IDEAS-QA4EO

Ground-based validation of satellite-derived Aerosol Layer Height and Ozone profiles

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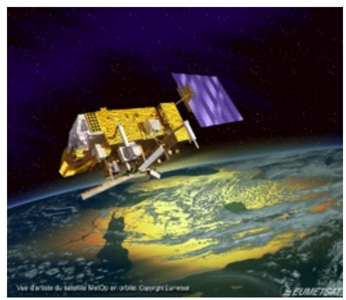
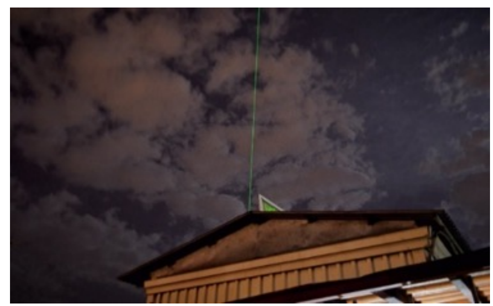
QA4EO Cal/Val WS | 31 Mar - 1 Apr 2022 | ESRIN

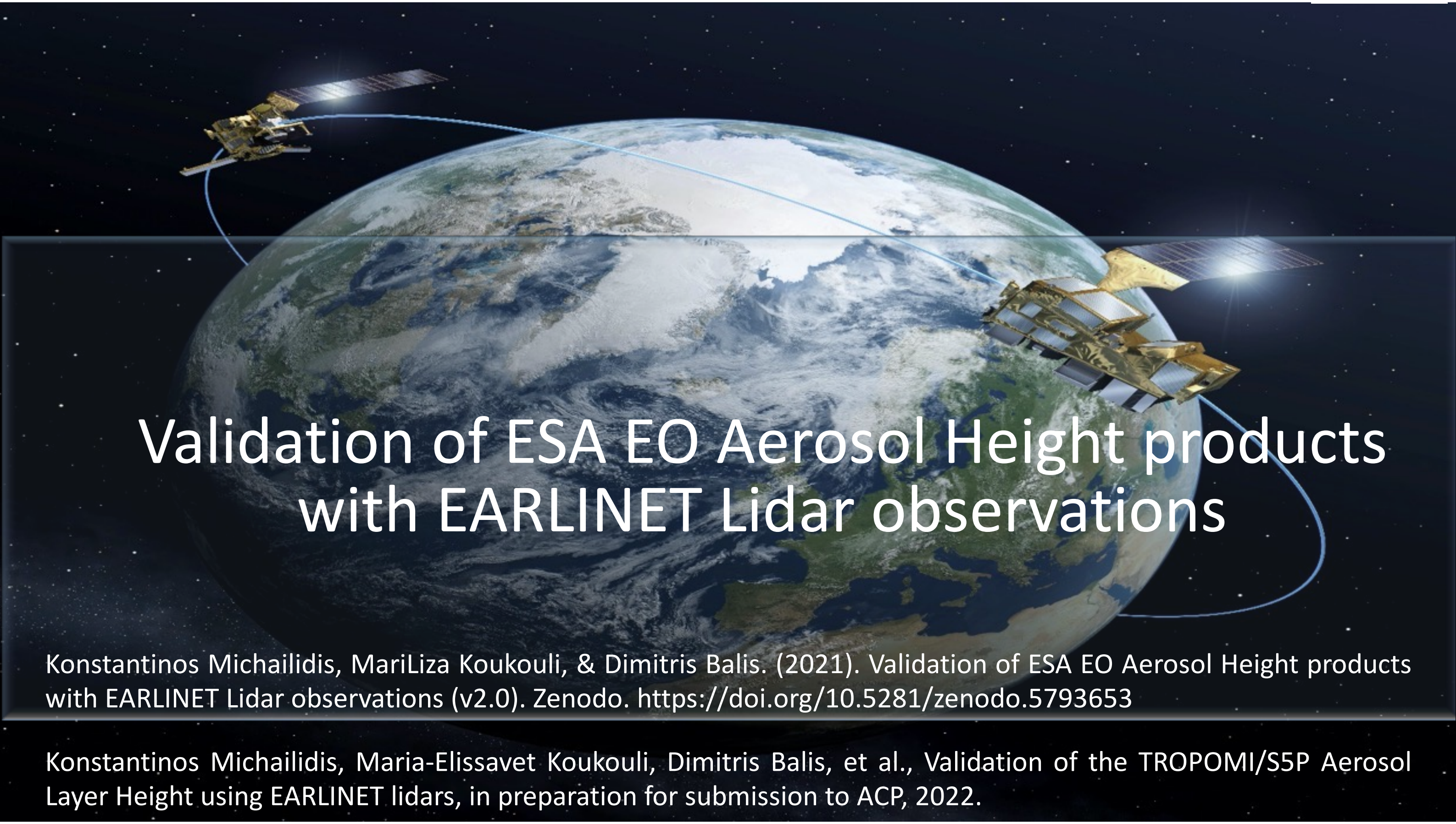
Involvement of AUTH in QA4EO

WP1 Validation of ESA EO Aerosol Height products with EARLINET Lidar observations

WP2 Umkehr Ozone Profile Analysis and Satellite Validation for the time period 2007-2020





