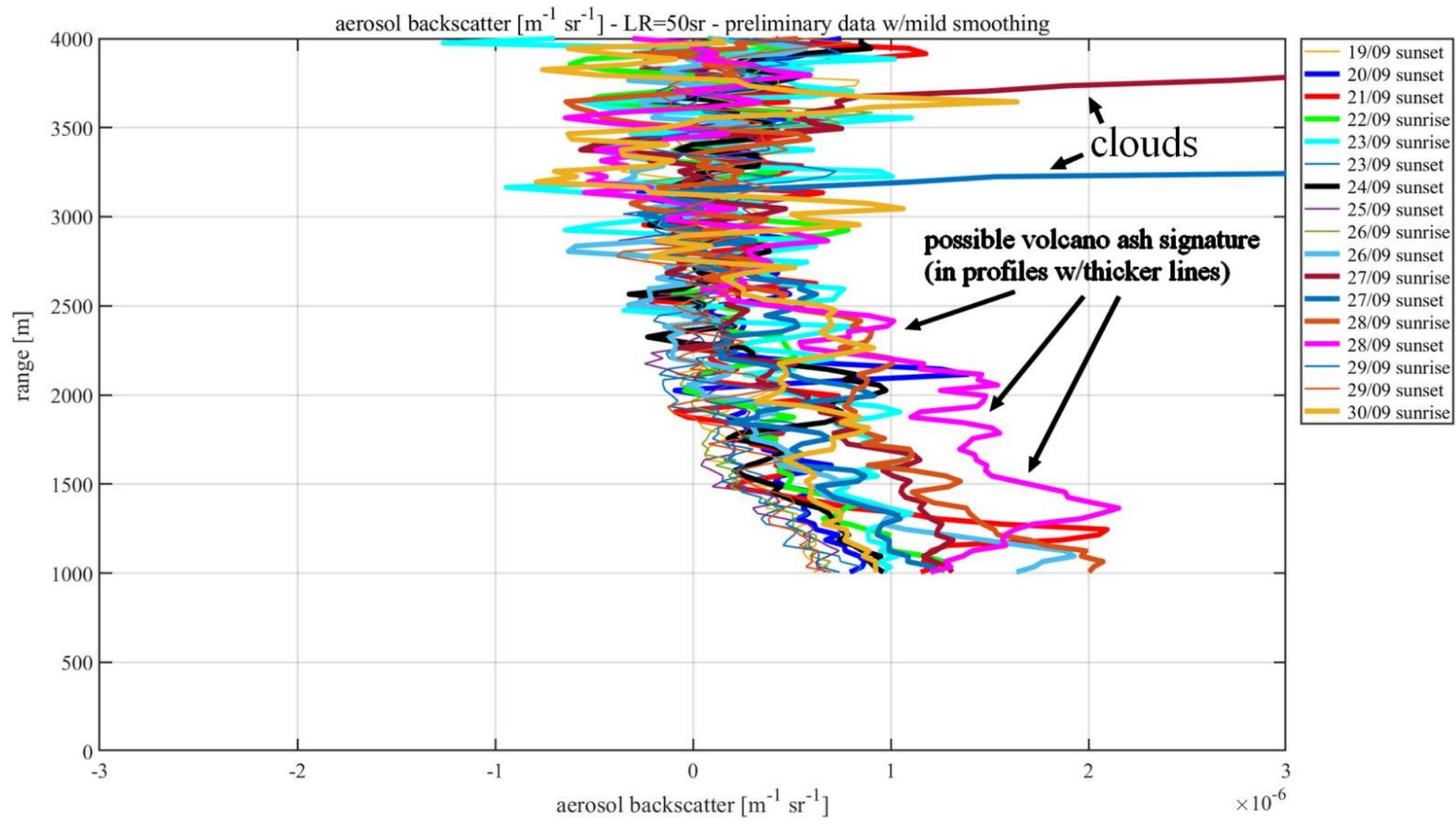


When the Lidar is NOT in a good shape... but the aerosol backscatter profile @355nm can be still retrieved from the elastic signal...

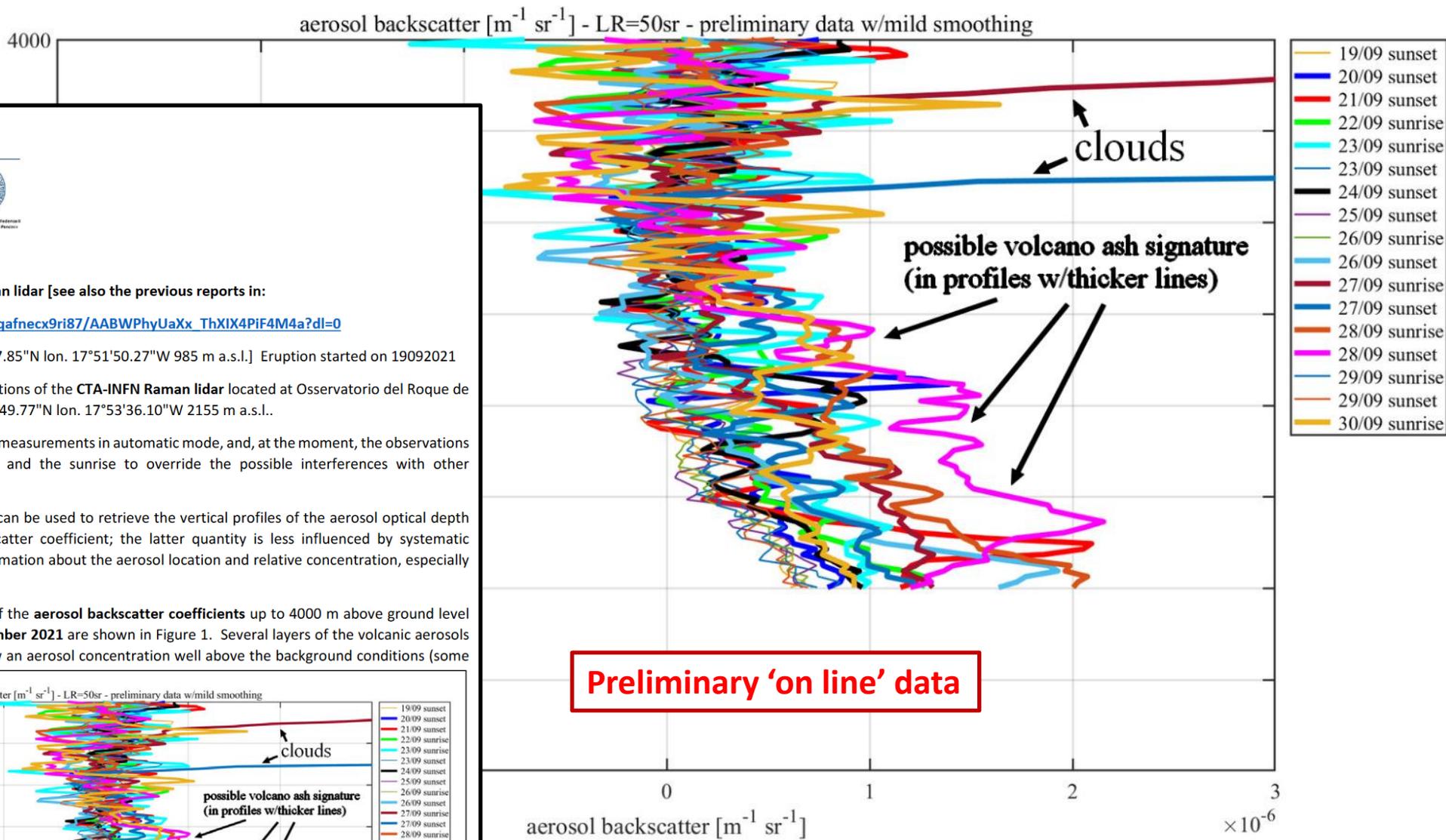


In 2021 the Raman channels experienced malfunctioning and no longer provide aerosol/water vapor profiles.





Cumbre Vieja eruption



ARCADE Raman lidar

Report 15102021 – CTA-INFN Raman lidar [see also the previous reports in:
https://www.dropbox.com/sh/rccqafnecx9ri87/AABWPhyUaXx_ThXIX4PiF4M4a?dl=0]

Cumbre Vieja volcano [lat. 28°36'57.85"N lon. 17°51'50.27"W 985 m a.s.l.] Eruption started on 19092021

This is a short report of the observations of the CTA-INFN Raman lidar located at Osservatorio del Roque de Los Muchachos (ORM) at lat. 28°45'49.77"N lon. 17°53'36.10"W 2155 m a.s.l.

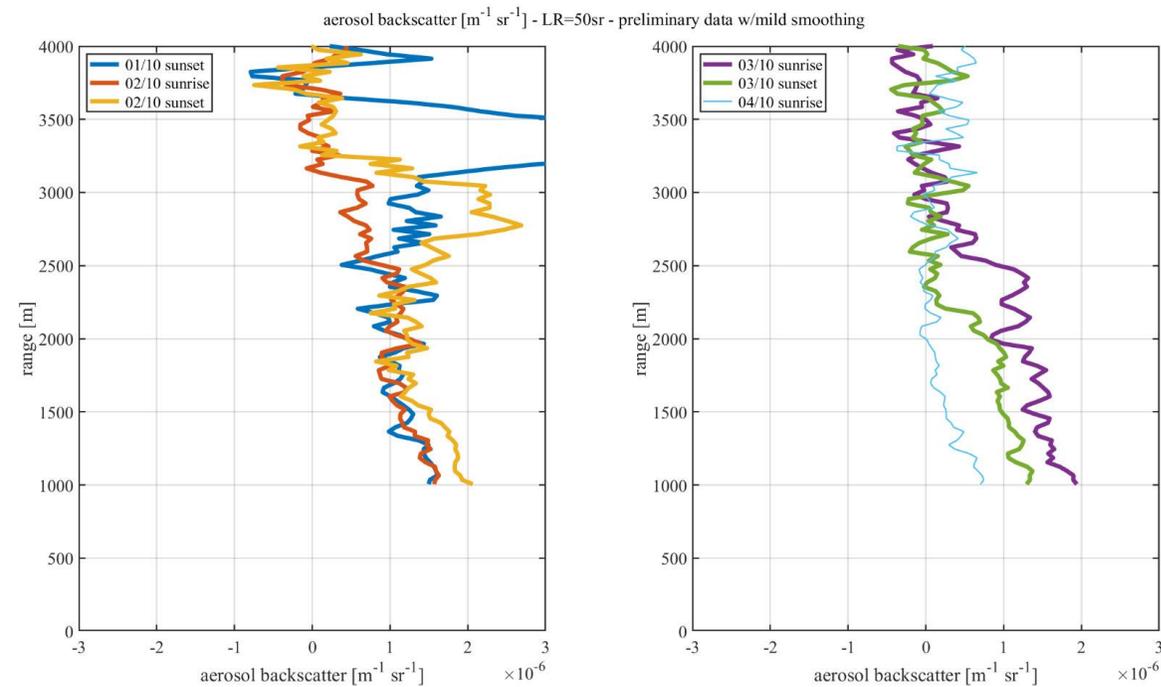
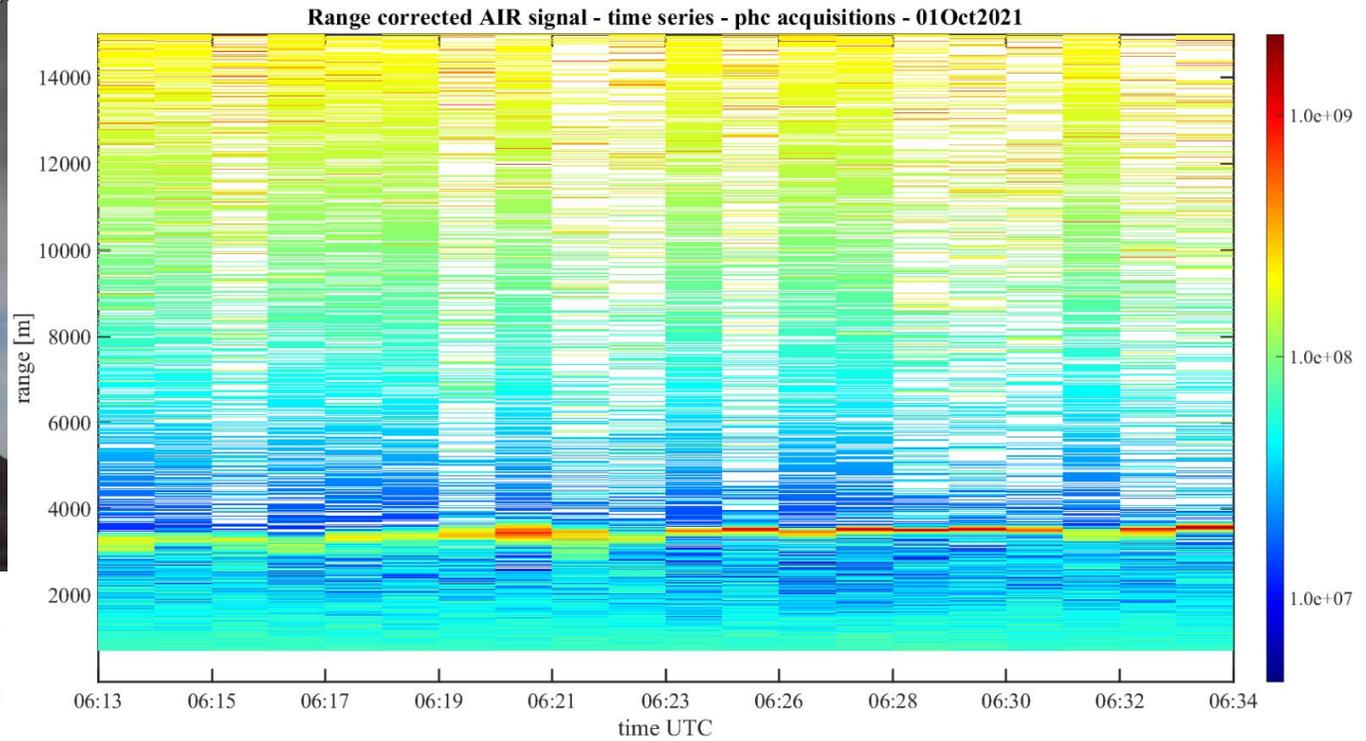
The CTA-INFN Raman lidar is taking measurements in automatic mode, and, at the moment, the observations are scheduled around the sunset and the sunrise to override the possible interferences with other experiments at ORM.

The CTA-INFN Raman lidar signals can be used to retrieve the vertical profiles of the aerosol optical depth and of the aerosol volume backscatter coefficient; the latter quantity is less influenced by systematic uncertainties, and gives direct information about the aerosol location and relative concentration, especially in the cases of high aerosol load.

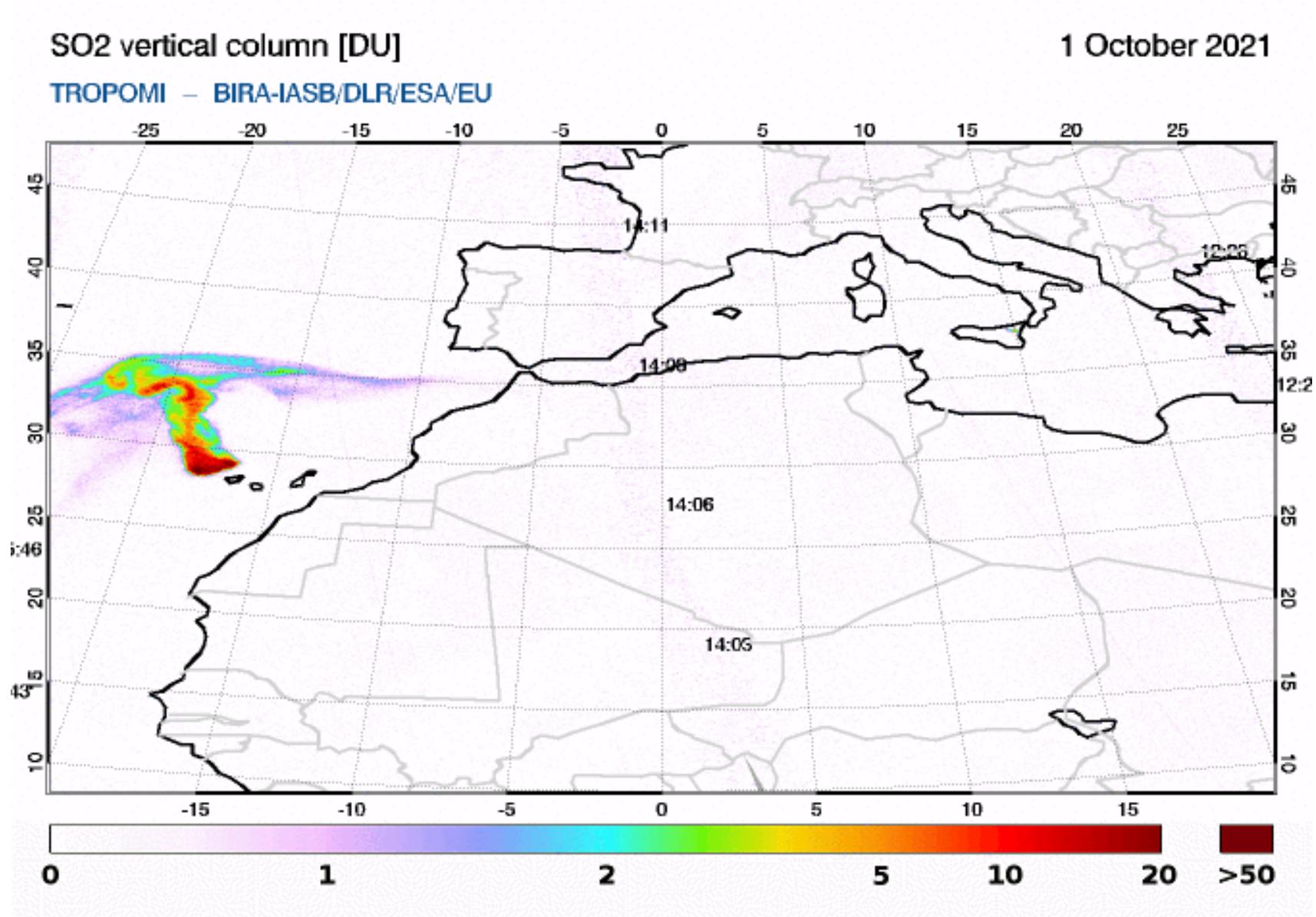
The (preliminary) vertical profiles of the aerosol backscatter coefficients up to 4000 m above ground level (a.g.l.) in the period 19 – 30 September 2021 are shown in Figure 1. Several layers of the volcanic aerosols have been detected, and they show an aerosol concentration well above the background conditions (some

Cumbre Vieja eruption

Preliminary 'on line' data



Cumbre Vieja eruption

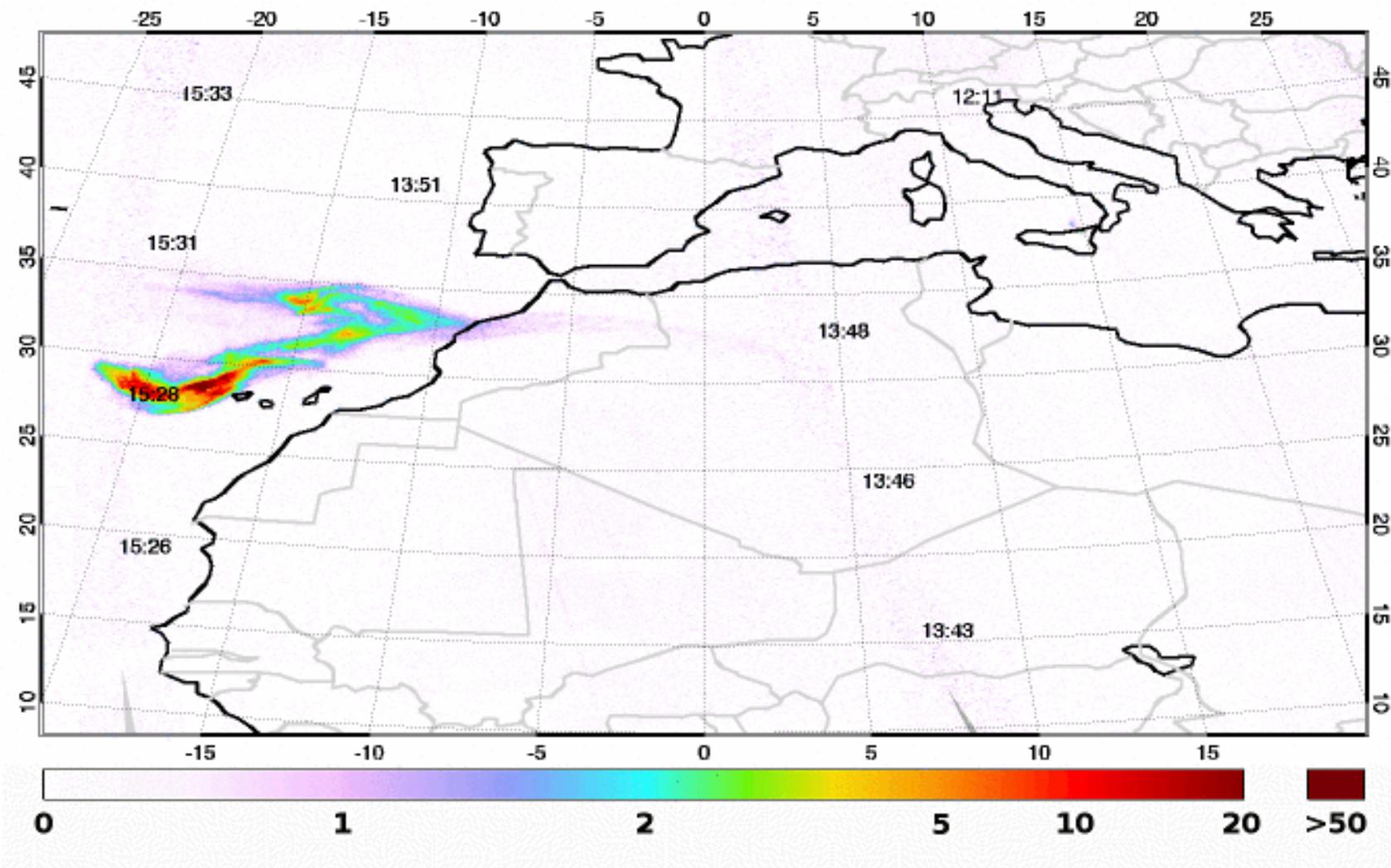


Cumbre Vieja eruption

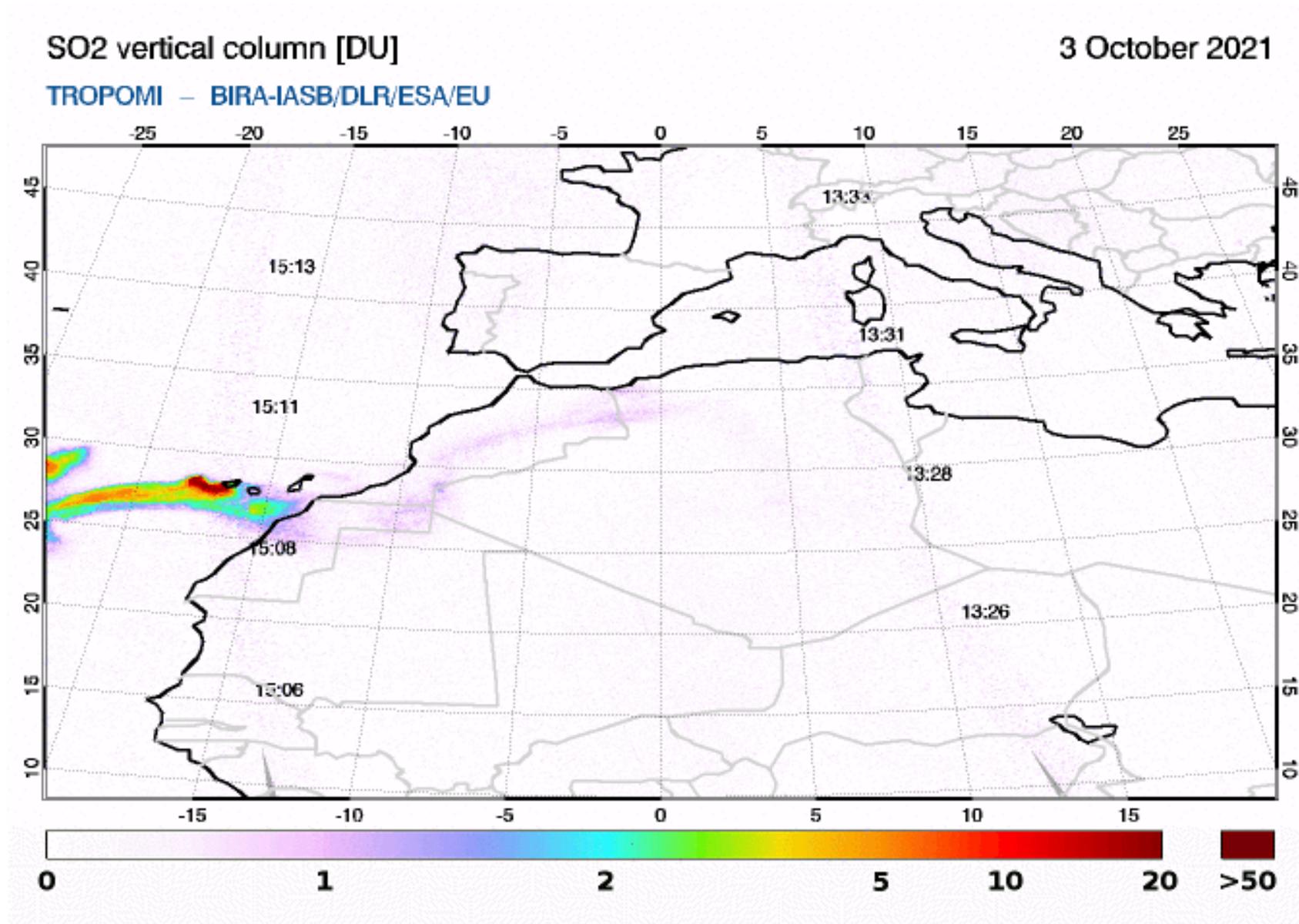
SO₂ vertical column [DU]

2 October 2021

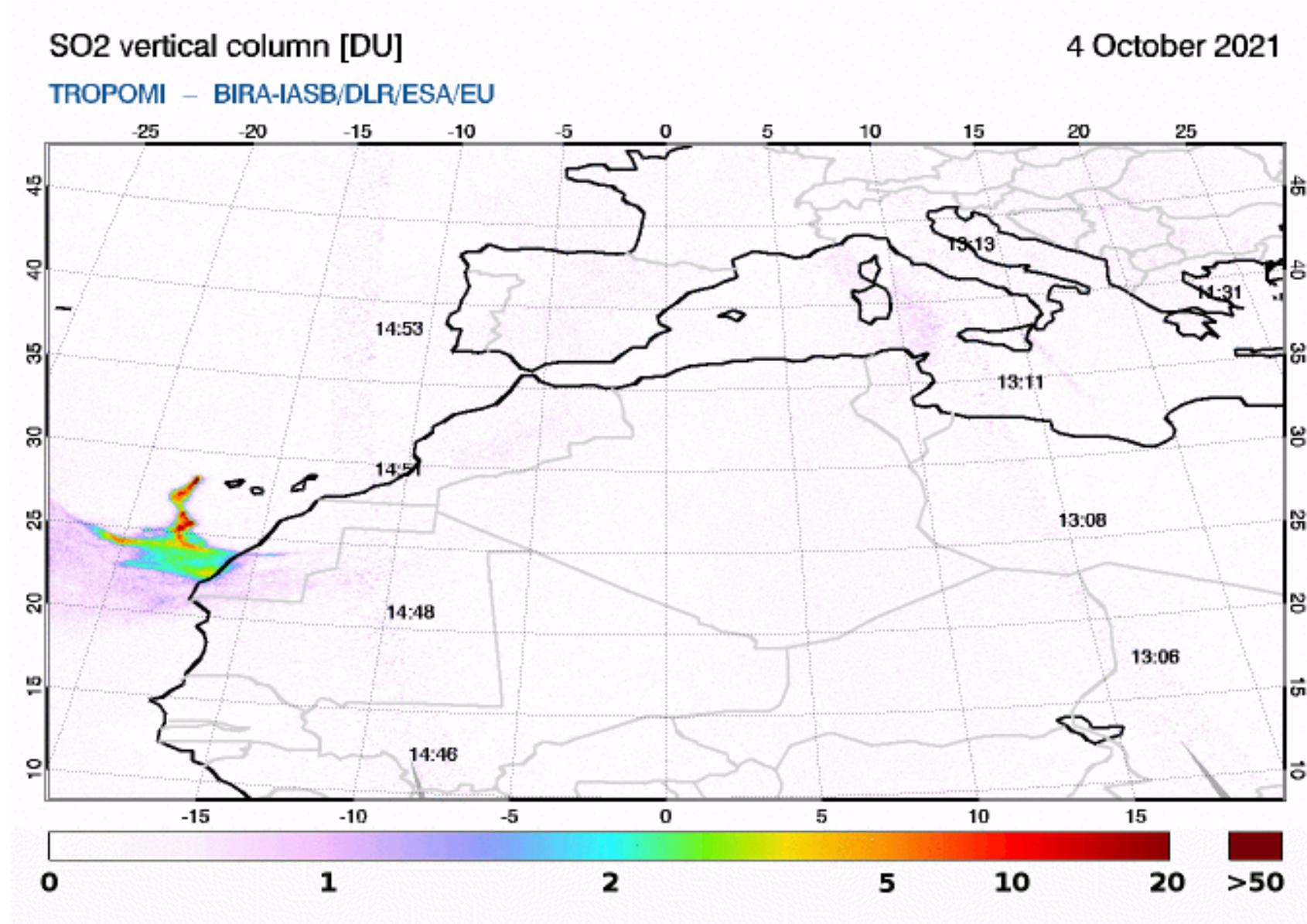
TROPOMI – BIRA-IASB/DLR/ESA/EU



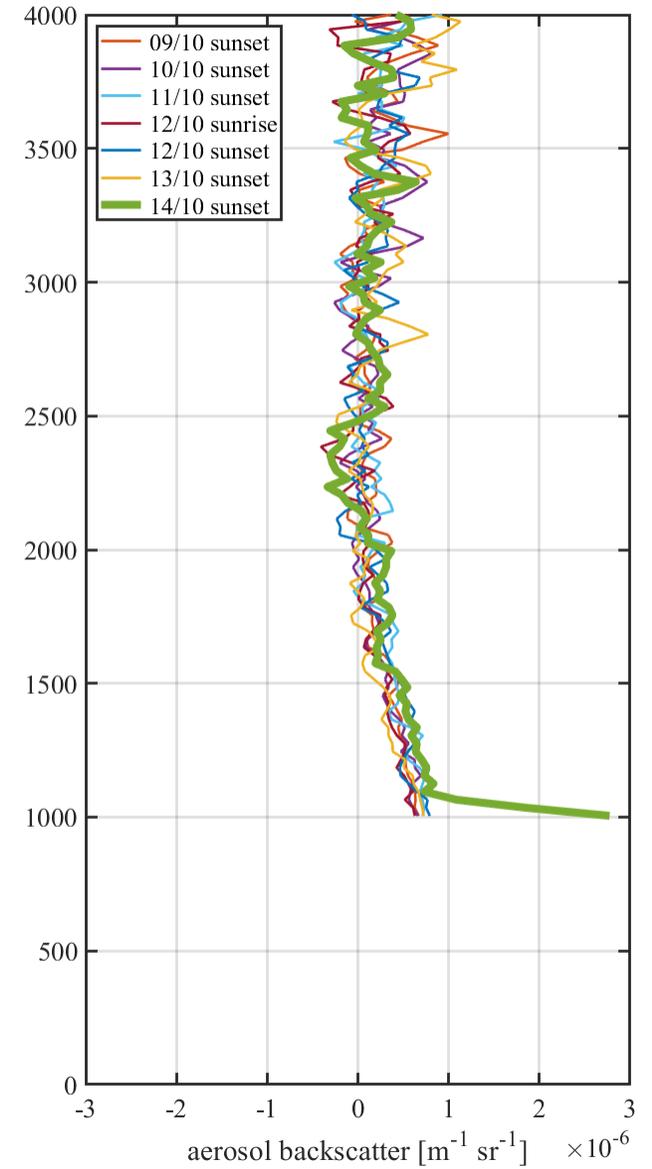
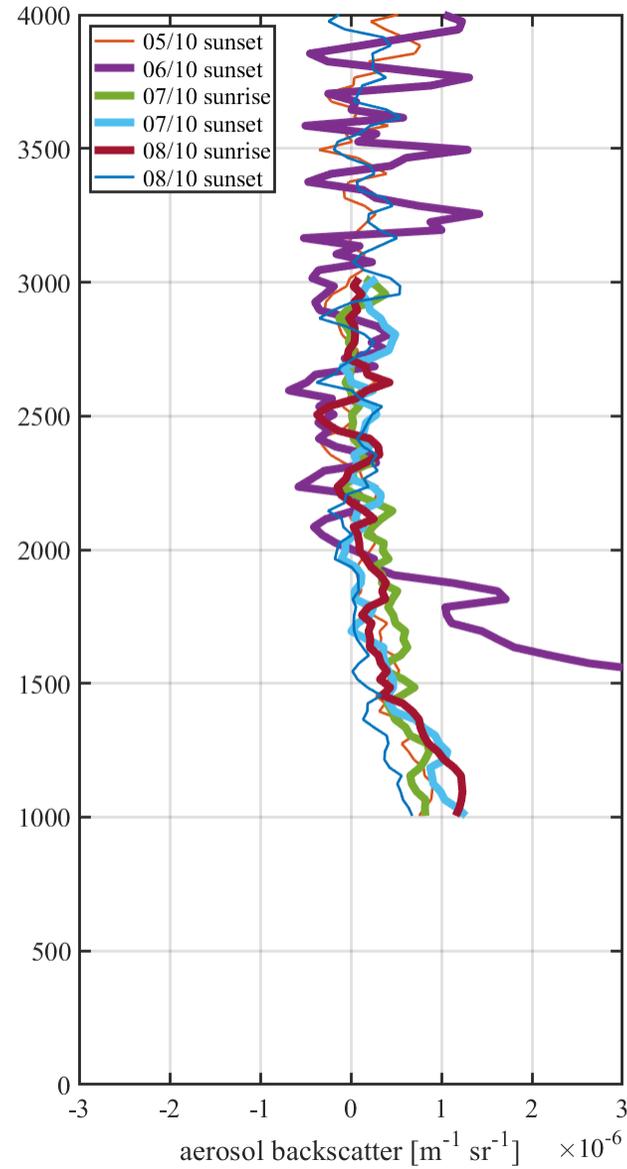
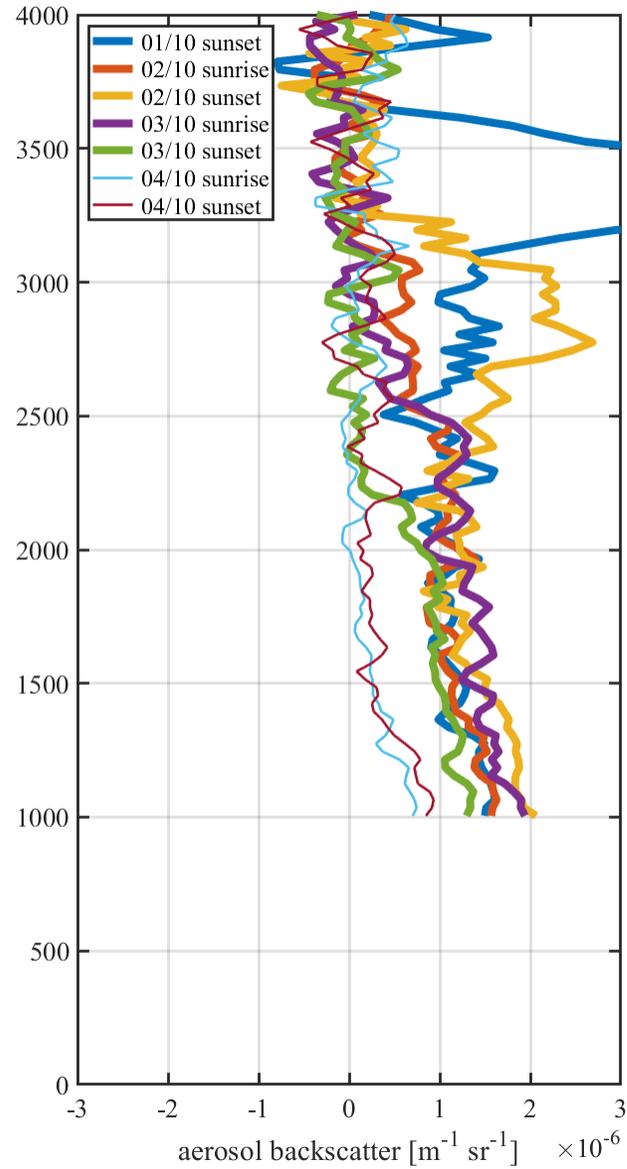
Cumbre Vieja eruption



