Improved and temporally extended Umkehr Ozone Profile retrievals and their application for Satellite Validation

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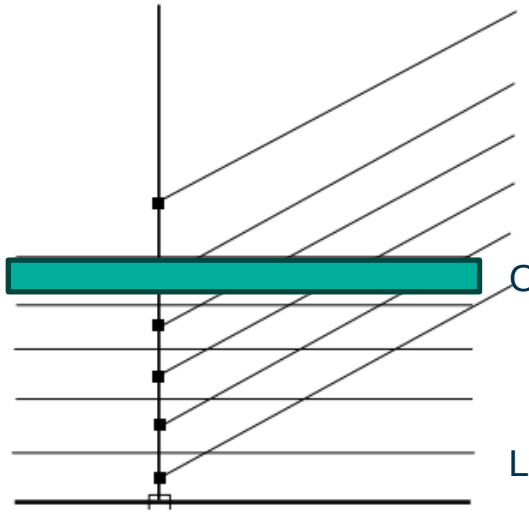
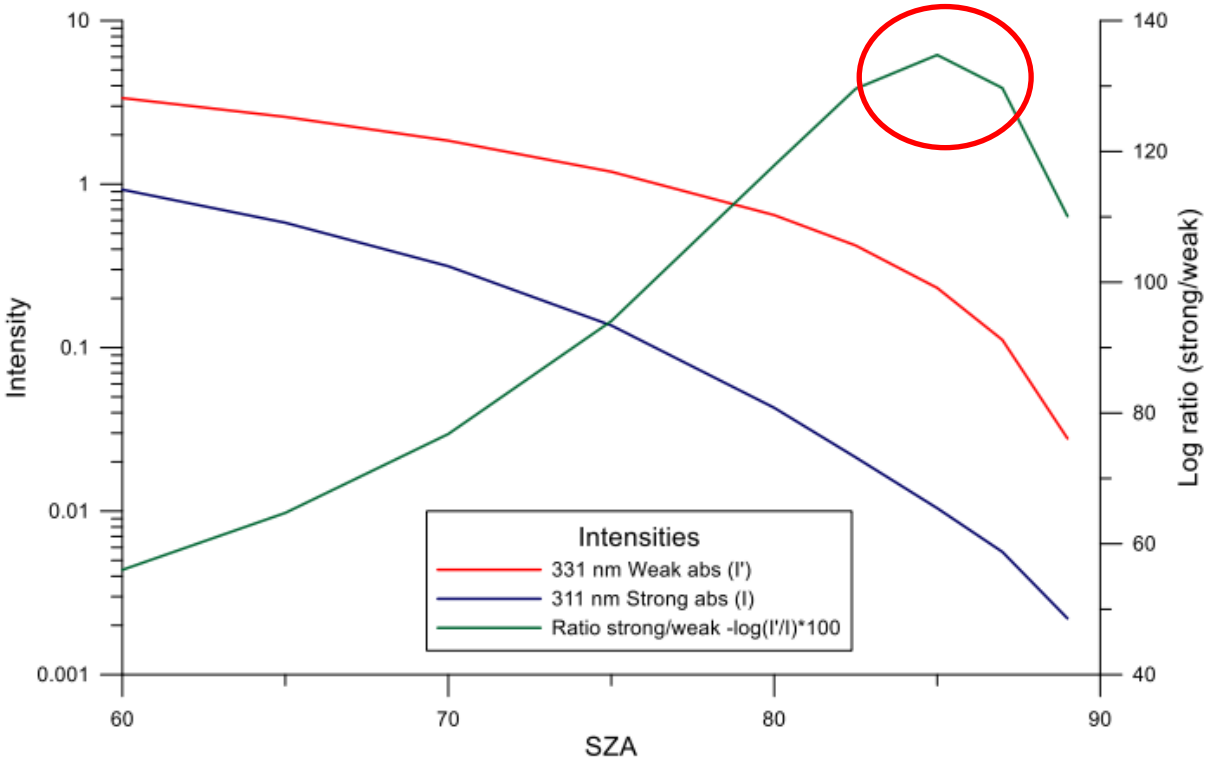
Umkehr measurements





- Radiation zenith measurements in wavelength pairs with strong and weak O_3 absorption, while the Sun sets/rises (SZAs 60-90°)
  [*Götz et al., 1931, 1934*]
- **Umkehr effect**: inversion of the 100·log(weak/strong) curve → N Values

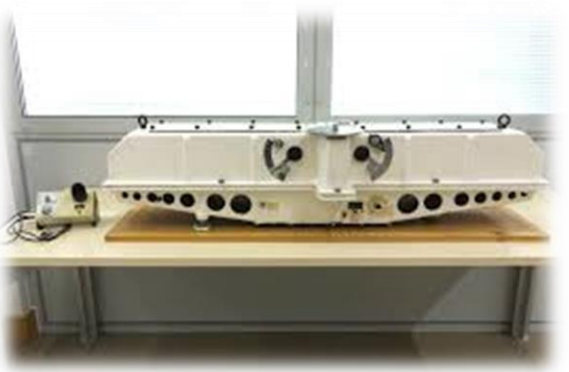
$$N(\theta) = 100 \cdot \log(I'(\theta)/I(\theta))$$

- The inversion implies the existence of a strong stratospheric ozone layer and denotes its height

Datasets

IDEAS-QA4EO

Project goal:
Optimize and homogenize the datasets
→ ready for sat. validation



- **Ground-based** ozone profiles (61-layer scheme)
  - 4 BREWER stations, EUBREWNET
    (8 wavelengths, 12 SZAs)
    software: O3BUmkehr (v3.9), *Martin Stanek*
  - 5 DOBSON stations , WOUDC, NOAA
    (A, C & D wavelength pairs, 14 SZAs)
    software: UMK04, *Petropavlovskikh et al., 2005*

- **Satellite** ozone profiles (S5P/TROPOMI, GOME-2 B&C)
  33 layers *40 layers*
- The respective ground-based and satellite AK and a-priori profiles
- Time period: 2017 – 2022

Station	Instrument Type/ Number	Latitude	Longitude
Thessaloniki	Brewer MKII (#005)	40.63 N	22.96 E
Hradec Kralove	Brewer MKIII (#184)	50.18 N	15.84 E
Madrid	Brewer MKIII (#186)	40.45 N	3.72 W
Warsaw	Brewer MKIII (#207)	52.25 N	20.94 E
Boulder	Dobson (#061)	40.02 N	105.25 W
Mauna Loa	Dobson (#076)	19.53 N	155.58 W
Haute Provence	Dobson (#085)	49.93 N	5.71 E
Lauder	Dobson (#072)	45.05 S	169.68 E
Arosa	Dobson (#051)	46.78 N	9.68 E