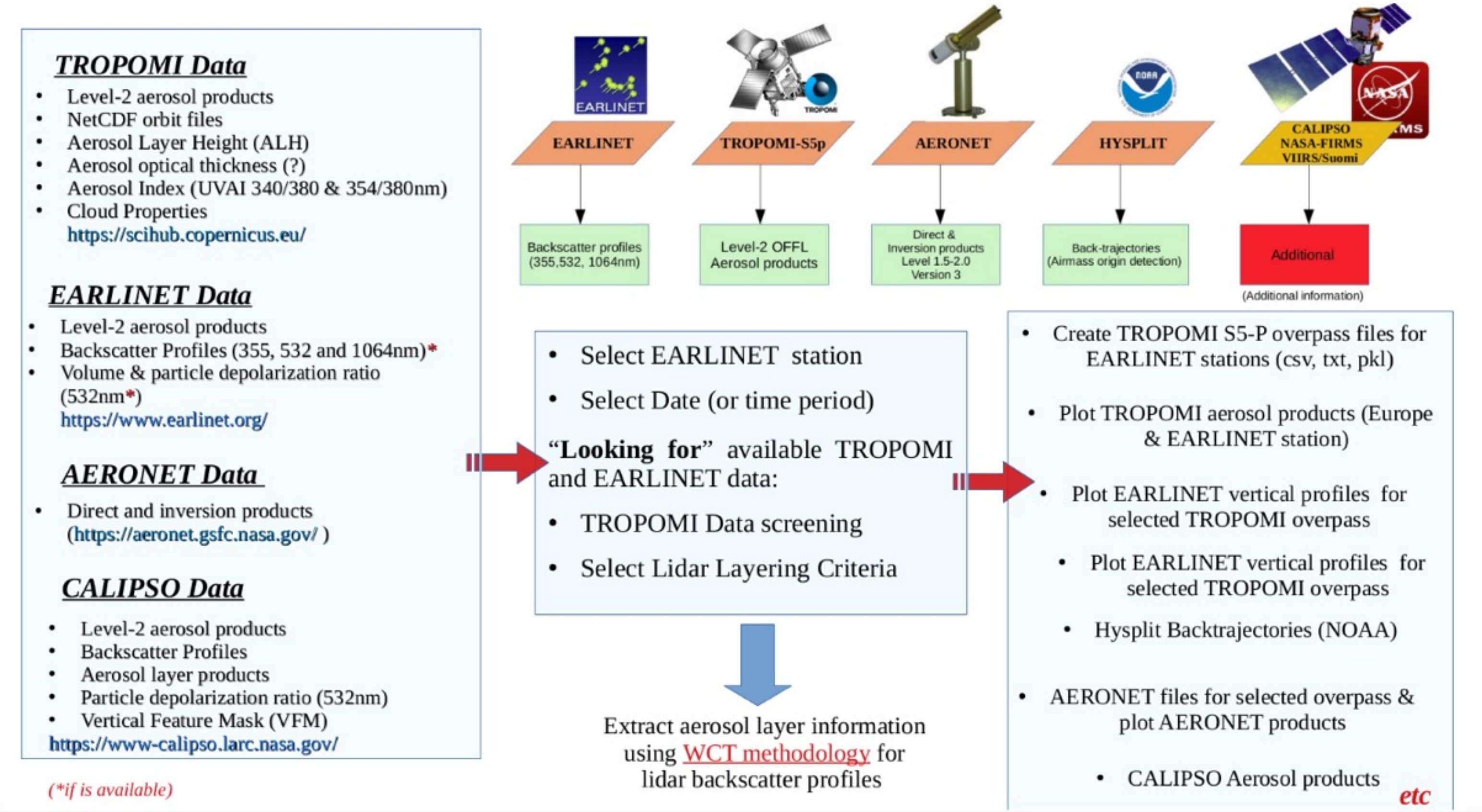


Validation of ESA EO Aerosol Height products with EARLINET Lidar observations

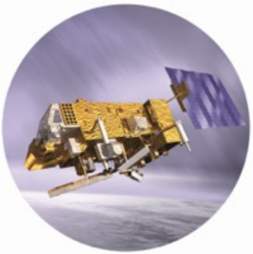
Konstantinos Michailidis, MariLiza Koukouli, & Dimitris Balis. (2021). Validation of ESA EO Aerosol Height products with EARLINET Lidar observations (v2.0). Zenodo. https://doi.org/10.5281/zenodo.5793653

Konstantinos Michailidis, Maria-Elissavet Koukouli, Dimitris Balis, et al., Validation of the TROPOMI/S5P Aerosol Layer Height using EARLINET lidars, in preparation for submission to ACP, 2022.

The LAP/Auth ALH/AAH validation chain

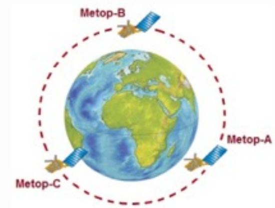


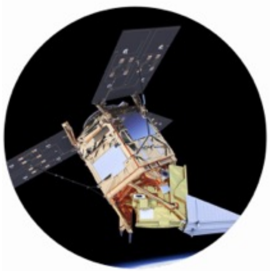
GOME-2 and TROPOMI Aerosol Layer Height



GOME-2 = Global Ozone Monitoring Experiment - 2
Satellite platform: MetOp (A-B-C)
Sun-synchronous polar orbit
Spatial resolution: 40x80km^2
Swath: 1920km
Equator crossing time: 09:30 am LT

MetOp-A (19 Oct 2006)
MetOp-B (17 Sep 2012)
MetOp-C (7 Nov 2018)





TROPOMI = Tropospheric Ozone Monitoring Instrument
Satellite platform: Sentinel-5 Precursor
Sun-synchronous polar orbit
Spatial resolution: 5.5x3.5km^2 (7x7km^2 until Aug 2019)
Swath: 2600km
Equator crossing time: 01:30 pm LT

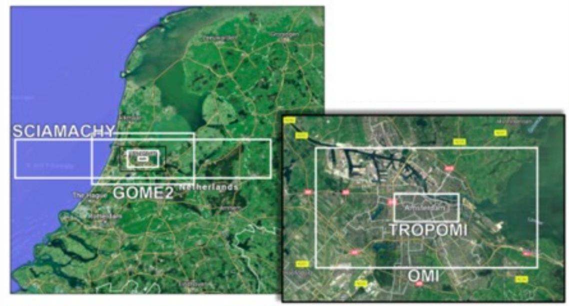
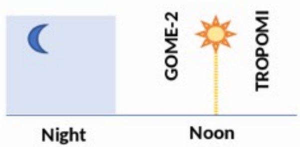


Figure 1: This figure demonstrates the satellite footprint size comparison between GOME-2/MetOp and S5P/TROPOMI.



- GOME-2 AAH operationally available from EUMETSAT ACSAF : https://acsaf.org/products/ars.php
- TROPOMI ALH operationally available from ESA Copernicus Open Access Hub: http://www.tropomi.eu/data-products/aerosol-layer-height

Extract layer height from lidar profiles

How can extract aerosol height from lidars?

Wavelet Covariance Transform (WCT)

- We can use the backscatter profiles to retrieve aerosol layer height (ALH).
- Aerosol geometrical properties carry information about the structure of lidar profile.
- **Longer wavelengths** = easier to identify aerosol layers (1064 or 532nm)
- We apply the WCT to the lidar data in order to extract aerosol geometrical structure.
- Also optical properties for each detected layer can be calculated.

(e.g. Siomos et al., 2019, Michailidis et al., 2021)

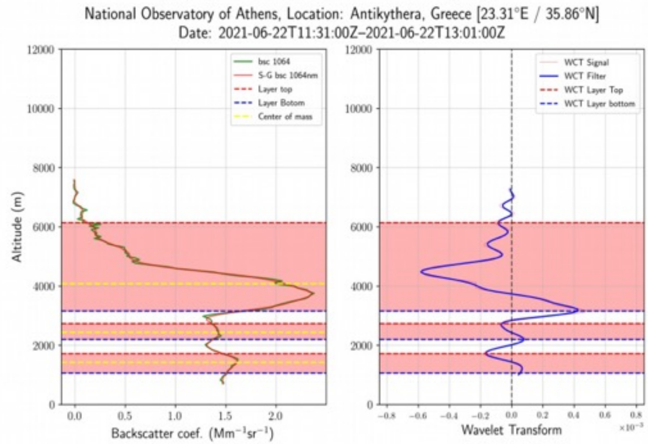


Figure 3. Lidar backscatter profile at 1064nm resulting WCT profile on 22[th] June 2021. The horizontal red dashed line represents the aerosol layer top and bottom and the yellow represent the center of mass.

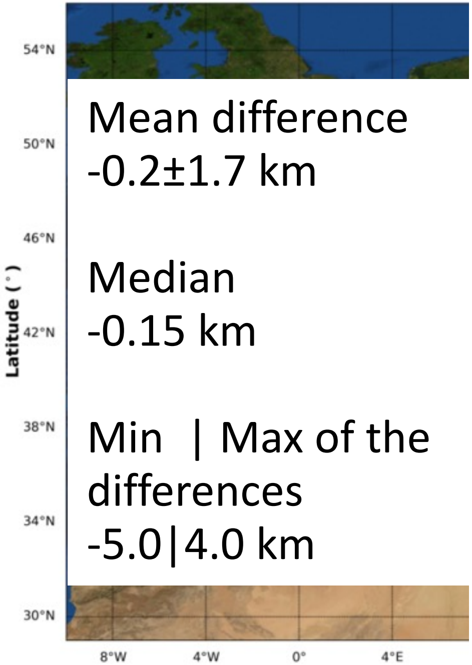
How we can compare ALH retrieved from passive satellites against lidars?

Weighted-backscatter altitude

$$Z_{w-bsc} = \frac{\int_{z_{base}}^{z_{top}} z \cdot \beta_{aer}(z)\, dz}{\int_{z_{base}}^{z_{top}} \beta_{aer}(z)\, dz}$$

- Siomos, N., Balis, D. S., Voudouri, K. A., et al., Are EARLINET and AERONET climatologies consistent? The case of Thessaloniki, Greece, Atmos. Chem. Phys., https://doi.org/10.5194/acp-18-11885-2018, 2018.
- Siomos, N., Voudouri, K. A., Filioglou, M., et al., Consistency of the single calculus chain for climatological studies using long-term measurements from thessaloniki lidar station, EPJ Web Conf., https://doi.org/10.1051/epjconf/201817609007, 2018.