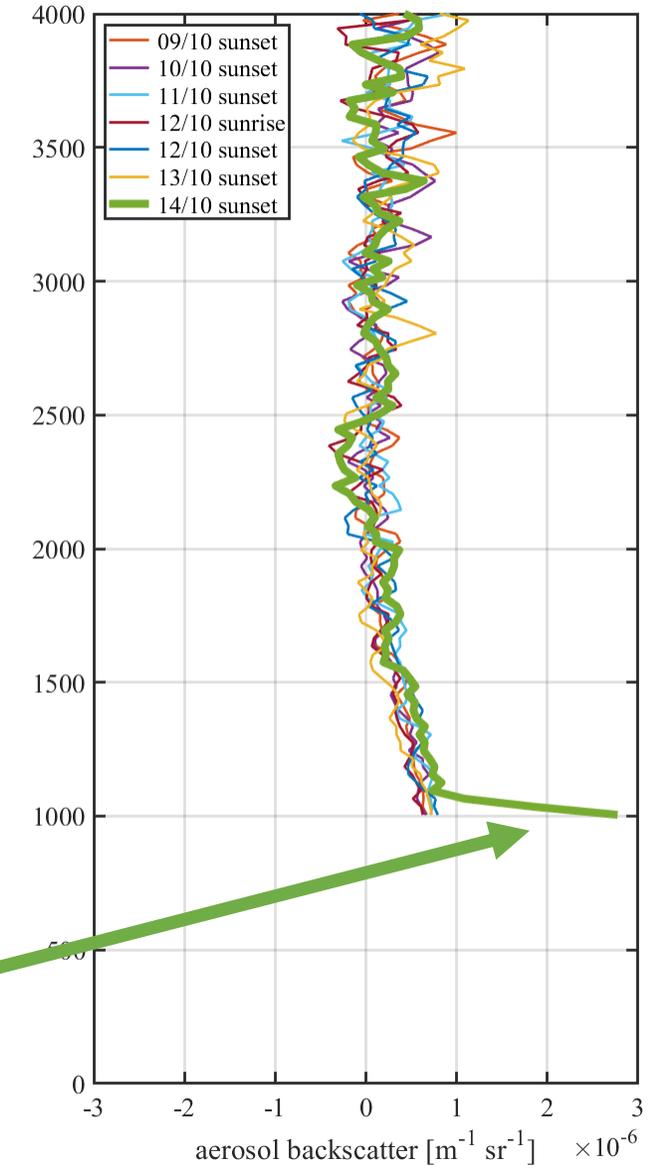
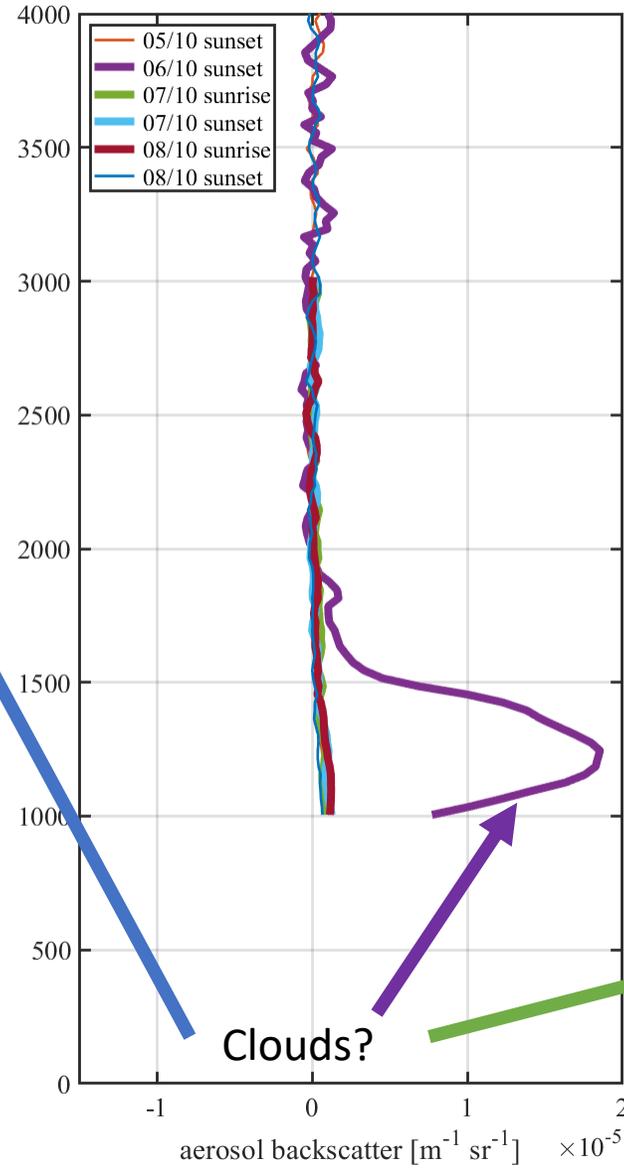
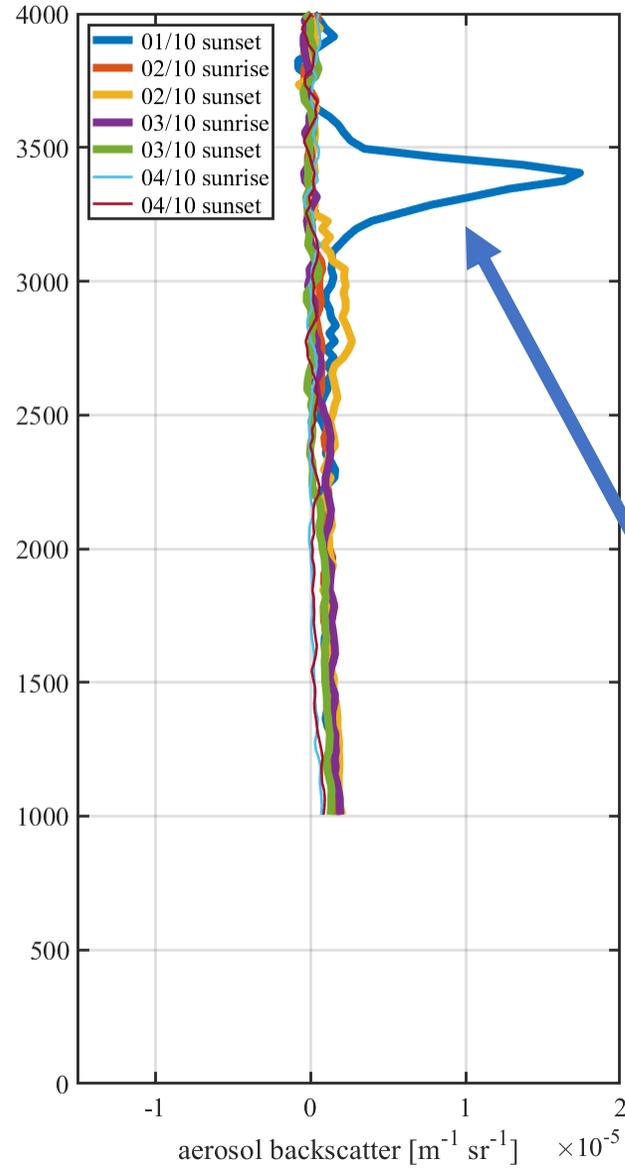
Cumbre Vieja eruption



aerosol backscatter [$\text{m}^{-1} \text{sr}^{-1}$] - LR=50sr - preliminary data w/mild smoothing

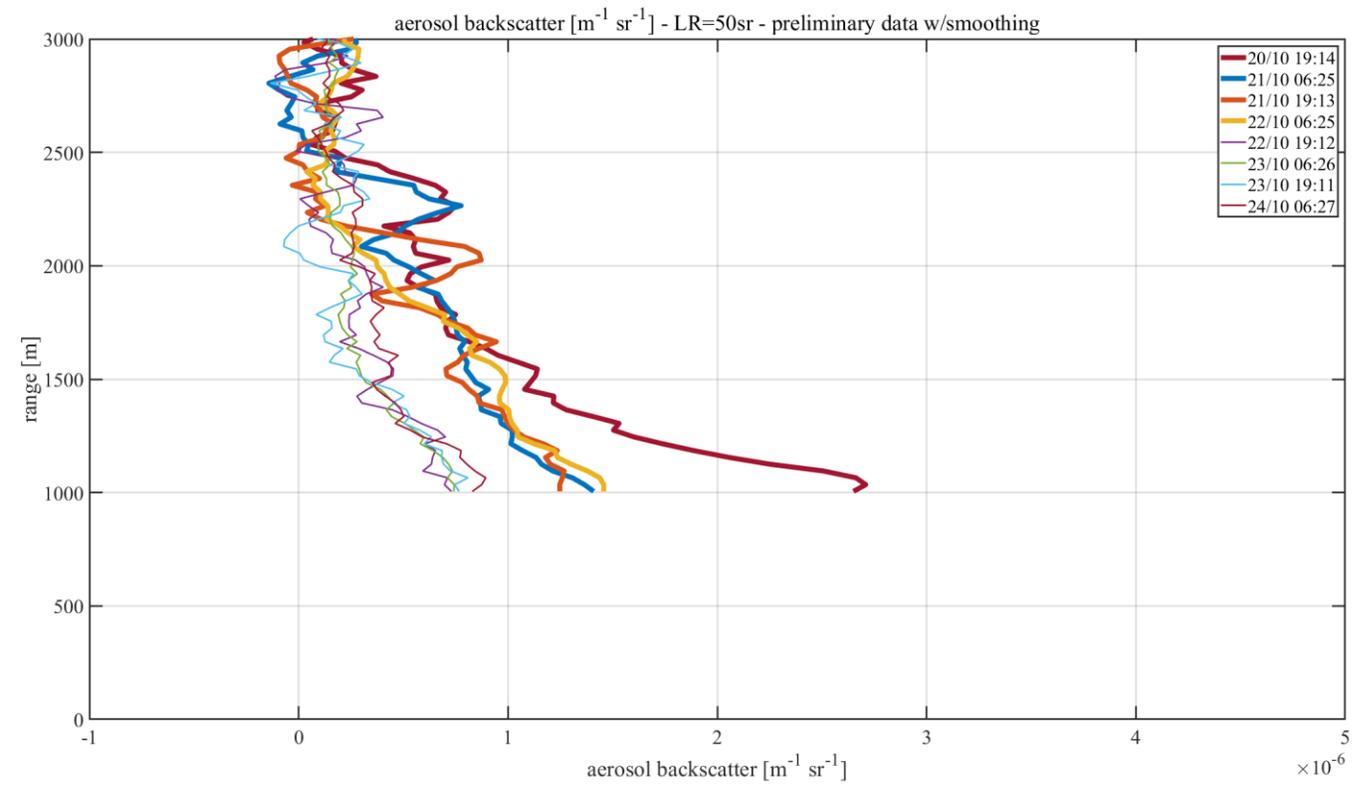
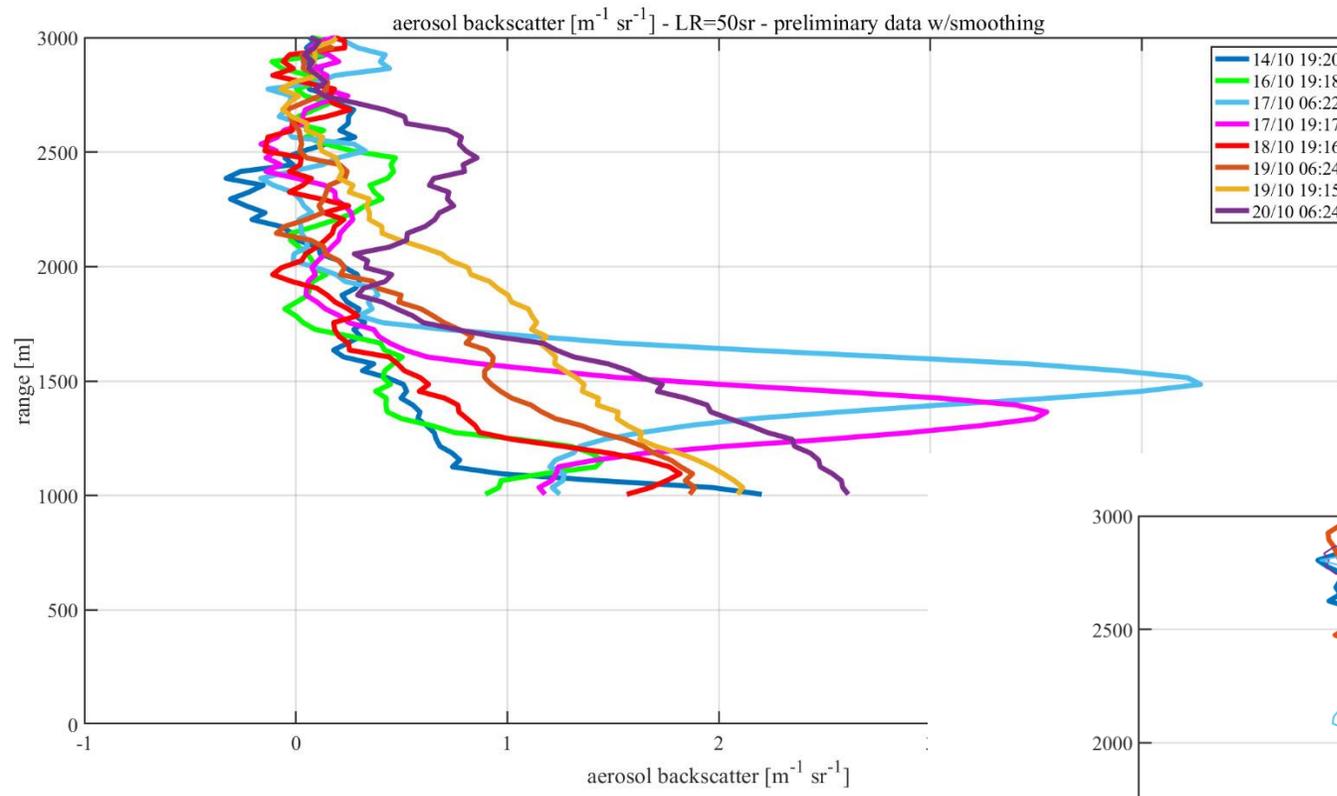


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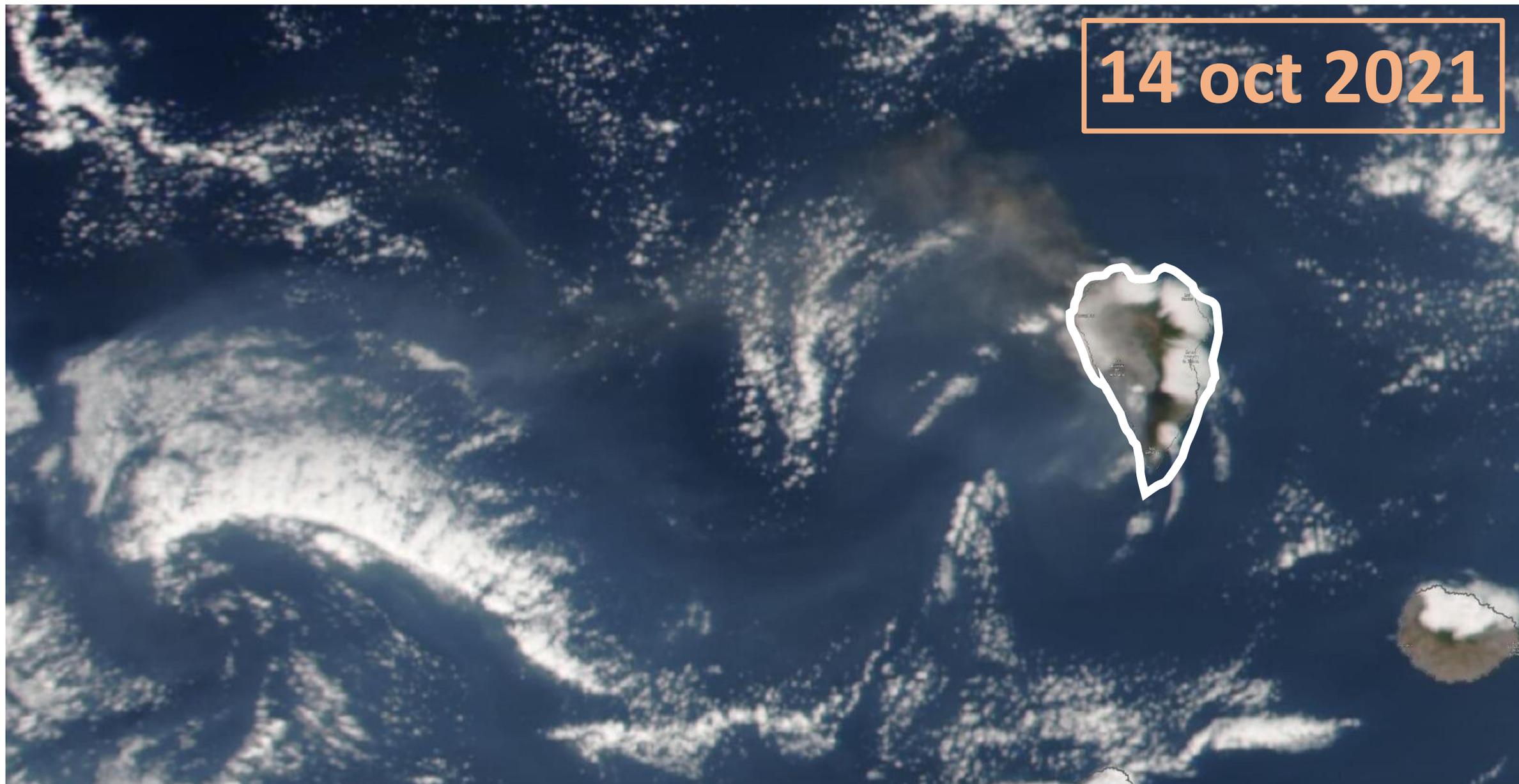


Cumbre Vieja eruption

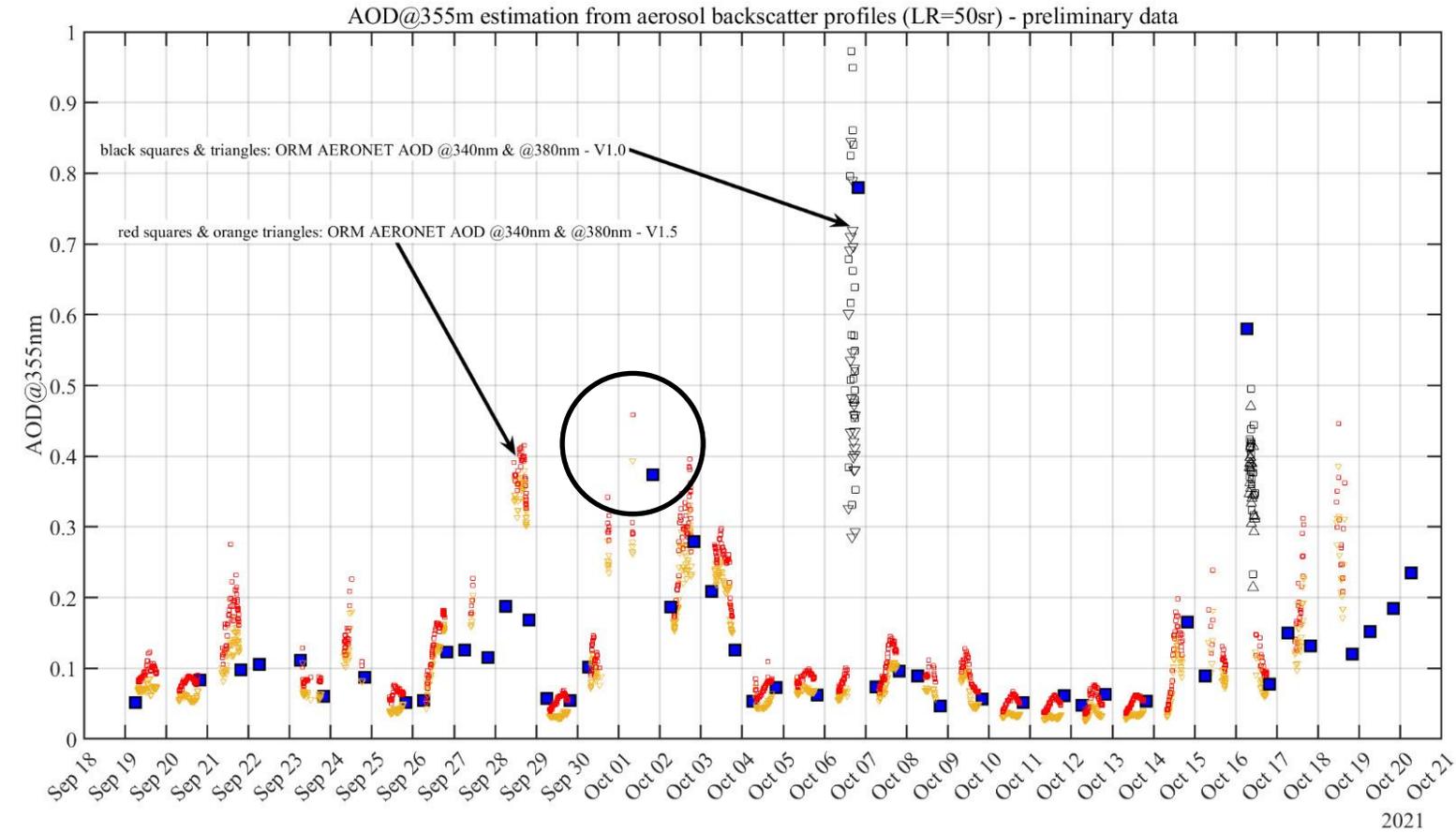
Preliminary 'on line' data



Cumbre Vieja eruption

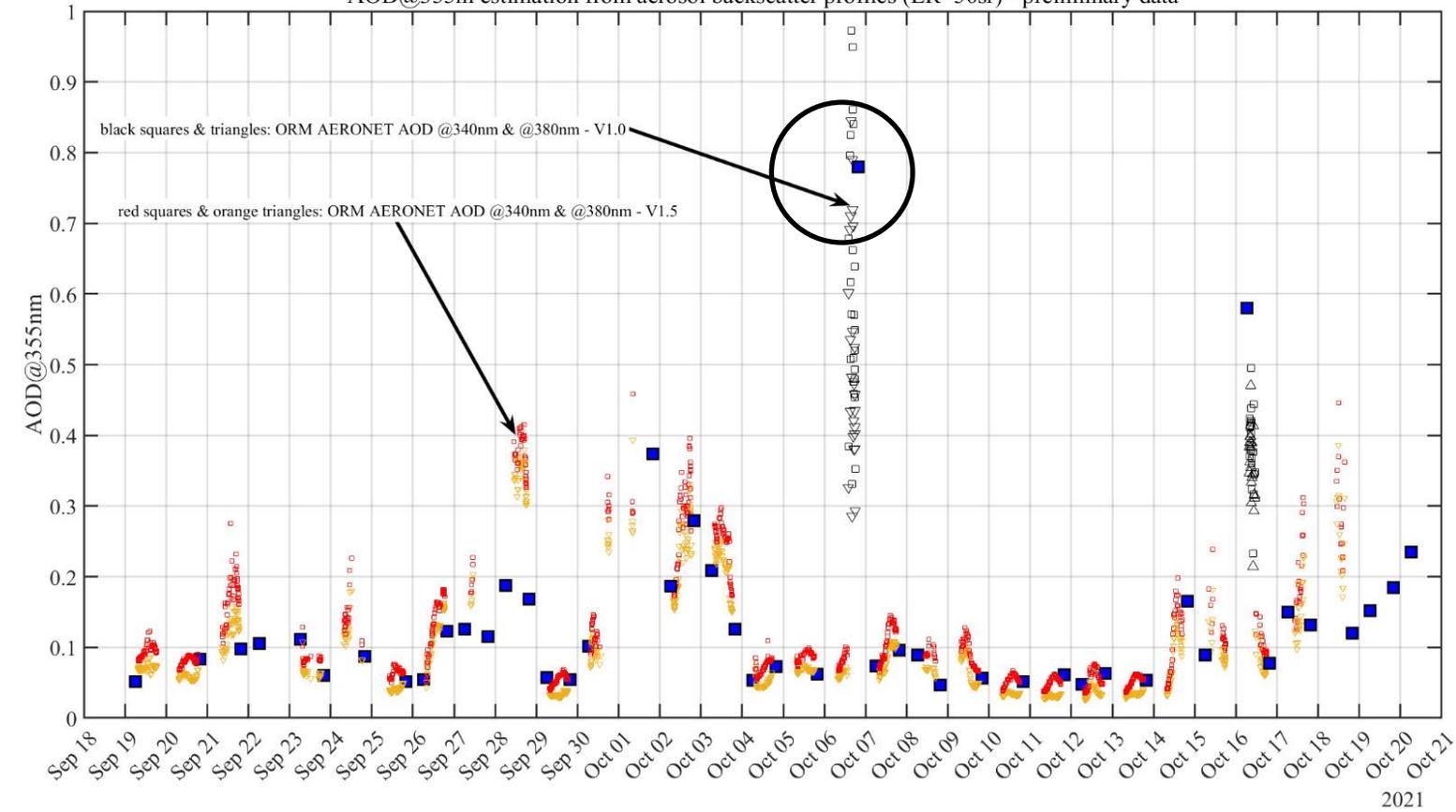


...and we become aware that AERONET data are available @ORM

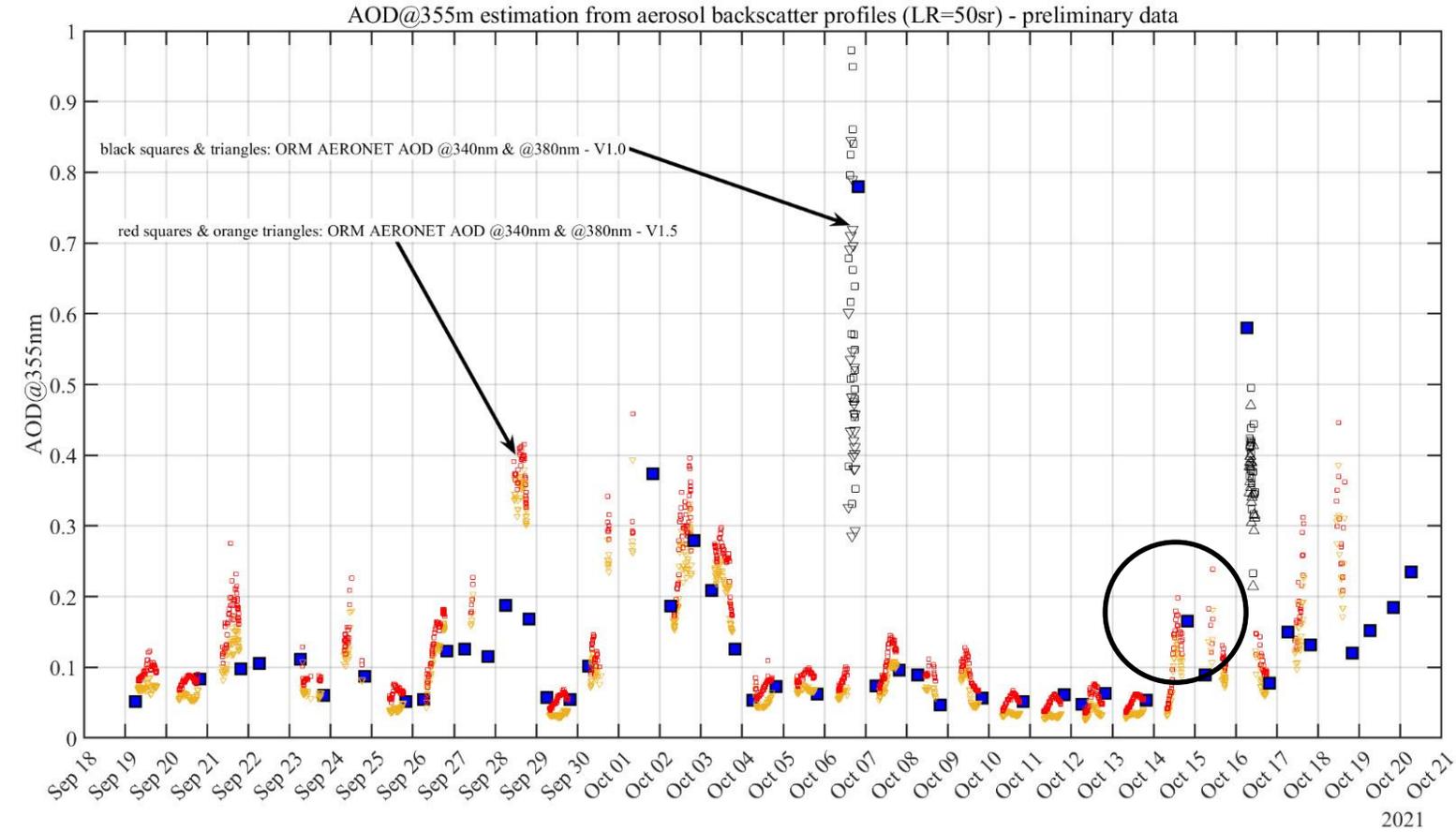


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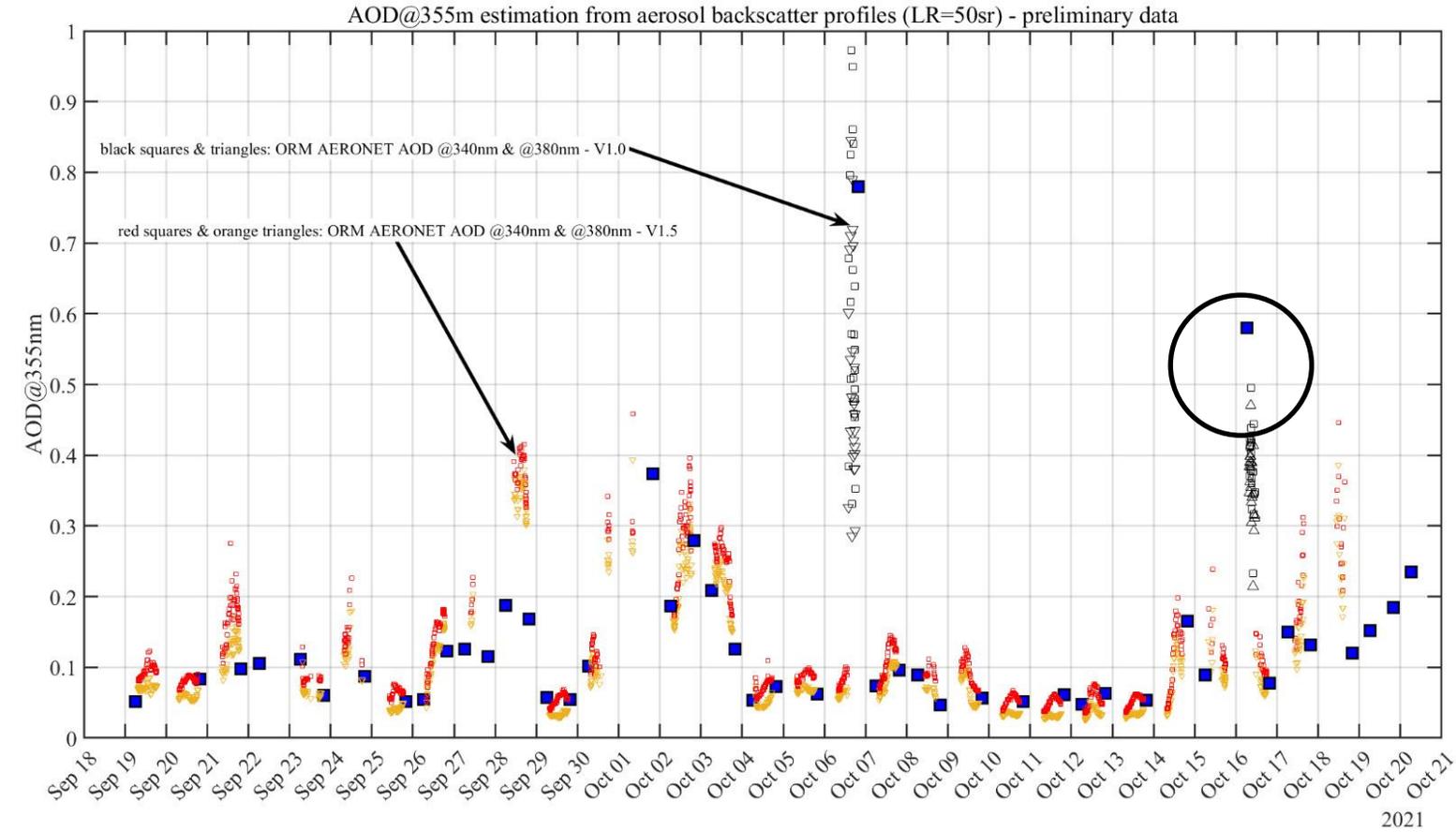
AOD@355nm estimation from aerosol backscatter profiles (LR=50sr) - preliminary data