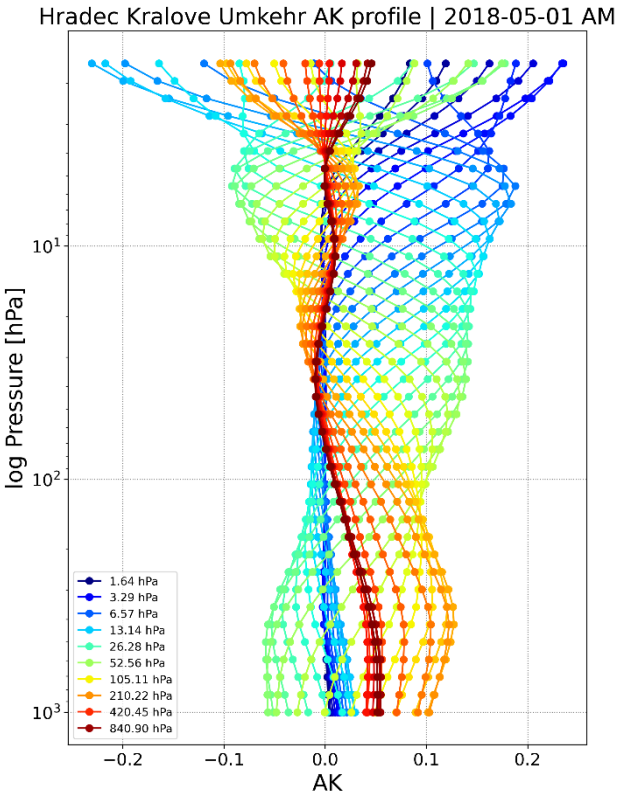
Analysis steps

- Interpolation of the satellite profiles to the Umkehr's vertical resolution
- Application of the Umkehr AK to the interpolated satellite ozone profiles

$$sat_{smoothed} = Umkehr_{apriori} + AK_{Umkehr} \times (sat_{interp} - Umkehr_{apriori})$$

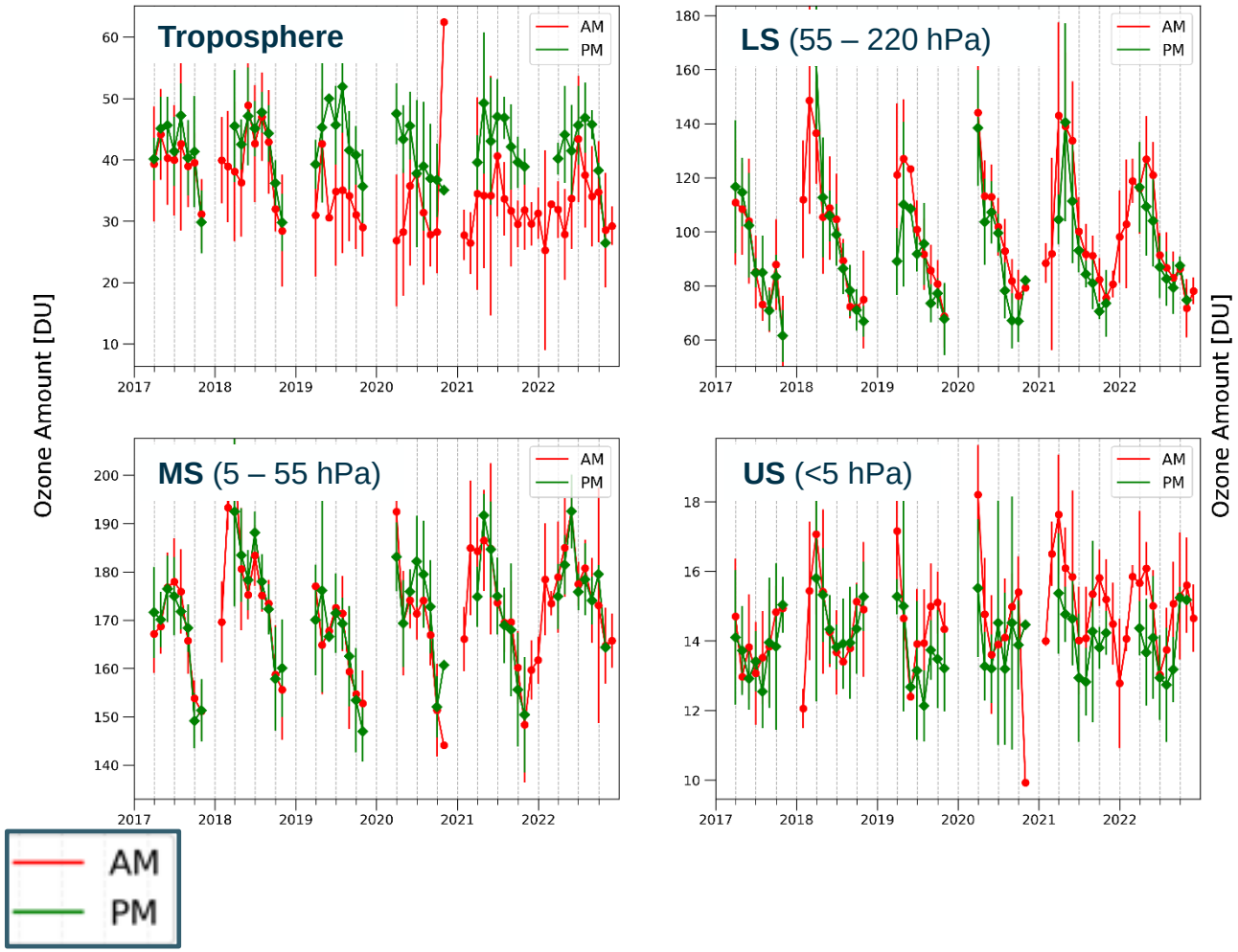
- Calculation of the mean percentage differences $\left(\frac{sat_{smoothed} - Umkehr}{\frac{sat_{smoothed} + Umkehr}{2}}\right) \cdot 100$
- Division of the atmosphere into 4 main layers:

Layers	Boundaries in km	Boundaries in hPa
Troposphere	surface – 11	1013.25 (surface) – 220
Lower Stratosphere (LS)	11 – 20	220 – 55
Middle Stratosphere (MS)	20 – 40	55 – 5
Upper Stratosphere (US)	40 – 50	5 – 2