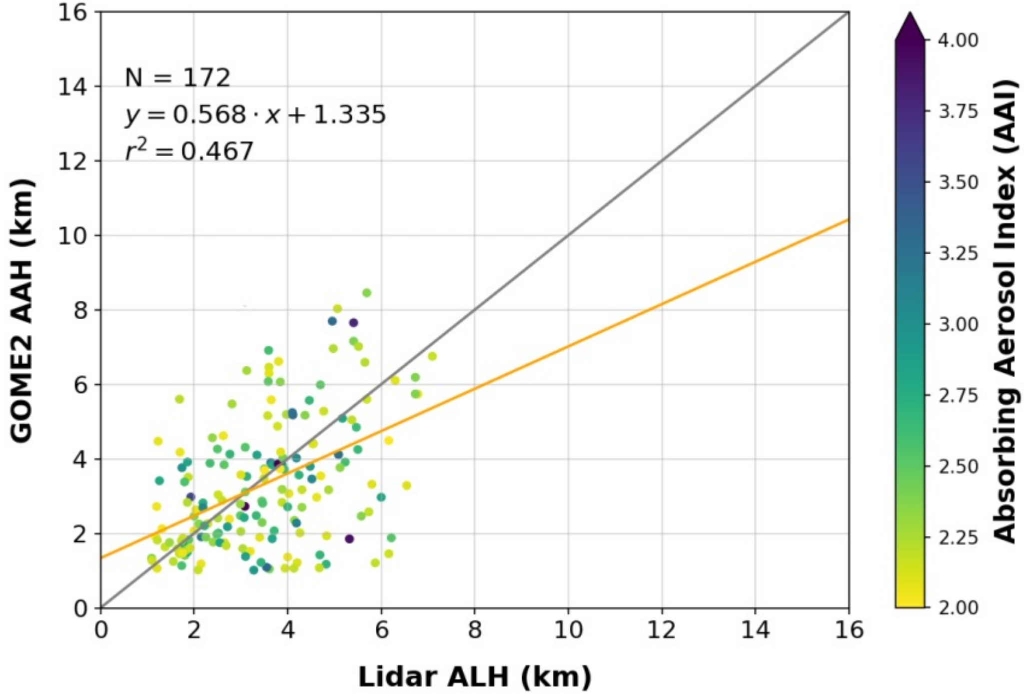
GOME-2 AAH validation | 2007-2019



Mean difference
-0.2±1.7 km

Median
-0.15 km

Min | Max of the differences
-5.0|4.0 km



Michailidis, K., Koukouli, M.-E., Siomos, N., Balis, D., Tuinder, O., Tilstra, L. G., Mona, L., Pappalardo, G., and Bortoli, D.: First validation of GOME-2/MetOp absorbing aerosol height using EARLINET lidar observations, Atmos. Chem. Phys., 21, 3193–3213, https://doi.org/10.5194/acp-21-3193-2021, 2021.

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TROPOMI Validation | Dust cases over Antikythera, Greece

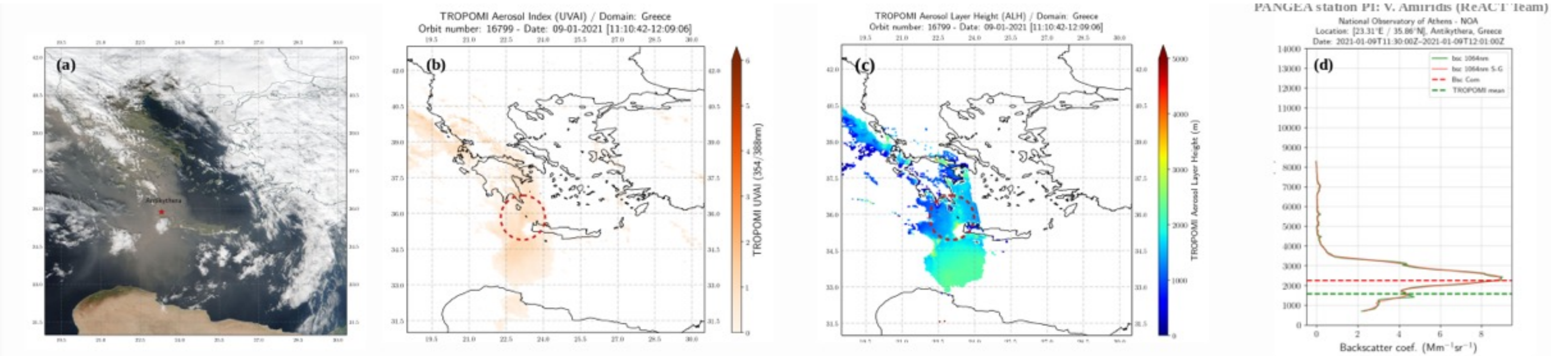


Figure 4. Dust case on 9 January 2021 at Antikythera, Greece. **(a)** VIIRS True color image, **(b)** TROPOMI UVAI, **(c)** TROPOMI ALH and **(d)** Backscatter vertical profile at 1064 nm attenuated from PollyXT

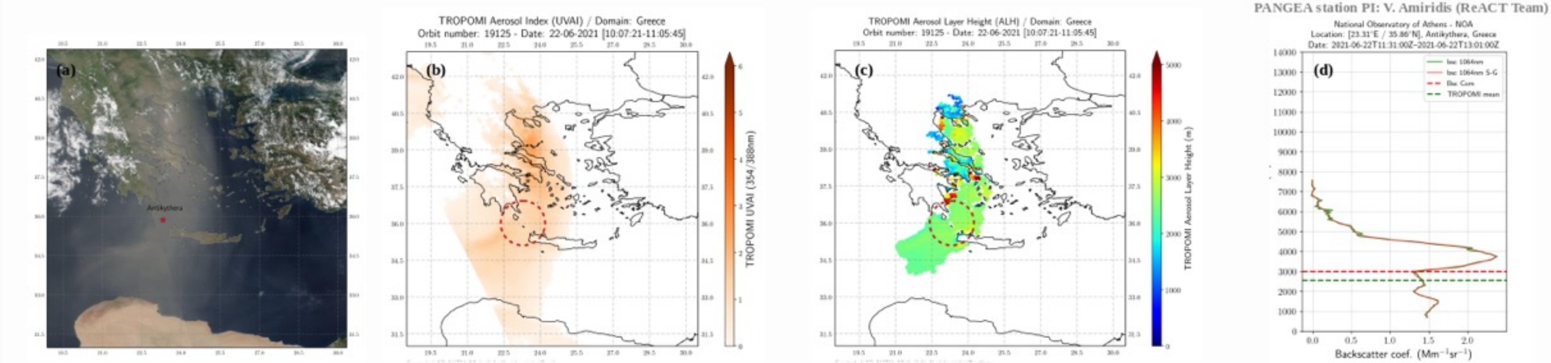
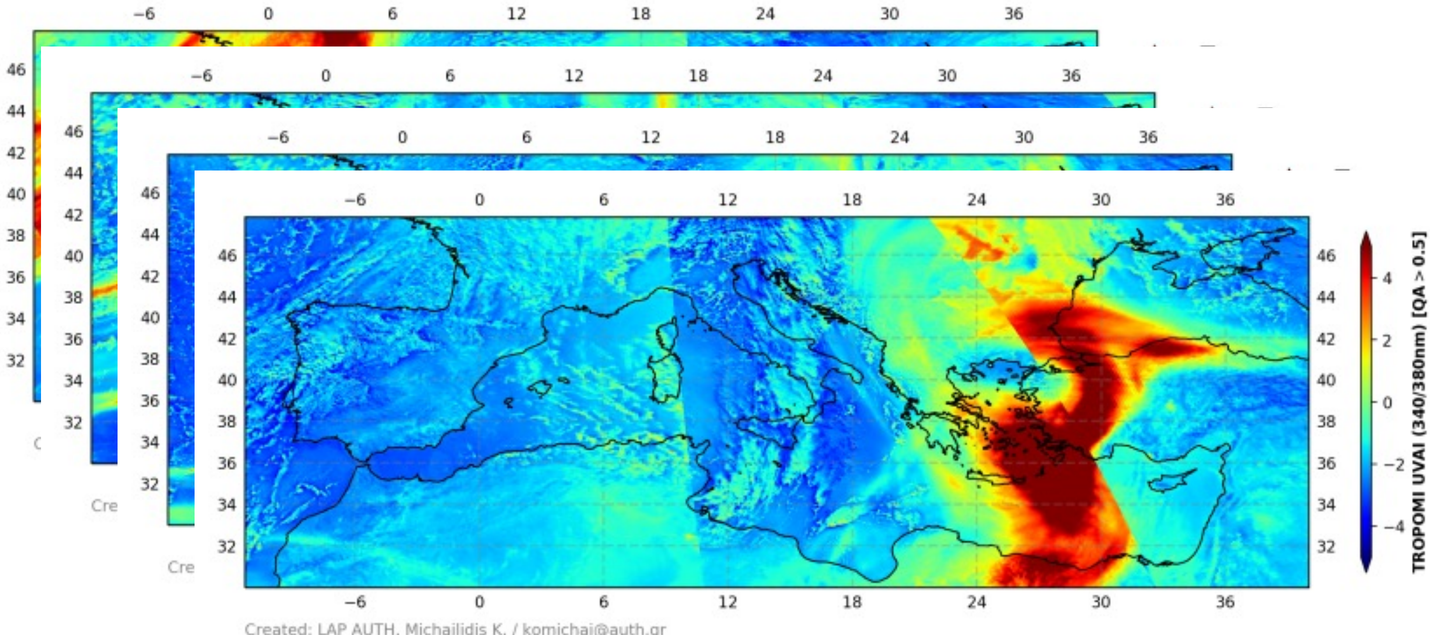