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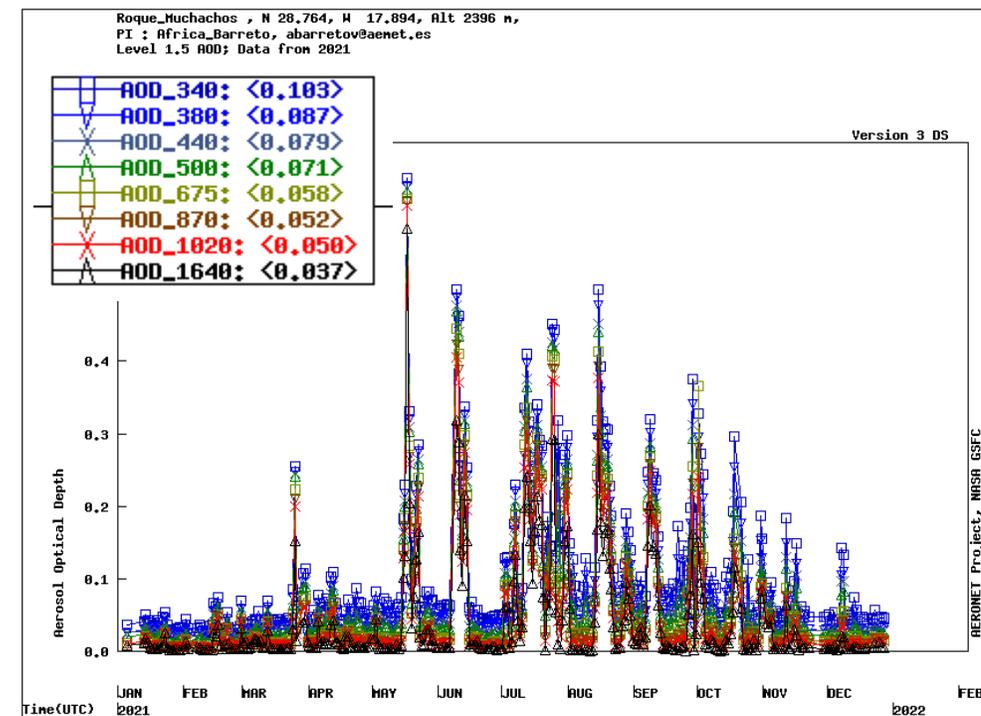
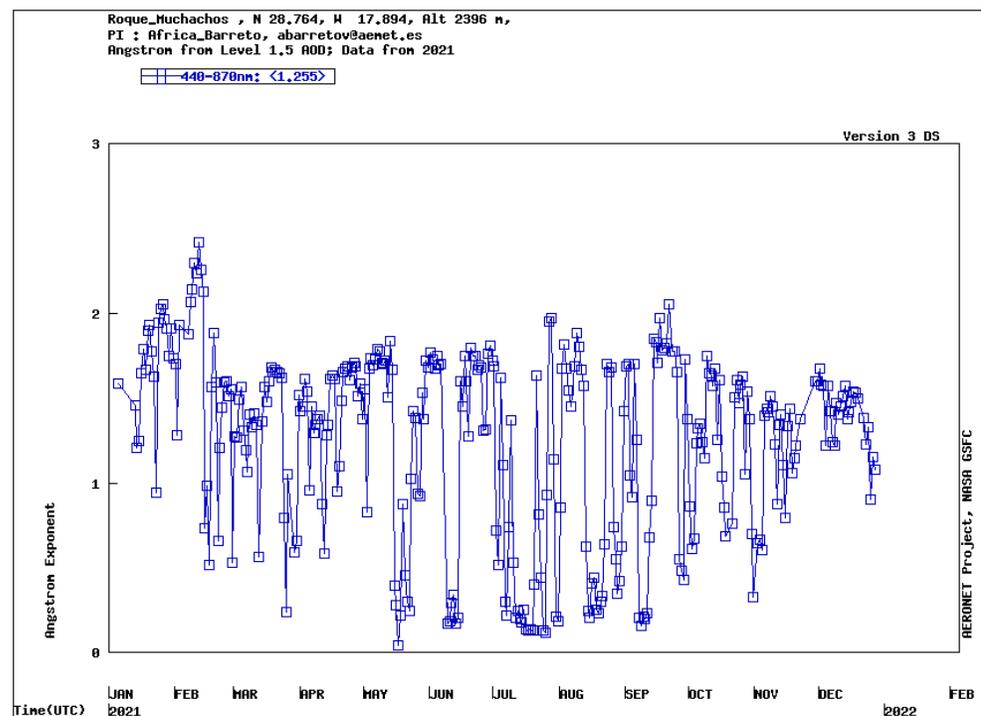


... and we exploit those data for:

- Extended intercomparison with LIDAR data
- Cloud id
- LIDAR aerosol retrieval tentative optimization

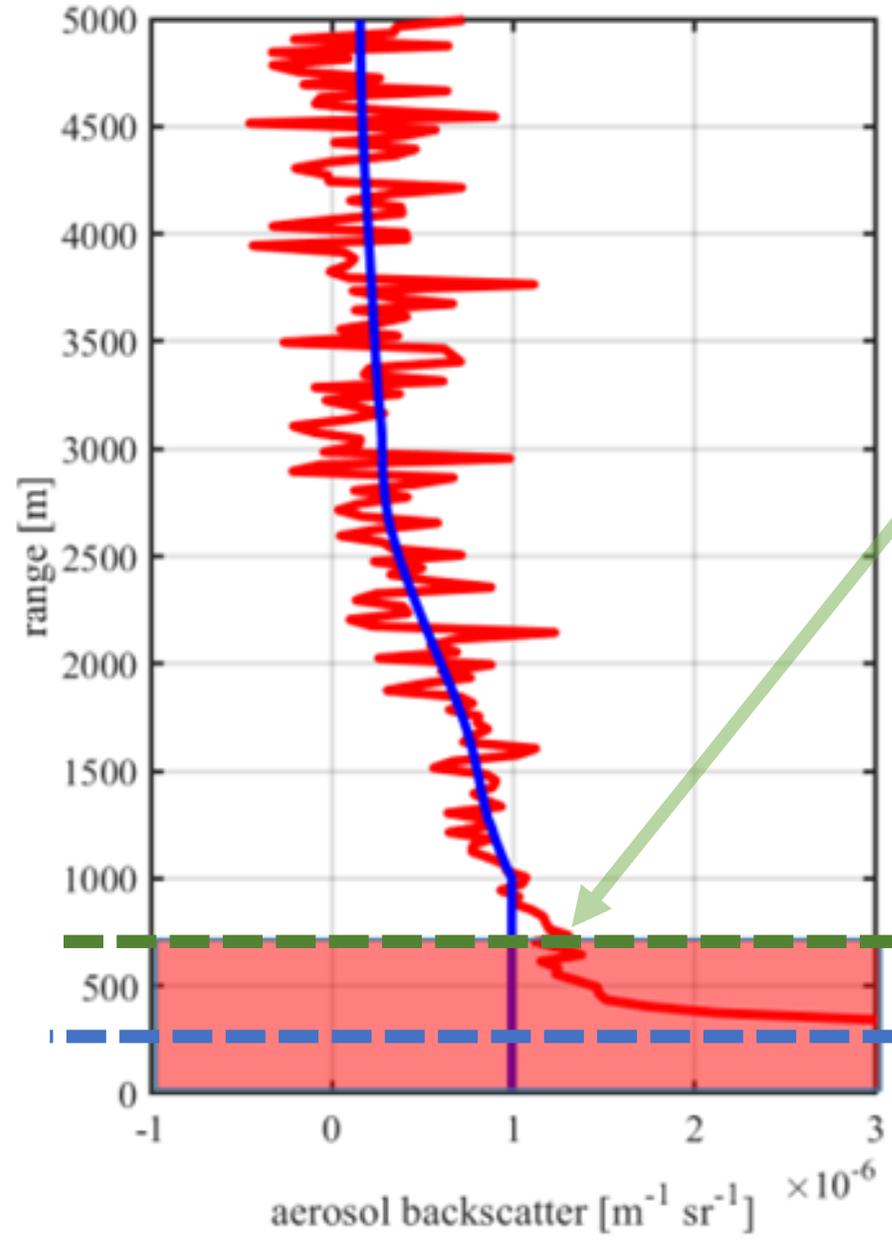
Roque_Muchachos AERONET site

Site Coordinates and Elevation:	<ul style="list-style-type: none">• Latitude: 28.76390° North• Longitude: 17.89390° West• Elevation: 2396.0 Meters
Site Description:	<ul style="list-style-type: none">• Roque_Muchachos site is a high-mountain station located on the rim of the Taburiente National Park in the municipality of Garafia (La Palma). The photometer is installed at the Roque de los Muchachos Observatory, belonging to the Instituto de Astrofísica de Canarias (IAC). The site currently hosts the largest optical-infrared telescope in the world, along with twenty other telescopes and instruments for various kinds of studies, including nocturnal observations, robotic observing, solar physics, and high energy astrophysics.



- LIDAR Aerosol retrieval optimized with AOD & ang exp from AERONET (stratification)

Optimization for simultaneous ($\Delta t < 3h$) AERONET/Lidar measurements



beta@AERONET(stratification):
from **beta@Rov**(WM)

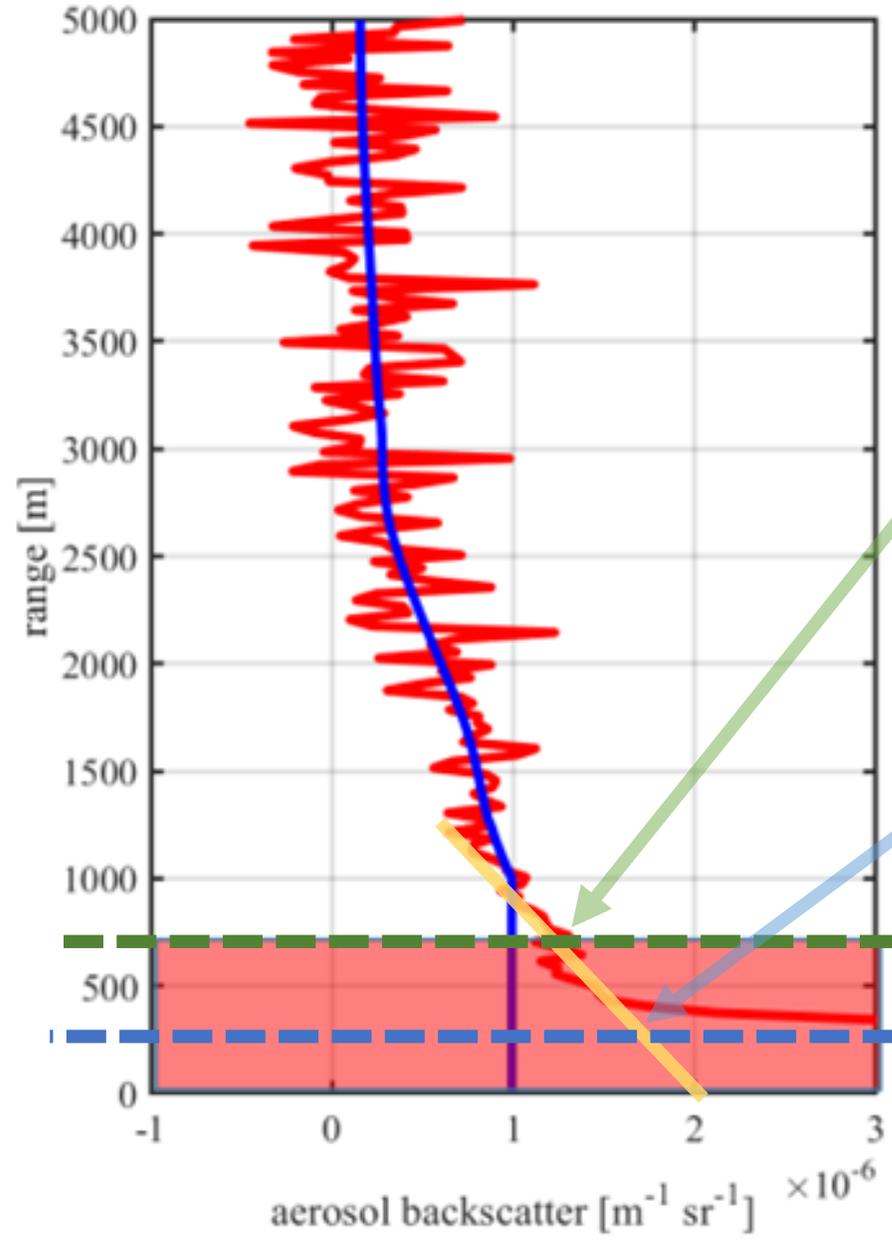
LR:
from 20sr to 90sr

— Rov: for $R > Rov$ overlap=1

— AERONET range (241m)

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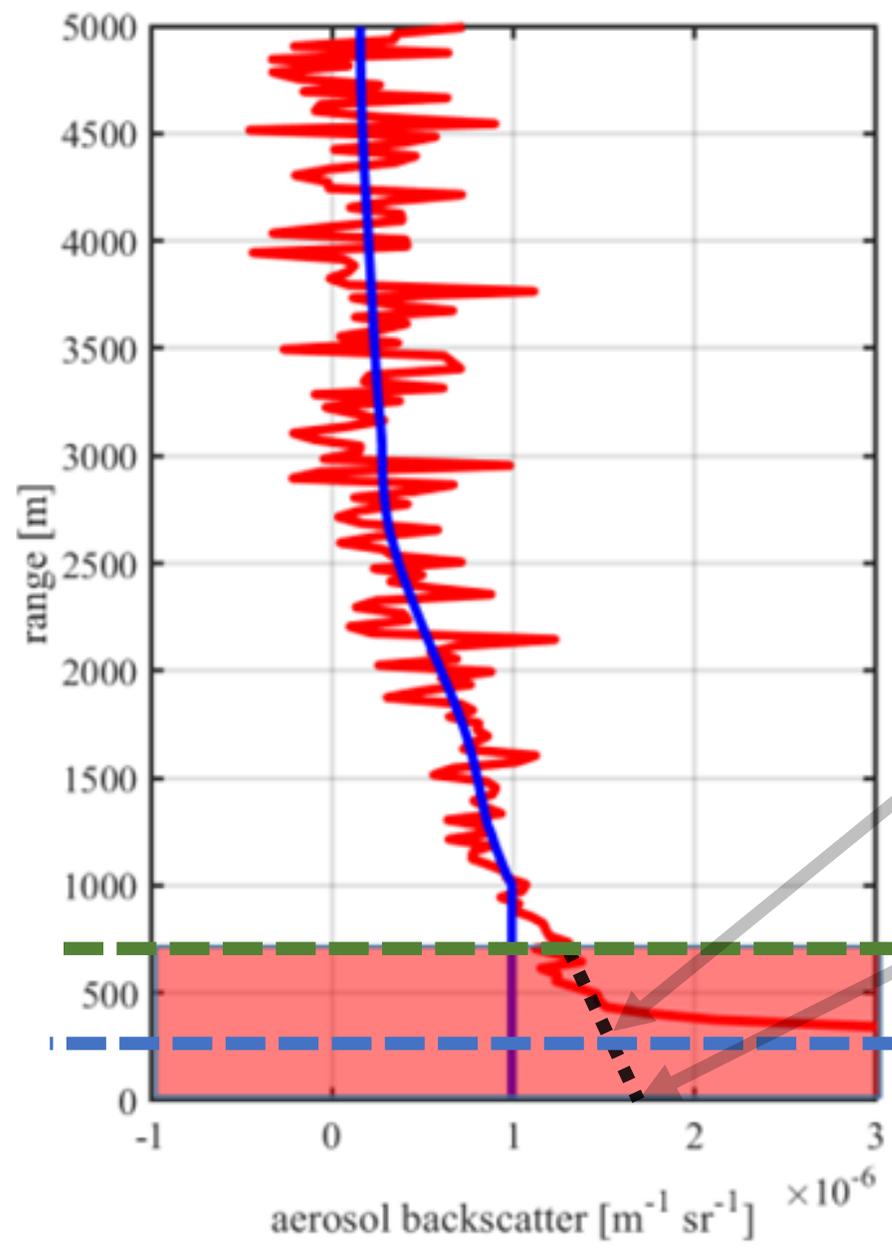
beta@AERONET(stratification):
 from **beta@Rov**(WM) to **beta_linear_fit@AERONET**(max stratification)

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 from 20sr to 90sr

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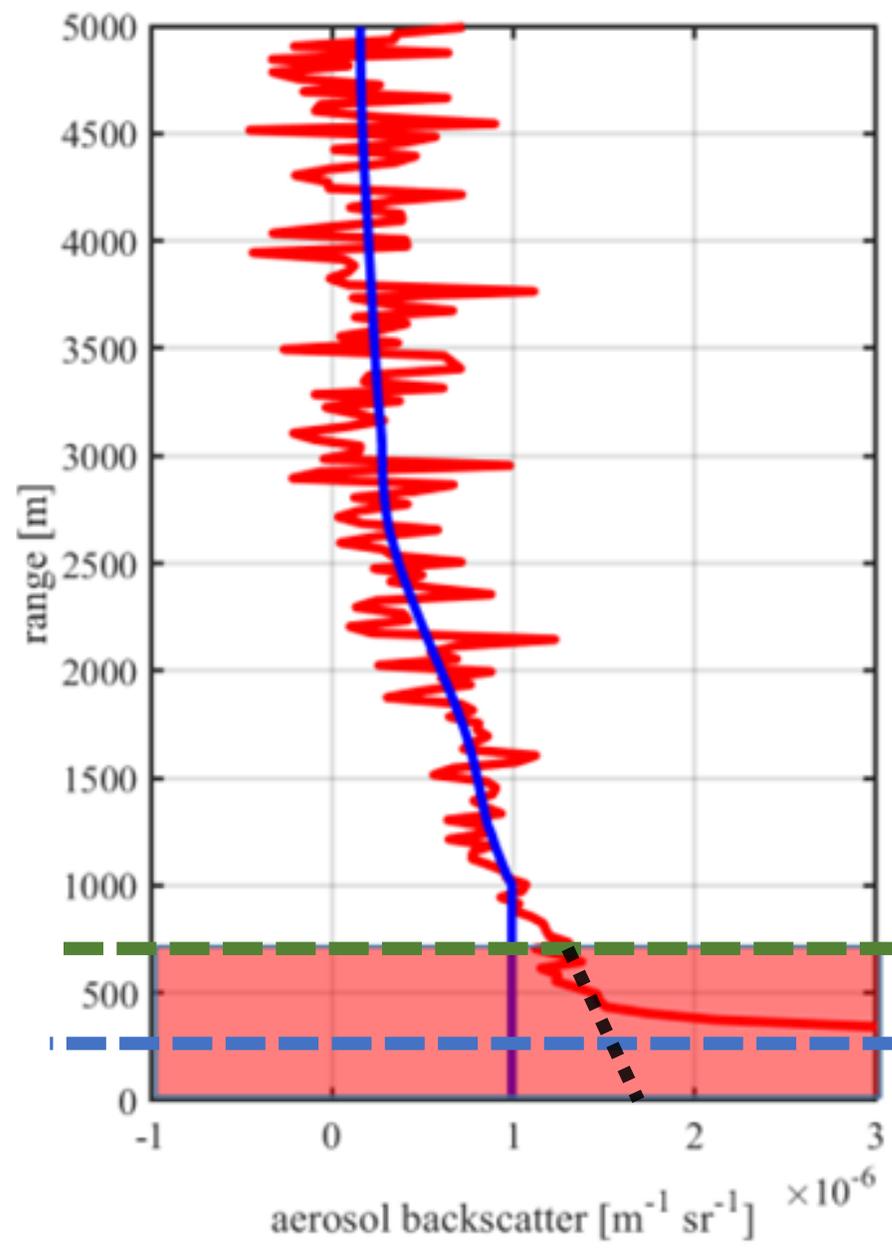
LR:
 from 20sr to 90sr

OPTimization:
 By varying **LR** & **beta@AERONET**:
 $\min(\text{abs}(\text{AOD@340nm}[\text{beta}(\text{LR}, \text{beta@AERONET}), \text{ang_exp}] - \text{AOD_AER@340nm}))$:
 ⇒ **OPT(beta@AERONET)**: stratification estimation & OPT(LR)
 ⇒ stratification factor = OPT(beta@ground)/beta@Rov: 1(WM) => ~3
 ⇒ beta@355(OPT), AOD@355(beta(OPT), LR(OPT))

Rov: for R>Rov overlap=1

AERONET range (241m)

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Optimization for simultaneous ($\Delta t < 3h$) AERONET/Lidar measurements

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 ⇒ stratification factor = OPT(beta@ground)/beta@Rov: 1(WM) => ~3
 ⇒ **beta@355(OPT), AOD@355(beta(OPT), LR(OPT))**

Similarly for Raman measurements but optimization applied to the aerosol extinction.

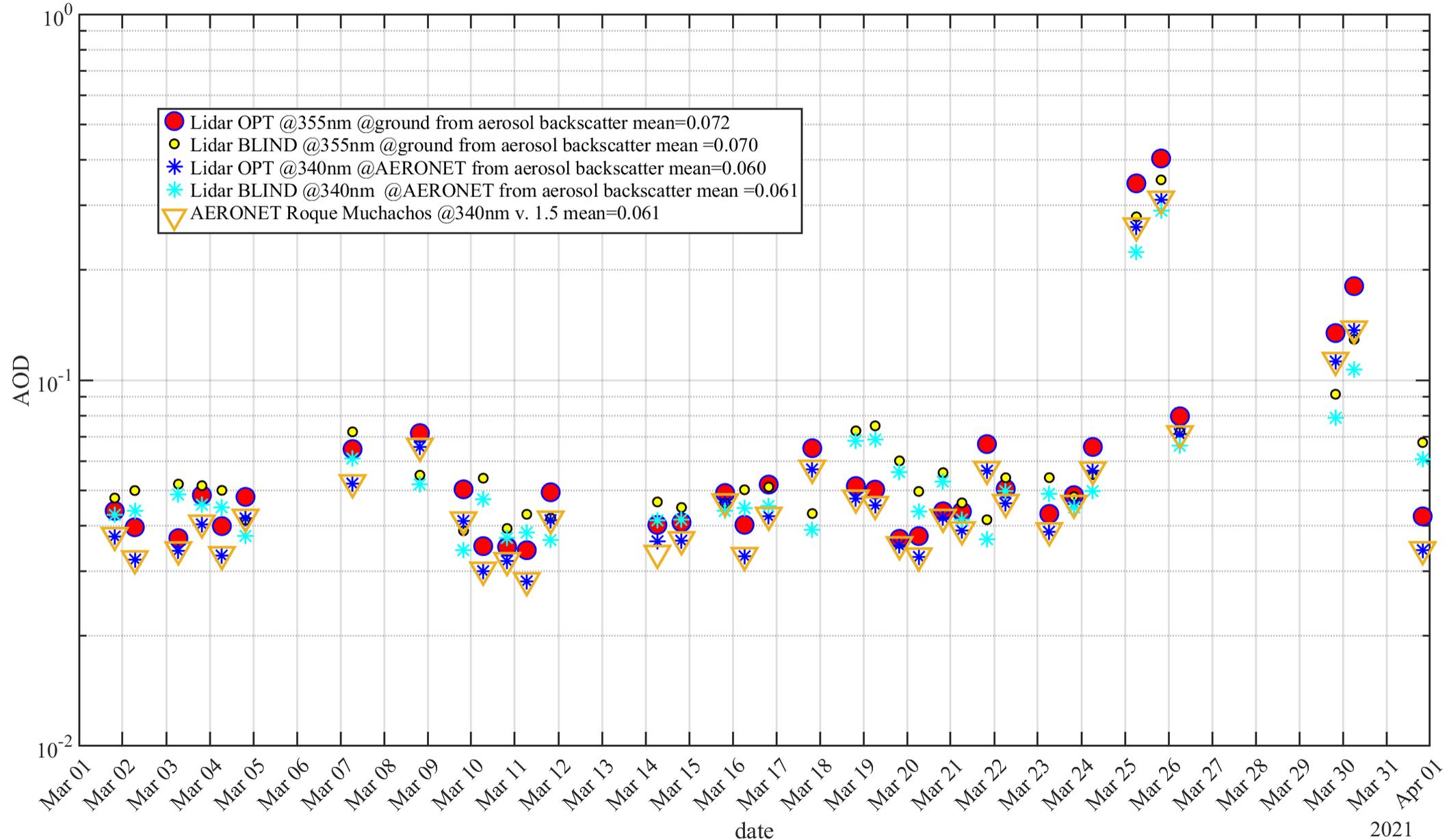
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— AERONET range (241m)

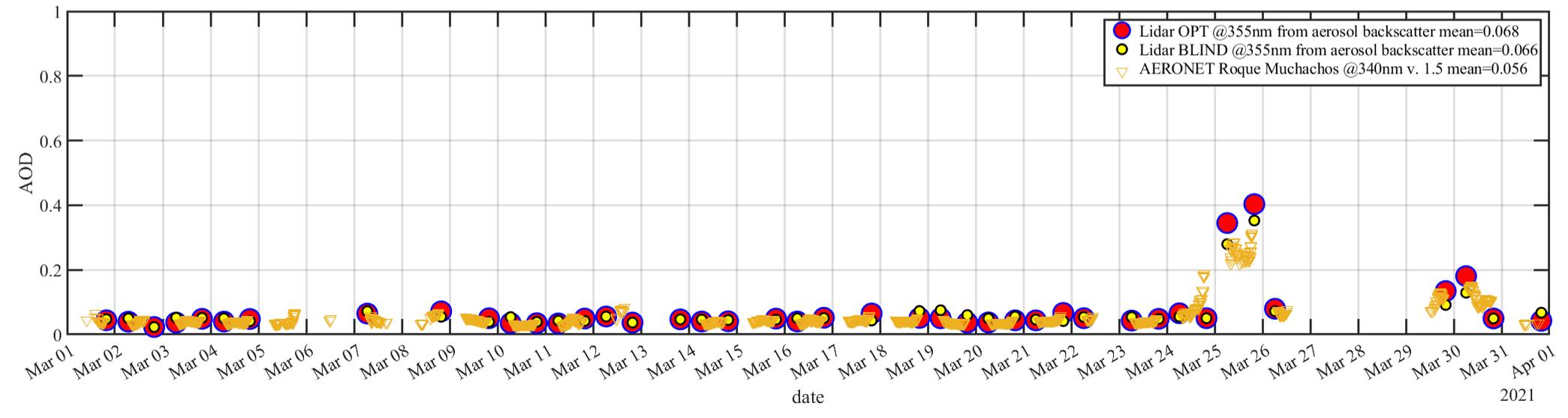
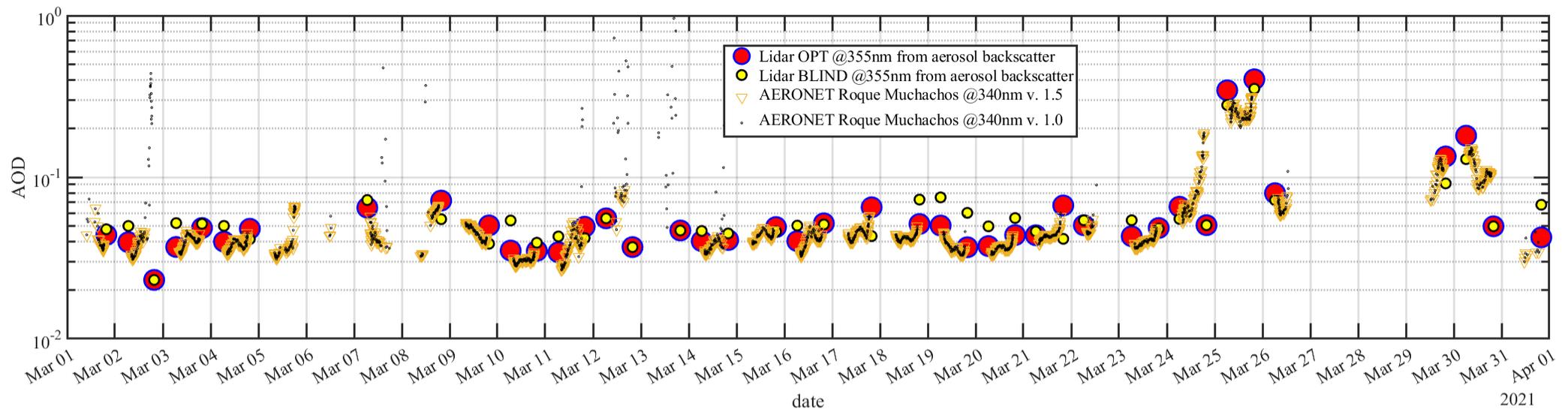
Not simultaneous -> **LR=50sr** , stratification factor=1.5 (also as scenario for BLIND retrieval). For aerosol extinction BLIND retrieval: stratification factor=2.