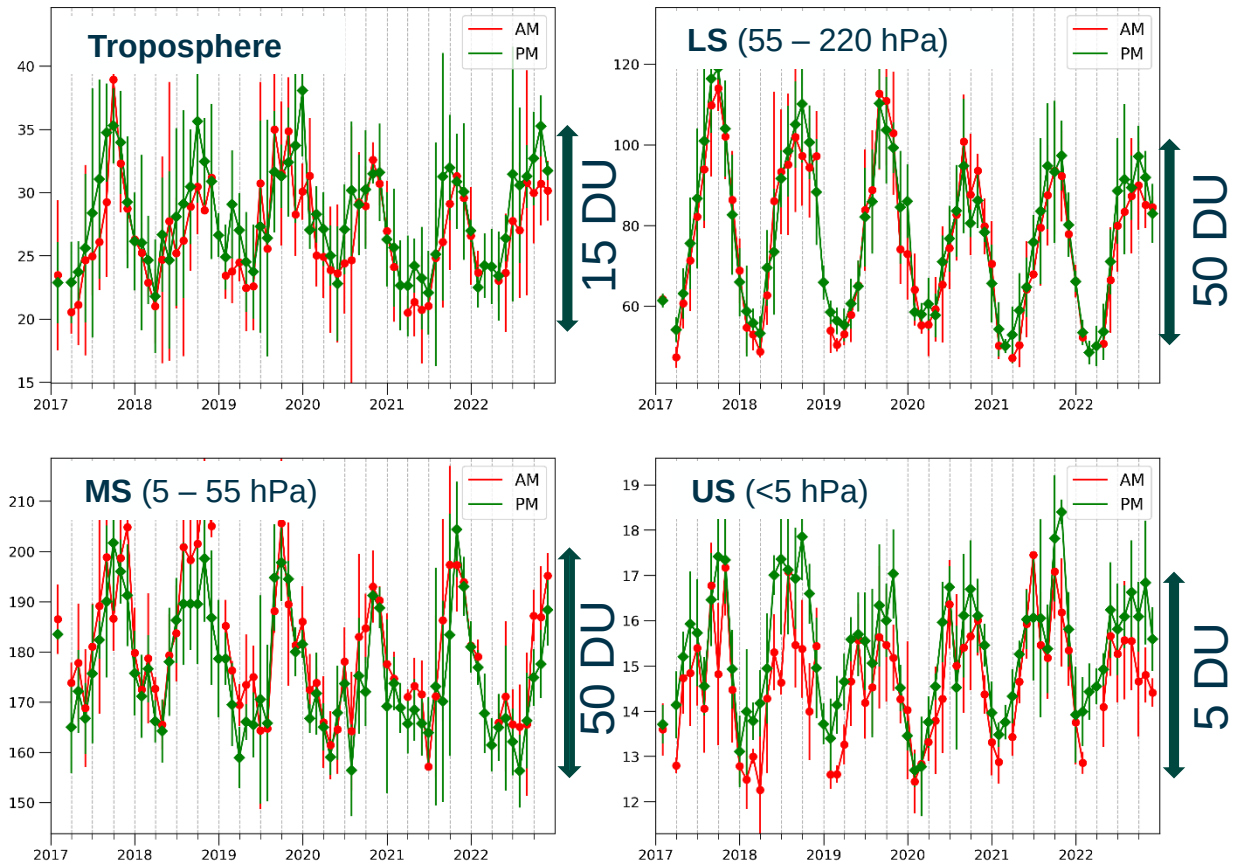


Updated Umkehr ozone profiles timeseries

Hradec Kralove (Brewer)



Lauder (Dobson)



Comparison results: S5P/TROPOMI w.r.t. Umkehr

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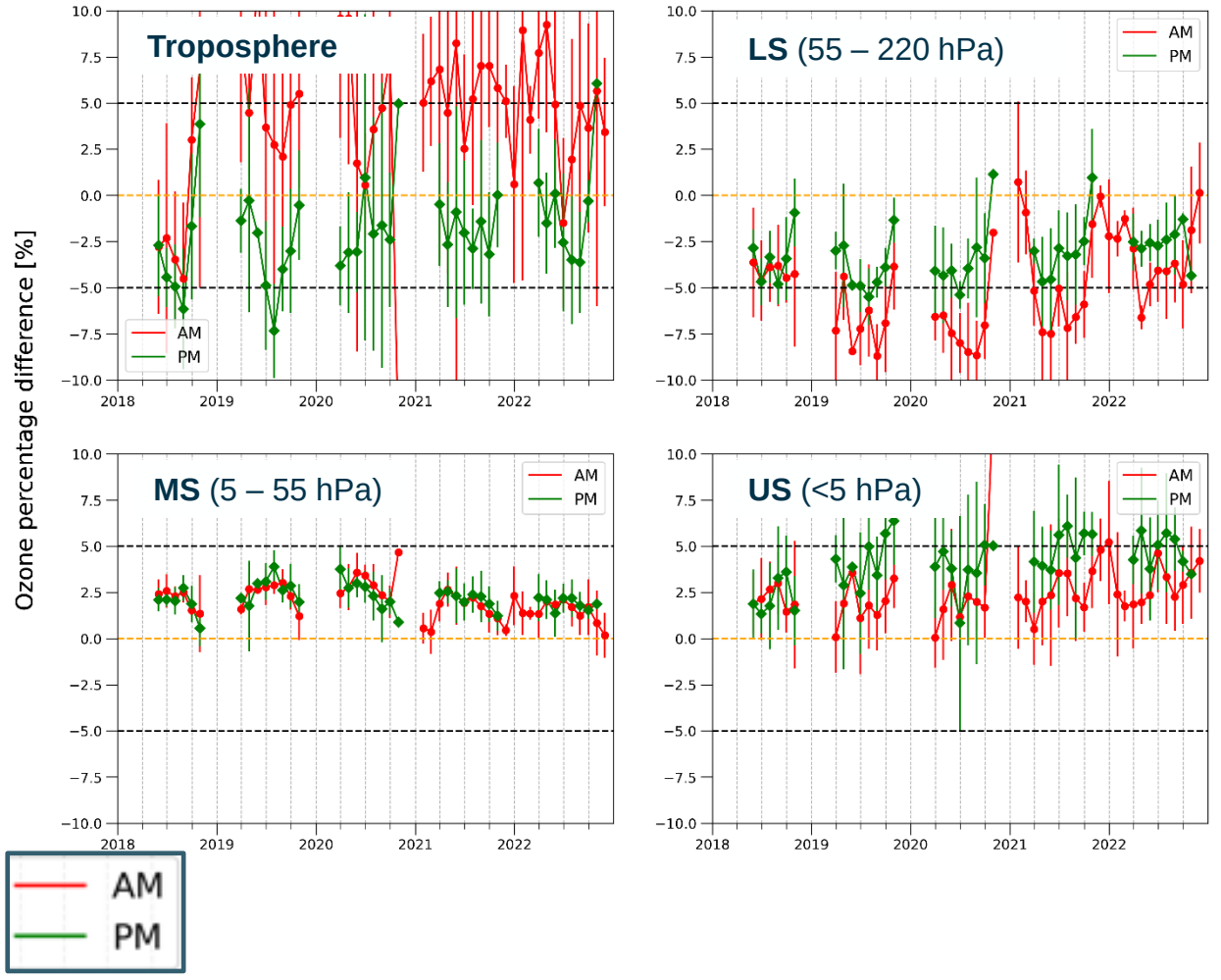

