



# Validation of satellite ozone profiles, using ground-based Umkehr measurements

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# Tasks and Deliverables

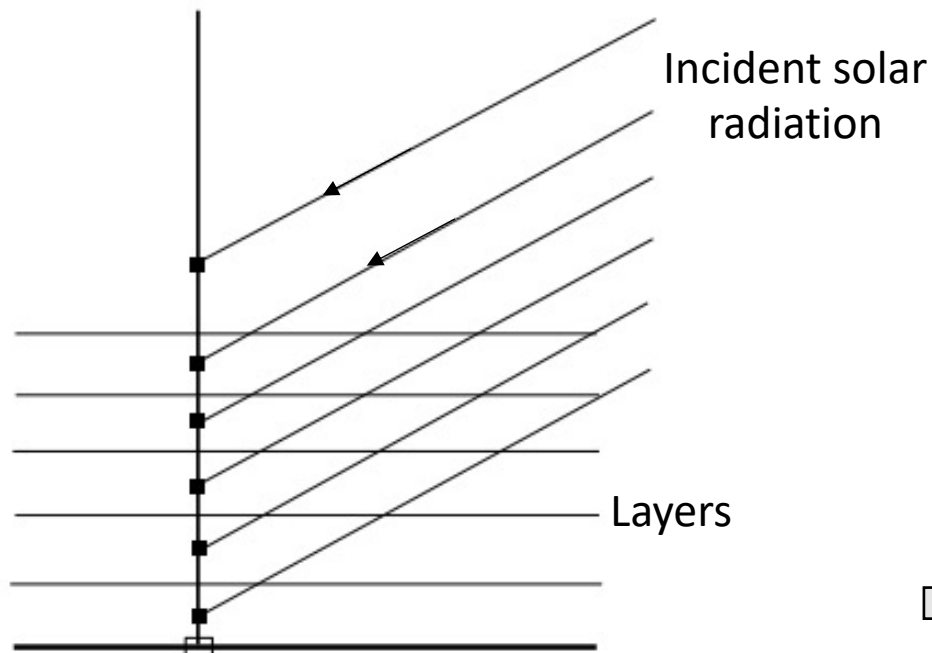
## ➤ Tasks

- Acquire Umkehr records from [WOUDC](#) and [EUBREWNET](#) for the period 2020 to 2022
- Further efforts for data homogenization
- Update the reprocessed Umkehr dataset (2007 – 2020) and extend until 2022
- Demonstrate the potential of Umkehr data for the TROPOMI nadir profile validation