- LIDAR Aerosol retrieval optimized with AOD & ang exp from AERONET (stratification)

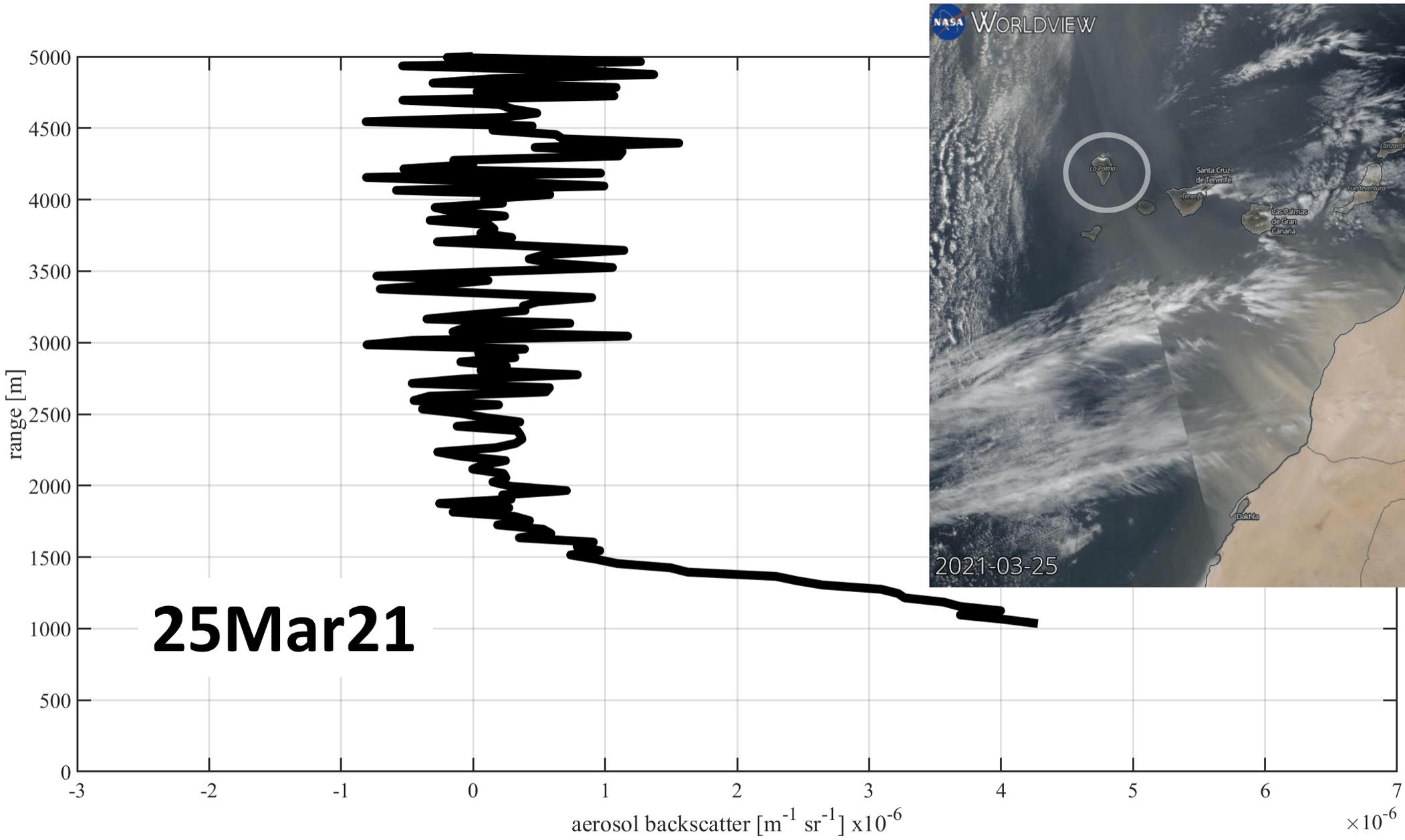
Simultaneous Measurements



- LIDAR Aerosol retrieval optimized with AOD & ang exp from AERONET (stratification)

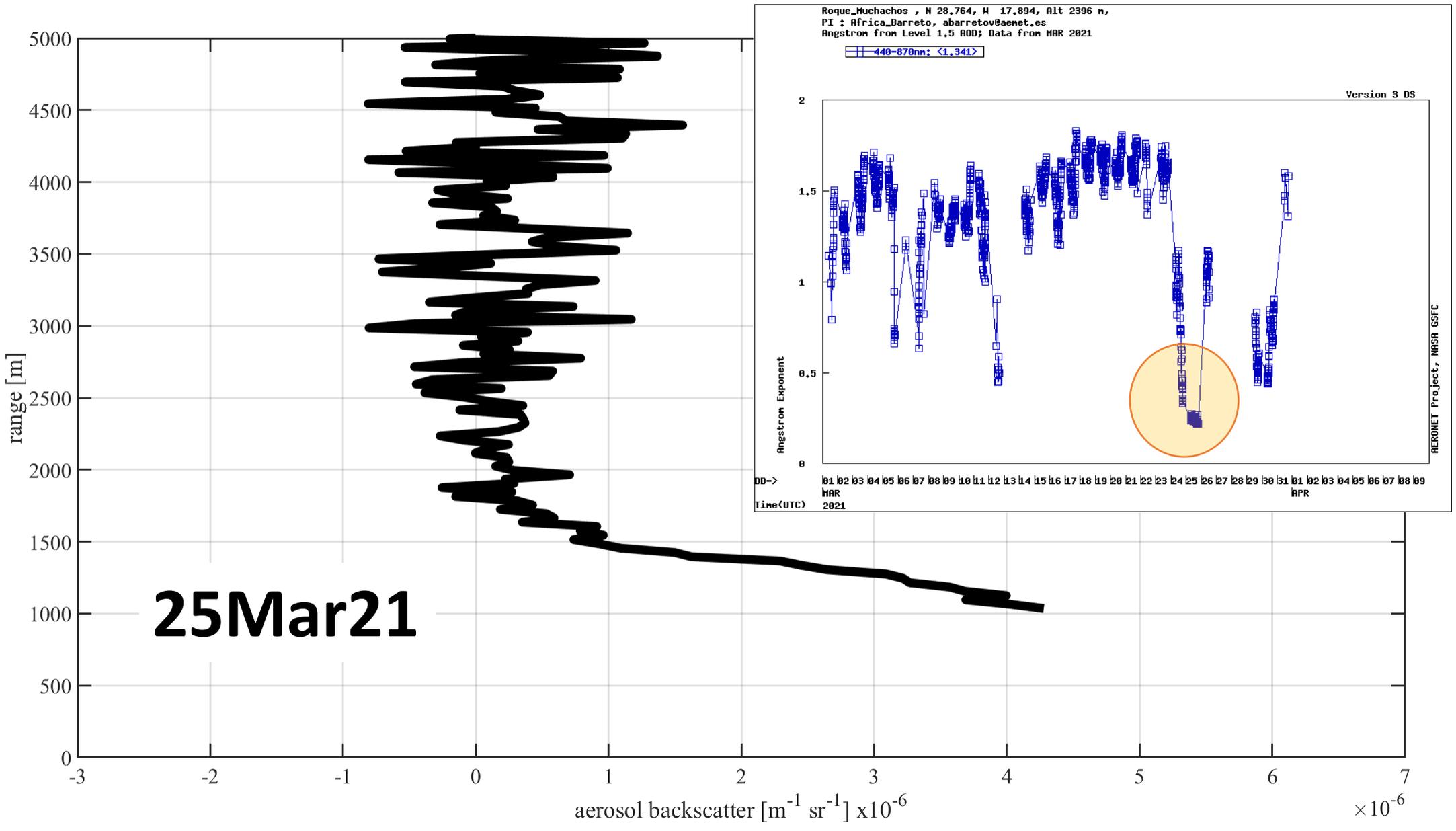


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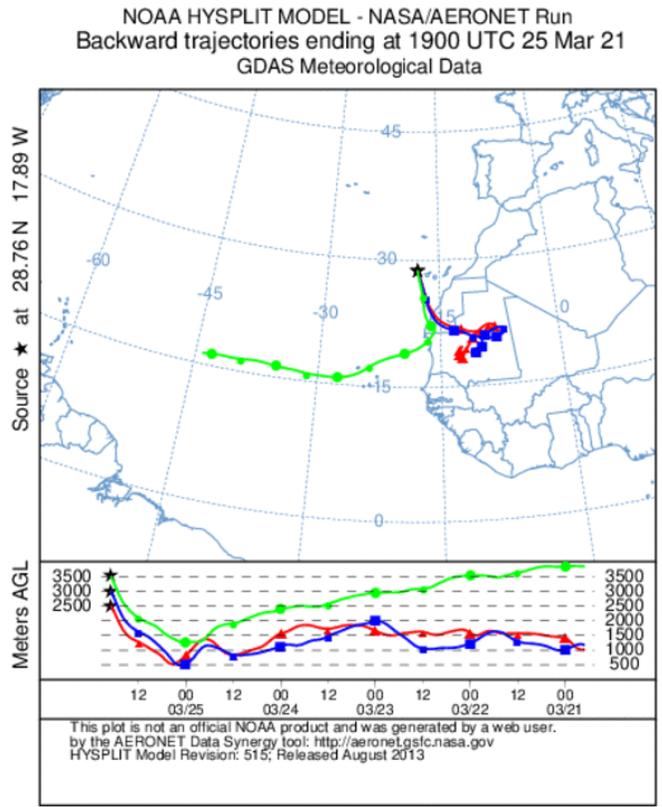
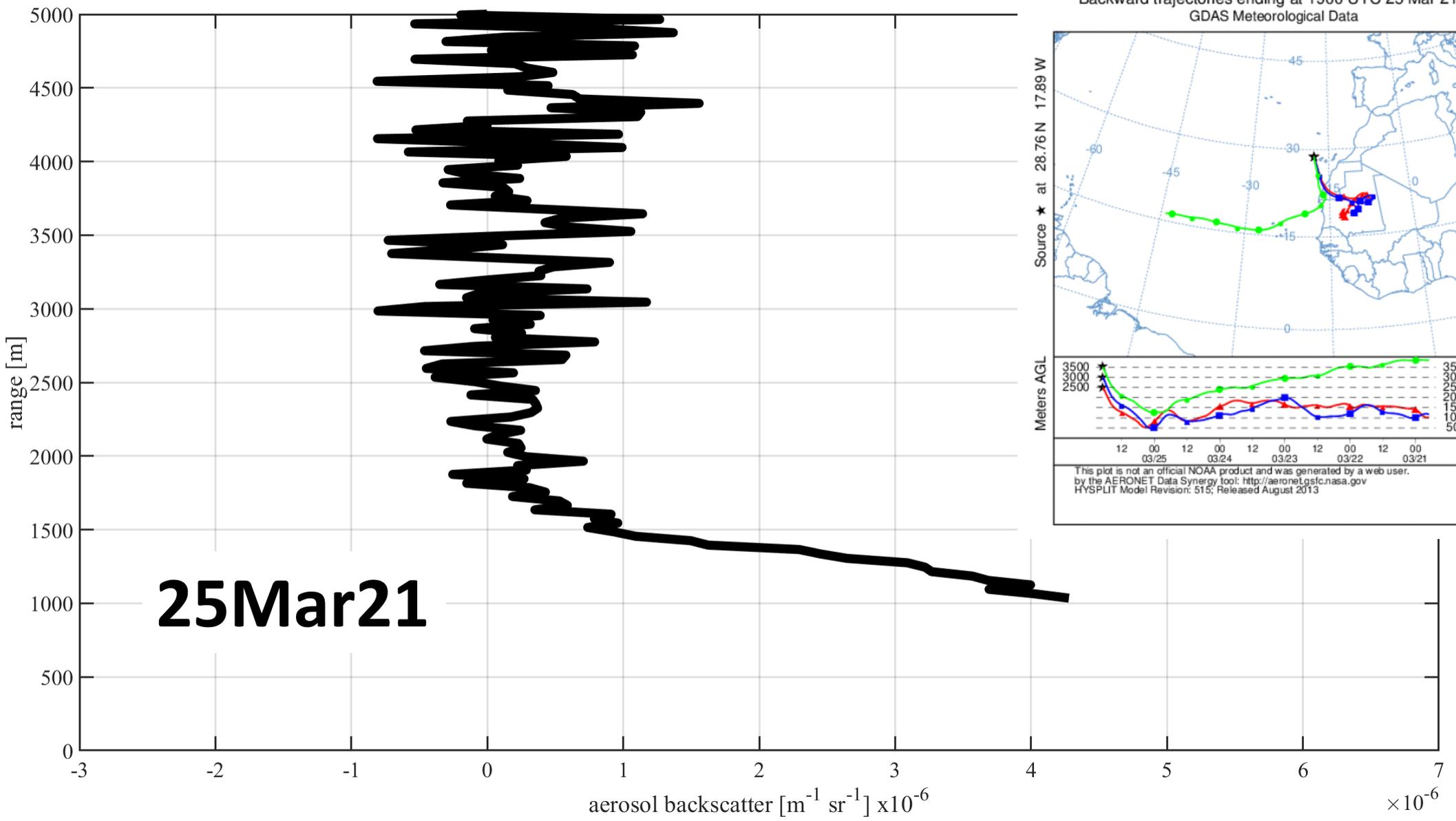


25Mar21

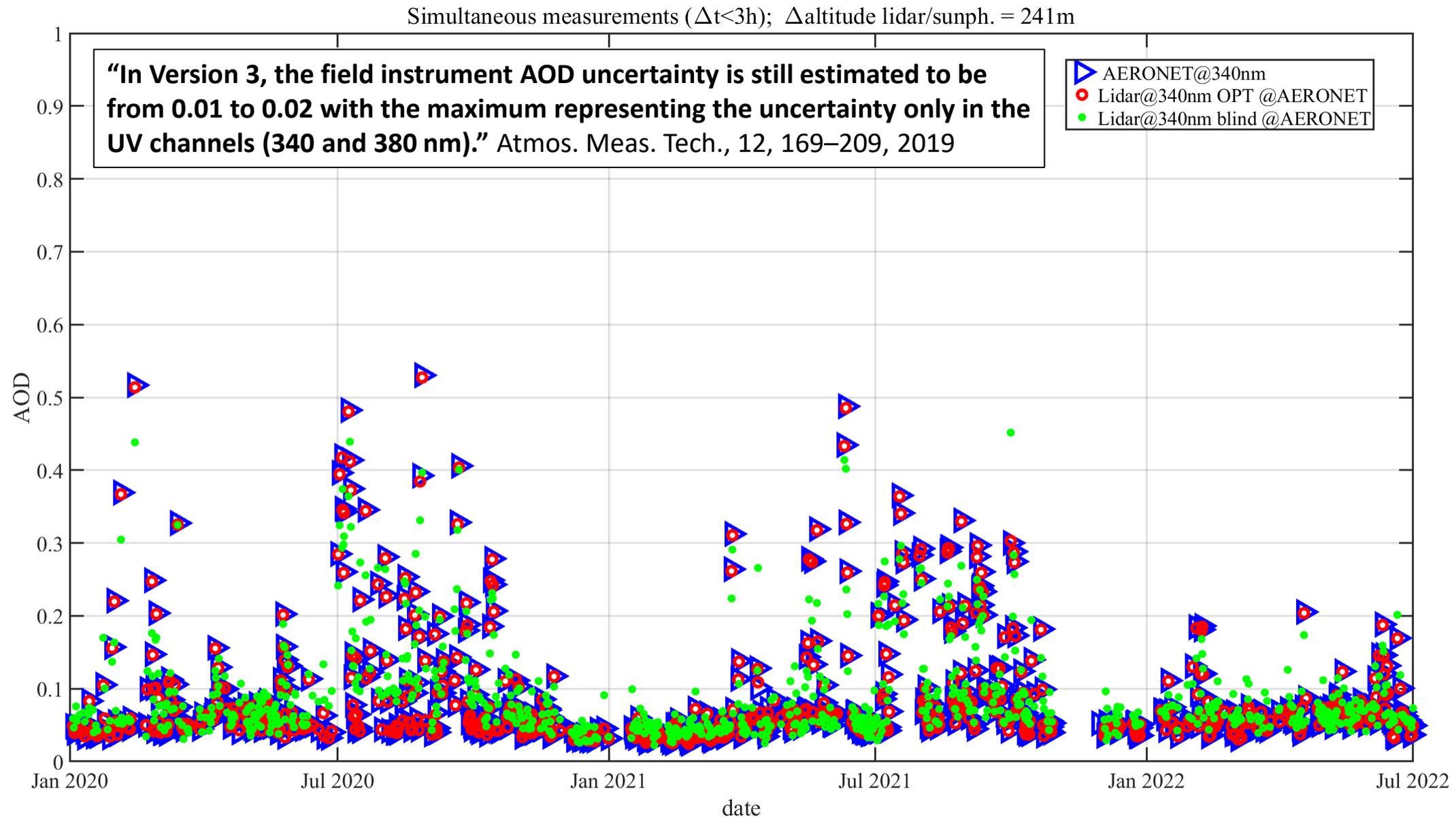
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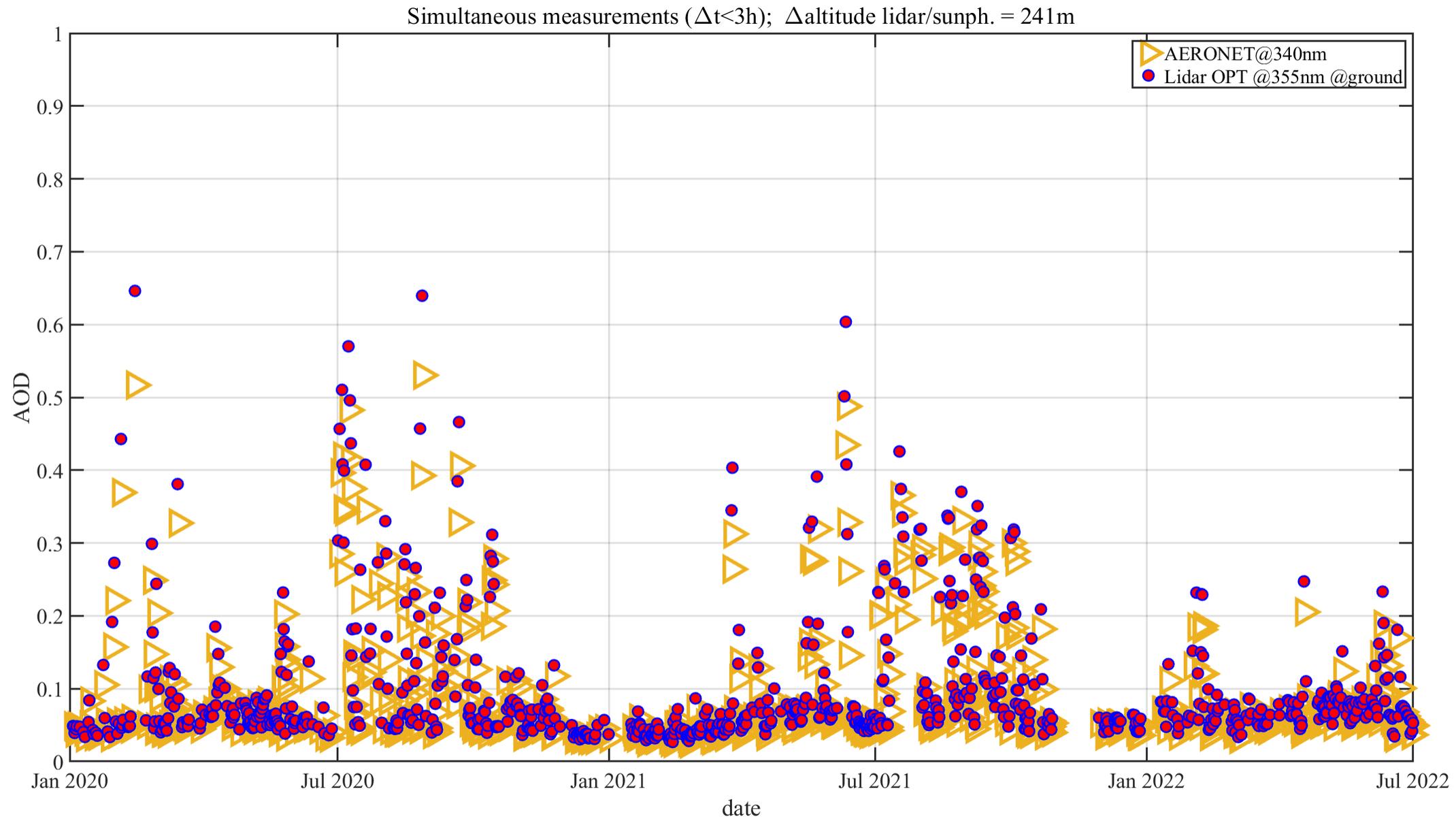
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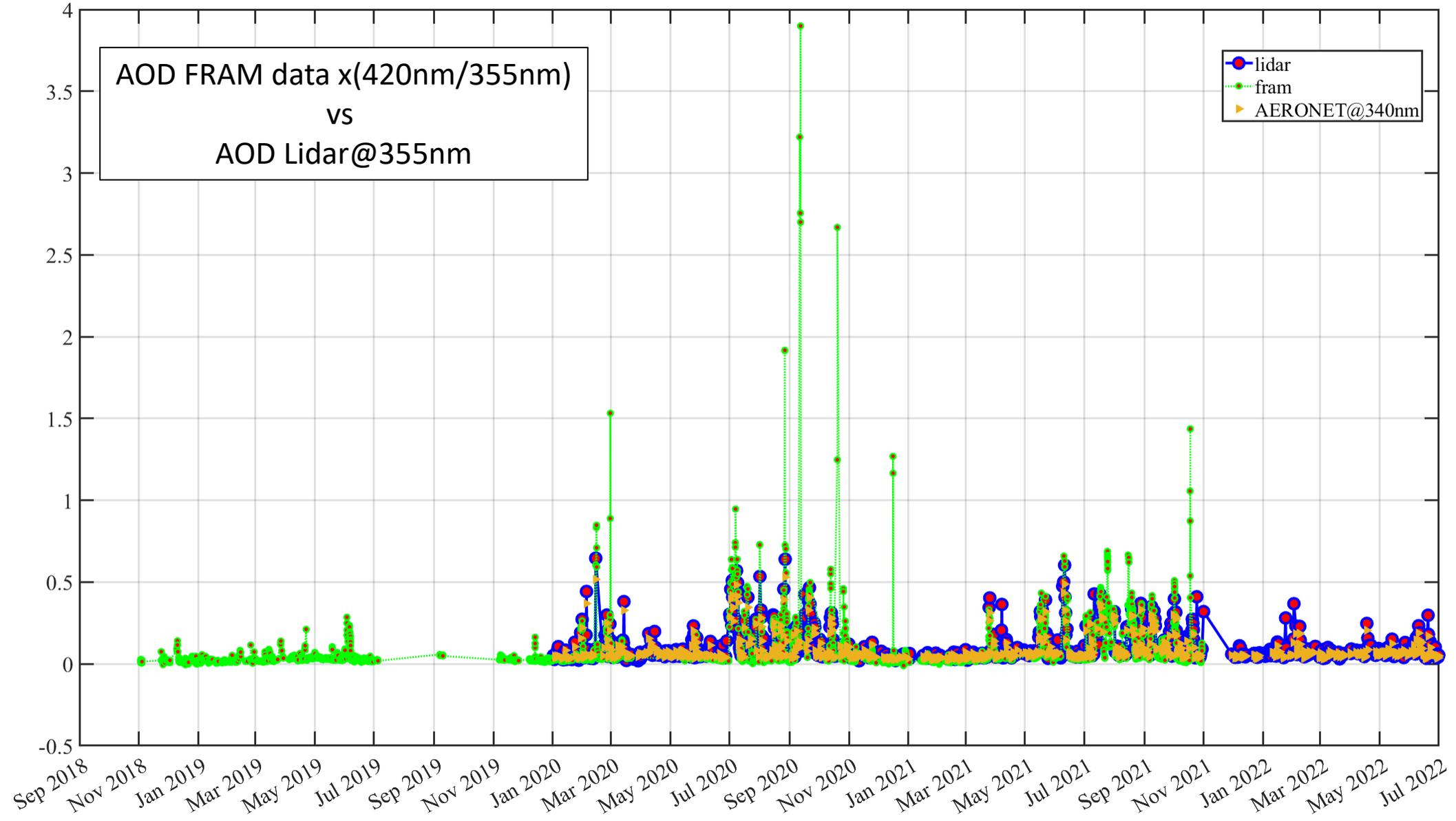
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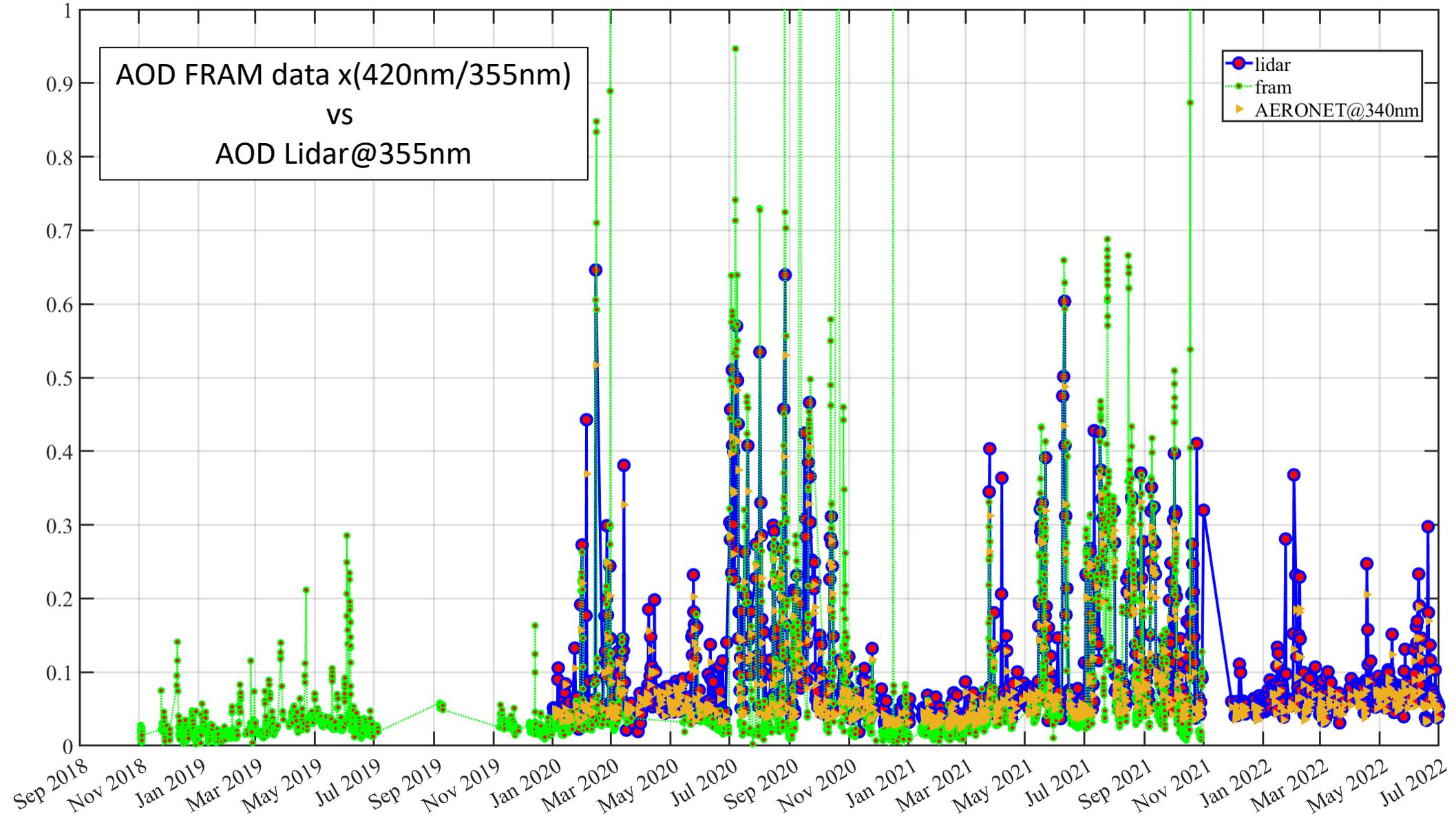
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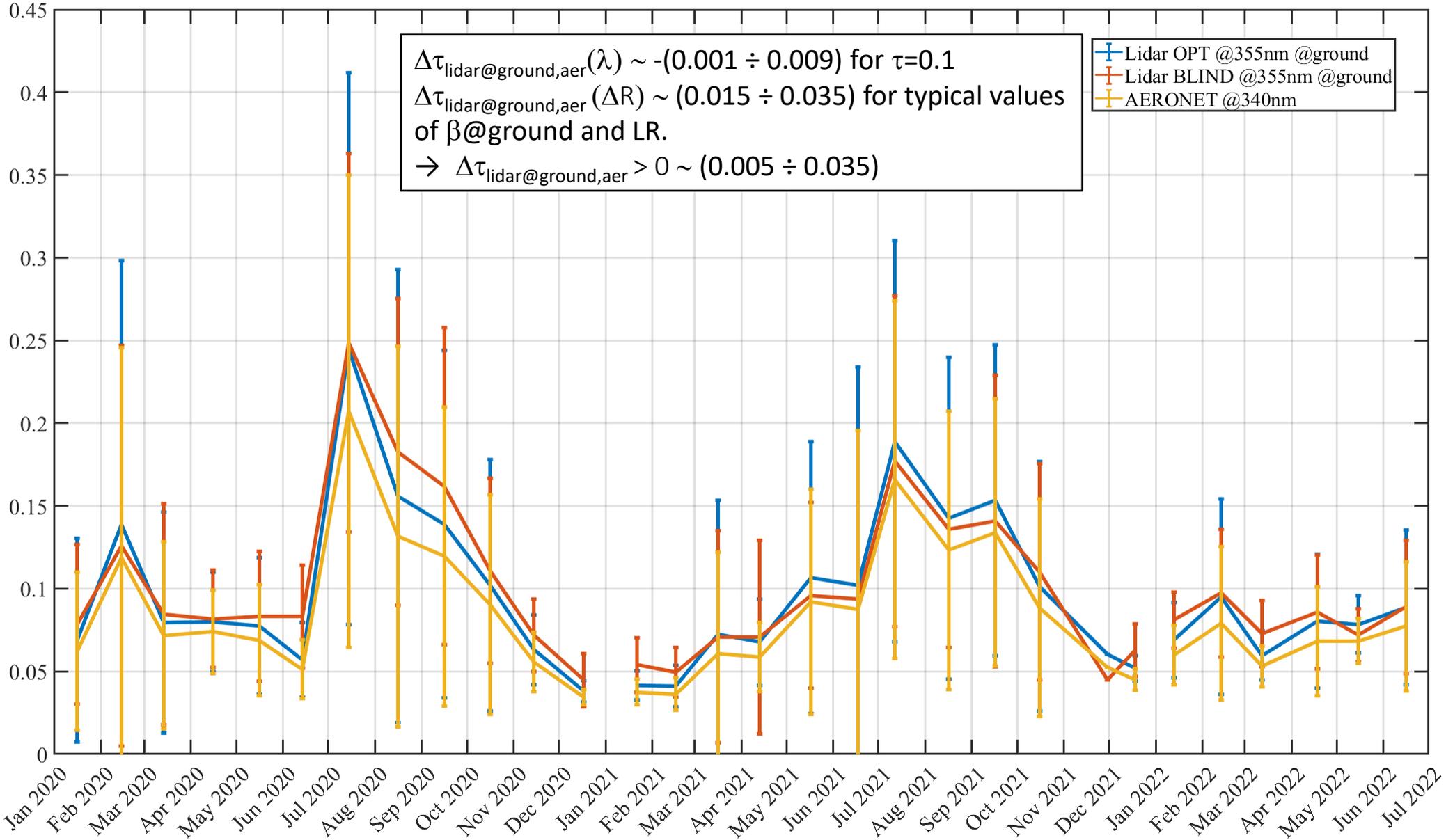


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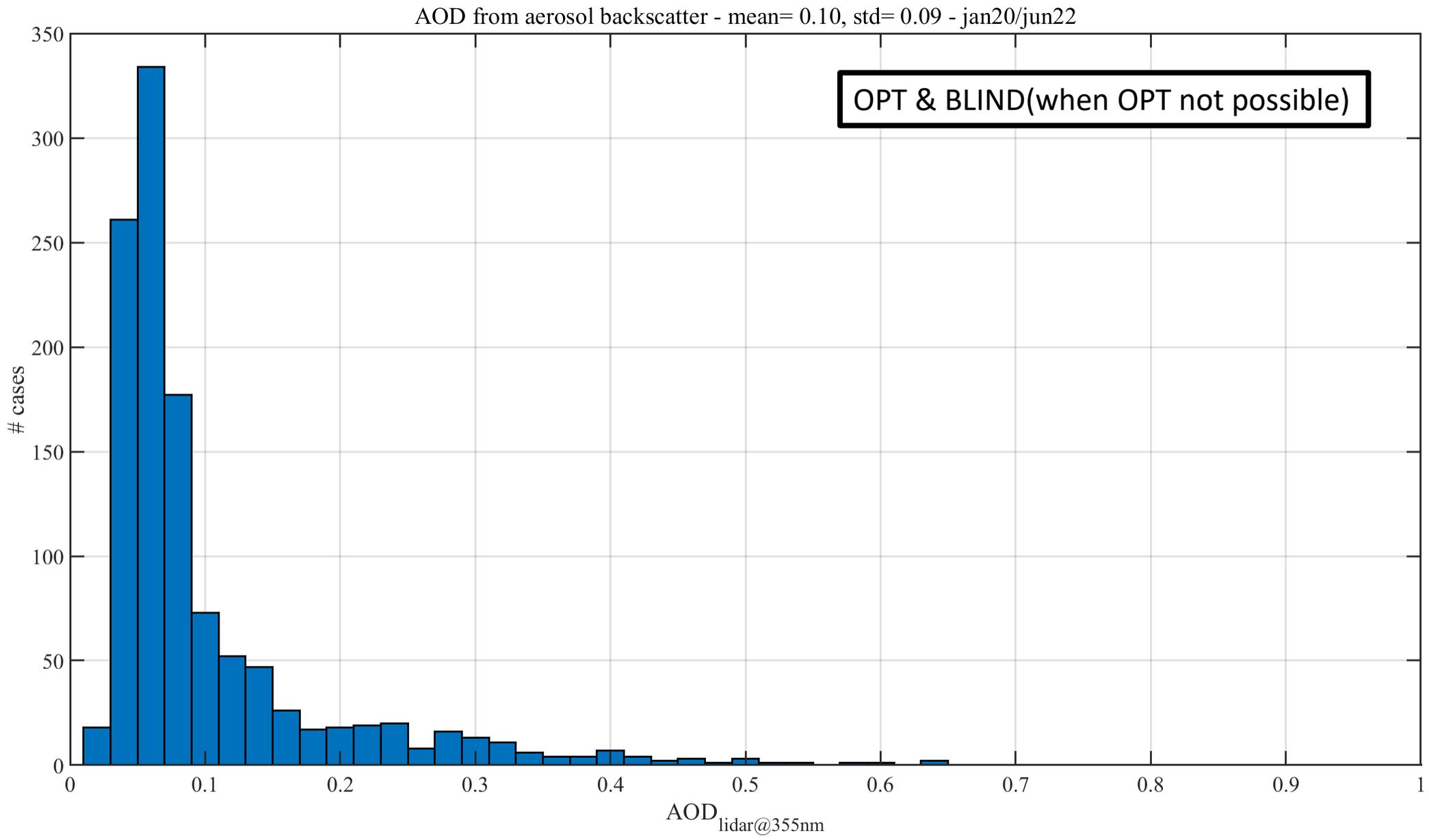