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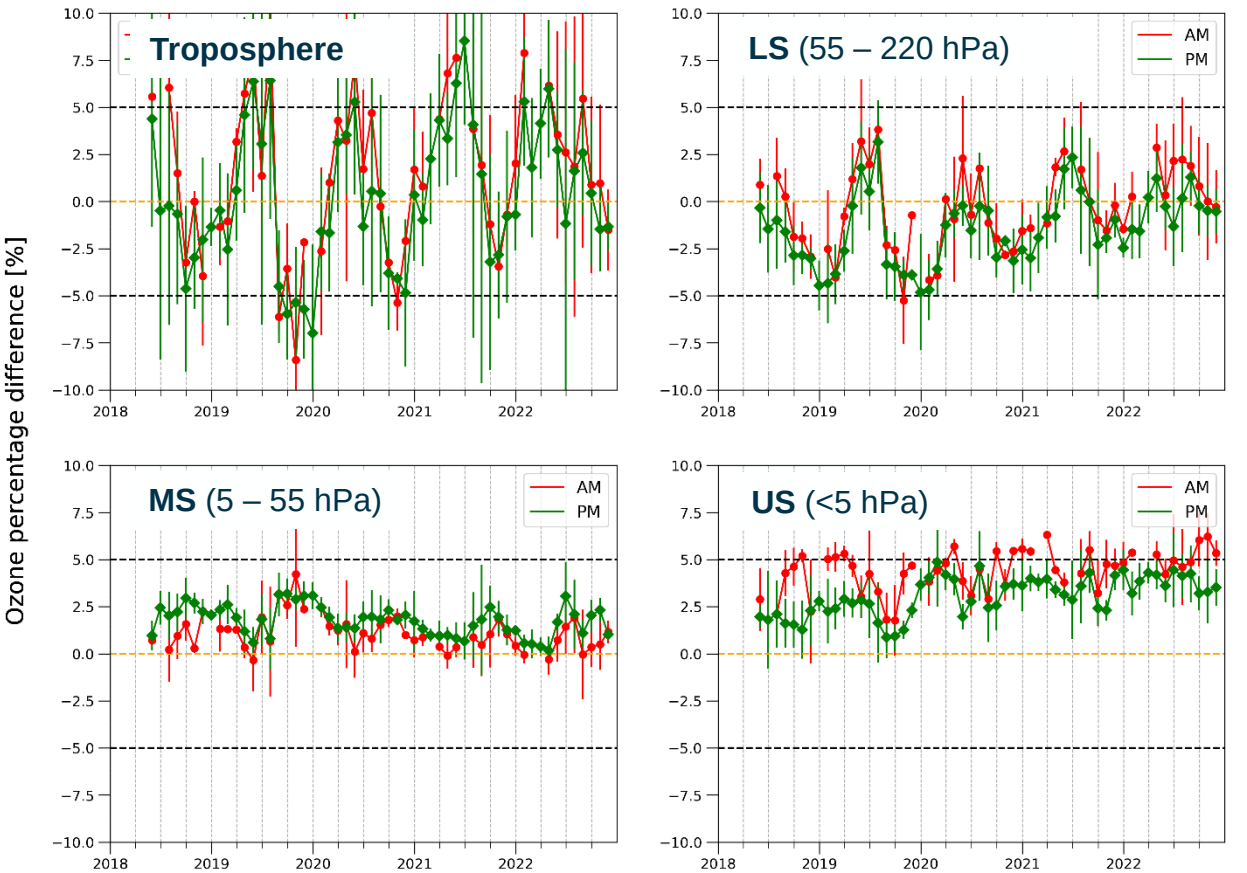