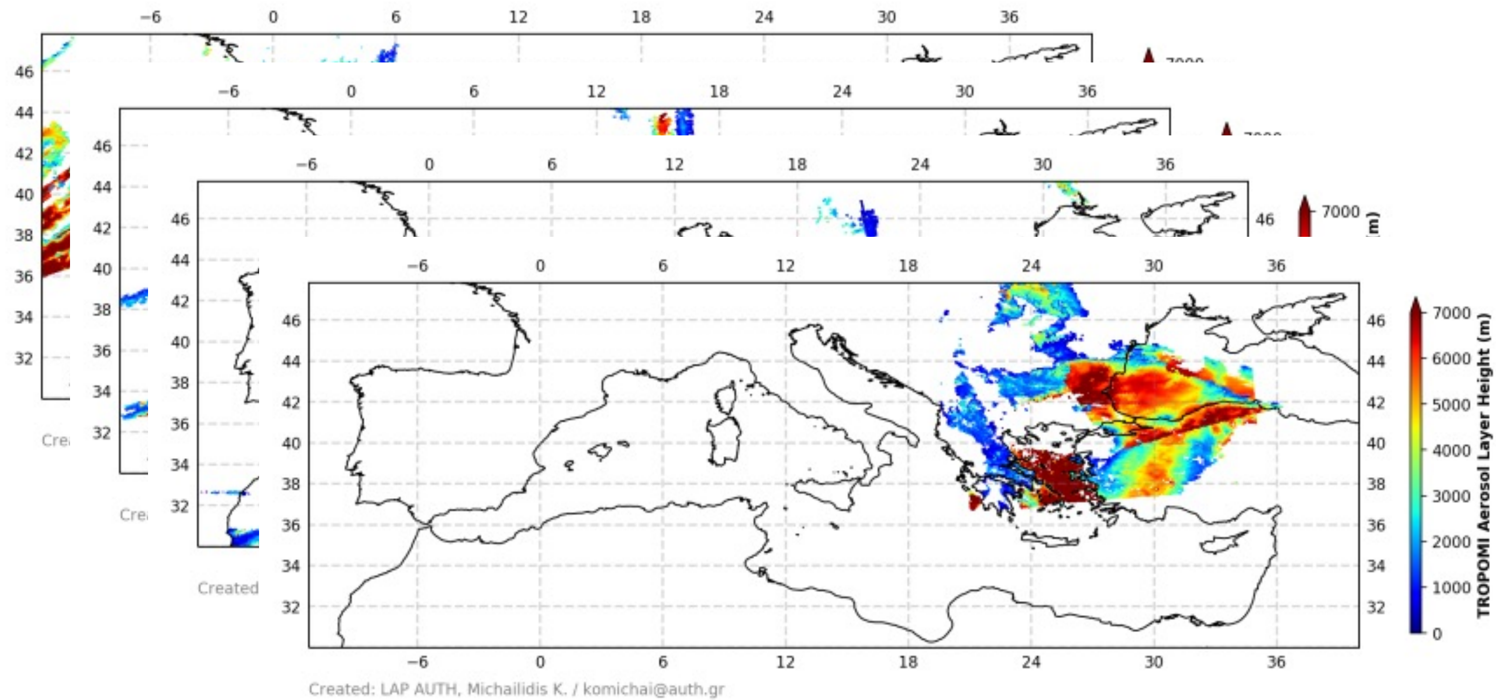
Figure 5. Dust case on 22 June 2021 at Antikythera, Greece. **(a)** VIIRS True color image, **(b)** TROPOMI UVAI, **(c)** TROPOMI ALH and **(d)** Backscatter vertical profile at 1064 nm attenuated from PollyXT

Smoke advection over the Mediterranean from Californian fires | 24-27 Oct 2020



TROPOMI Aerosol Index

Smoke advection over the Mediterranean from Californian fires | 24-27 Oct 2020



TROPOMI Aerosol Height

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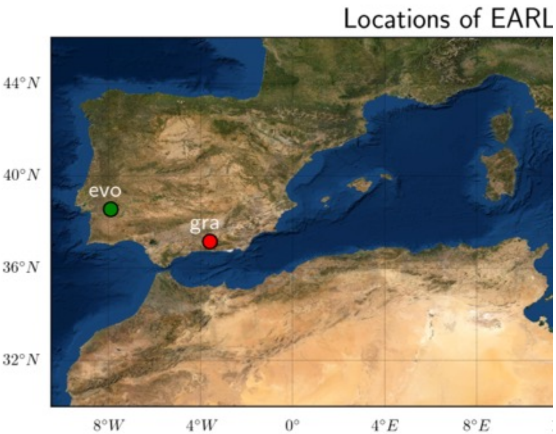
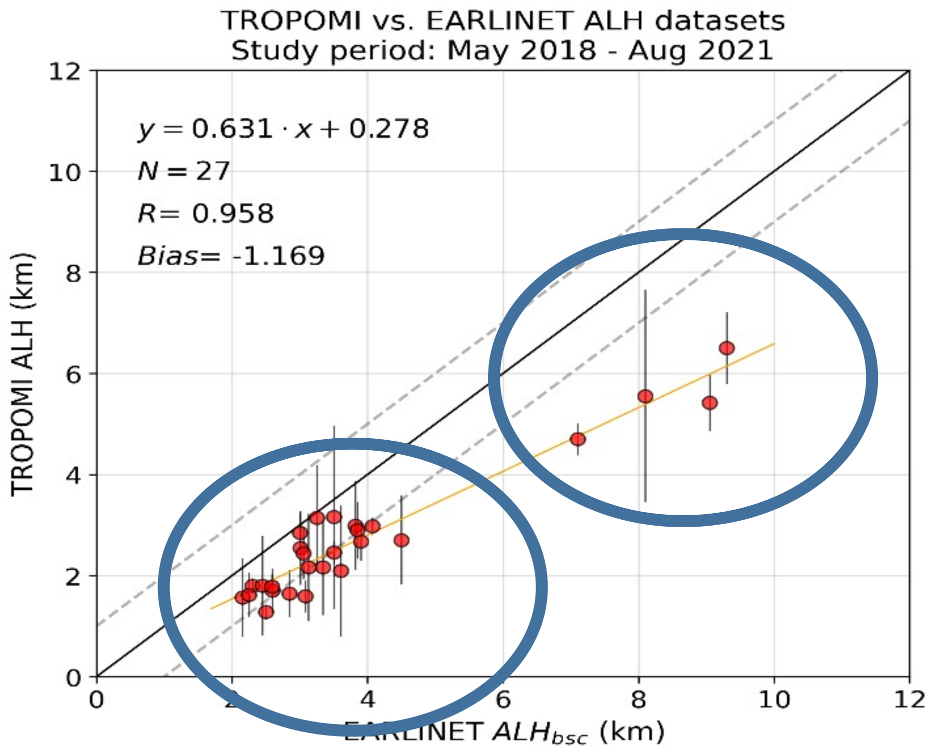
TROPOMI ALH validation