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Simultaneous Measurements

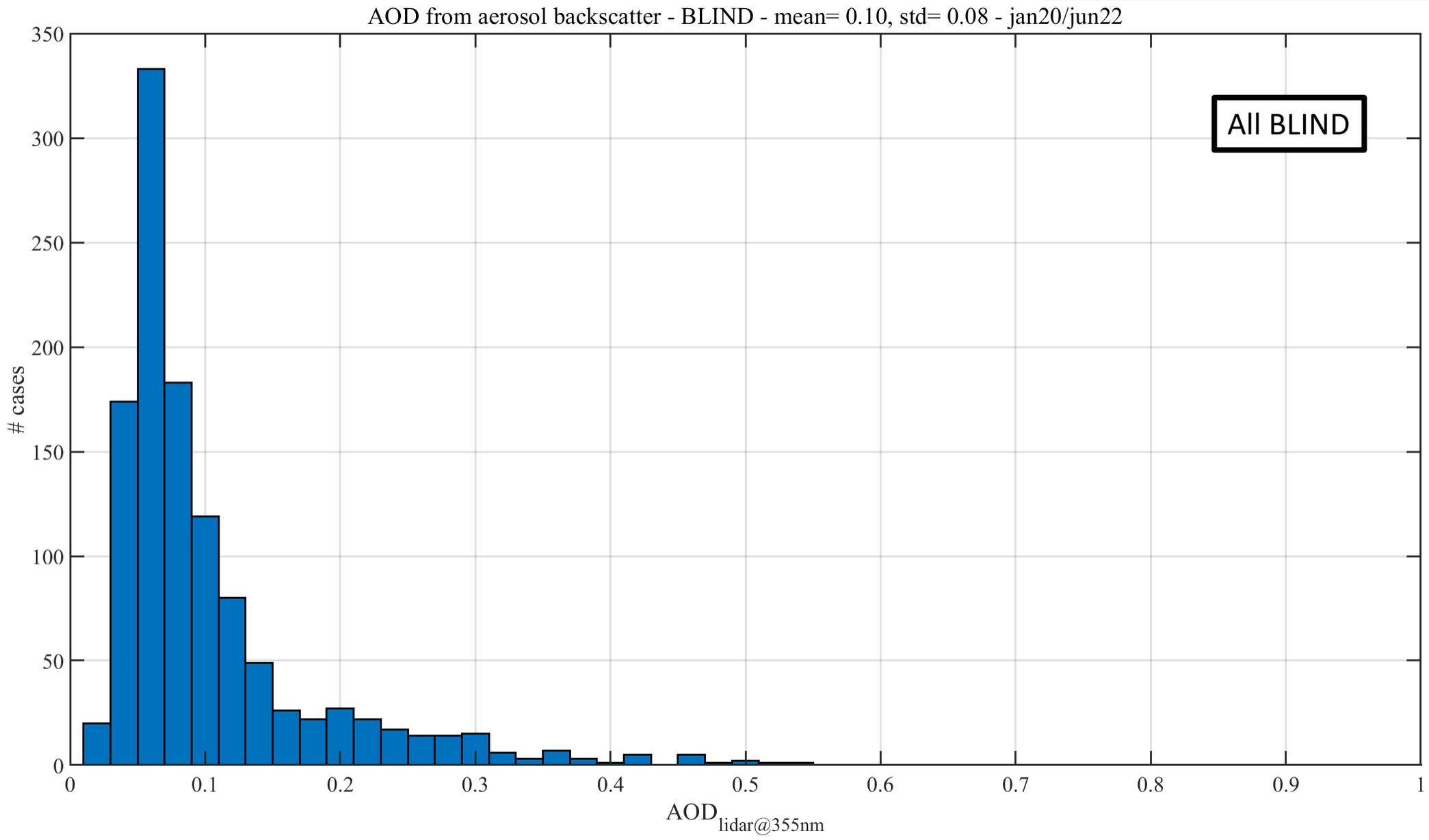


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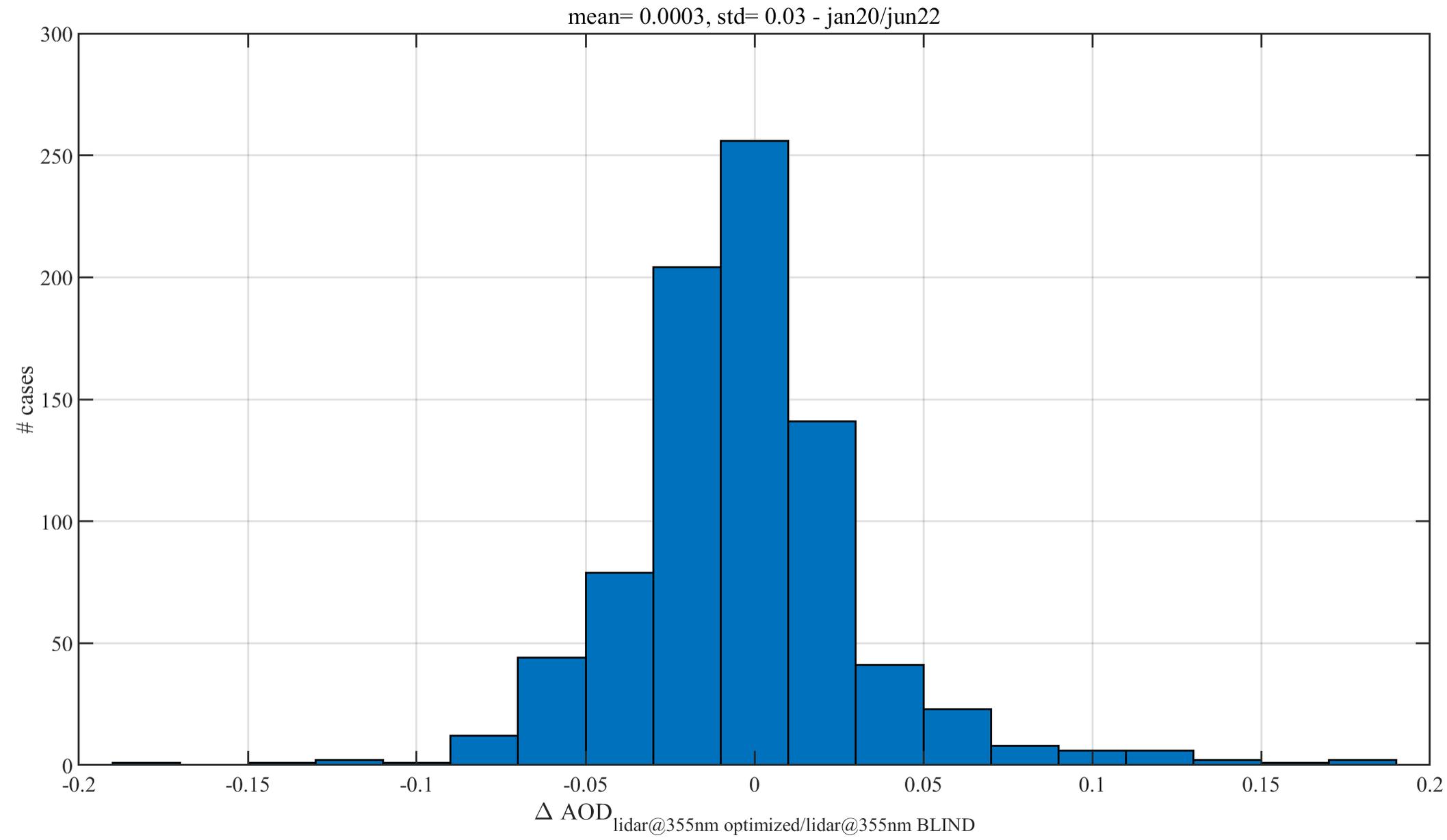


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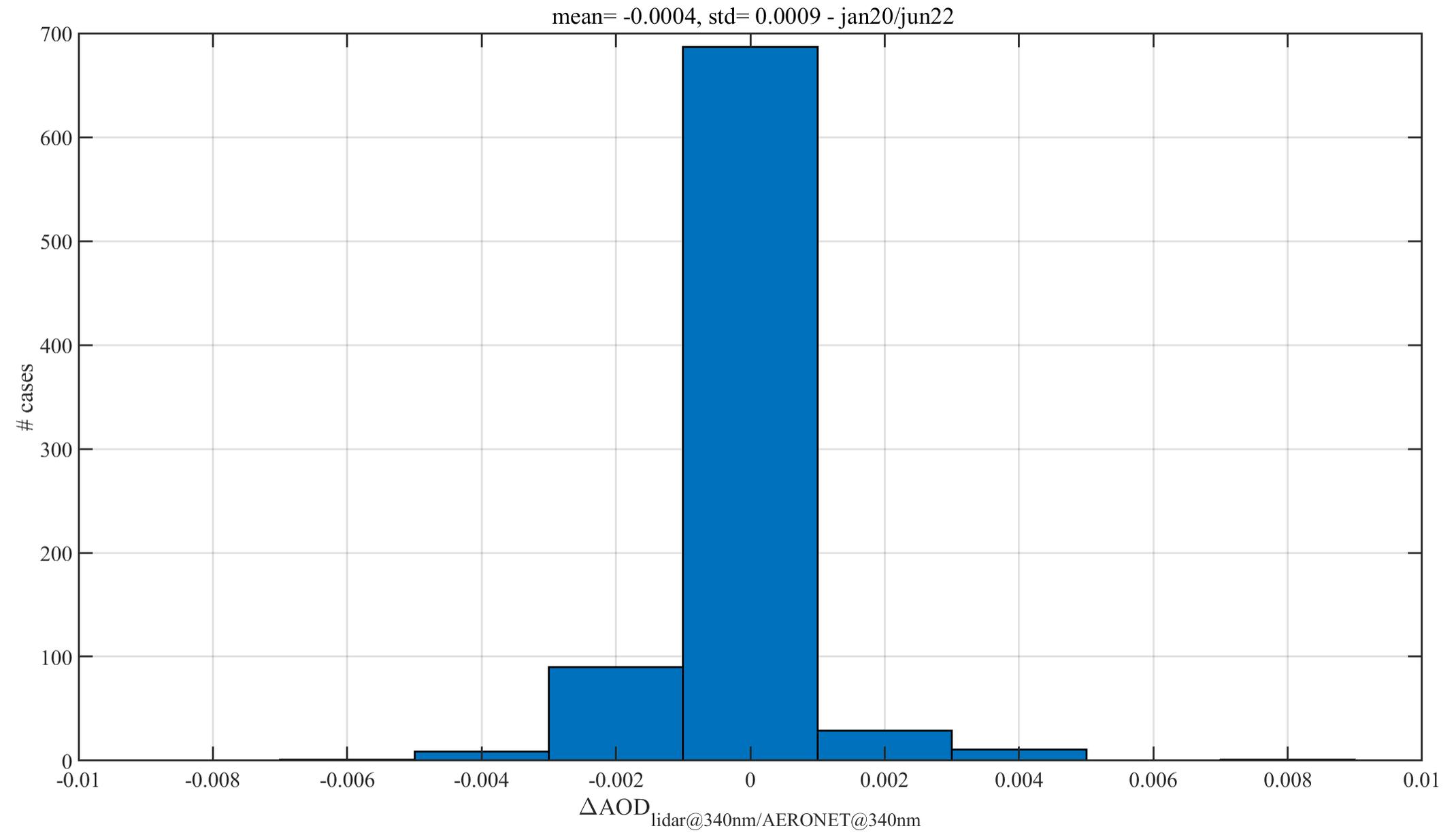
LR=50sr , stratification factor=1.5



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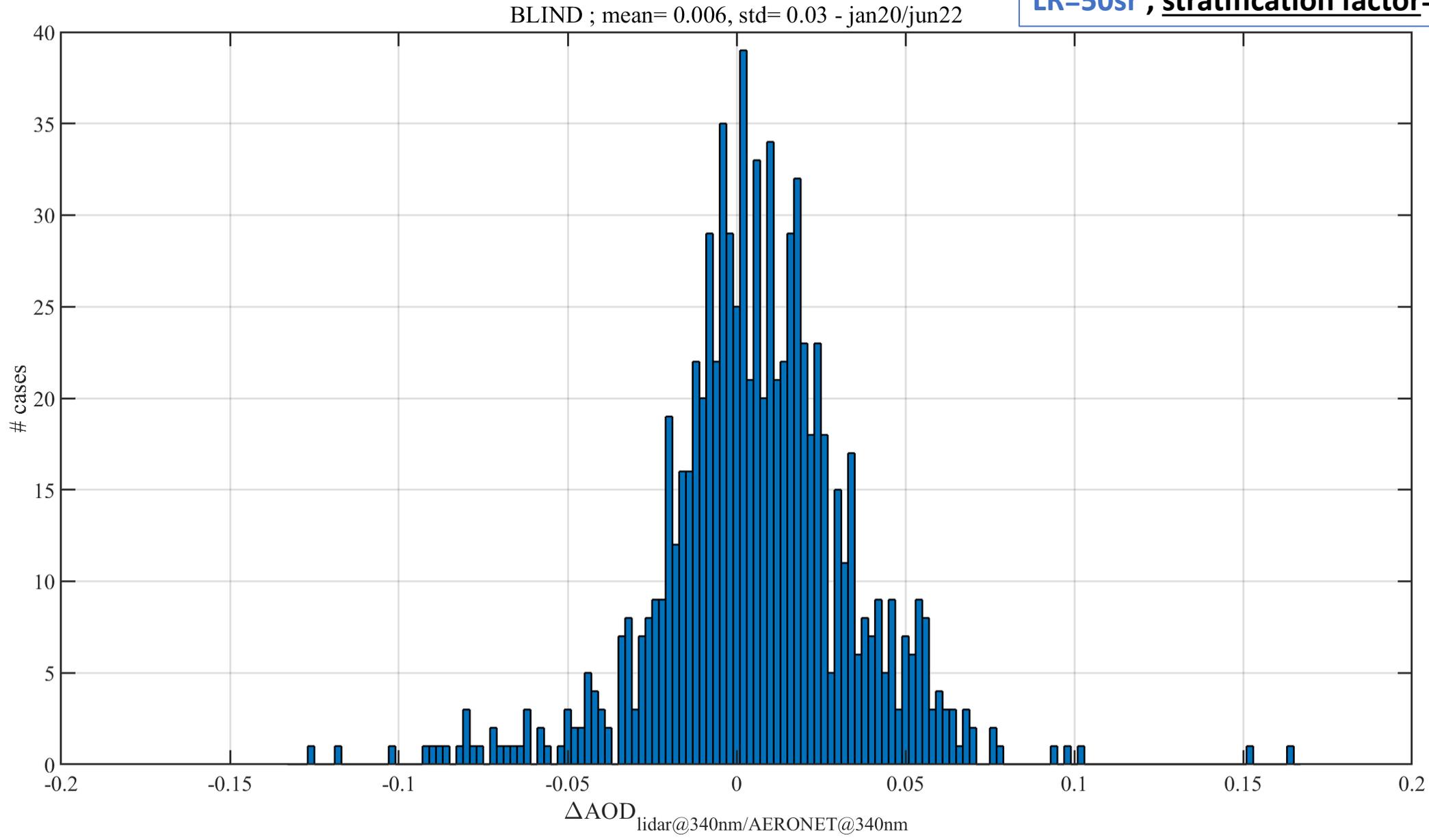


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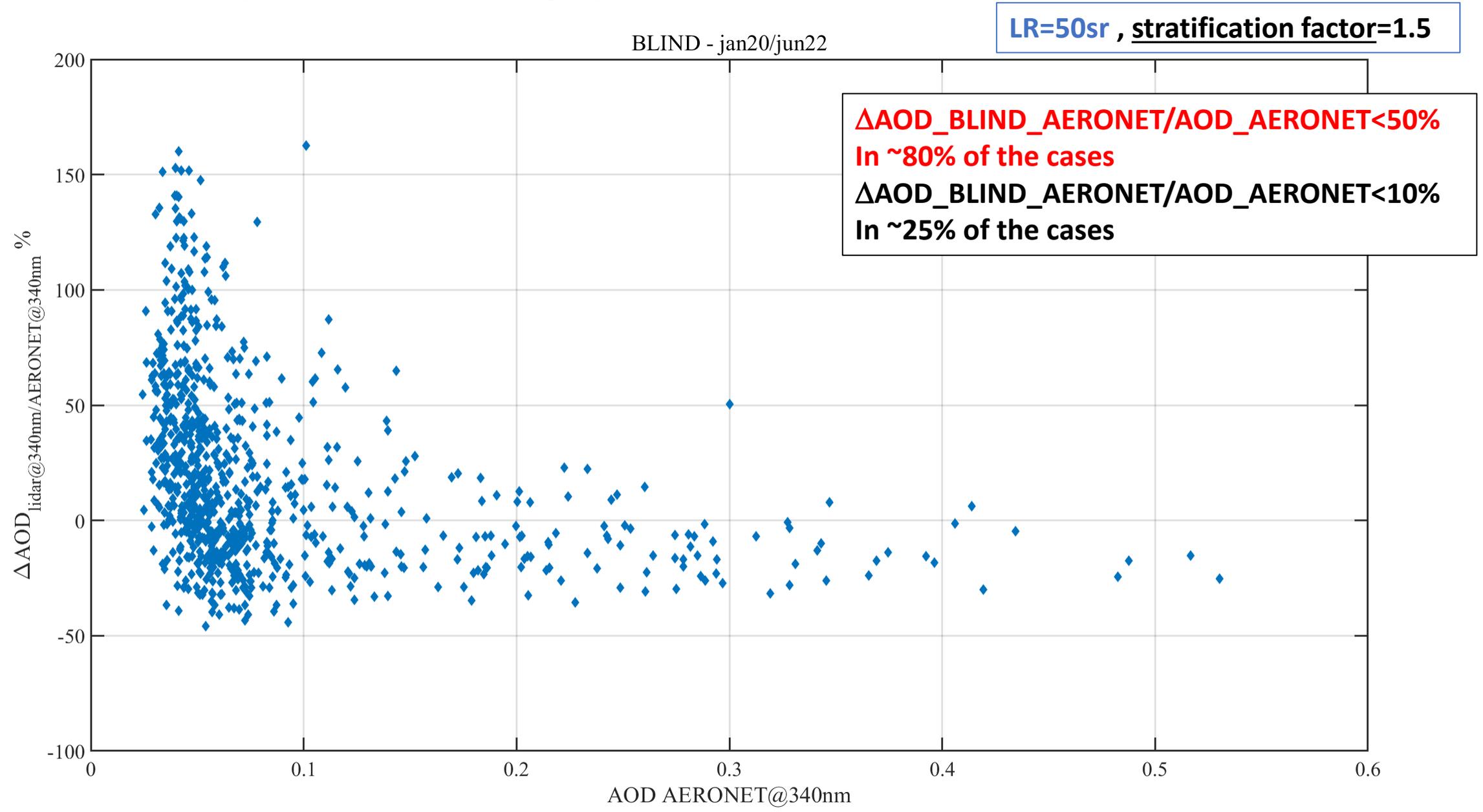


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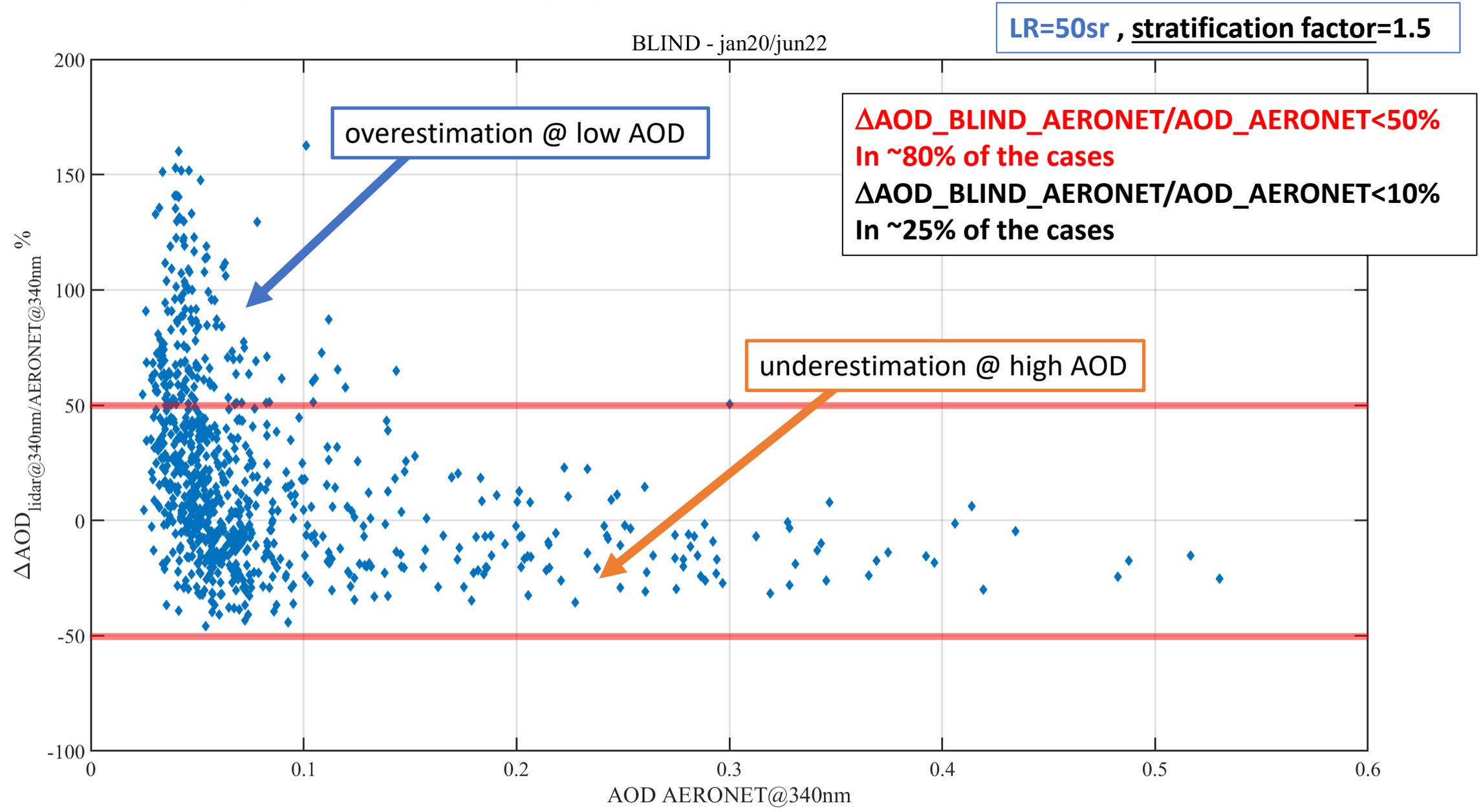
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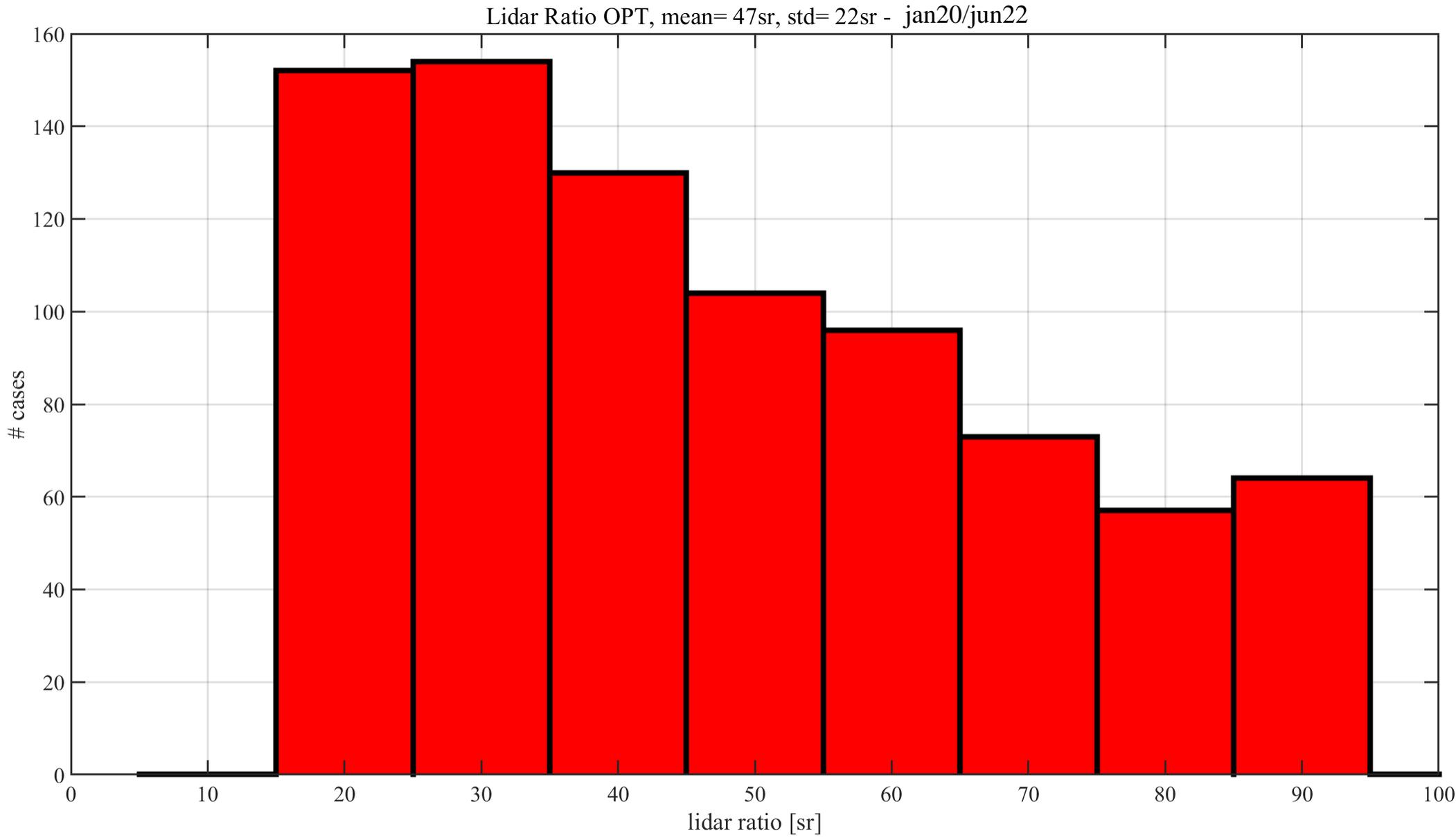
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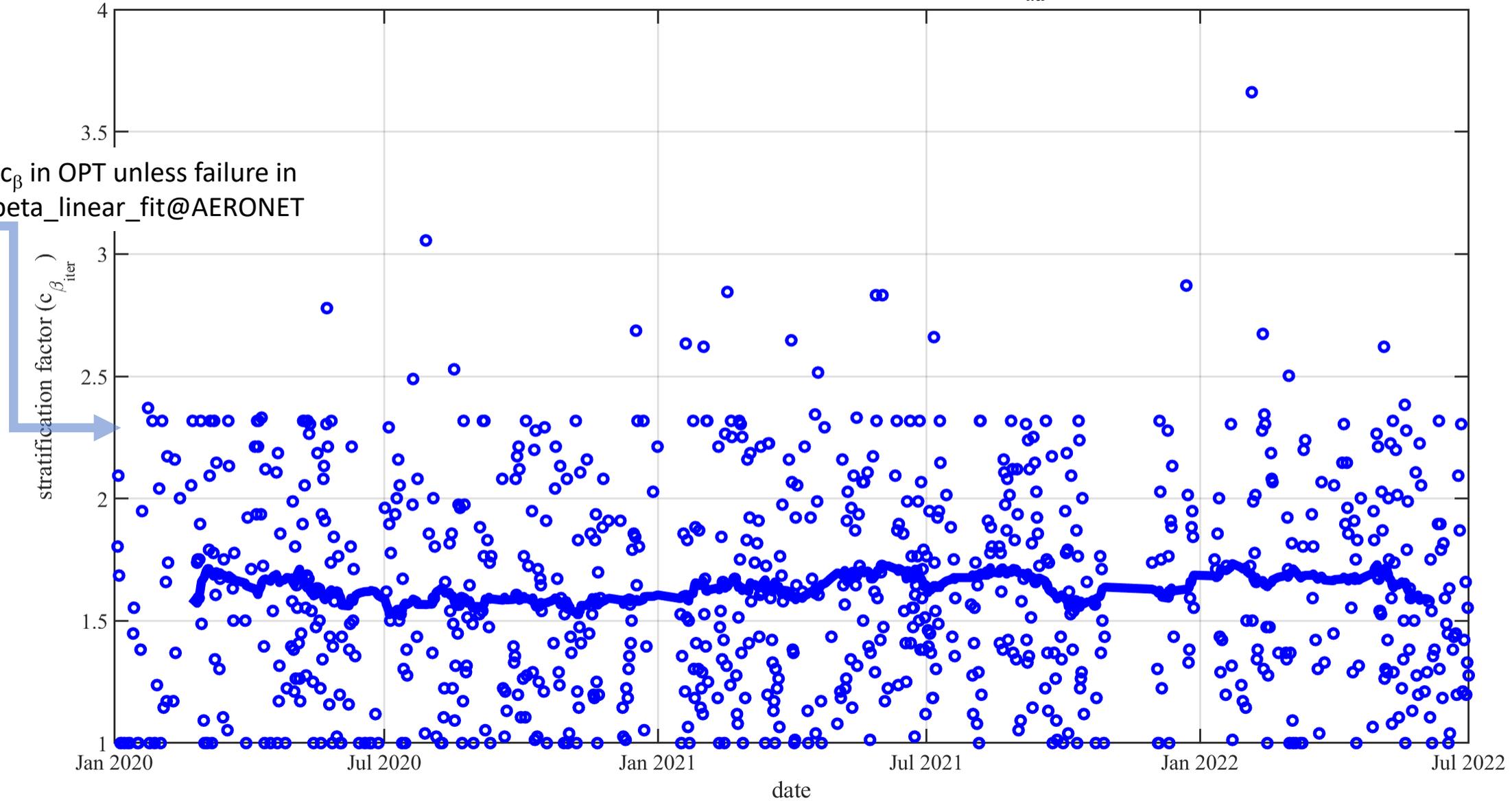
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• LIDAR Aerosol retrieval optimized with AOD & ang exp from AERONET (stratification)

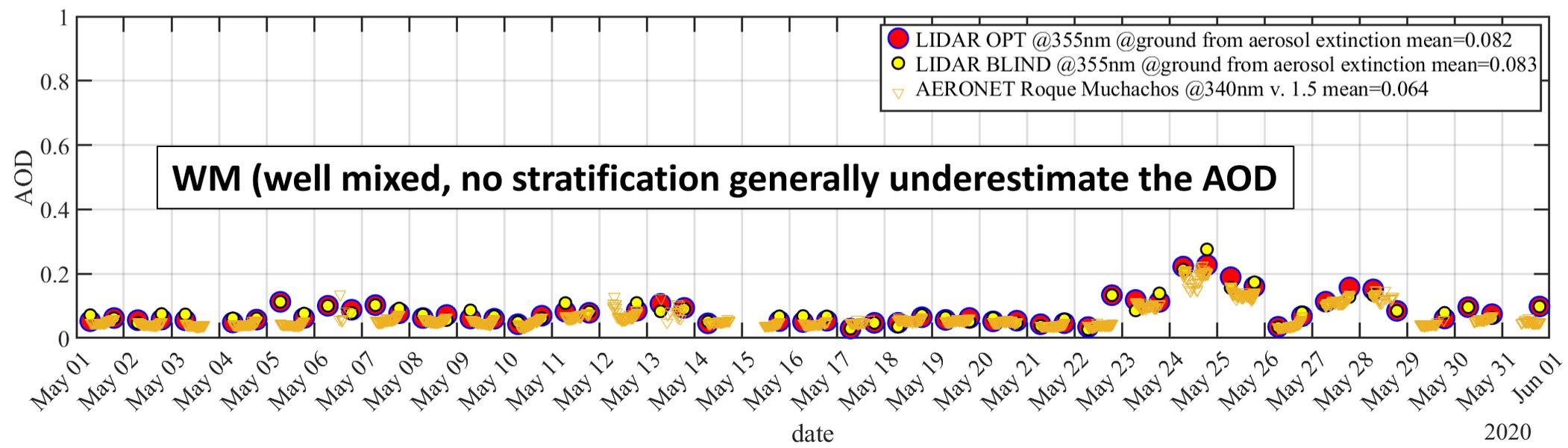
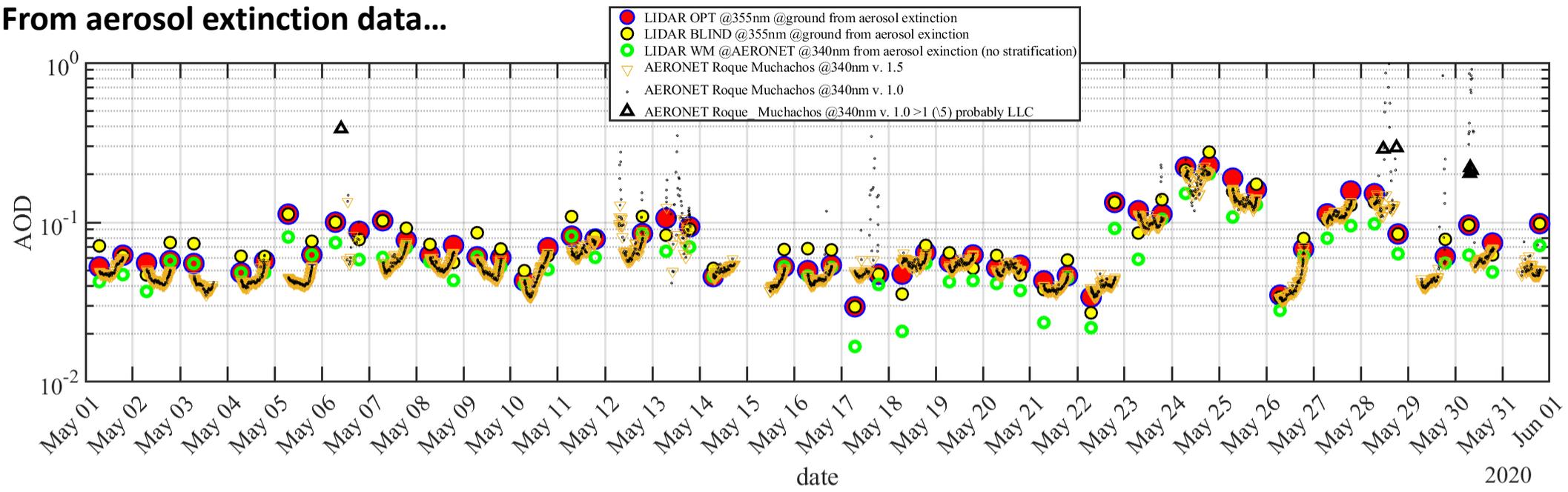
Sim. meas. ($\Delta t < 3h$); $\Delta alt. \text{ lidar/sunph.} = 241m$; mean $c_{\beta_{iter}} = 1.627$

No max c_{β} in OPT unless failure in finding beta_linear_fit@AERONET



• LIDAR Aerosol retrieval optimized with AOD & ang exp from AERONET (stratification)

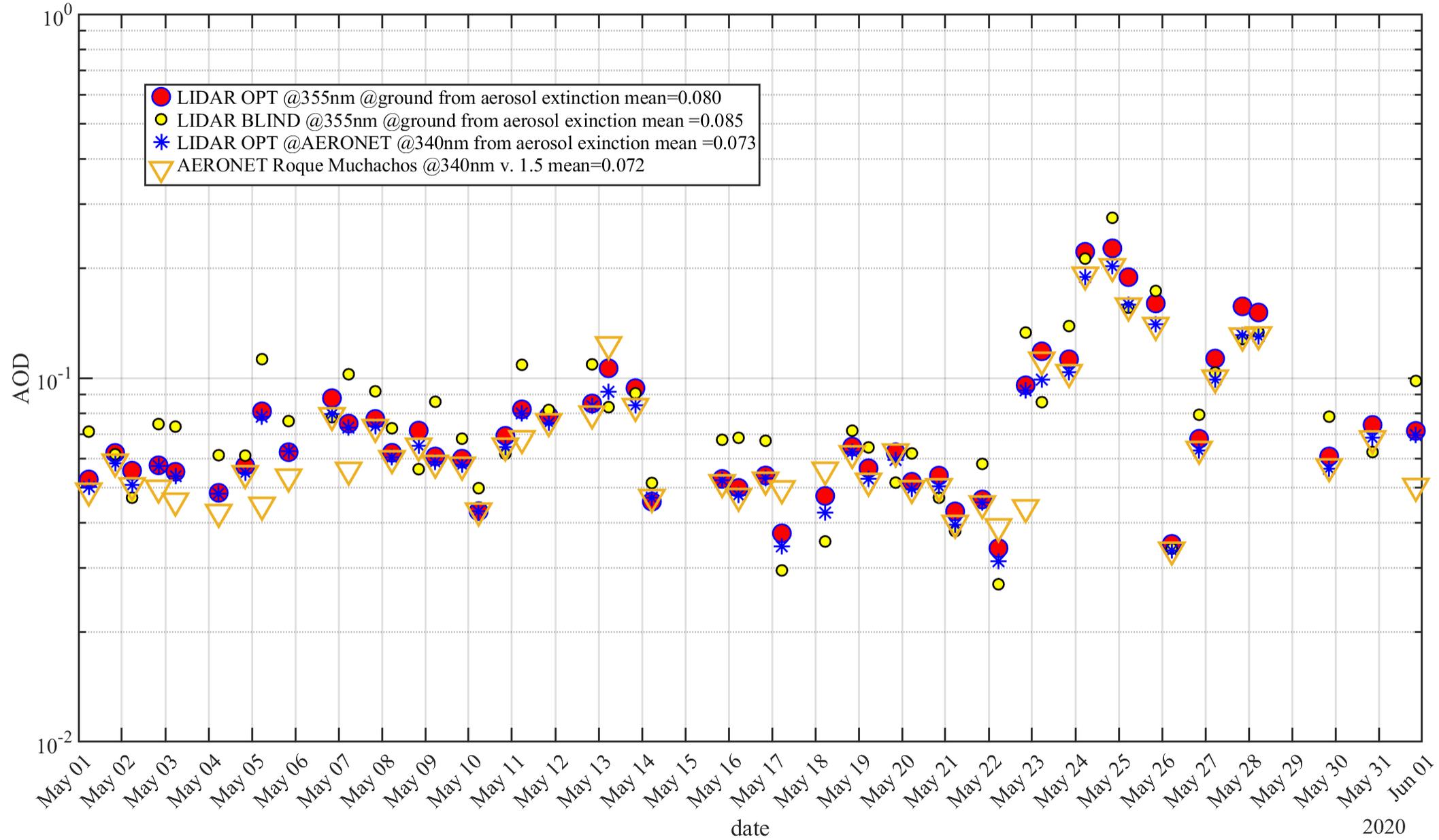
RAMAN - From aerosol extinction data...