Comparison results: GOME-2B w.r.t. Umkehr

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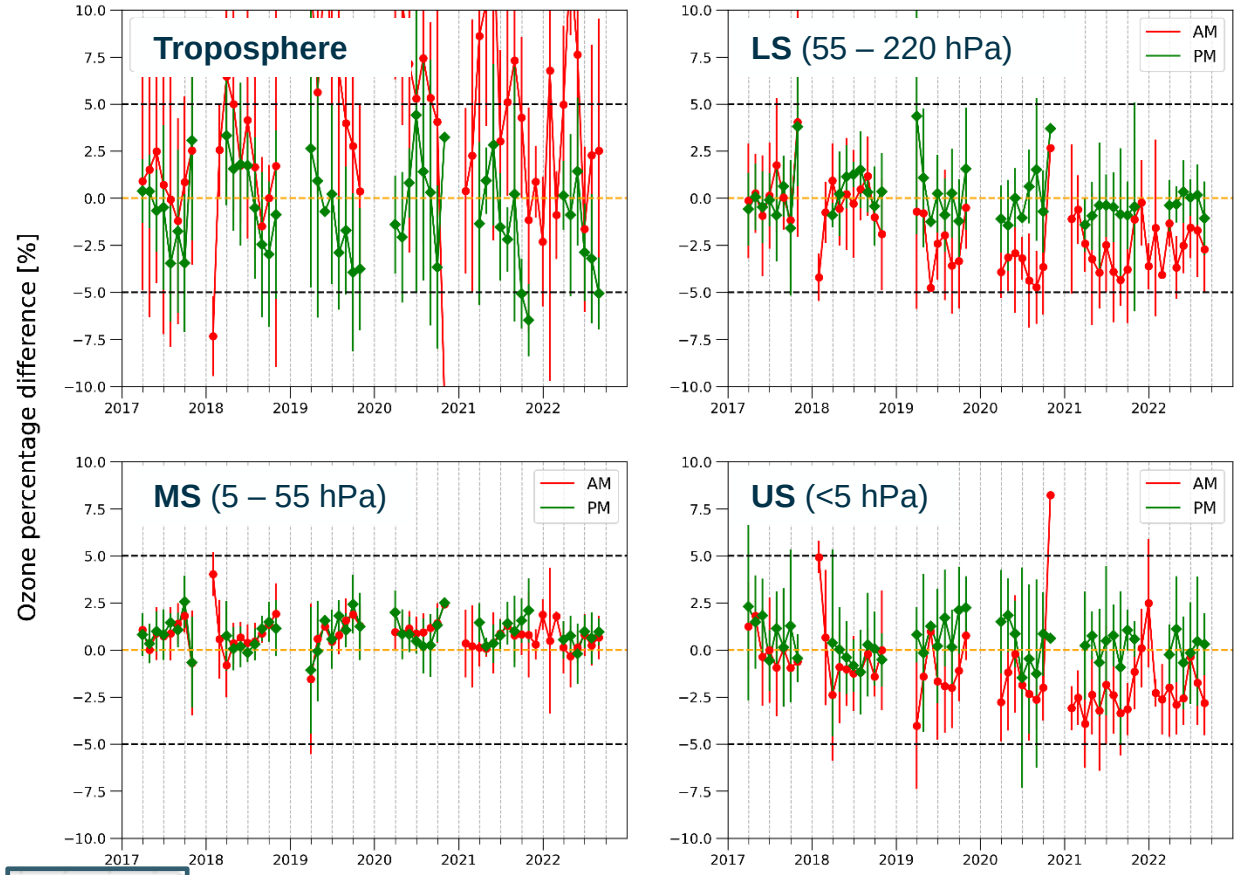
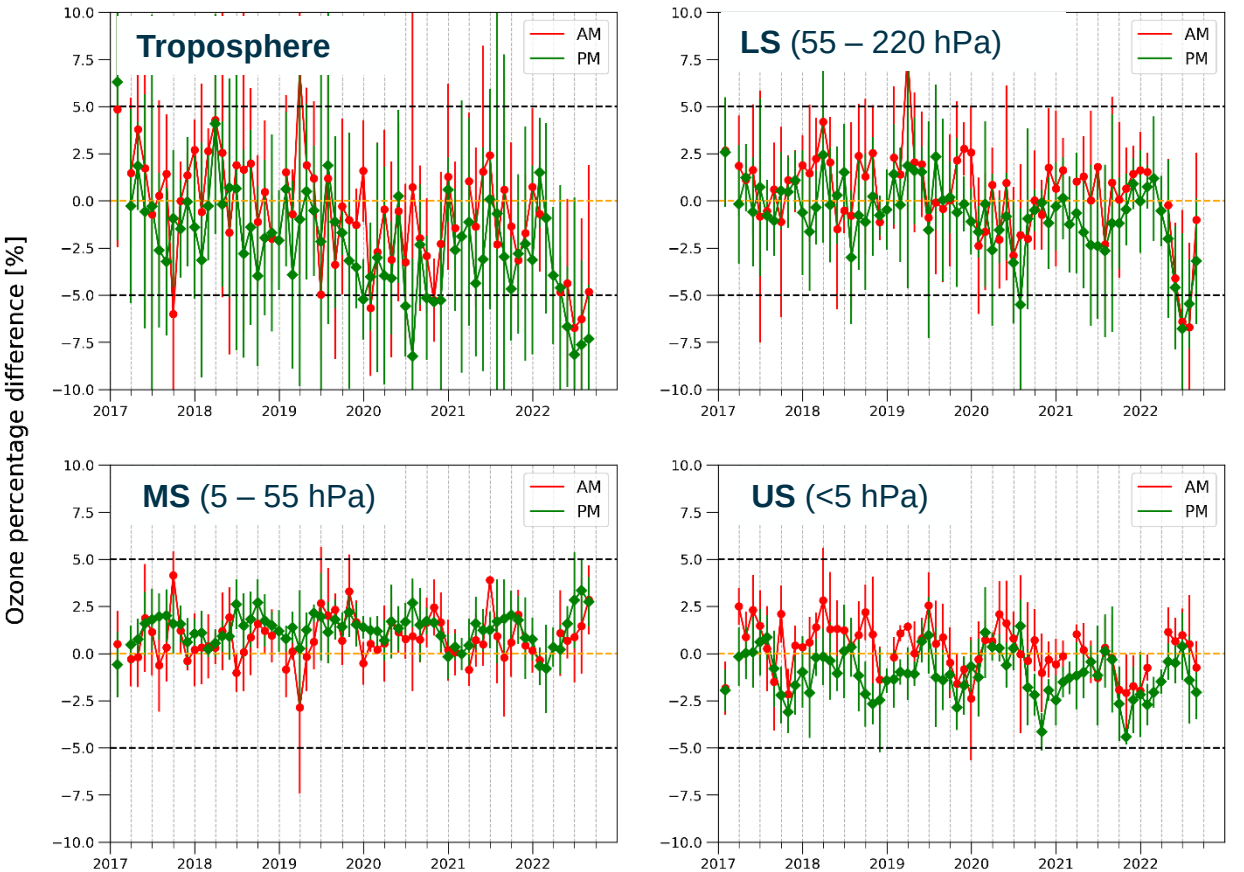
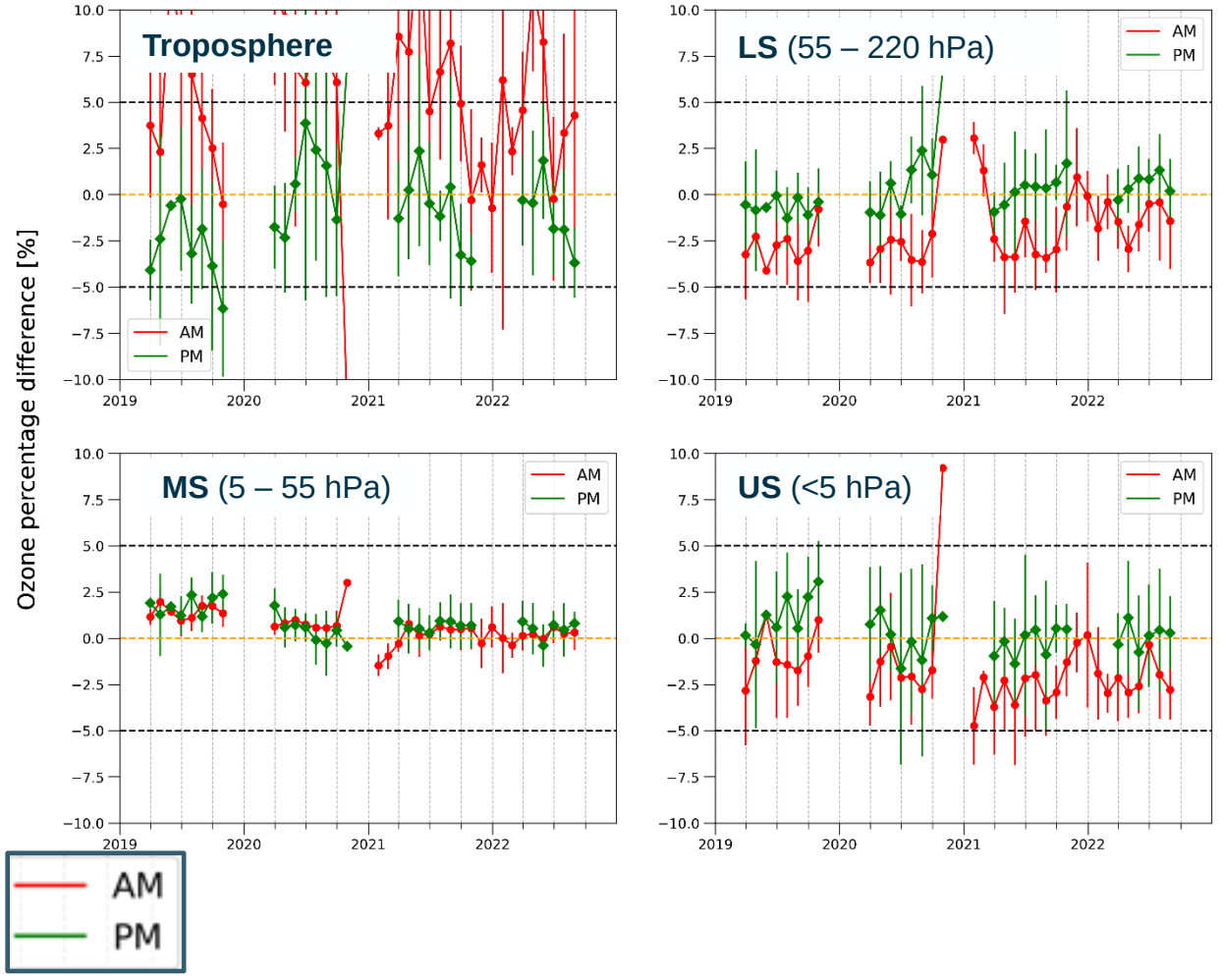