	N[a]	R[b]	Slope[c]	Y[d]	MB[e]	RMSE[f]	MRB[g]
TROPOMI-EARLINET	27	0.96	0.63	0.30	-1.17km	1.42km	-28.8%

Summary and Outlook

- We have developed a optimal “tool” for aerosol monitoring using EARLINET and TROPOMI aerosol products
- The results of the GOME-2 AAH against EARLINET data, encourages the operational usage of the WCT - based algorithms based algorithms in validation processes.
- The automated tools for the comparison of the TROPOMI products with EARLINET datasets are run for selected desert dust cases and fire plumes. **VERY promising** first results!

Future work during Phase II:

- Calculate aerosol layer center of mass (COM) and Aerosol optical depth (AOD) for each lidar backscatter profile. It provides additional information on the height where the majority of the particles are located.
- To investigate the capabilities of the reprocessed TROPOMI ALH dataset over land.

IDEAS-QA4EO

Umkehr Ozone Profile Analysis and Satellite Validation for the time period 2007-2020.

Garane, Katerina, Koukouli, MariLiza, Fragkos, Konstantinos, Miyagawa, Koji, Fountoukidis, Panagiotis, Petropavlovskikh, Irina, Balis, Dimitris, & Bais, Alkiviadis. (2021). Umkehr Ozone Profile Analysis and Satellite Validation (1.0). Zenodo. https://doi.org/10.5281/zenodo.5584472

- The Umkehr measurements from four Brewer instruments operating at Madrid, Spain; Hradec Kralove, Czech Republic; Warsaw, Poland and Thessaloniki, Greece were studied for the period 2017 – 2020.
- The original measurements were extracted from the European Brewer Network (http://www.eubrewnet.org/) database.

- Umkehr measurements from four Dobson stations (Boulder, USA; MLO, USA; Lauder, New Zealand and Haute Provence, France) have been optimized and are presented for the same period of time.

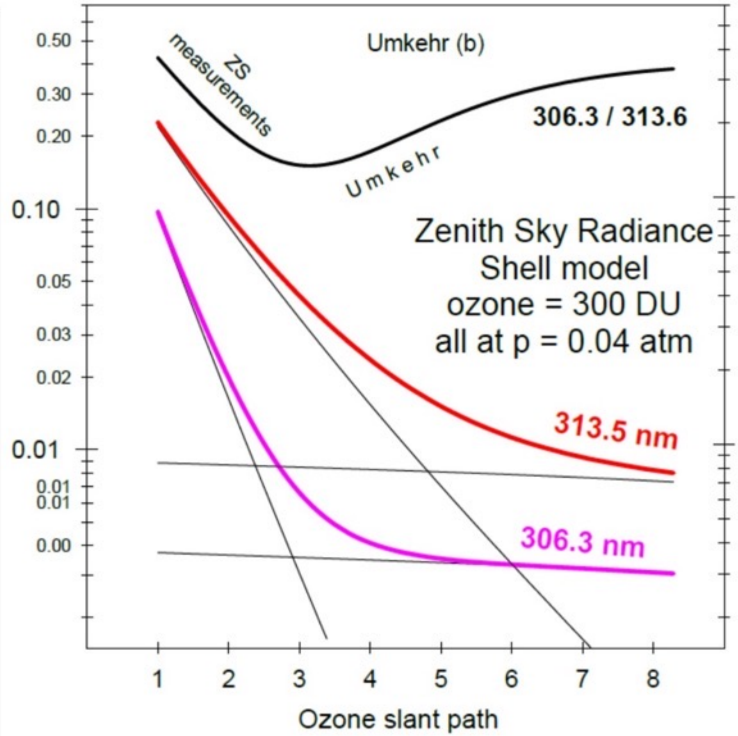
- The Dobson Umkehr optimization algorithm includes updates for the a priori profiles in the retrieval code, standardized stray light corrections, and N-value empirical corrections derived using the subset of the ozone and temperature profiles from the NASA M2GMI Chemistry Transport Model matched to the Umkehr station location. Furthermore, within the Umkehr optimization algorithm, the NOAA version of the combined SBUV/OMPS ozone profile data, COH, were employed (Petropavlovskikh et al. 2021).

What is the Umkehr Effect?

The (logarithmic) plot of the ratio of intensities at two wavelengths against the ozone slant path shows a turn-around or Umkehr where the short wavelength begins, paradoxically, to lose intensity more slowly than the longer wavelength which has the smaller absorption coefficient.

This model Umkehr depends on the height of the ozone.

Therefore, information on the ozone profile can be retrieved from measured zenith sky radiance ratios.



Scattering geometry information is weighted by different layers as sun sets/rises

What is the Umkehr technique?

Brewer or Dobson spectrophotometers record the zenith sky intensity at two different UV wavelengths ("short" and "long"), with the shorter being more strongly absorbed by ozone (311/332 nm for Dobsons and 310/326 nm for Brewers for the temporal range 60°-90° SZA).

$$N(\theta) = 100 \times \log\left(\frac{I'(\theta)}{I(\theta)}\right)$$

N-Values are interpolated at 12 nominal SZAs: 60°, 65°, 70°, 74°, 77°, 80°, 83°, 85°, 86.5°, 88°, 89° and 90°)

The algorithm for the ozone retrieval (Petropavlovskikh et al., 2005) is provided with the ozone profile from two models (forward and inverse). The ozone profile is reported in 16 layers, but only 8 contain independent information.