- LIDAR Aerosol retrieval optimized with AOD & ang exp from AERONET (stratification)

RAMAN - From aerosol extinction data...

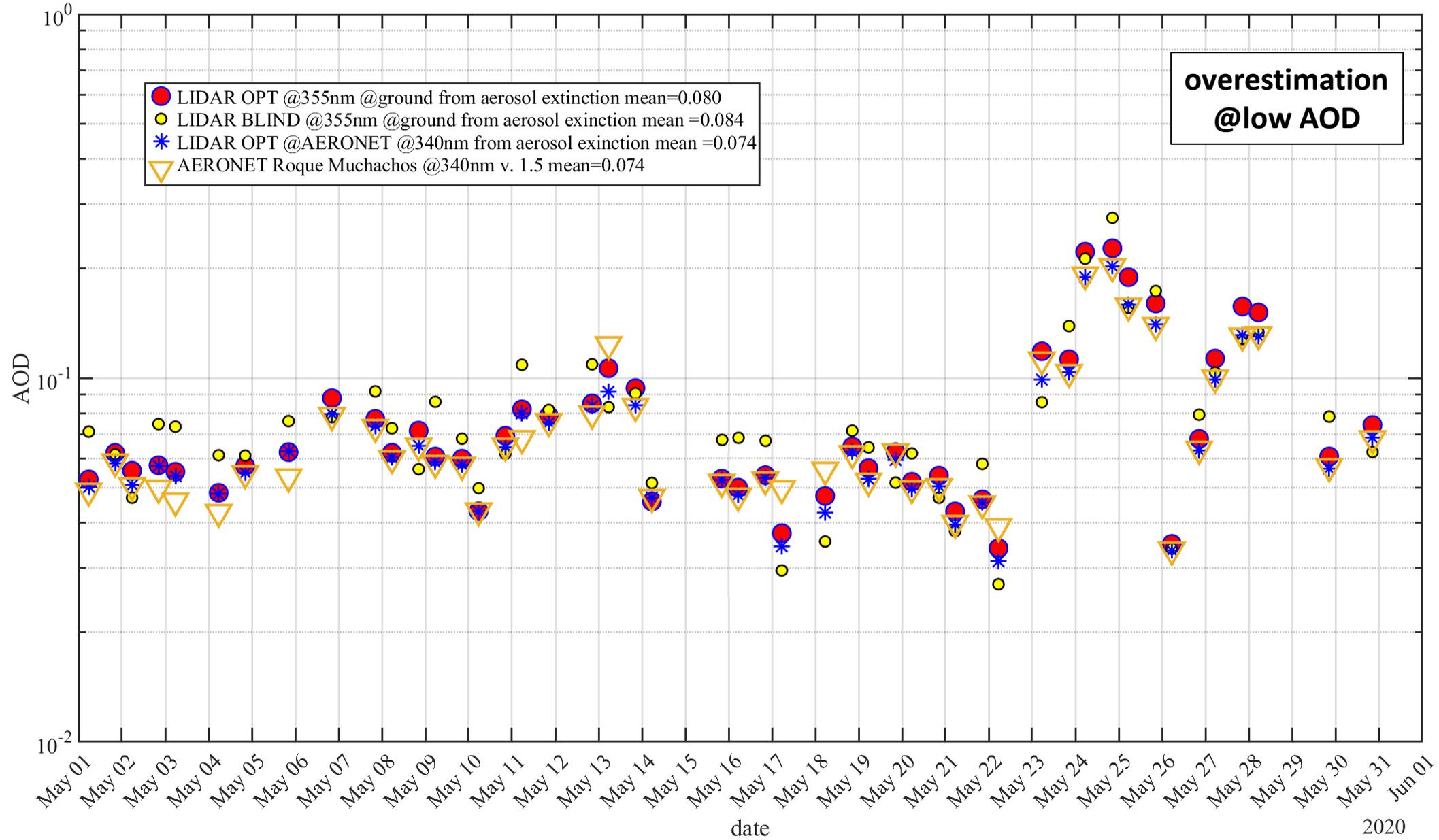
Simultaneous Measurements



- LIDAR Aerosol retrieval optimized with AOD & ang exp from AERONET (stratification)

RAMAN - From aerosol extinction data...

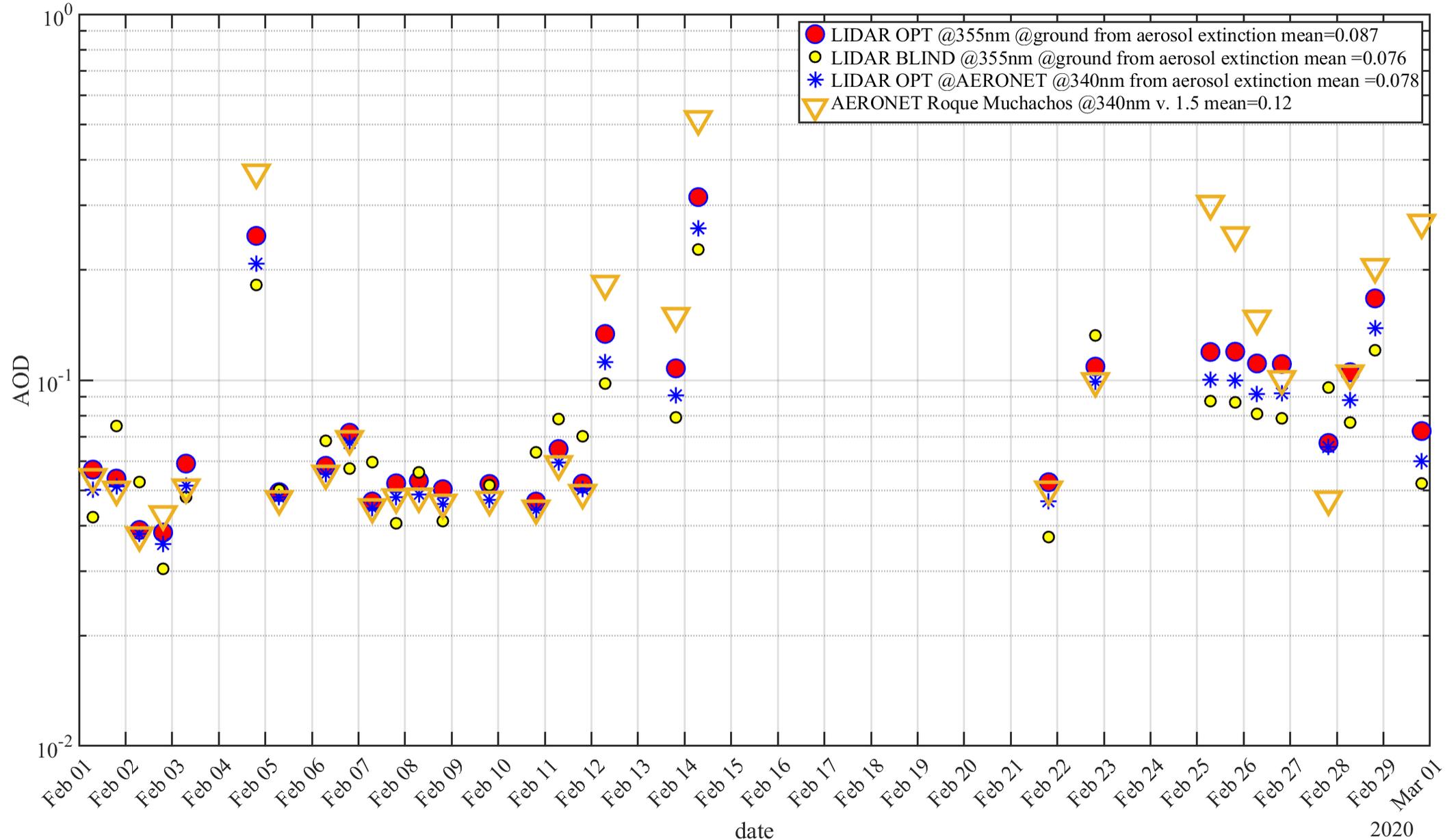
Simultaneous Measurements



- LIDAR Aerosol retrieval optimized with AOD & ang exp from AERONET (stratification)

RAMAN - From aerosol extinction data...

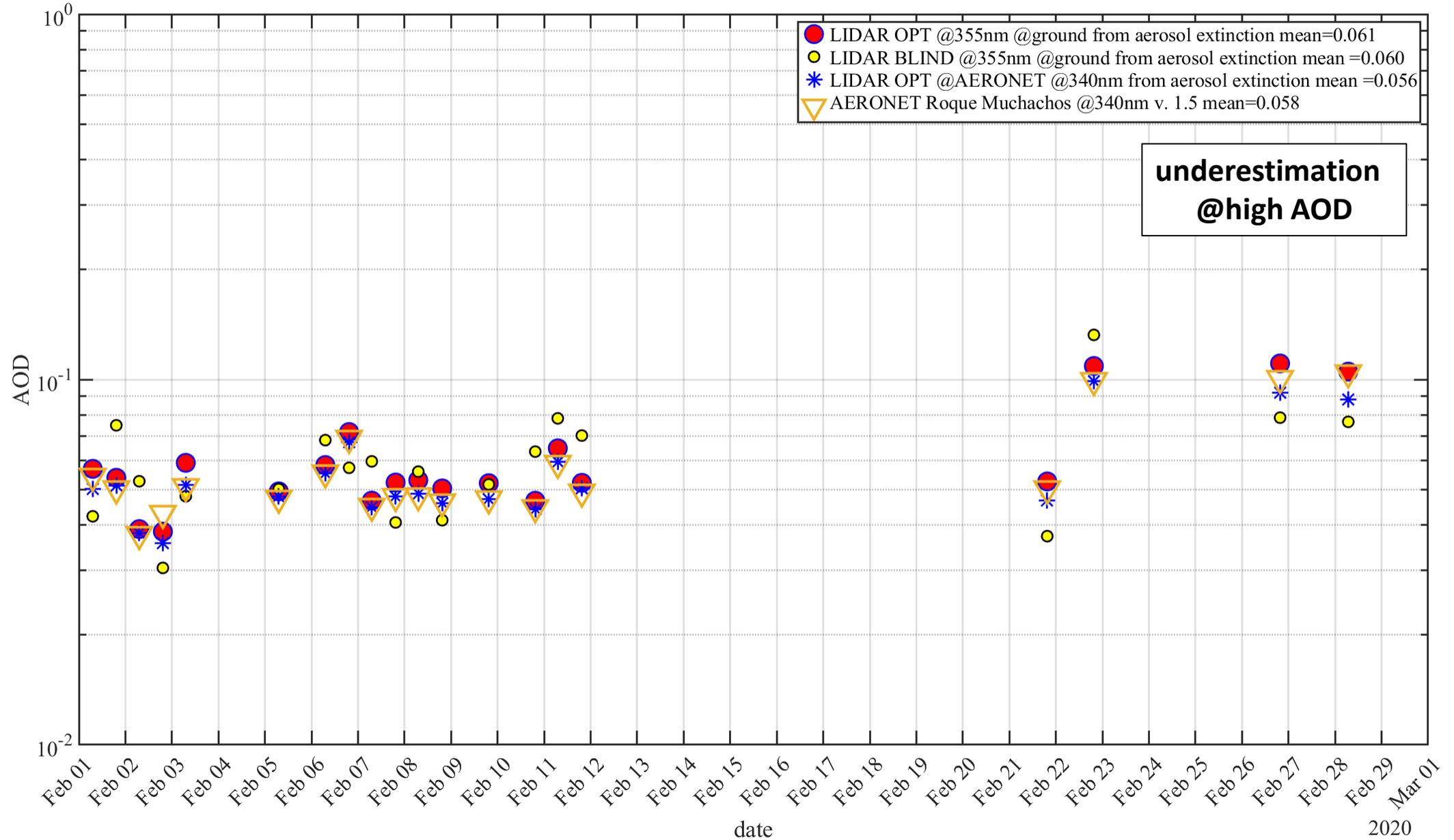
Simultaneous Measurements



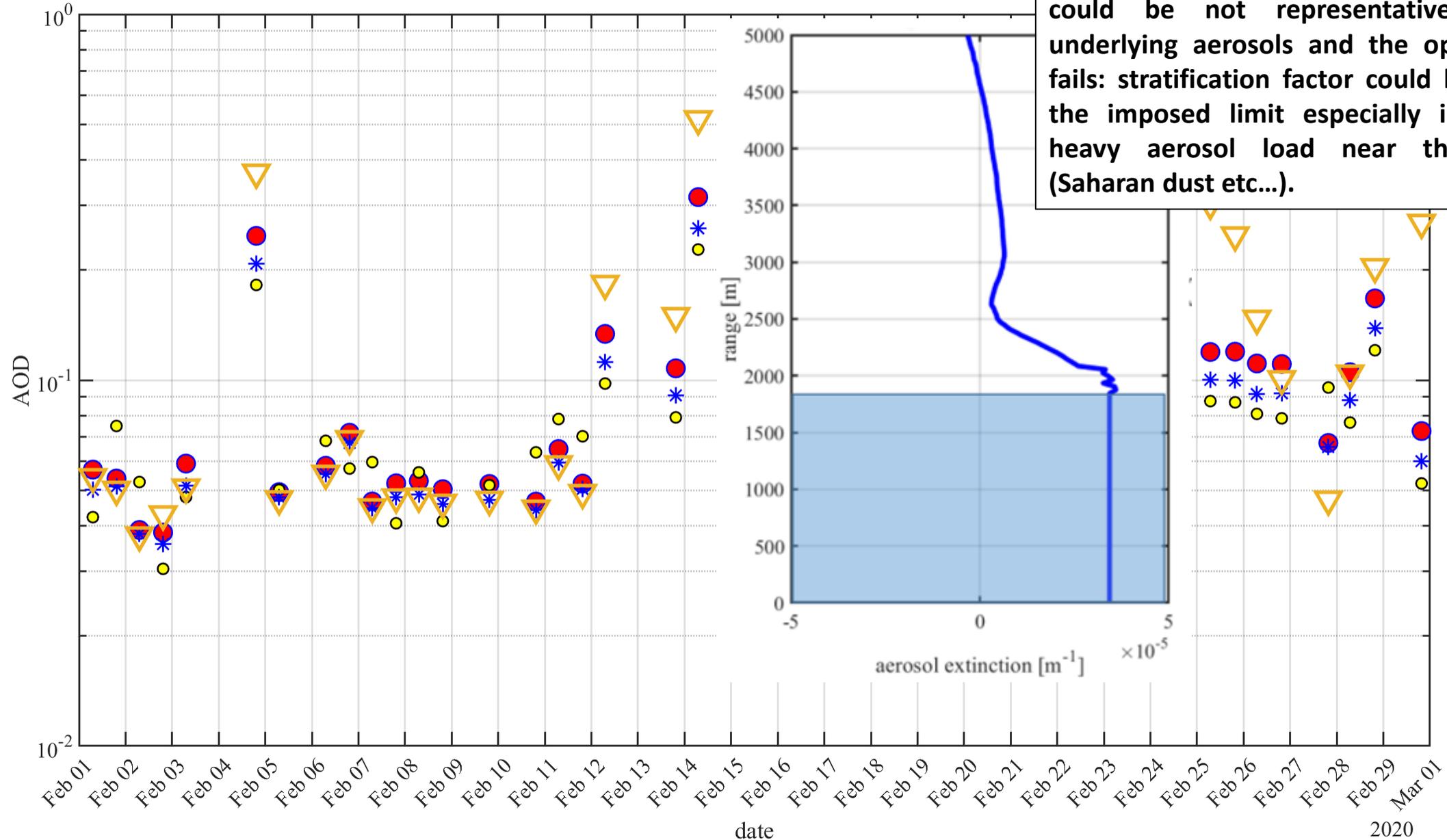
- LIDAR Aerosol retrieval optimized with AOD & ang exp from AERONET (stratification)

RAMAN - From aerosol extinction data...

Simultaneous Measurements



- LIDAR Aerosol retrieval optimized with AOD & ang exp from AERONET (stratification)
- RAMAN - From aerosol extinction data...**

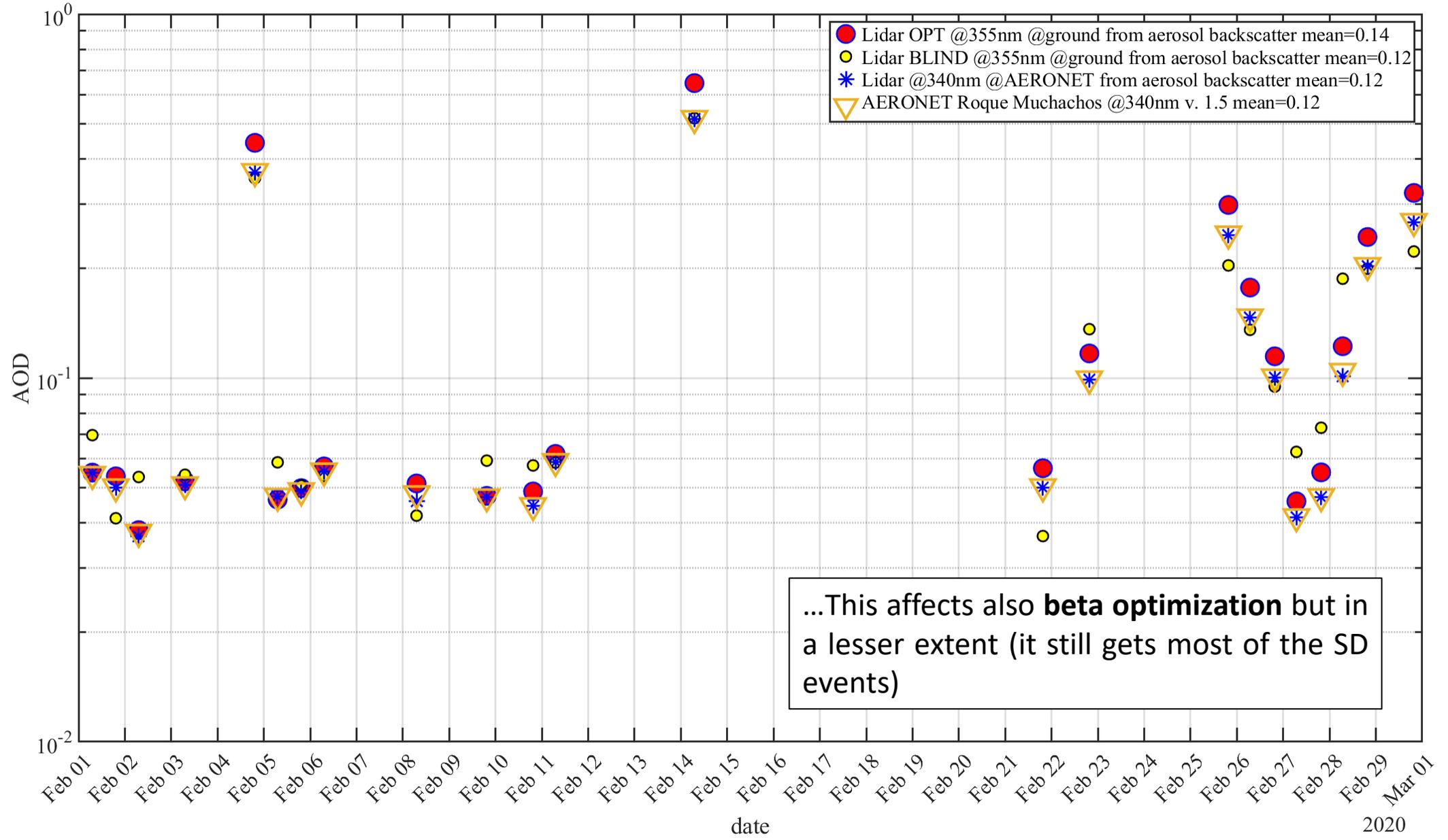


Overlap < 1 effect more pronounced for aerosol extinction (low pass derivative) and could be not representative of the underlying aerosols and the optimization fails: stratification factor could be outside the imposed limit especially in case of heavy aerosol load near the ground (Saharan dust etc...).

- LIDAR Aerosol retrieval optimized with AOD & ang exp from AERONET (stratification)

RAMAN - From aerosol extinction data...

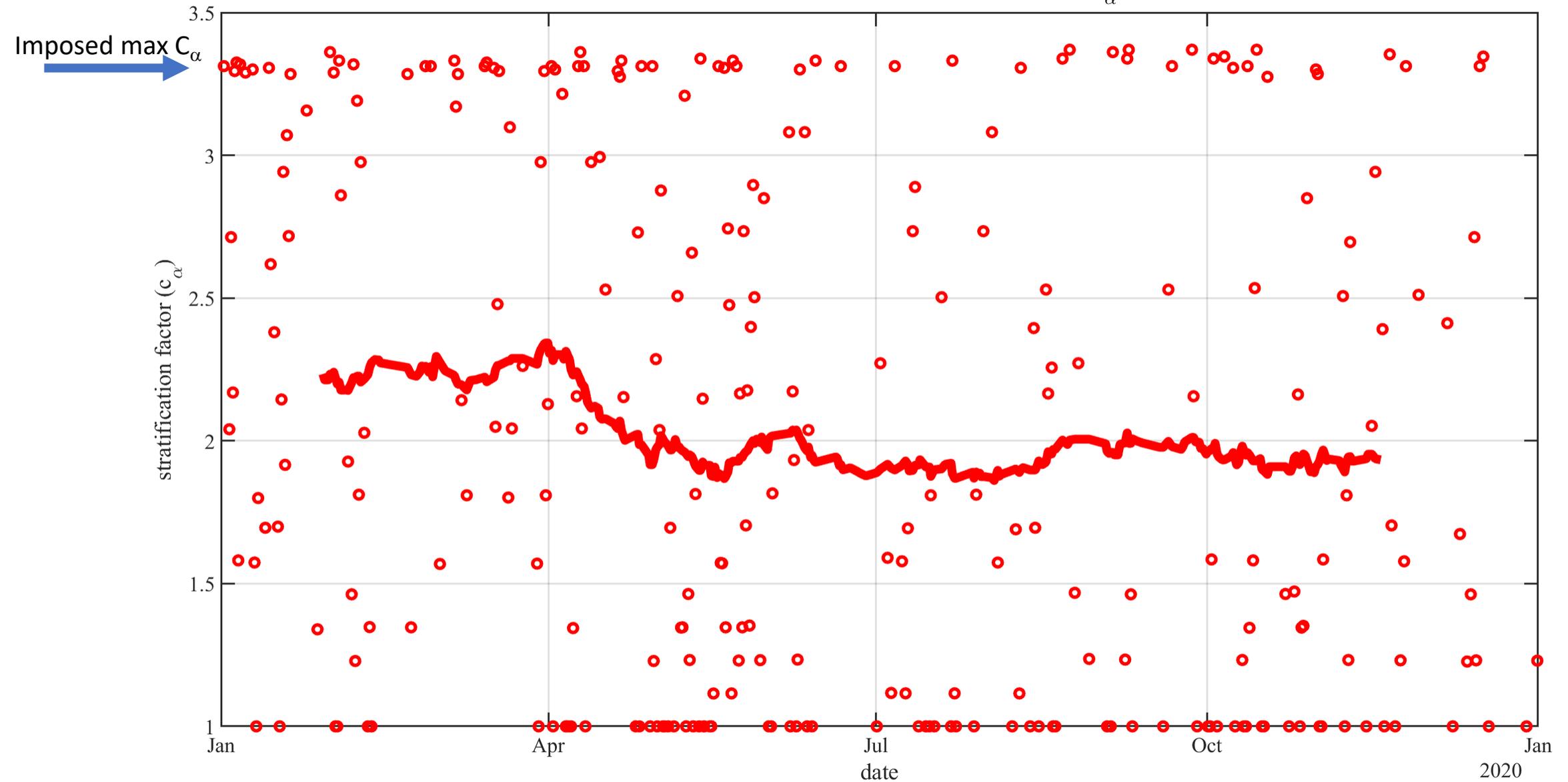
Simultaneous Measurements



- LIDAR Aerosol retrieval optimized with AOD & ang exp from AERONET (stratification)

RAMAN - From aerosol extinction data...

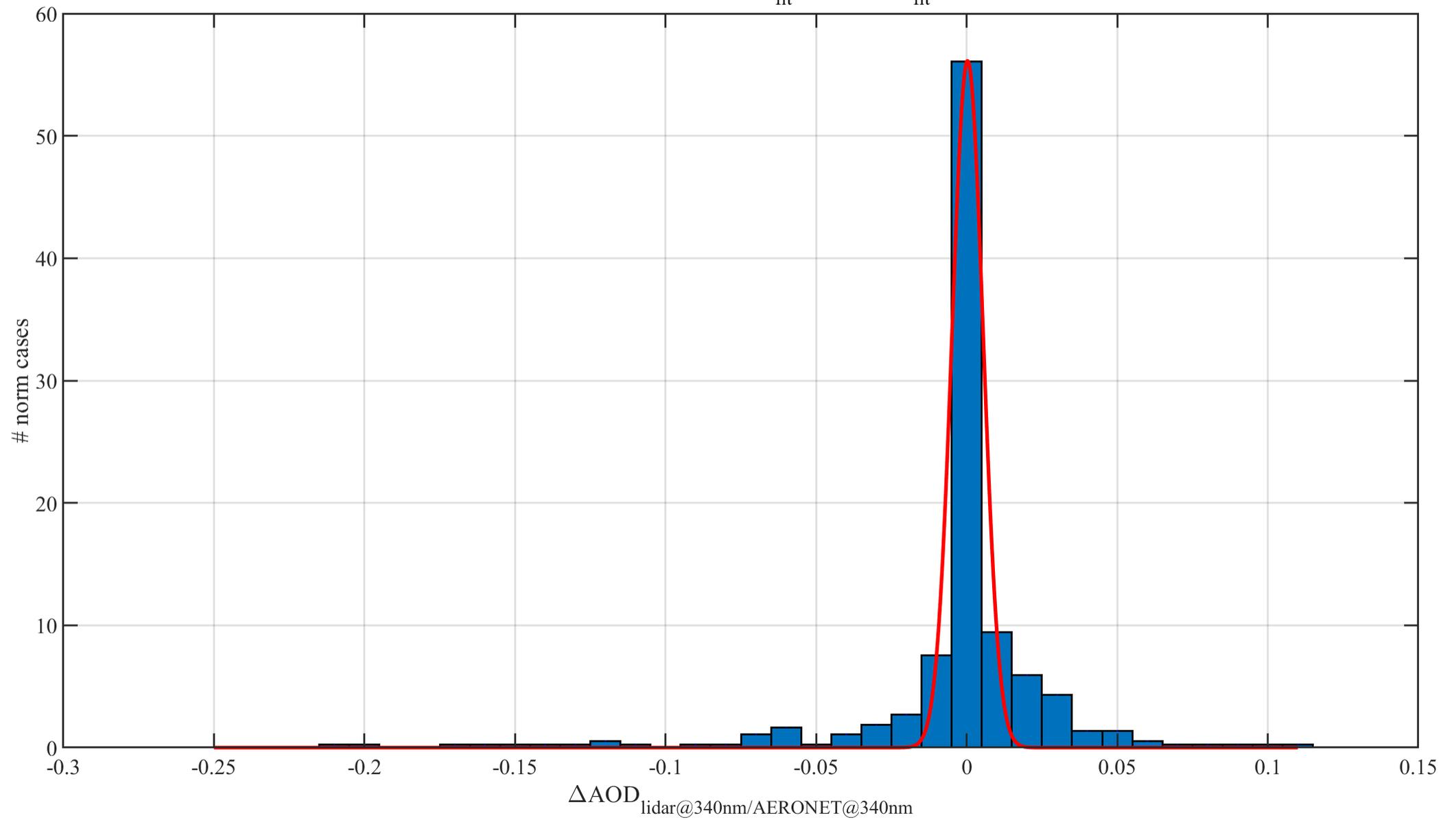
Sim. meas. ($\Delta t < 3h$); $\Delta alt. lidar/sunph. = 241m$; mean $c_\alpha = 2.054$



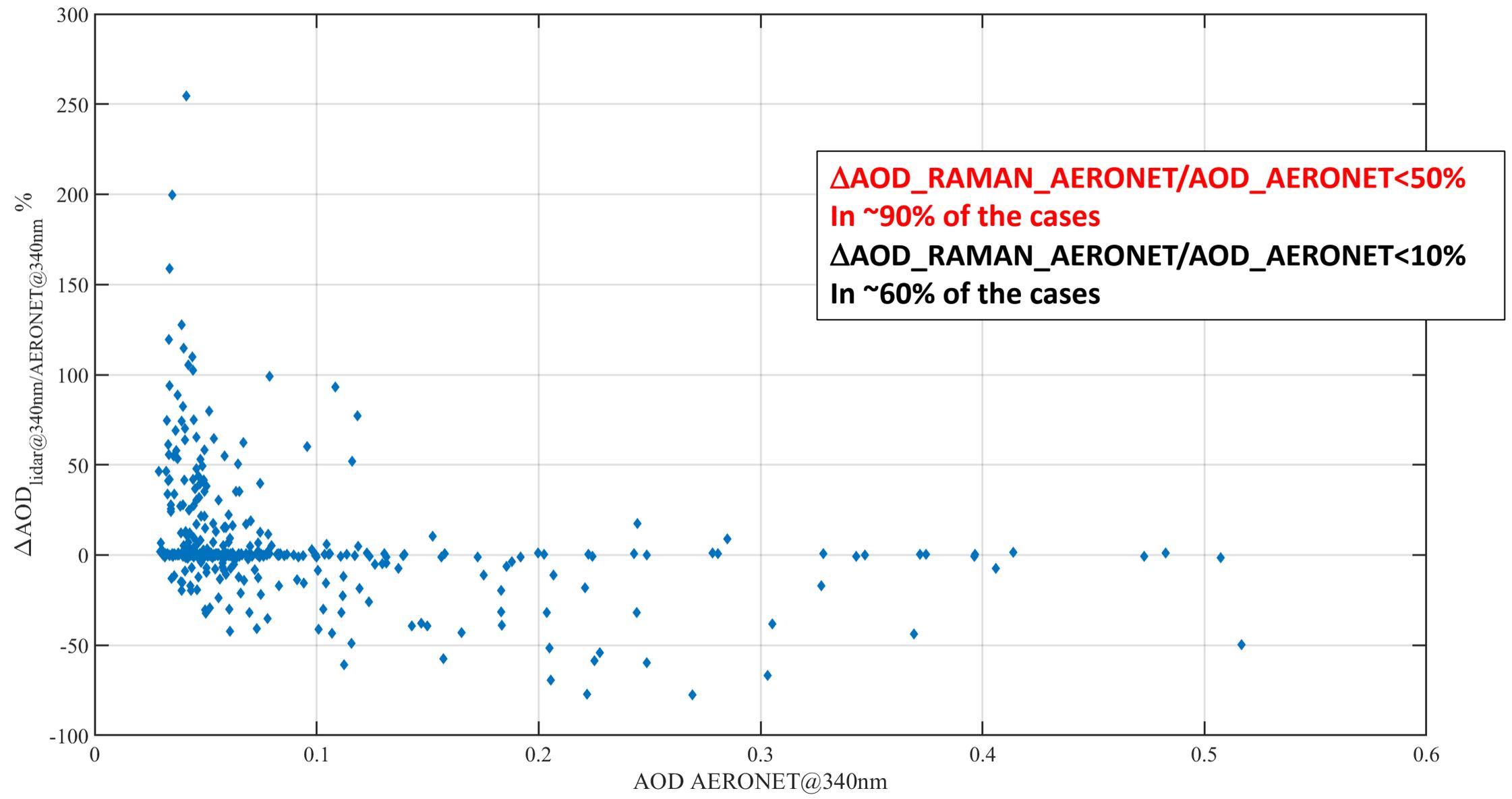
- LIDAR Aerosol retrieval optimized with AOD & ang exp from AERONET (stratification)

RAMAN - From aerosol extinction data...