Lauder (Dobson)

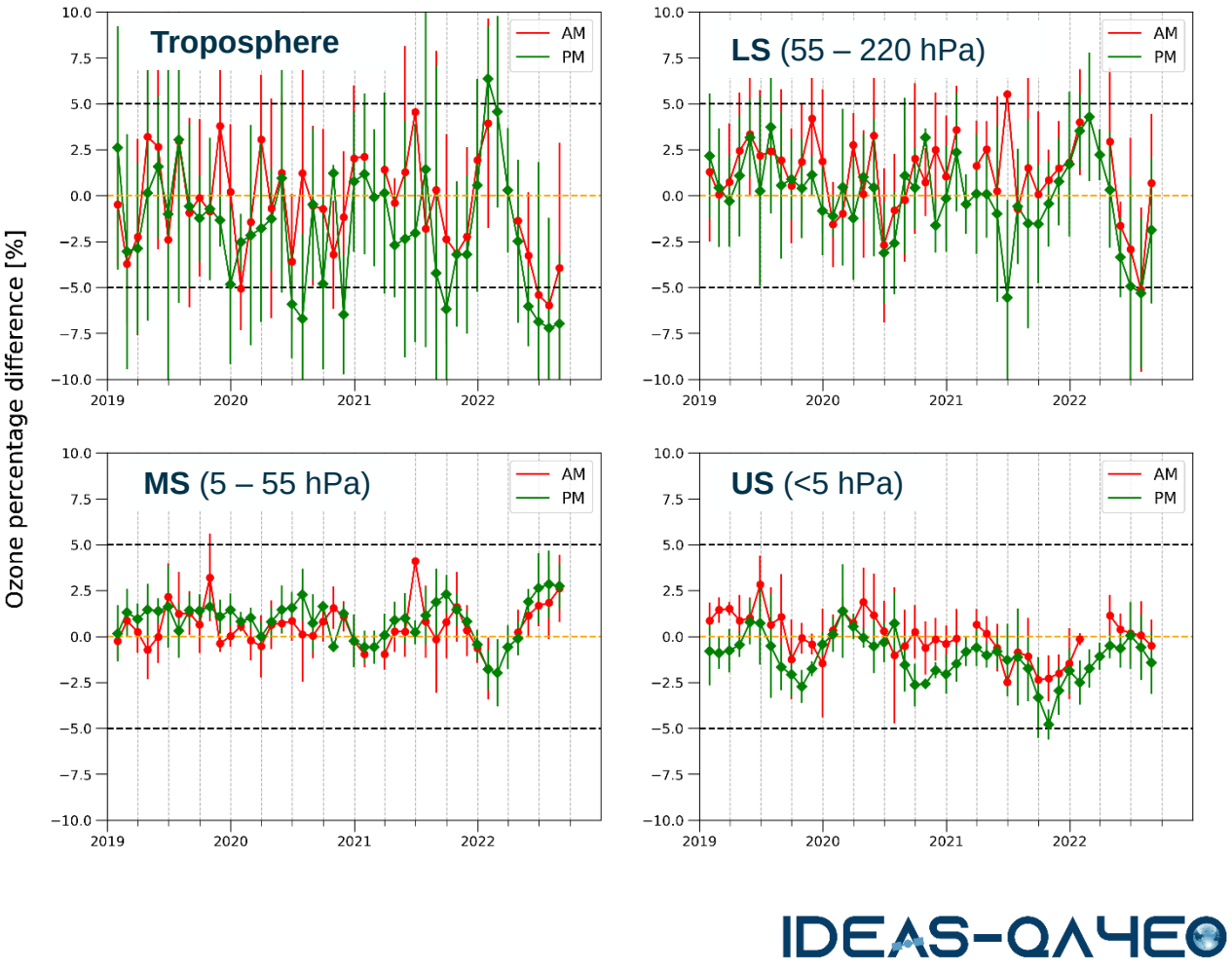


Comparison results: GOME-2C w.r.t. Umkehr

Hradec Kralove (Brewer)



Lauder (Dobson)



Comparison results: S5P/TROPOMI w.r.t. Umkehr

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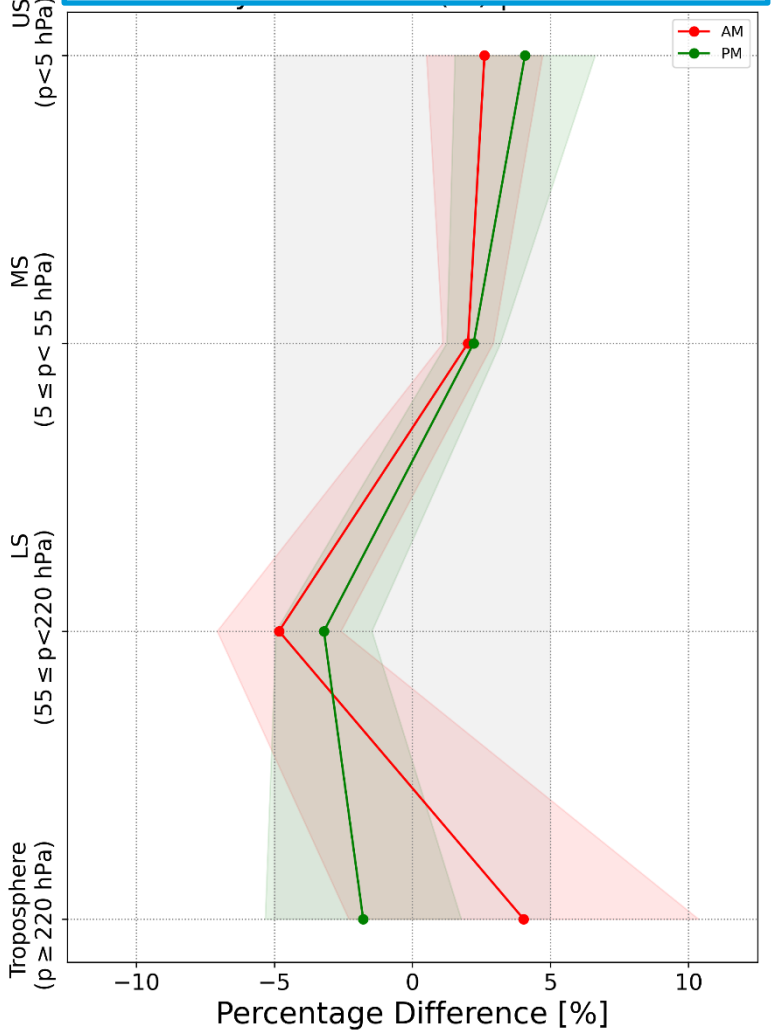