Layer	Layer Boundary (km)	Pressure limits (hPa)
0+1	0 – 10.3	1013 – 253.25
2+3	10.3 – 19.1	253.25 – 63.31
4	19.1 – 23.5	63.31 – 31.66
5	23.5 – 28	31.66 – 15.83
6	28 – 32.6	15.83 – 7.91
7	32.6 – 40	7.91 – 3.96
8	40 – 45	3.96 – 1.98
8+	40 – top of the atmosphere	3.96 – 0

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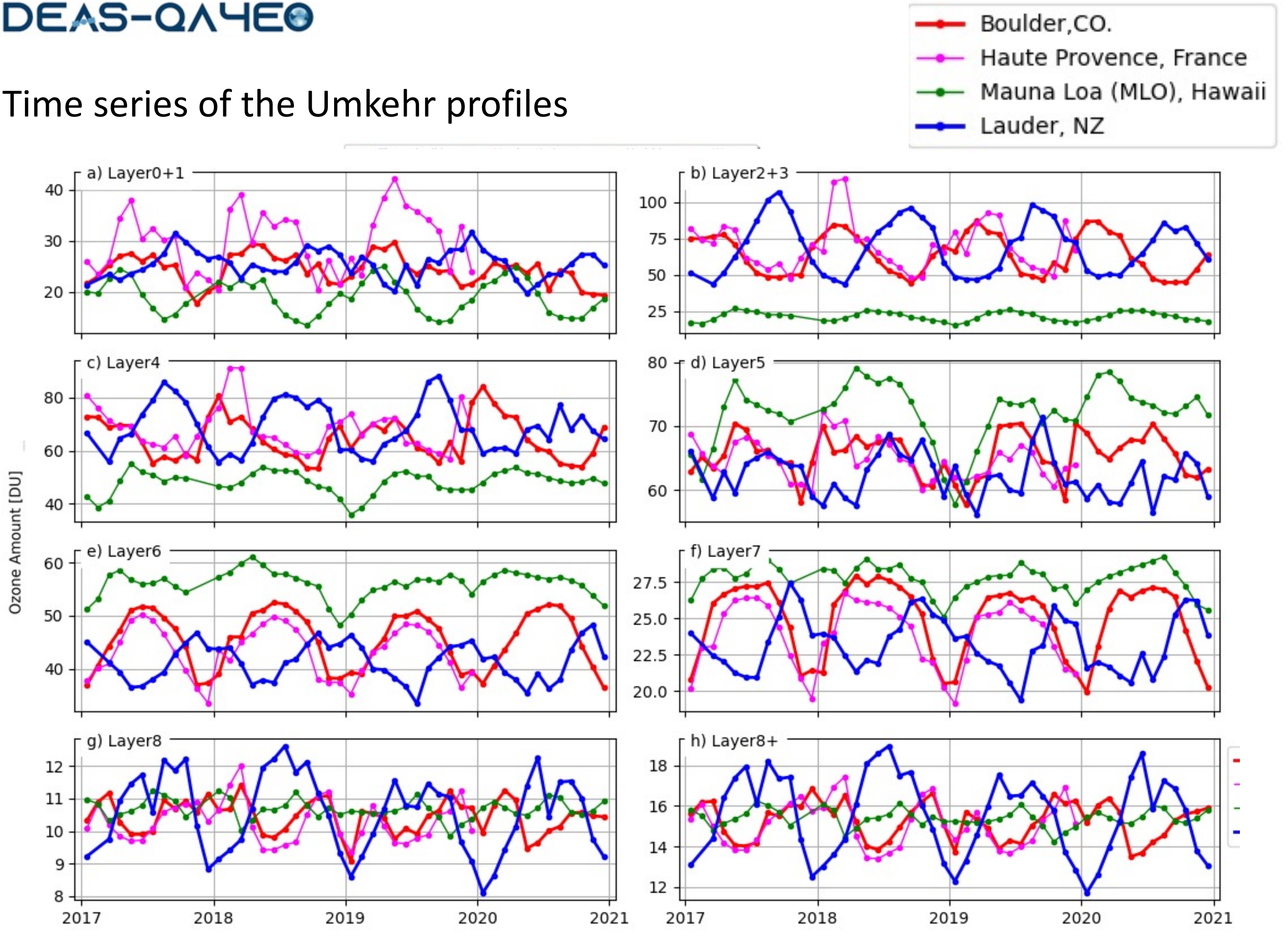
Time series of the Umkehr profiles



Comparison of Umkehr and Satellite overpasses

- SBUV v8.7 overpasses have been provided by Stacey Frith, part of the SBUV Merged Ozone Dataset (https://acd-ext.gsfc.nasa.gov/Data_services/merged/index.html).
- GOME2/MetOp ozone profiles are the operational the EUMETSAT AC SAF project (https://acsaf.org/) datasets, kindly provided by Olaf Tuinder.
- All GOME2 profiles within 0.5° from the ground-based station were averaged and compared to the Umkehr profile for that day, both for the dawn and dusk observations using the recommended filters (Tuinder, 2020).

- Satellite profiles were interpolated to the Umkehr layer levels and then further smoothed using the Umkehr average kernels and a priori profiles (Miyagawa et al., 2009.)

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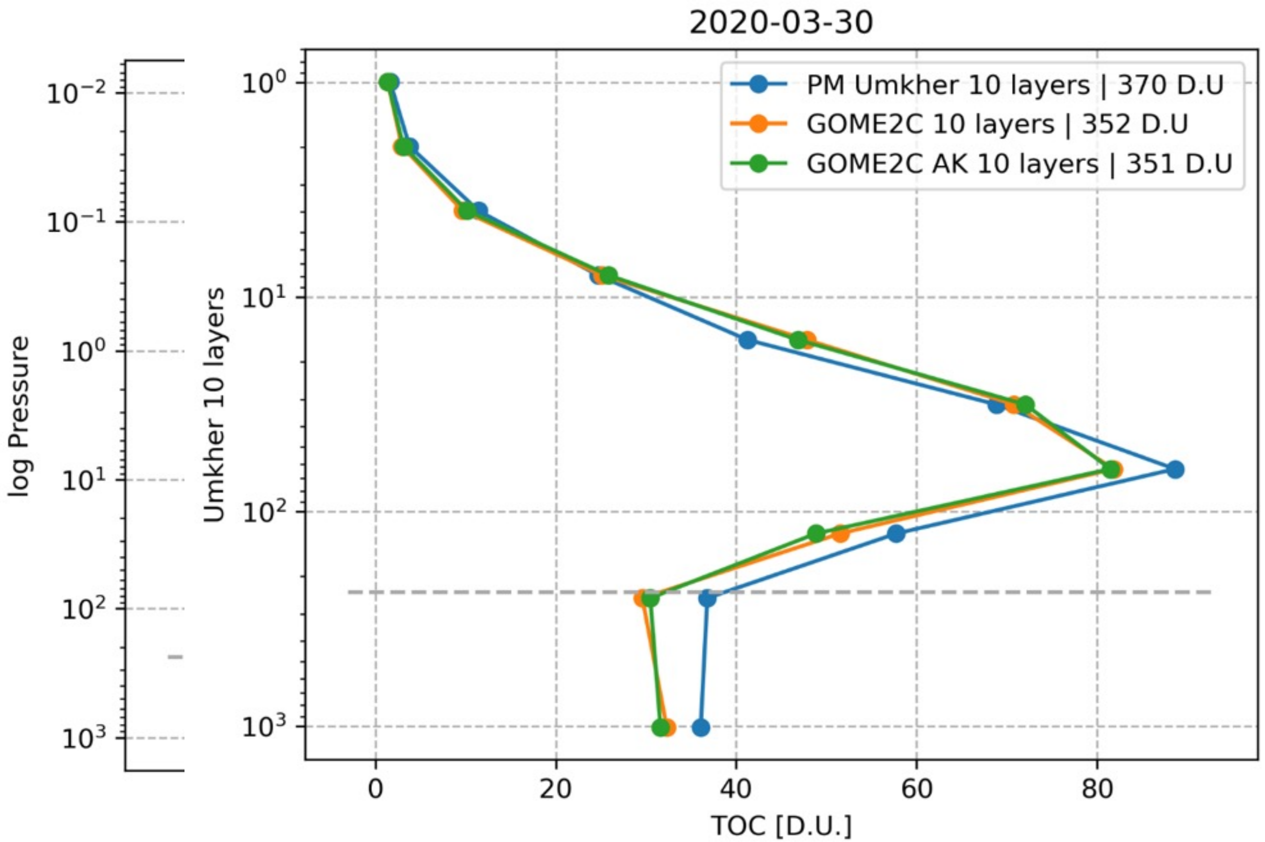
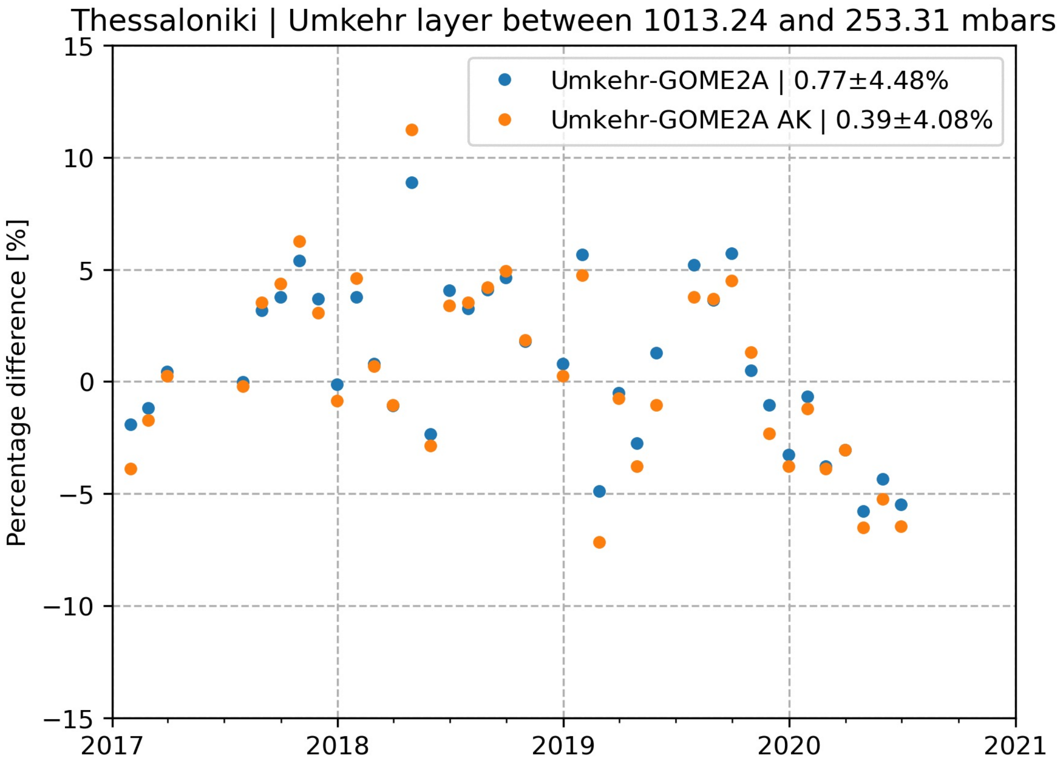
How are the profiles matched?