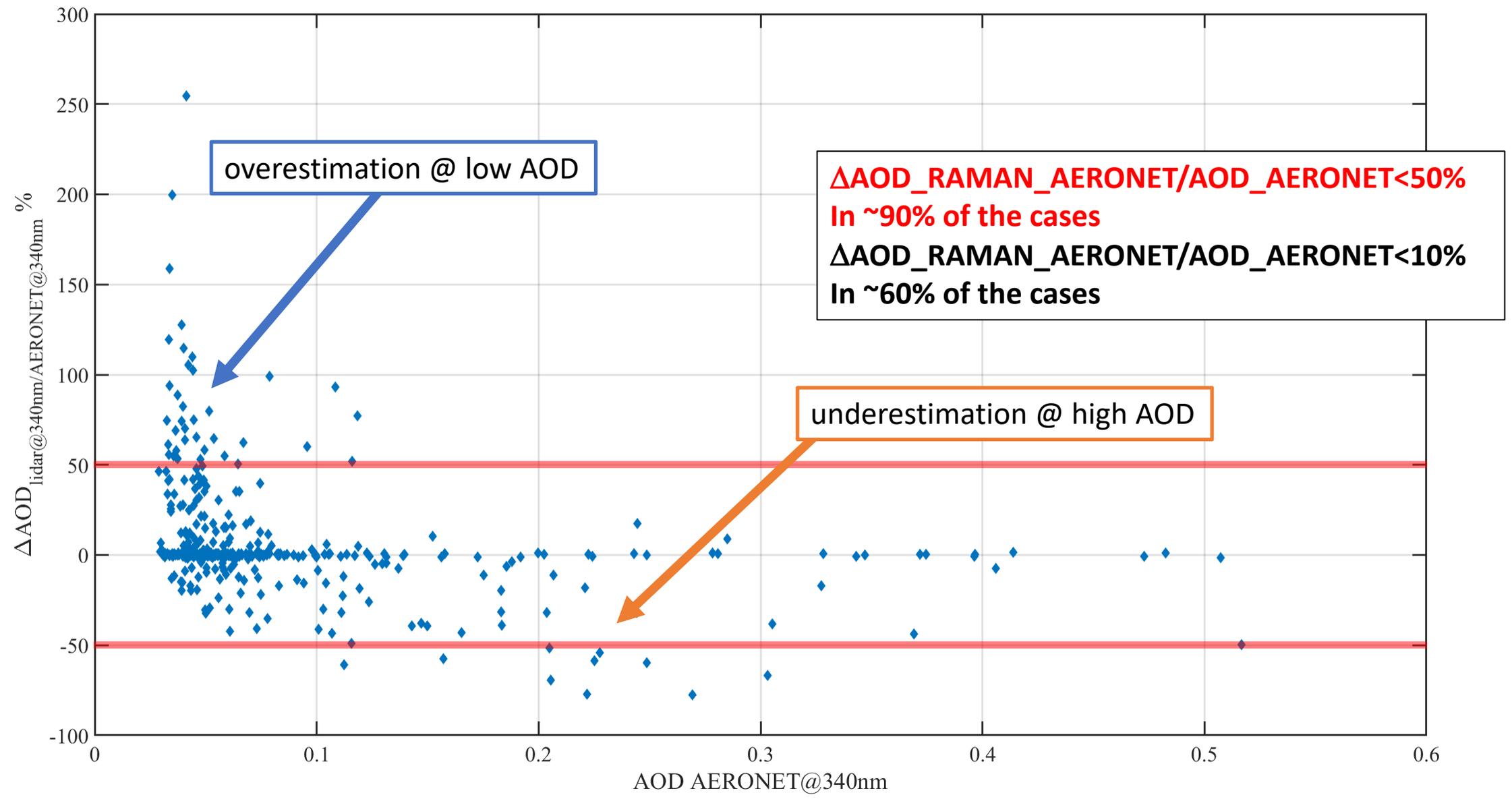
RAMAN - mean= -0.003, std= 0.04, - mean_{fit}=0.0003, std_{fit}=0.007 - jan20/dec20



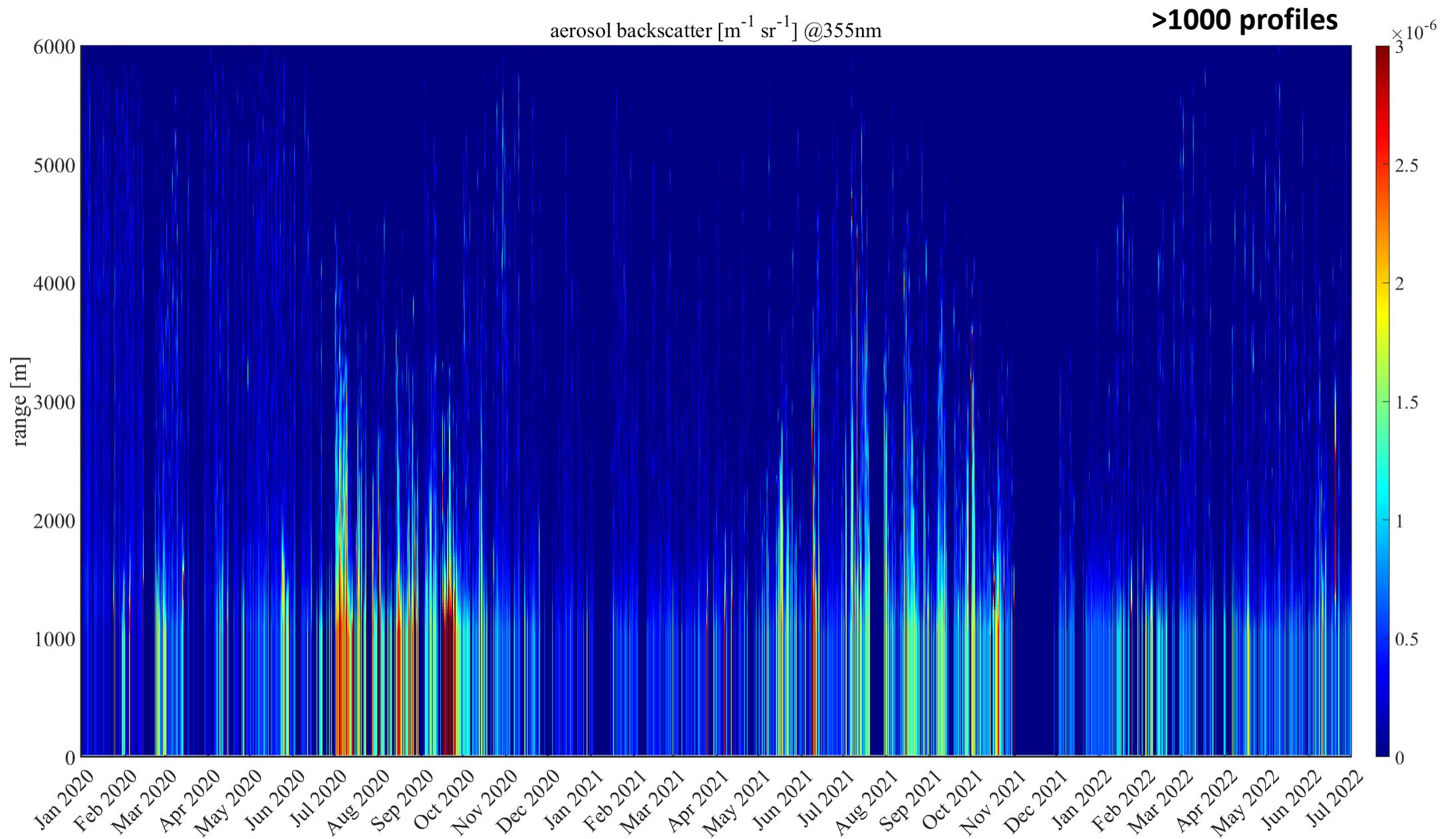
- LIDAR Aerosol retrieval optimized with AOD & ang exp from AERONET (stratification)



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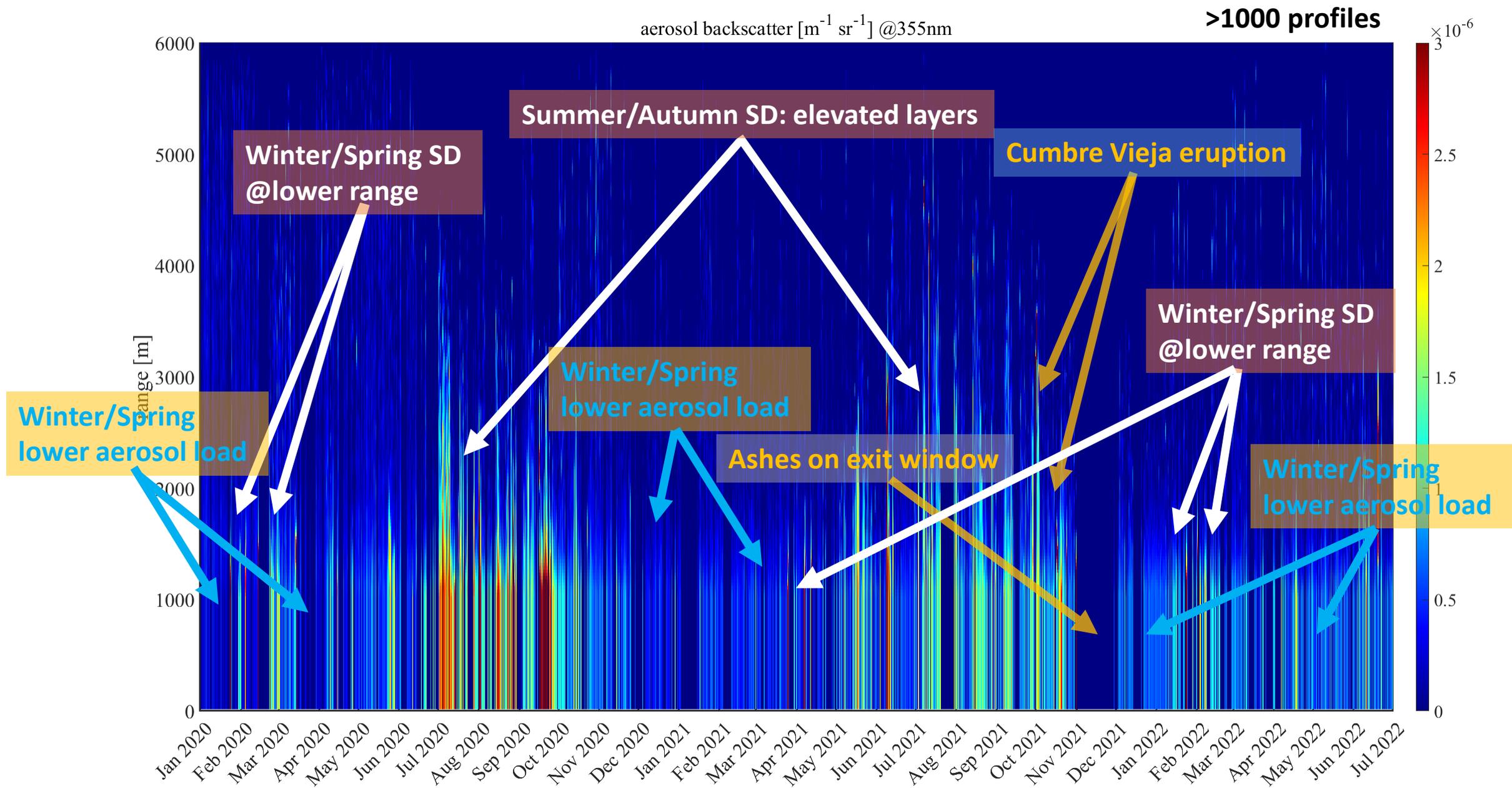


Vertical Profiles

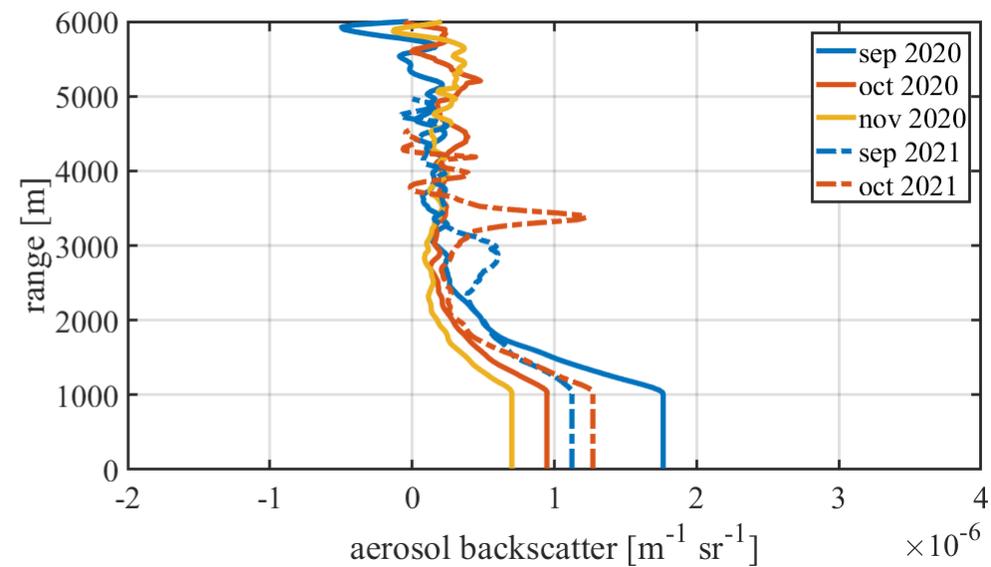
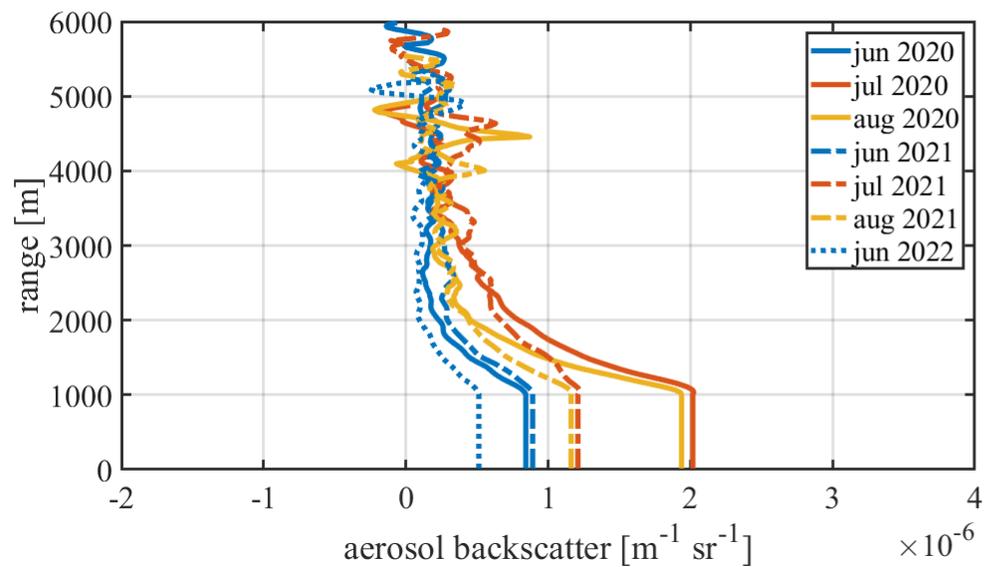
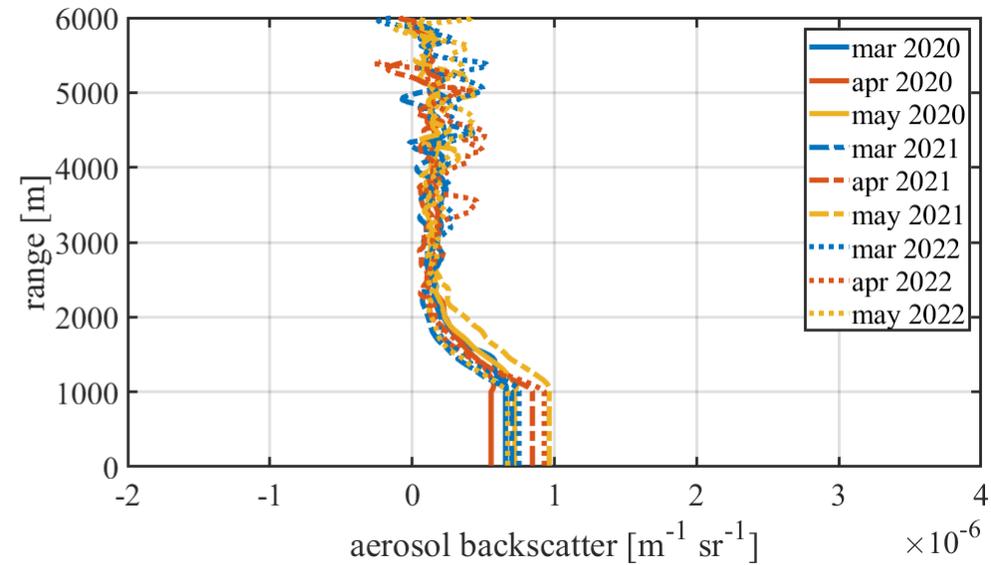
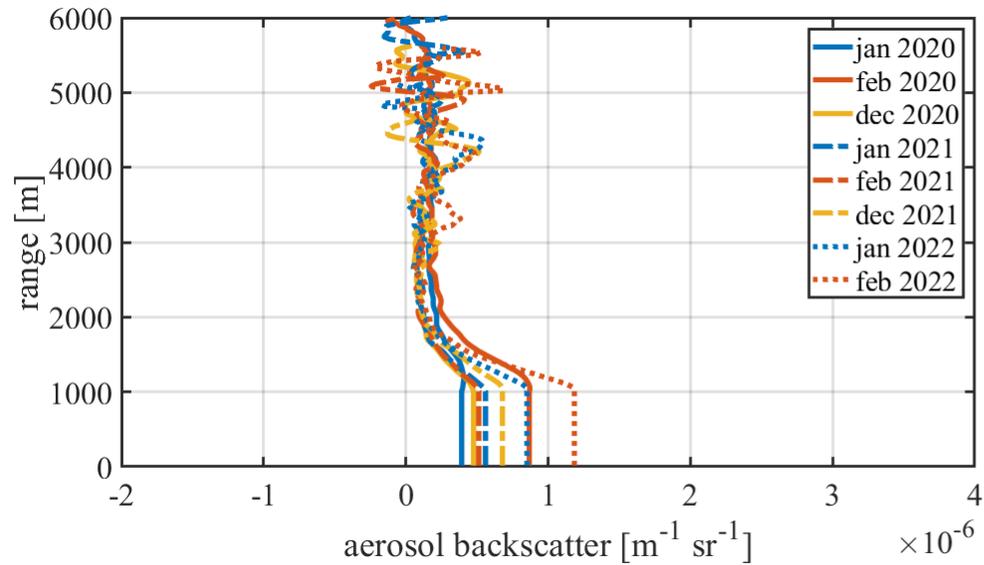


AtmoHEAD 2022, 13 - 15 July (Capri, Italy)

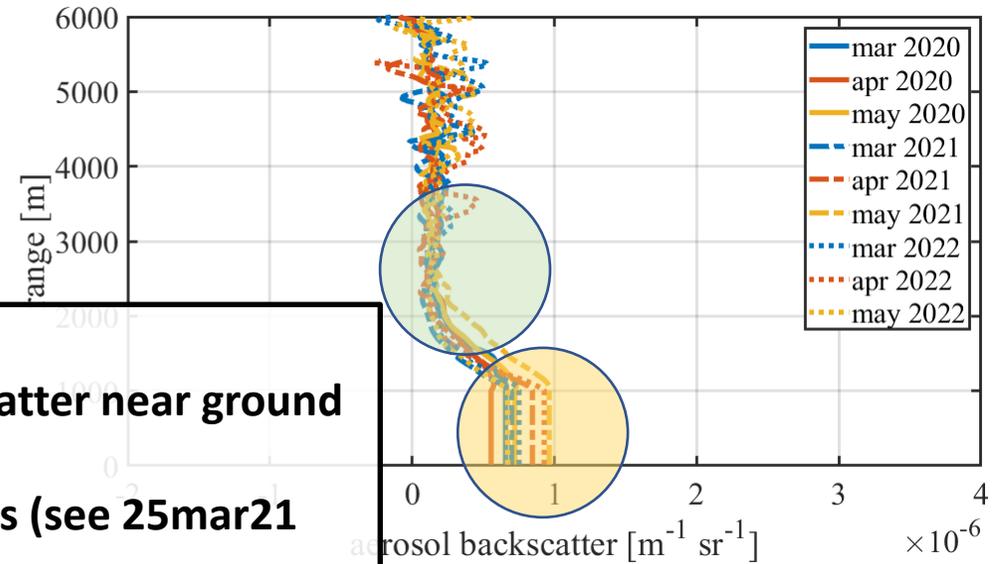
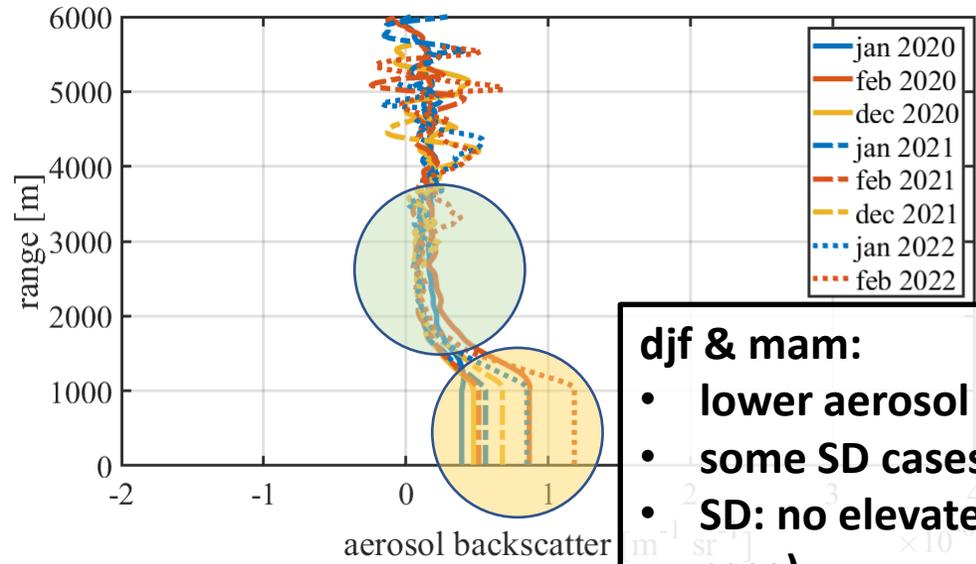
Vertical Profiles



Vertical Profiles

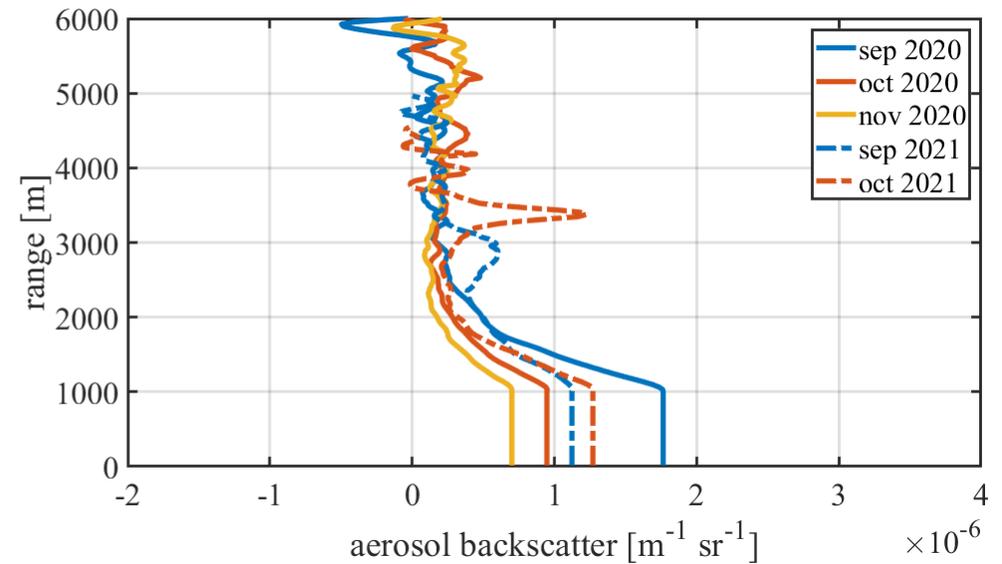
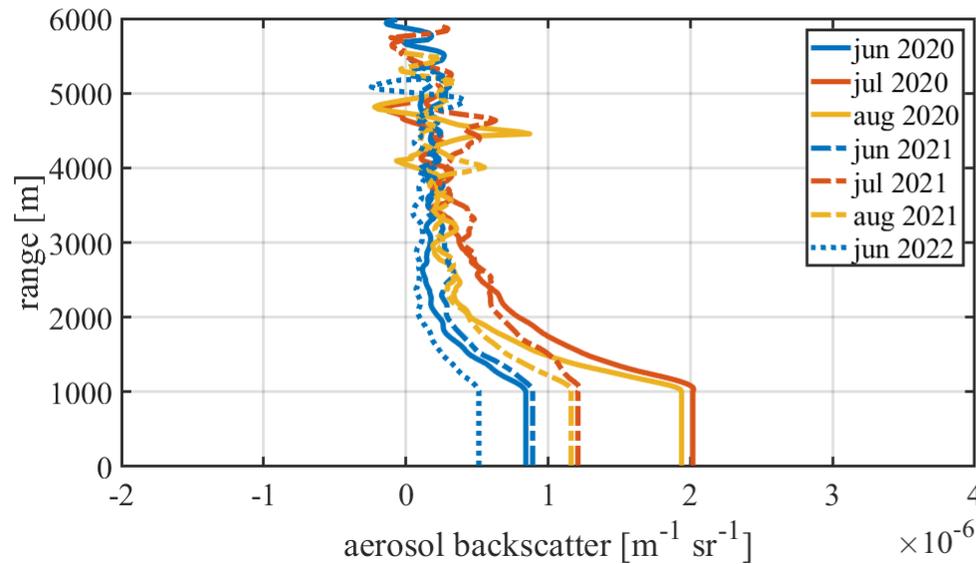


Vertical Profiles

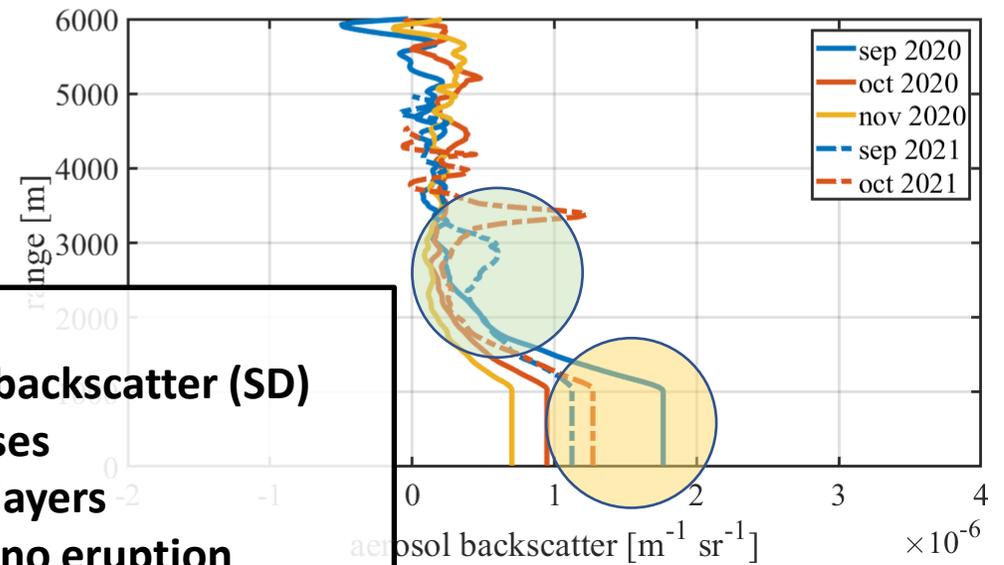
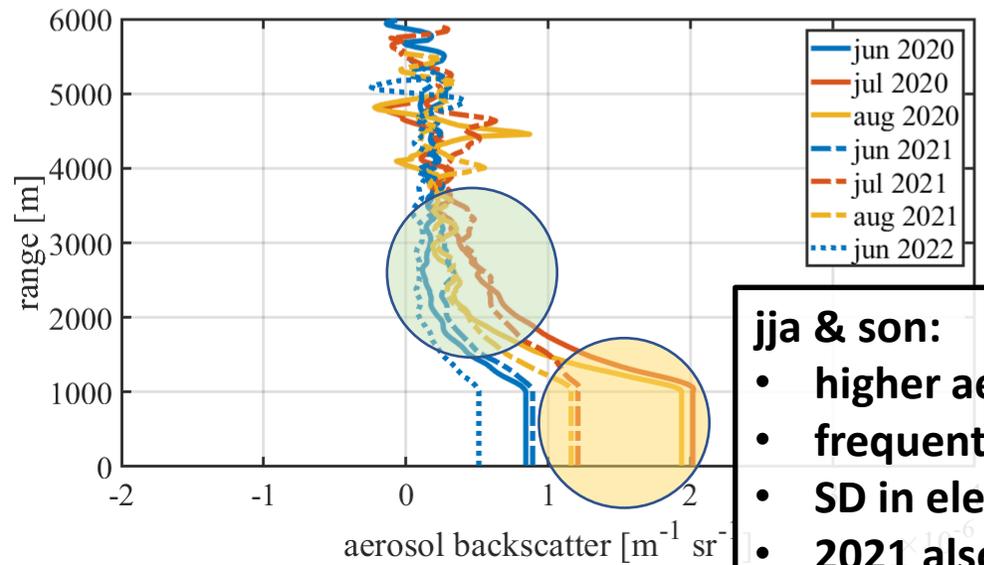
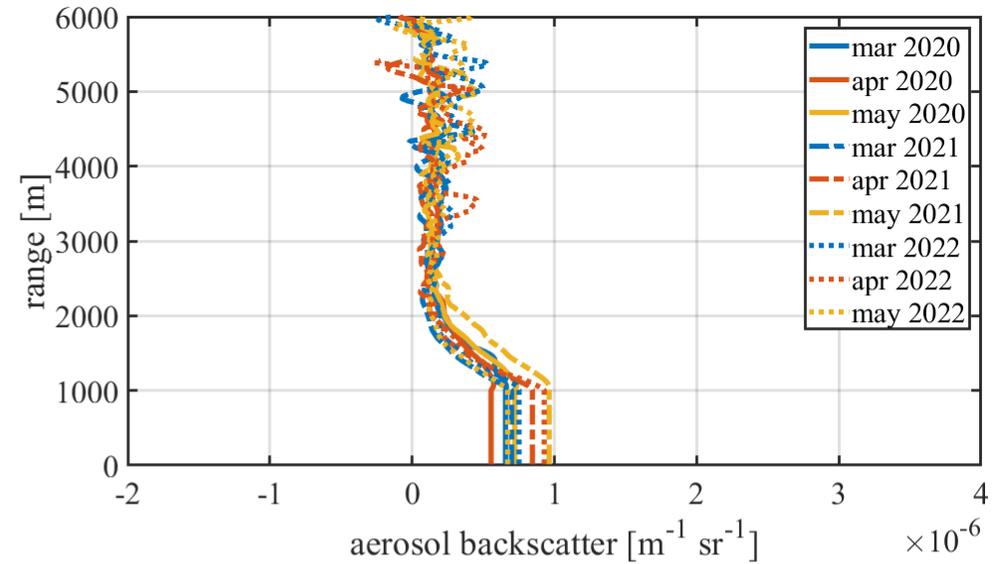
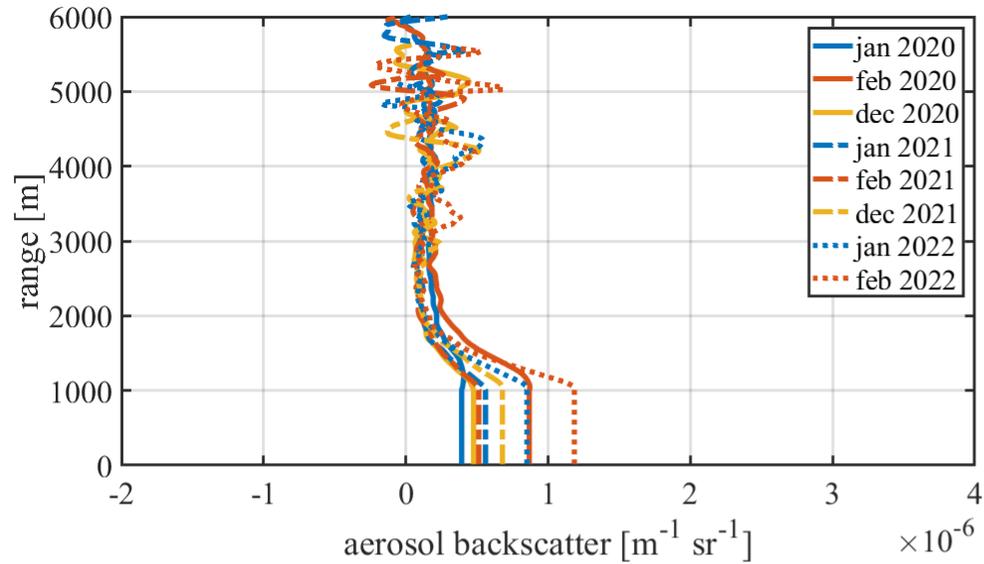


djf & mam:

- lower aerosol backscatter near ground
- some SD cases
- SD: no elevated layers (see 25mar21 case).