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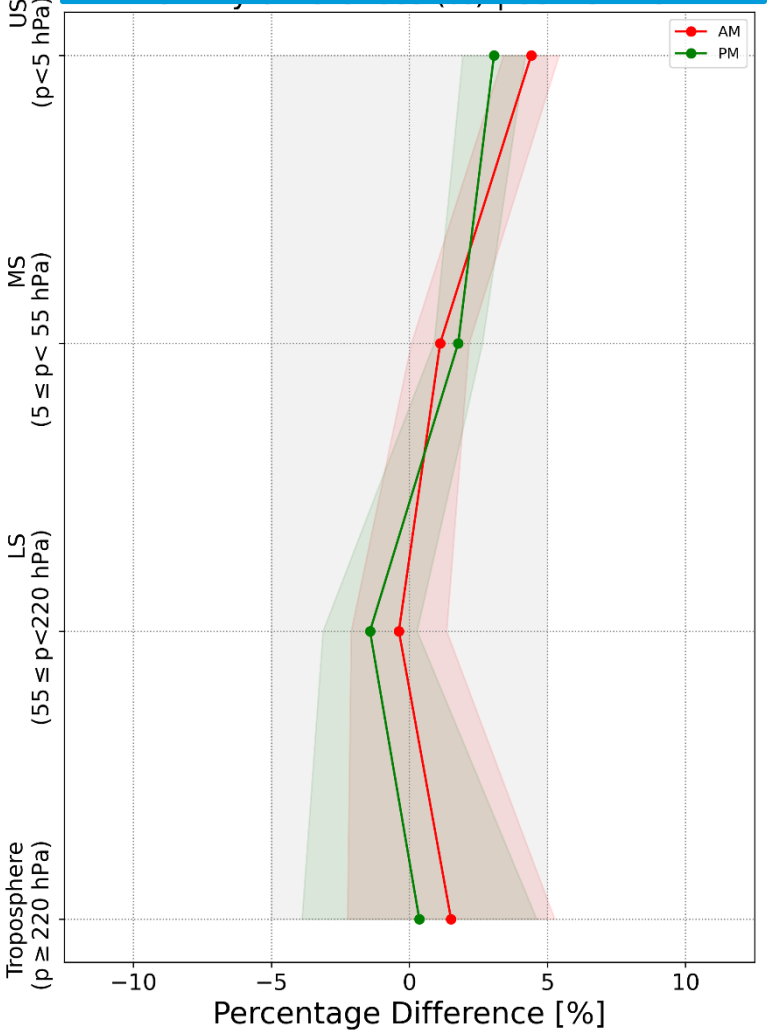


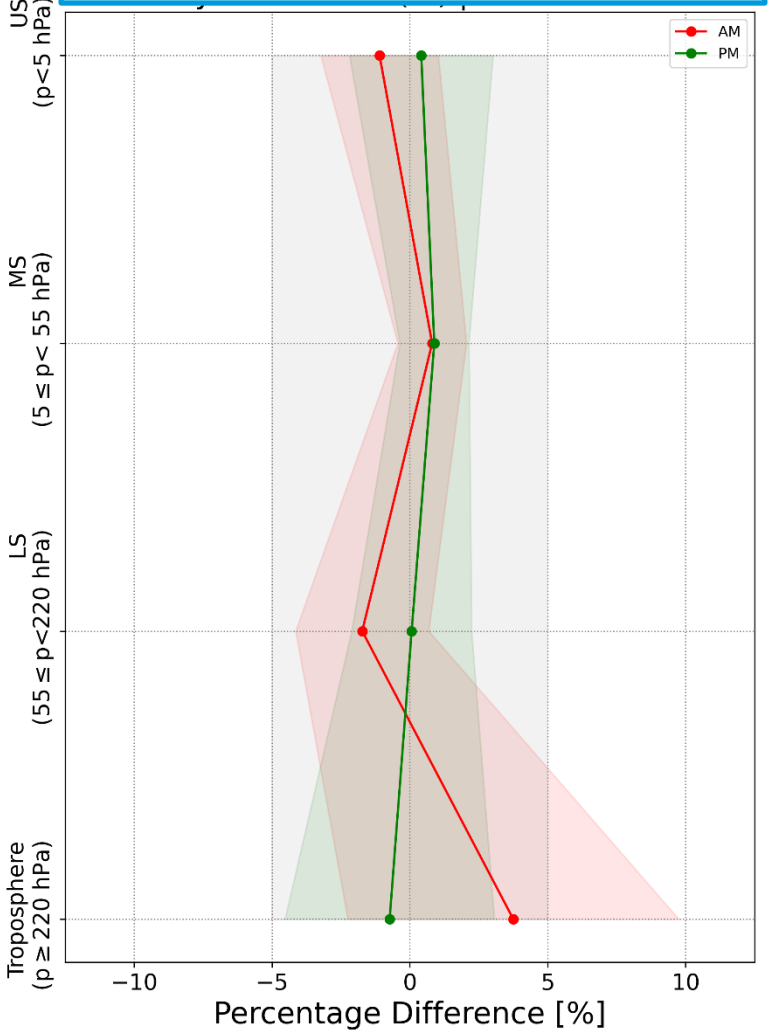
- Troposphere:
  AM → +3 ± 4 %,
  PM → +1 ± 4 %
  - Higher positive % differences at high elevation stations
  - Higher variability
- Differences between the two sensors:

	TROPOMI	GOME2
LS:	-2 ± 2 %	+1 ± 2 %
MS:	**+1.5 ± 1%**	**+0.5 ± 1%**
US:	+3 ± 1.5%	-0.5 ± 1.5 %

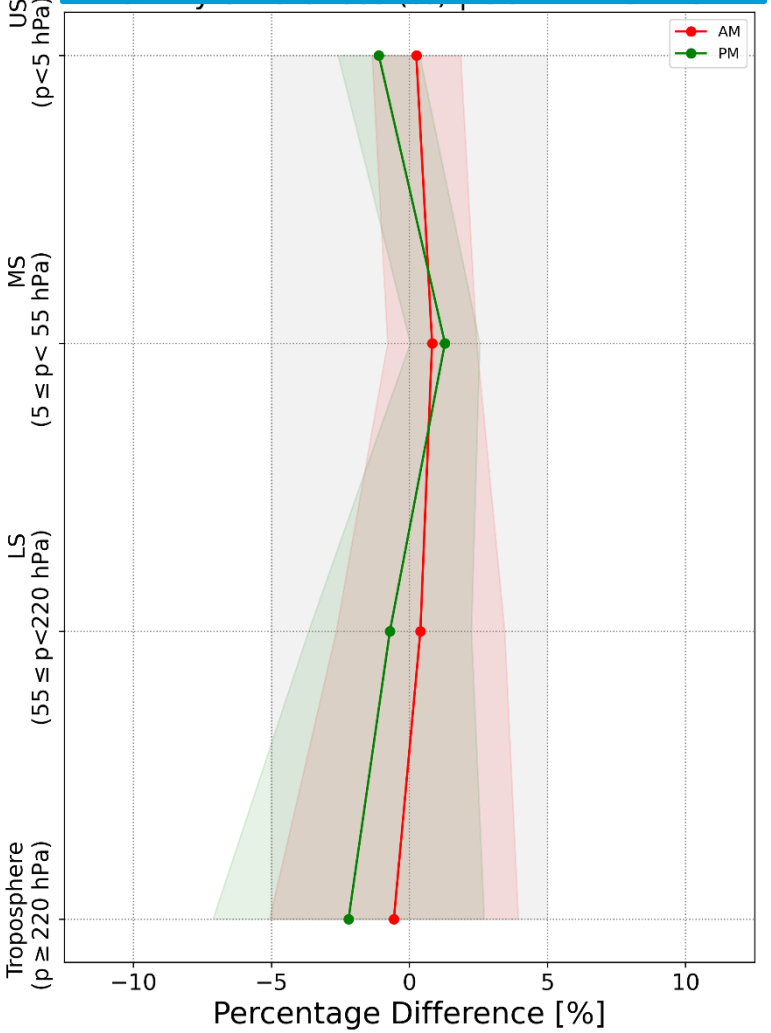
- **Overall, differences within ± 5%**

Comparison results: GOME-2B w.r.t. Umkehr

Hradec Kralove (Brewer)



Lauder (Dobson)



AM
PM

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Comparison results: GOME-2C w.r.t. Umkehr

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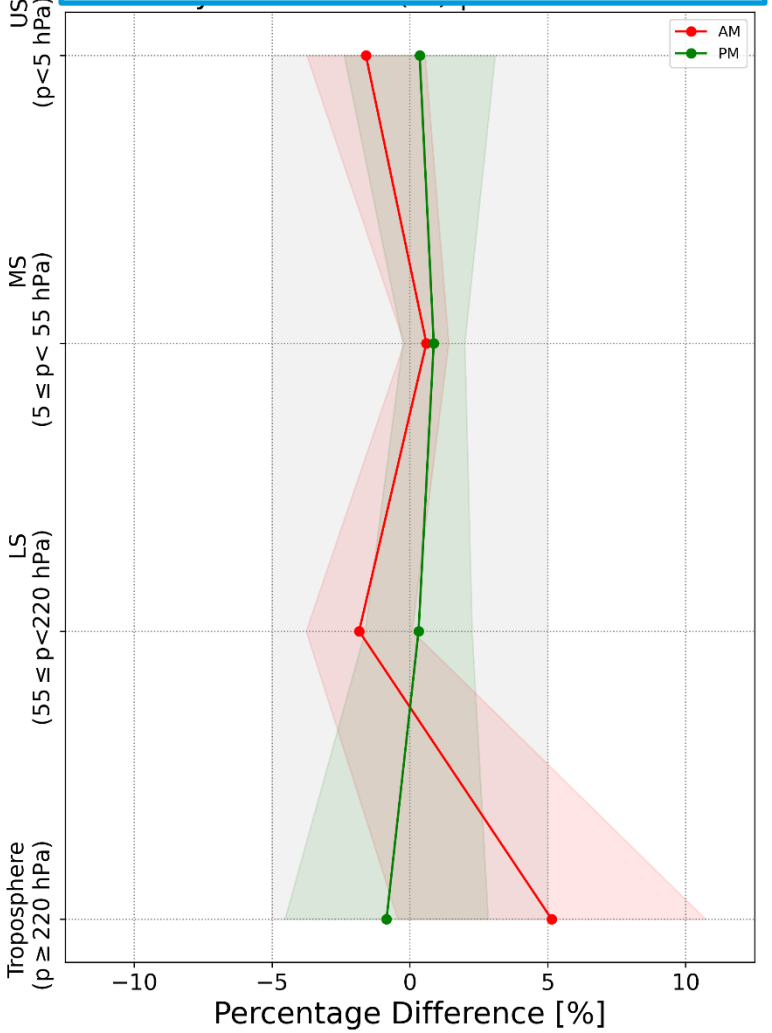

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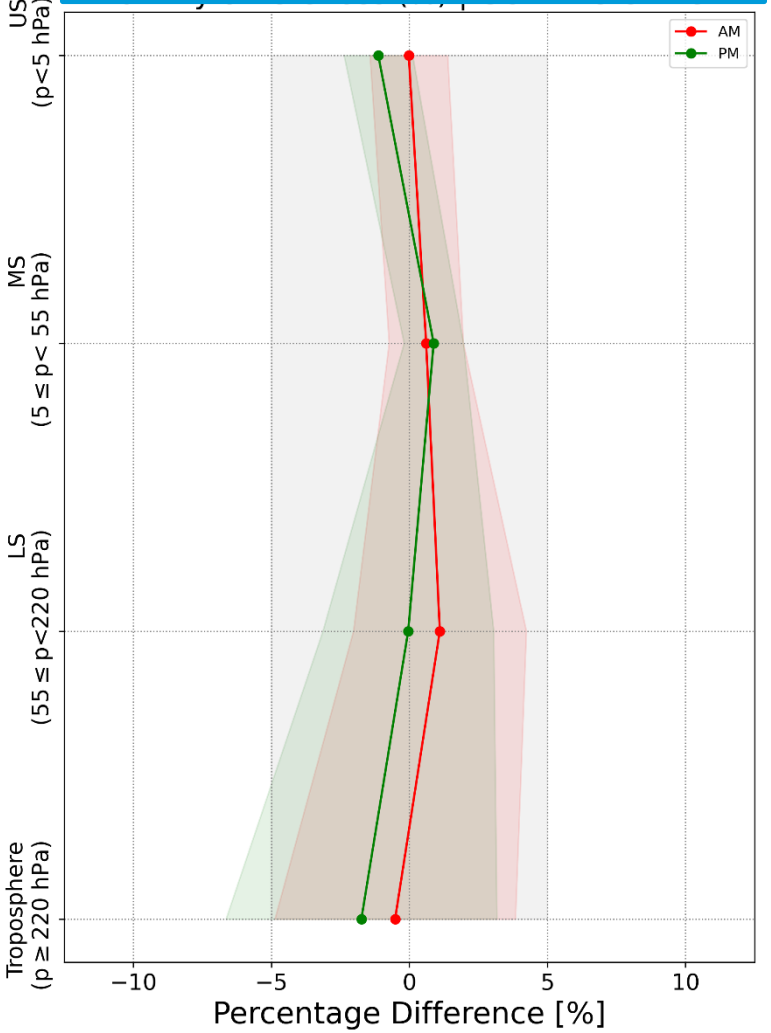

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Conclusions

- Good agreement (within ±5%) for the mean percentage differences between the Umkehr and the satellite profiles

- The re-evaluated Umkehr ozone profiles from Dobson and Brewer instruments show a high potential and can be utilized as fiducial measurements for the validation of various satellite ozone profile products.

Thank you for your attention!

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Final Report available in zenodo

Updated Umkehr ozone timeseries, available upon request (contact balis@auth.gr)

We thank the PIs of the Brewer instruments for providing their Umkehr measurements