GOME2C example over Thessaloniki

Monthly timeseries per layer



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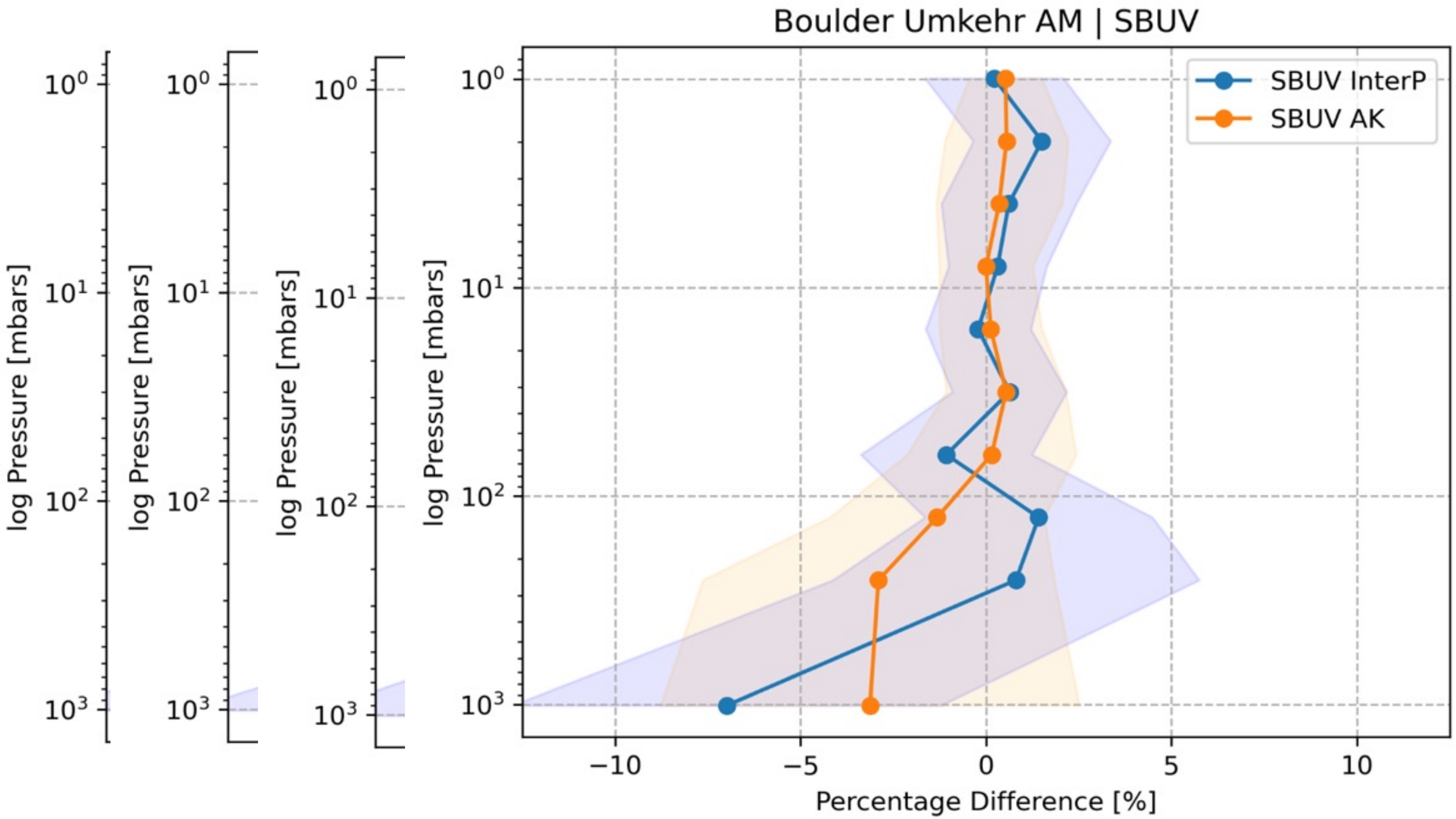
Using the AK for the comparisons