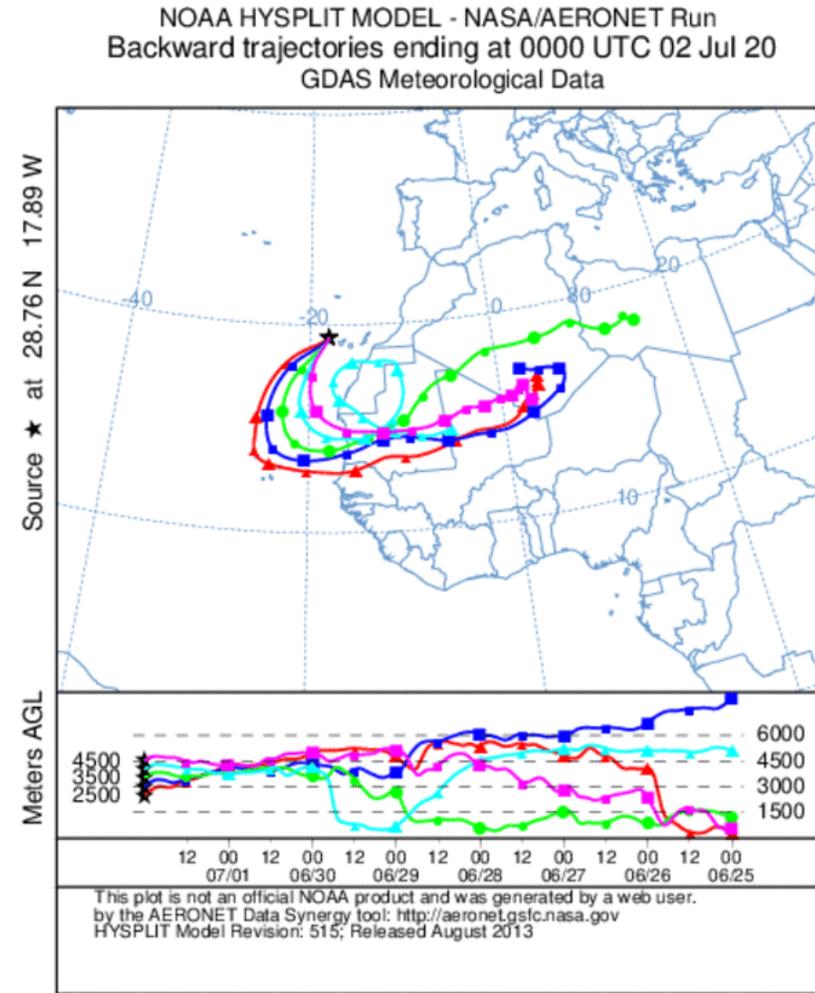
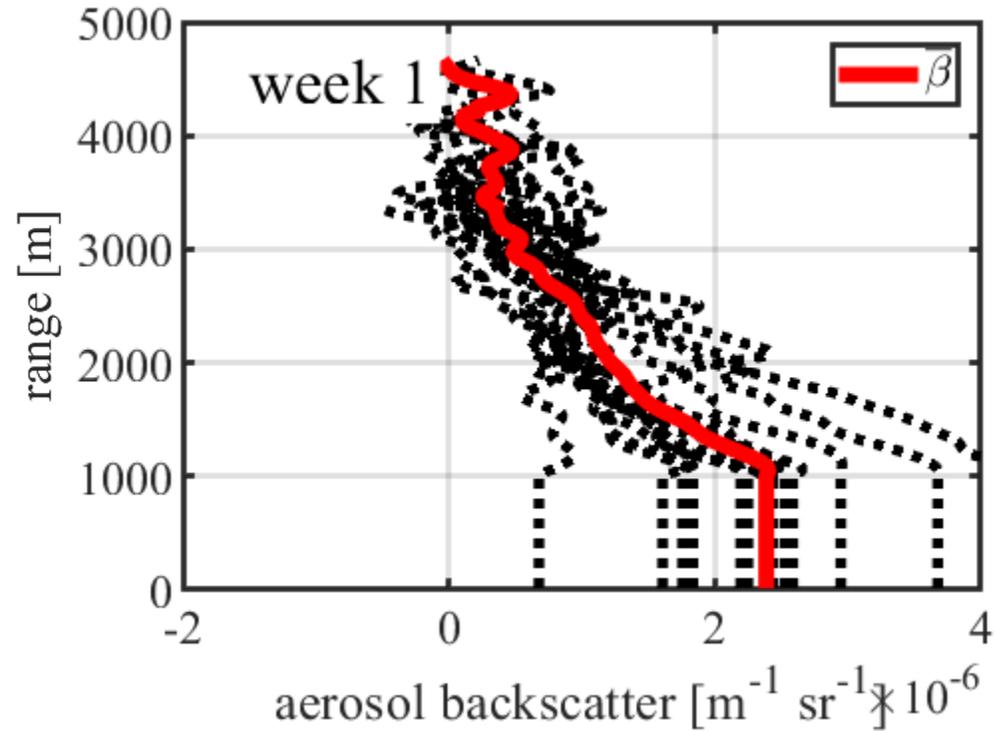
Vertical Profiles



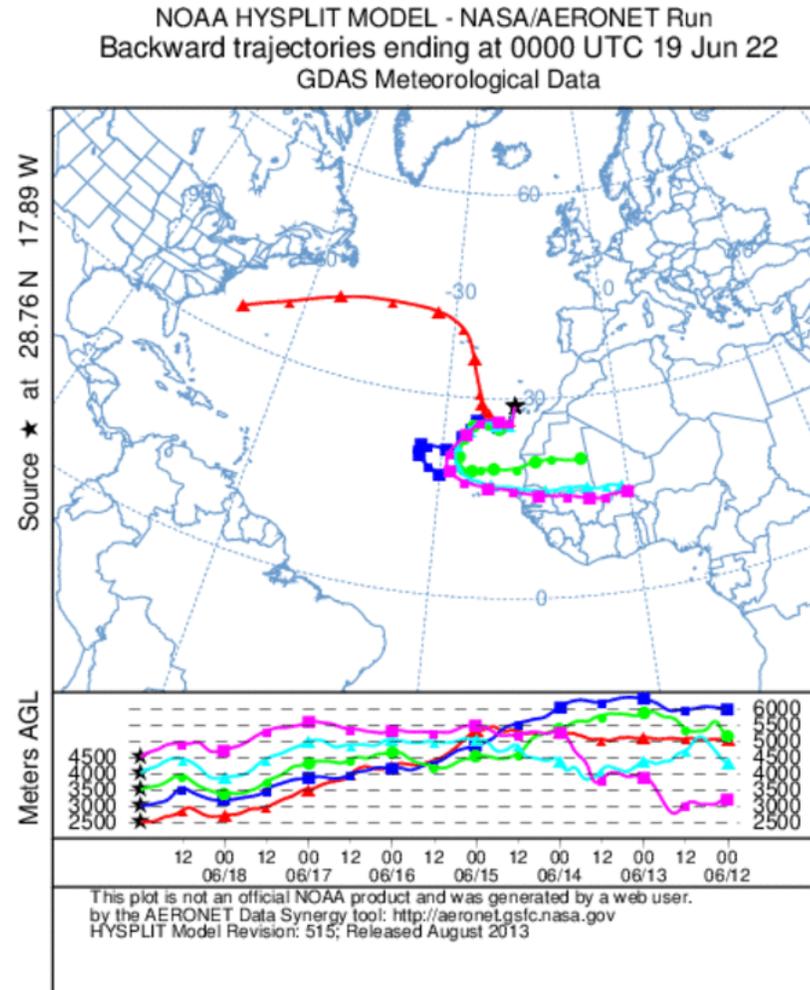
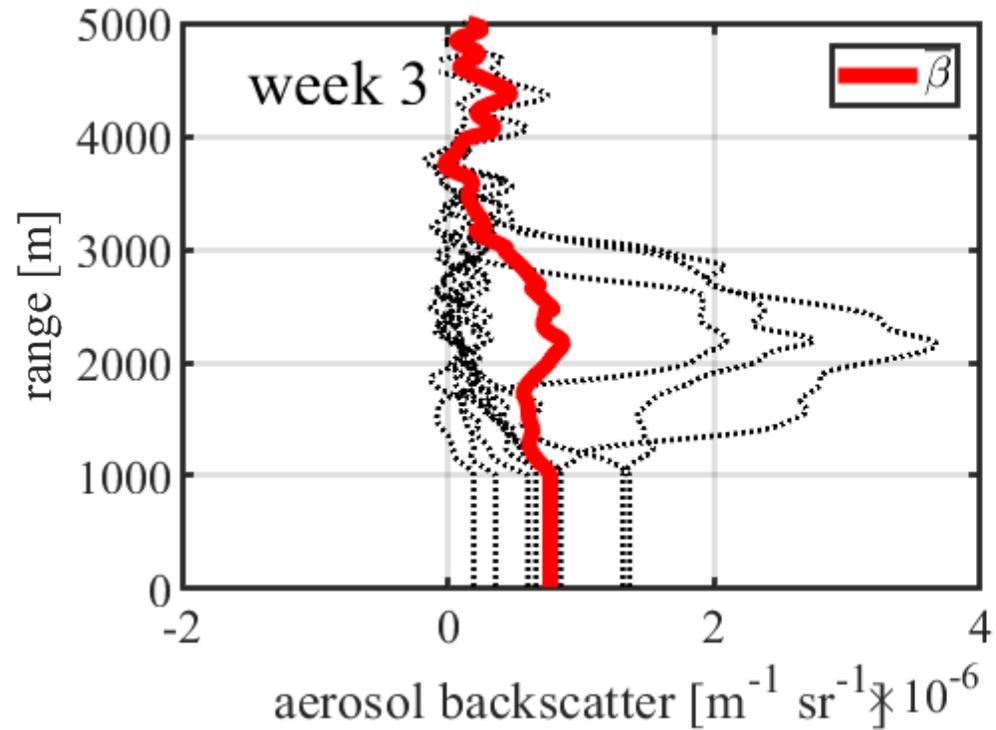
jja & son:

- higher aerosol backscatter (SD)
- frequent SD cases
- SD in elevated layers
- 2021 also volcano eruption

July 20 - SD **also** in elevated layers

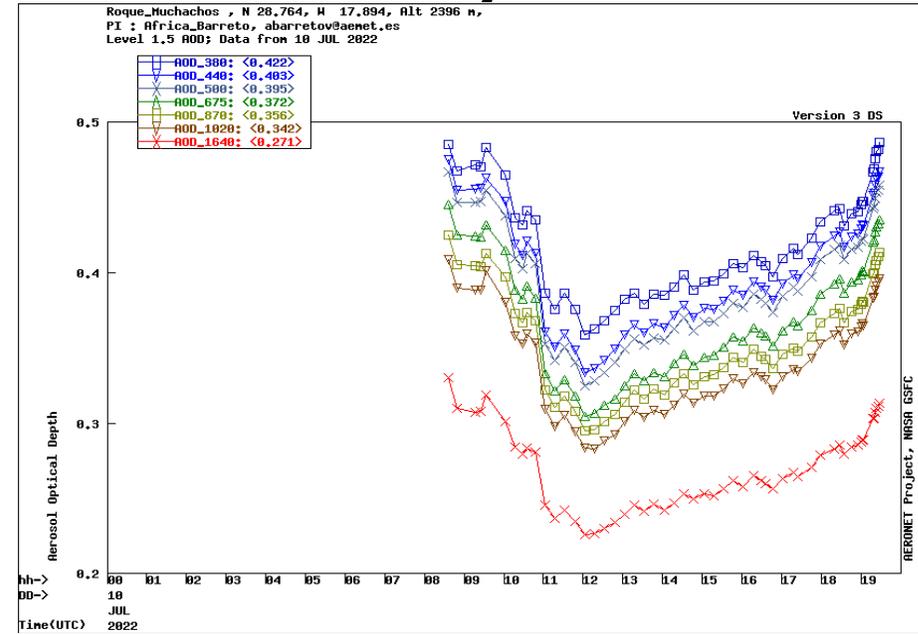
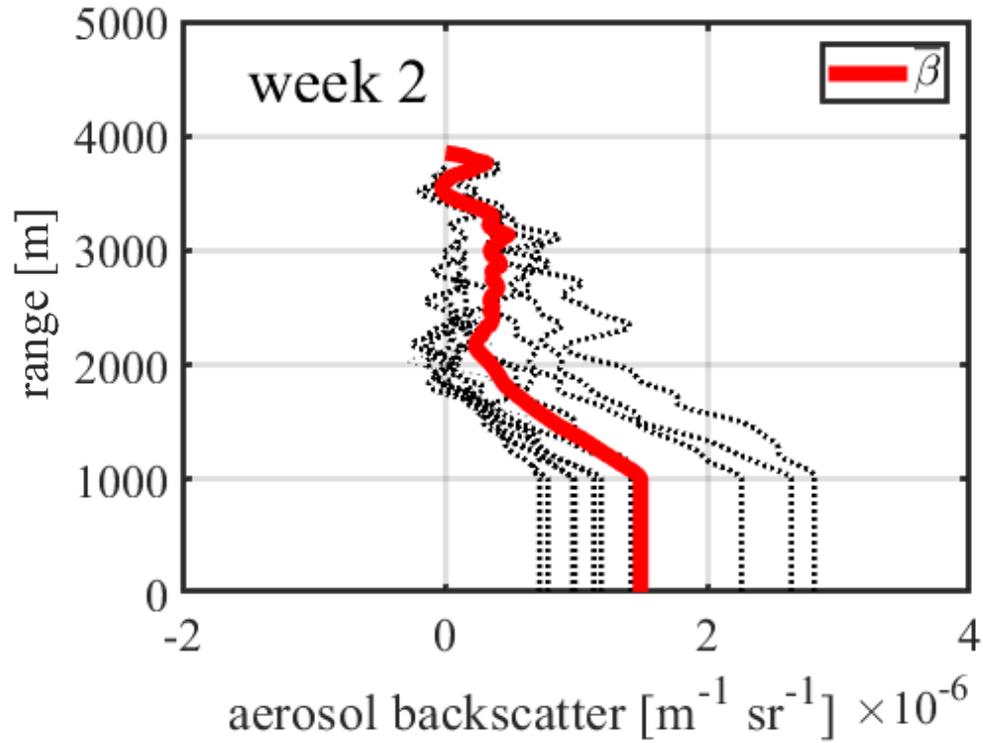


June 22 - SD in elevated layers



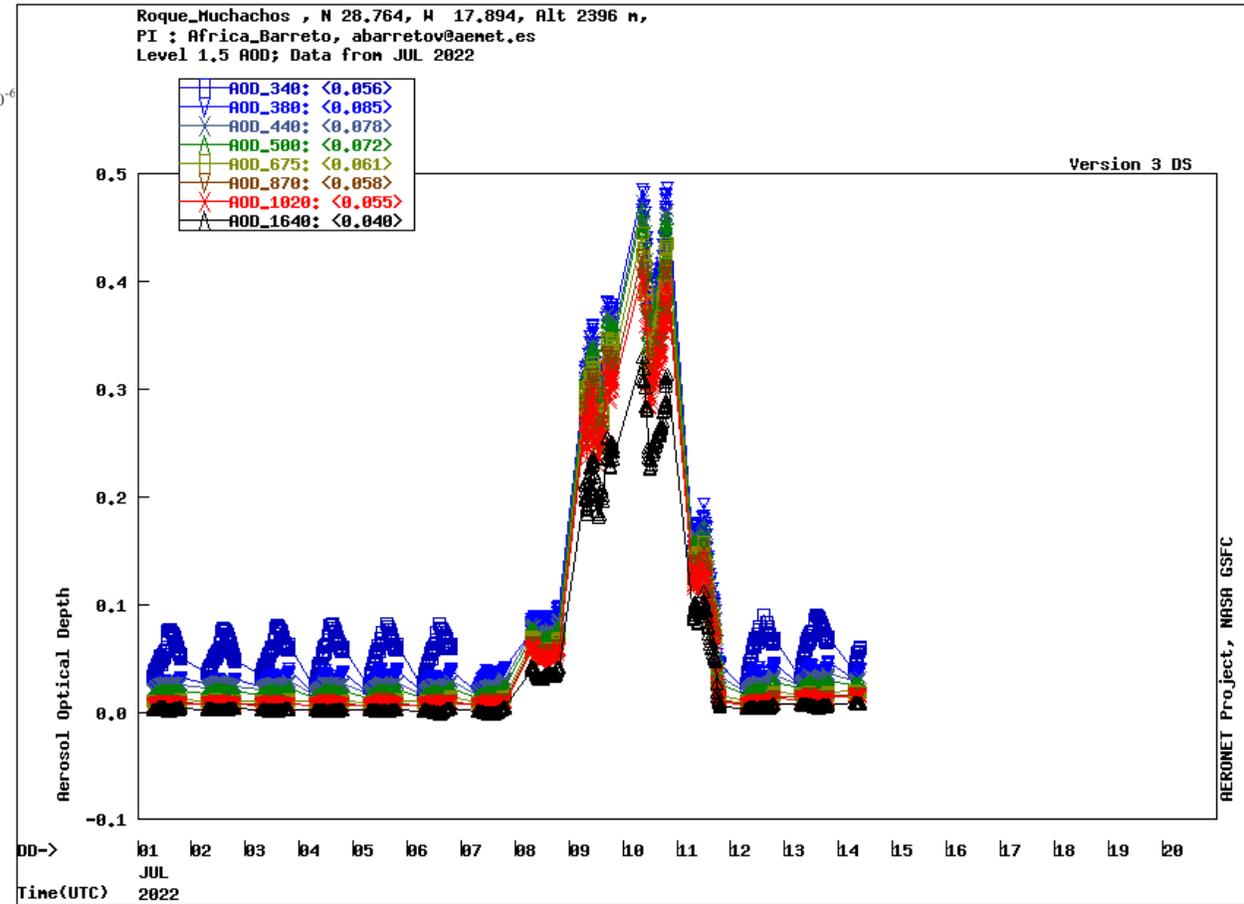
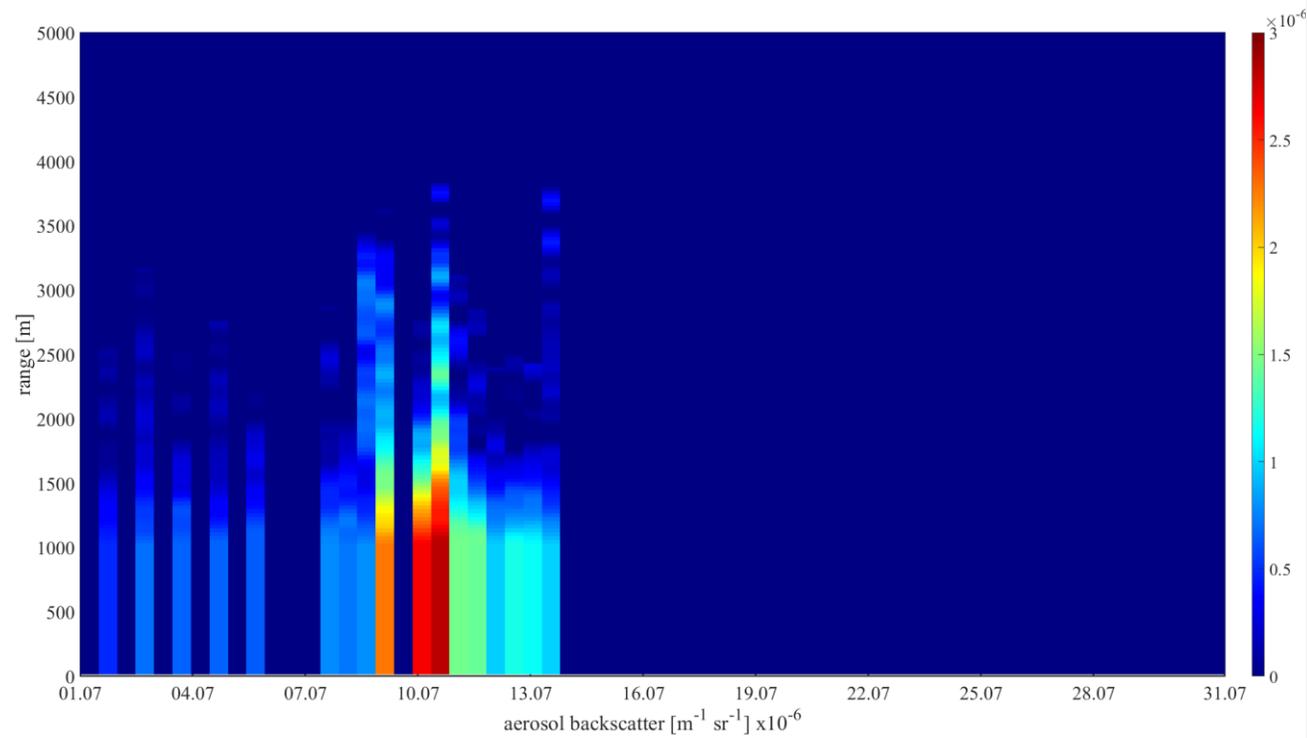
July 22 - SD also in elevated layers

Last measurements 14/07/22 05:31



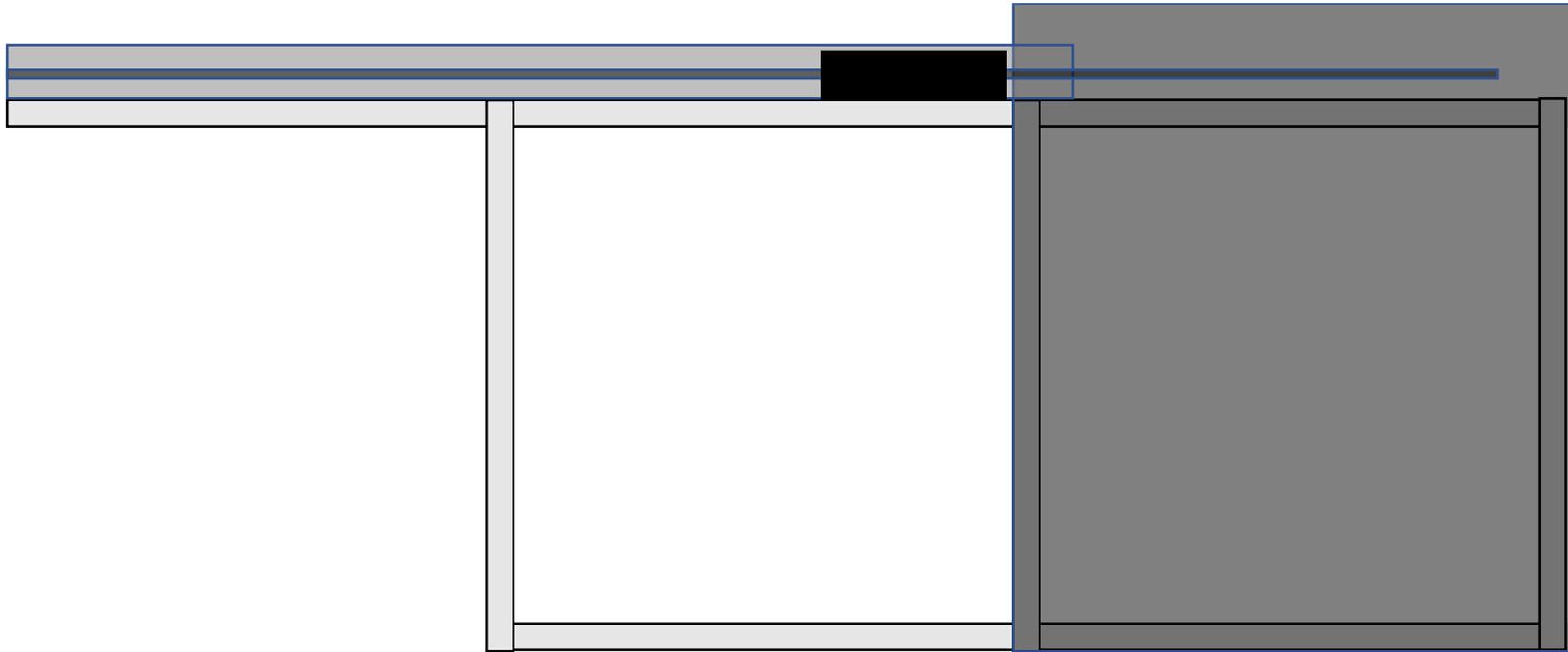
July 22 - SD **also** in elevated layers

Last measurements 14/07/22 05:31



- **Future Upgrades**
ROOF HATCH scale 1:10

top view



Aluminium bars – motorized metallic cover

- **Future Upgrades**

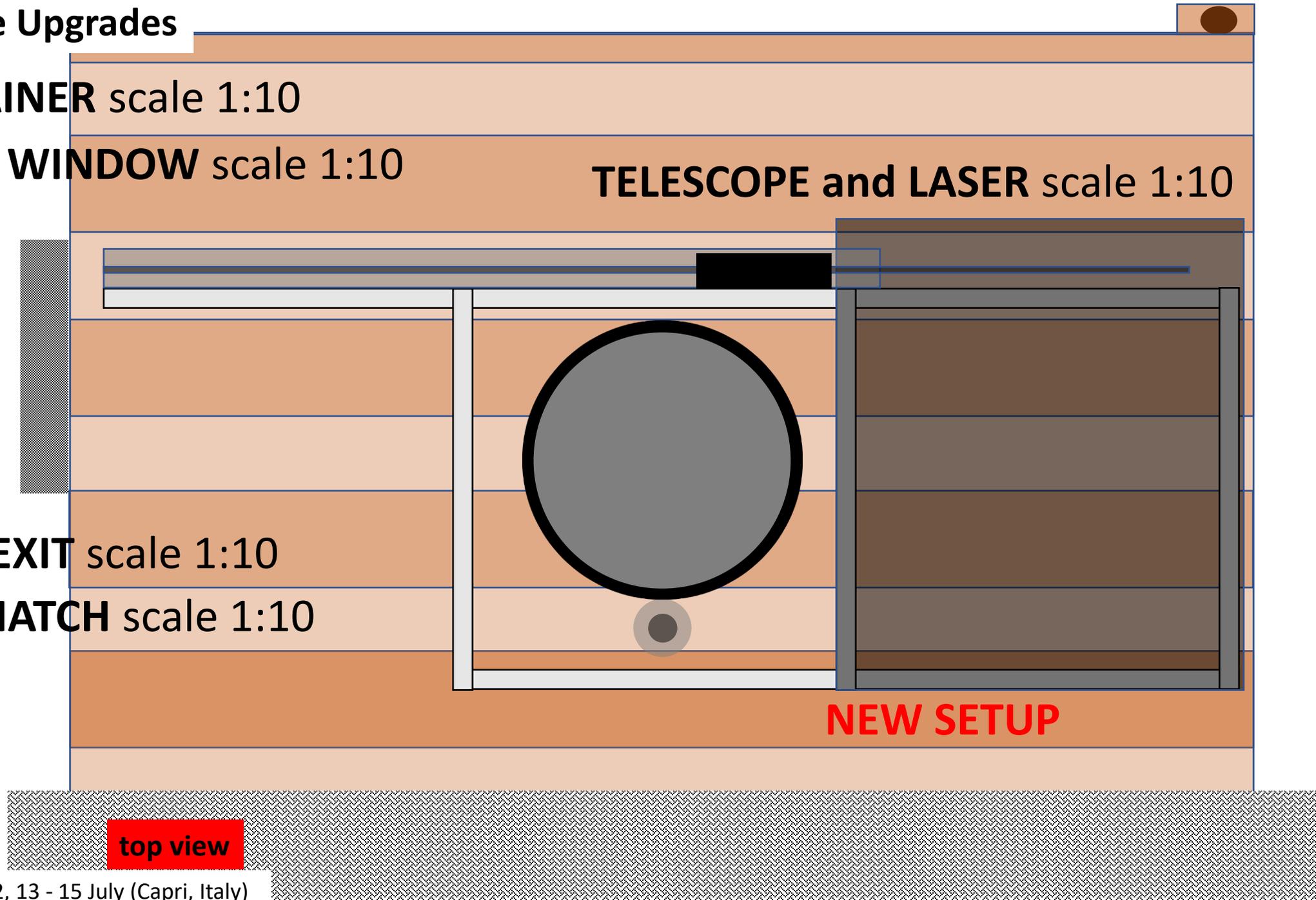
CONTAINER scale 1:10

Si EXIT WINDOW scale 1:10

TELESCOPE and LASER scale 1:10

LASER EXIT scale 1:10

ROOF HATCH scale 1:10



top view

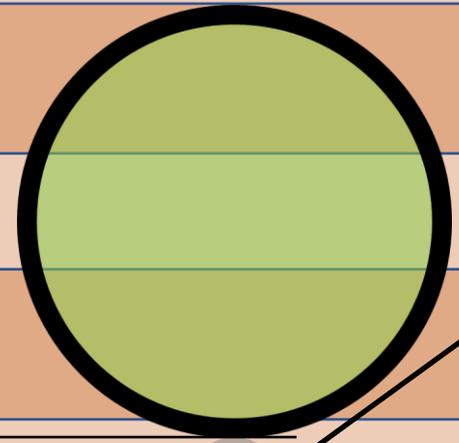
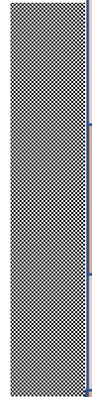
NEW SETUP

• Future Upgrades

CONTAINER scale 1:10

Si EXIT WINDOW scale 1:10

HOLDERS to be soldered



HOLE \varnothing MAX 80 mm

LASER EXIT scale 1:10

60 mm



top view

HOLDERS to be soldered

- **Future Upgrades**



The roof hatch (structure) in the right position: reference points are indicated on the container and on the holders.

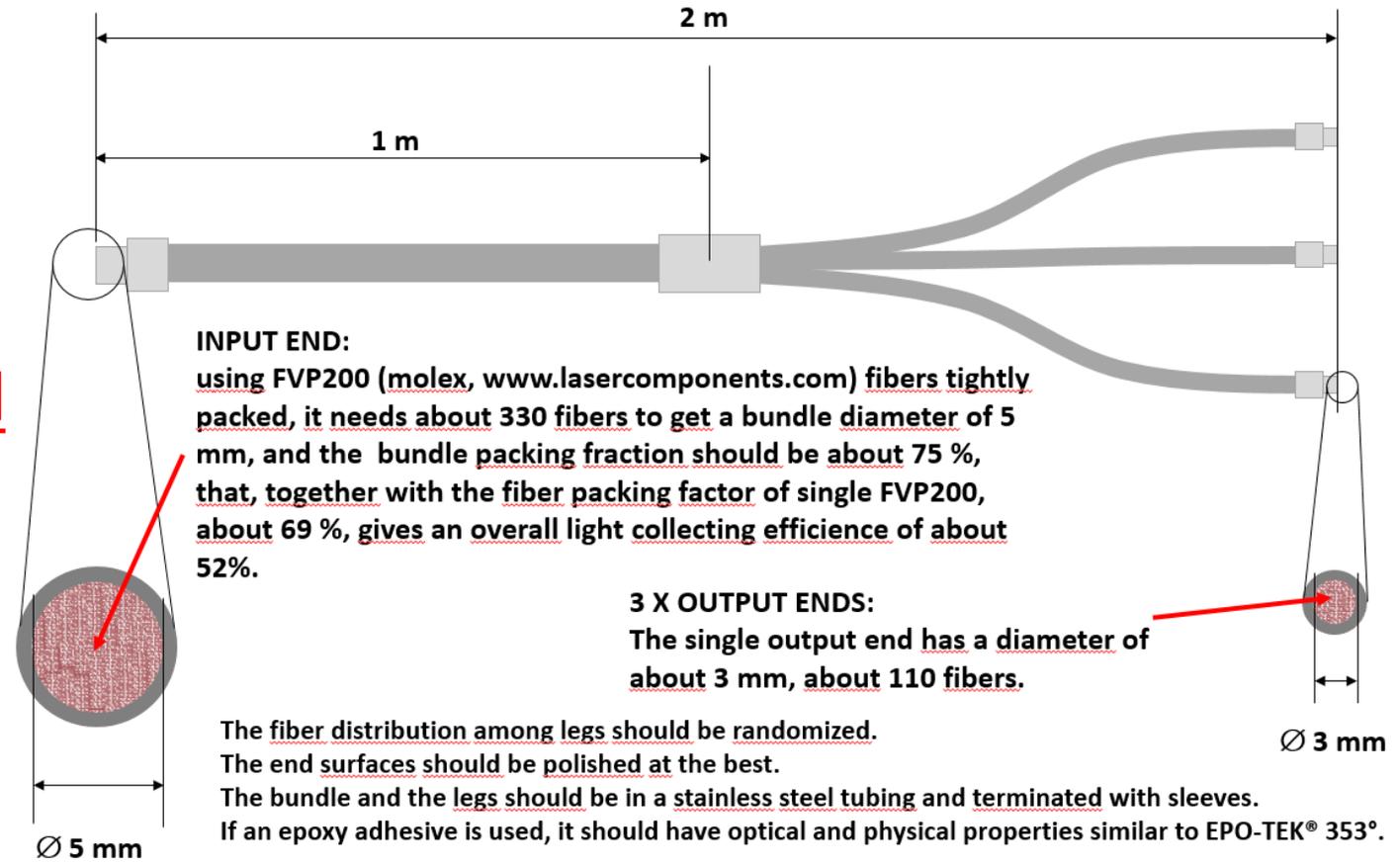
7 HOLDERS to be soldered

- Future Upgrades

- Complete the cover/new beam exit: **less stray lights, cleaner window.**

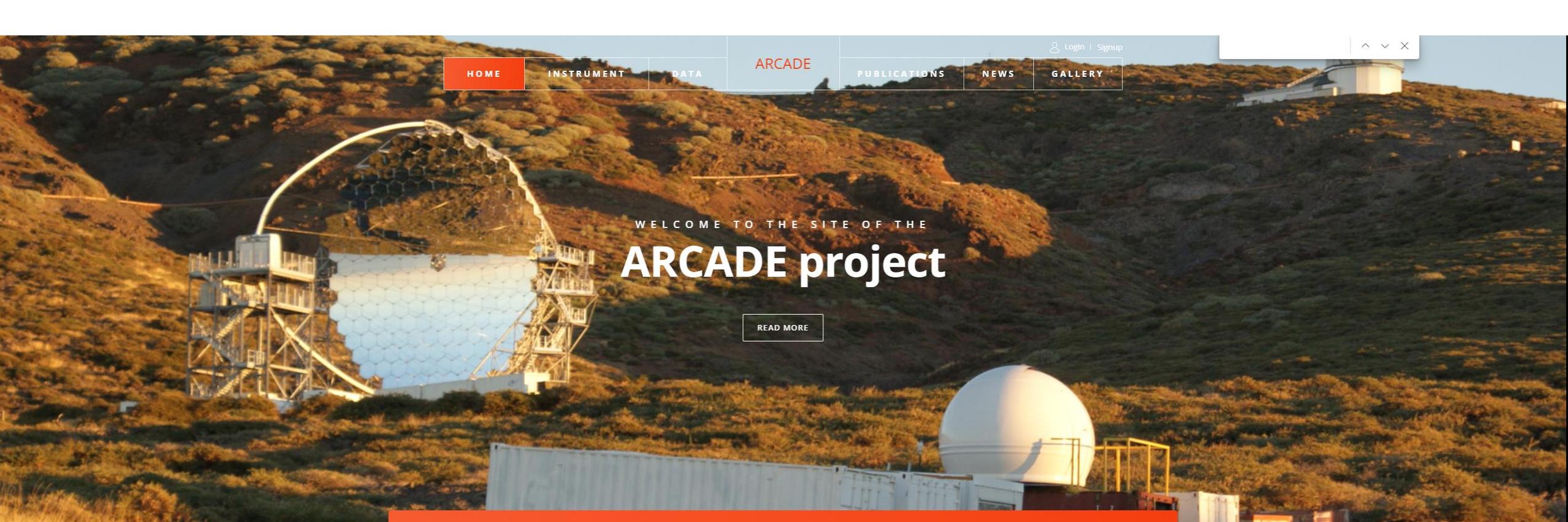
- Change the telescope/receiver coupling from mirrors to optical fiber: improved optical stability/performances, better overlap function & lower systematics on data products.

Optical fiber design



Conclusions

- **The Raman Lidar is robust** (even considering the offline Raman channels): in the last years it has collected vertical profiles of aerosol optical properties and water vapour in automatic and unattended mode.
- **The Raman Lidar data appears of good quality** considering the characteristics and the operation constraints of the instrument.
- **The data analysis has been tested and improved** by the comparison with aerosol measurements taken by a nearby located AERONET sunphotometer.
- **The analysis of the profiles of the aerosol optical properties evidenced a seasonal cycle** linked to the Saharan dust events characteristics, superimposed to a generally low aerosol load.
- Although the **optimization** with AERONET data gives interesting results **(that requires further tuning and investigation) we want to provide improved and independent results.**
This implies:
 - The **Raman channels** must be back online.
 - The **overlap function** must be significantly reduced.
- ... for this reason, **technical upgrades have been designed and are ready to be implemented on the instrument to improve its performances.**



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Data available

Search for profiles using the calendar. Days with valid observations are marked with a different colour. The plus sign at the top right appears when both morning and evening observations are present.

June 2022						
Mon	Tue	Wed	Thu	Fri	Sat	Sun
6	7	1	2	3	4	5
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

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Thanks!