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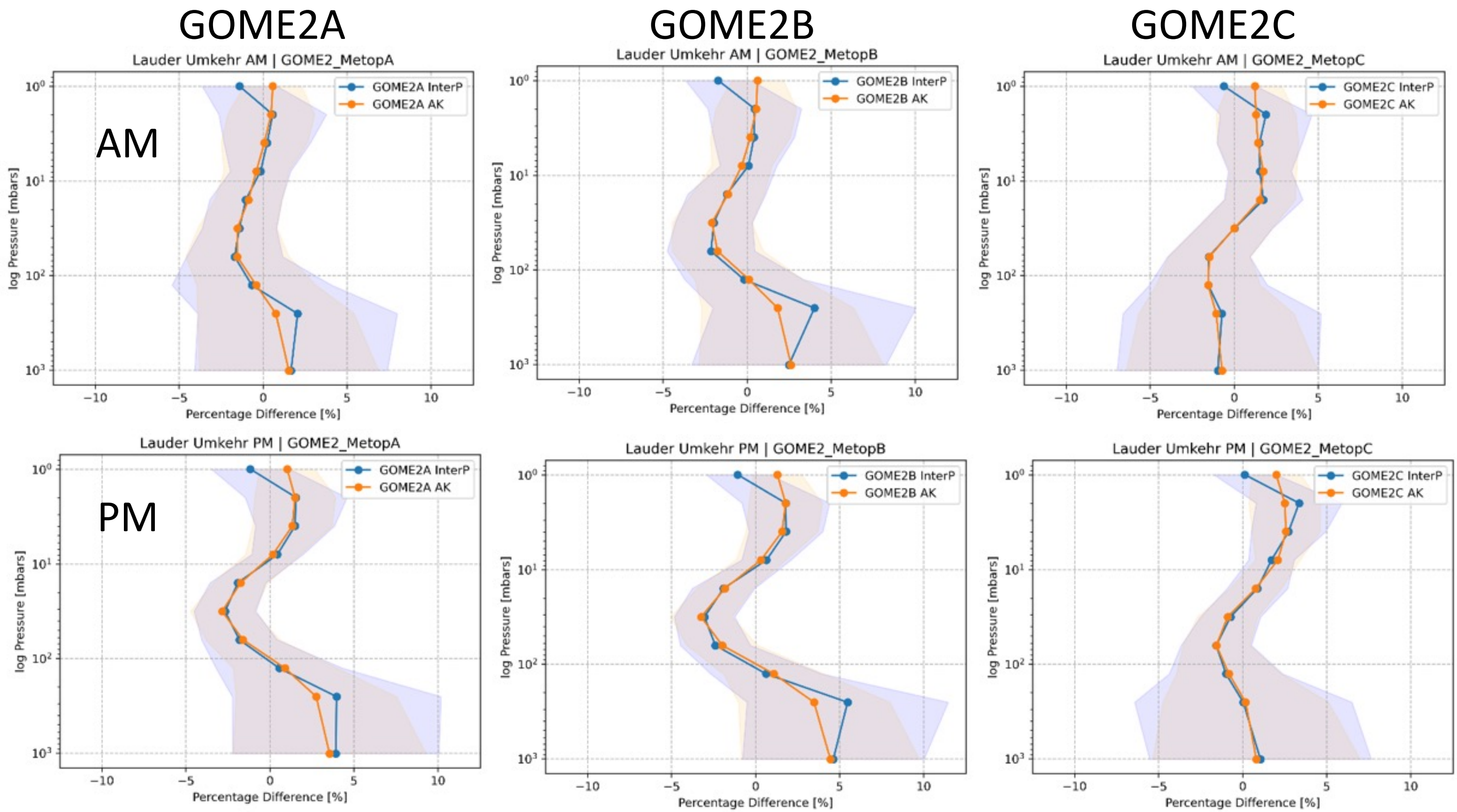
The AM/PM possible effect | Lauder



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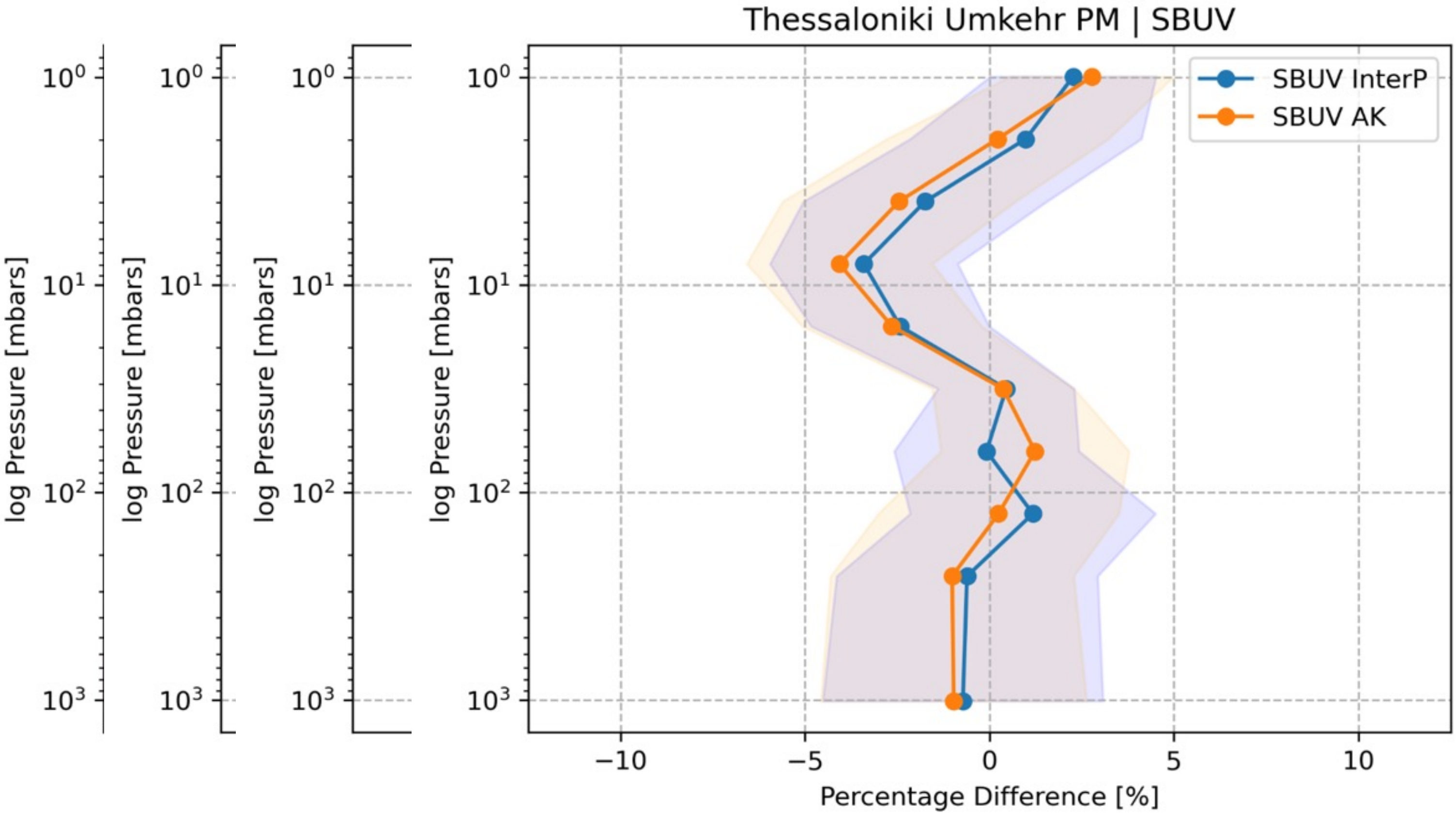
SBUV v8.7 validation | Brewer Umkehr



Summary and Outlook

- The main advantage of the Umkehr technique is that it is an inexpensive way to retrieve the ozone profile in a coarse resolution. Since it is a self-calibration method it can be used by any Dobson or Brewer spectrophotometer around the globe and provide a solid dataset for monitoring the ozone layer changes and as well as for the assessment of satellite measurements.
- In the framework of ESA IDEAS+ QA4EO, we demonstrate the ability of good quality Umkehr measurements, obtained from a selected number of Brewer and Dobson spectrophotometers, to be used for the validation of satellite retrievals.
- The Umkehr profiles show a very good agreement (±5%) with different satellite datasets.

Future work during Phase II:

- The methodology for the optimization of Dobson Umkehr profiles future will be applied to the Brewer profiles .
- Validation of the TROPOMI ozone profiles will be included. [already in the works!]

IDEAS-QAYEO


RAIBH MAITH AGAT
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KIA ORA
NIRRINGRAZZJAK
UA TSAUG RAU KOJ
MULTUMESC
MOCHCHAKKERAM
OBRIGADO
SPASIBO
SALAMAT
RAIBH MAITH AGAT
MAMANA
MATONDO
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MOCHCHAKKERAM
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