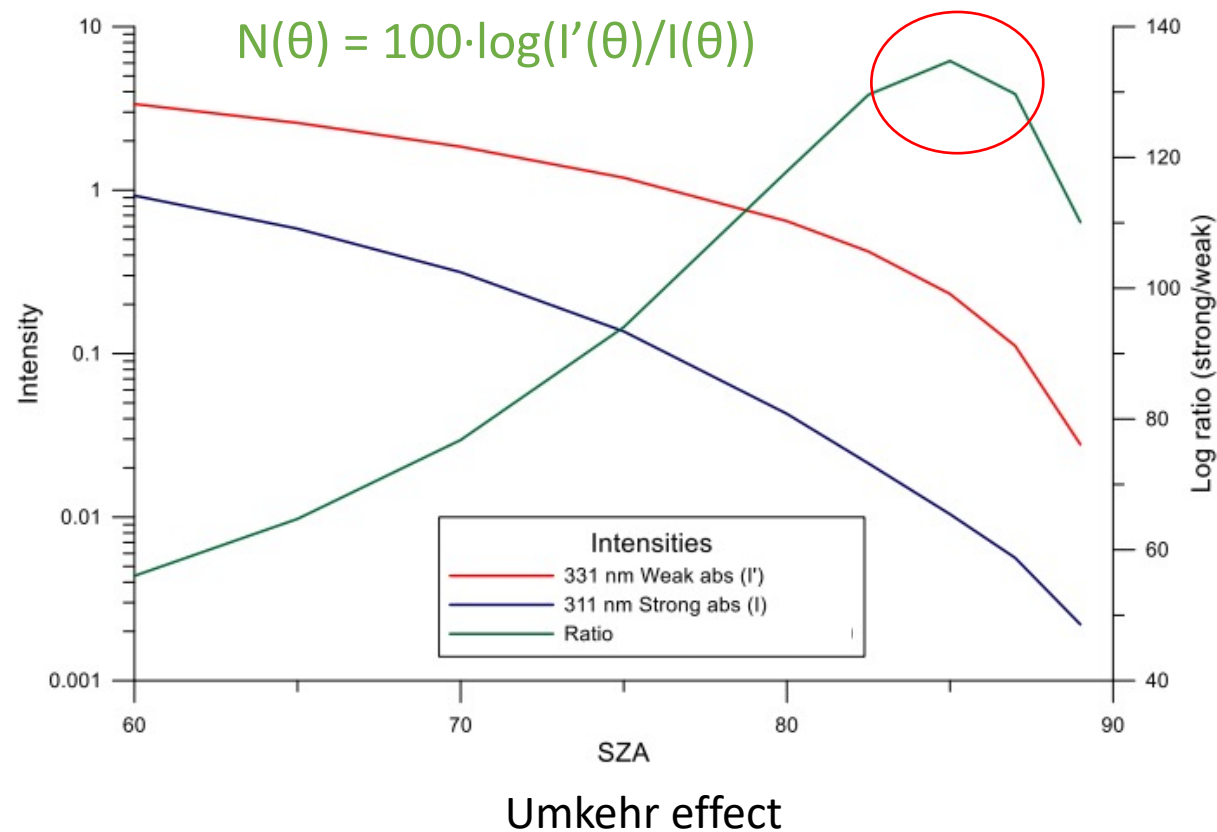
## ➤ Deliverables

- Quarterly Reports
- Final Report (available in [zenodo](#))
- Updated Umkehr ozone timeseries, available upon request (contact [balis@auth.gr](mailto:balis@auth.gr))

# Umkehr measurements (1)



- Radiation measurements at zenith, while the Sun rises/sets
- Measurements in wavelength pairs with strong and weak O<sub>3</sub> absorption
- Calculate the N Values →  $100 \cdot \log(\text{weak}/\text{strong})$
- “Inversion” of the N Values curve



## Umkehr measurements (2)

### ➤ Instruments for Umkehr measurements:

- Automated DOBSON spectrophotometer (A, C & D wavelength pairs, 60° – 90° SZA)
- BREWER spectrophotometer (8 wavelengths, 70° – 90° SZA)



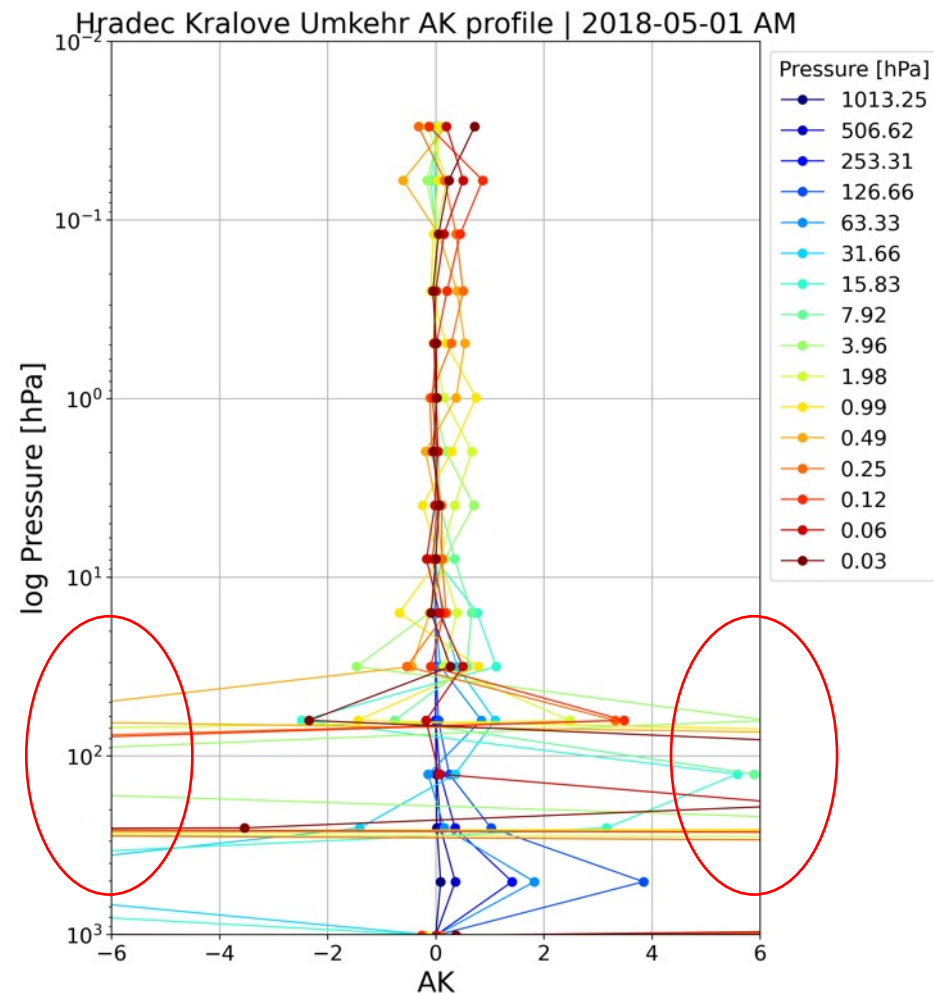
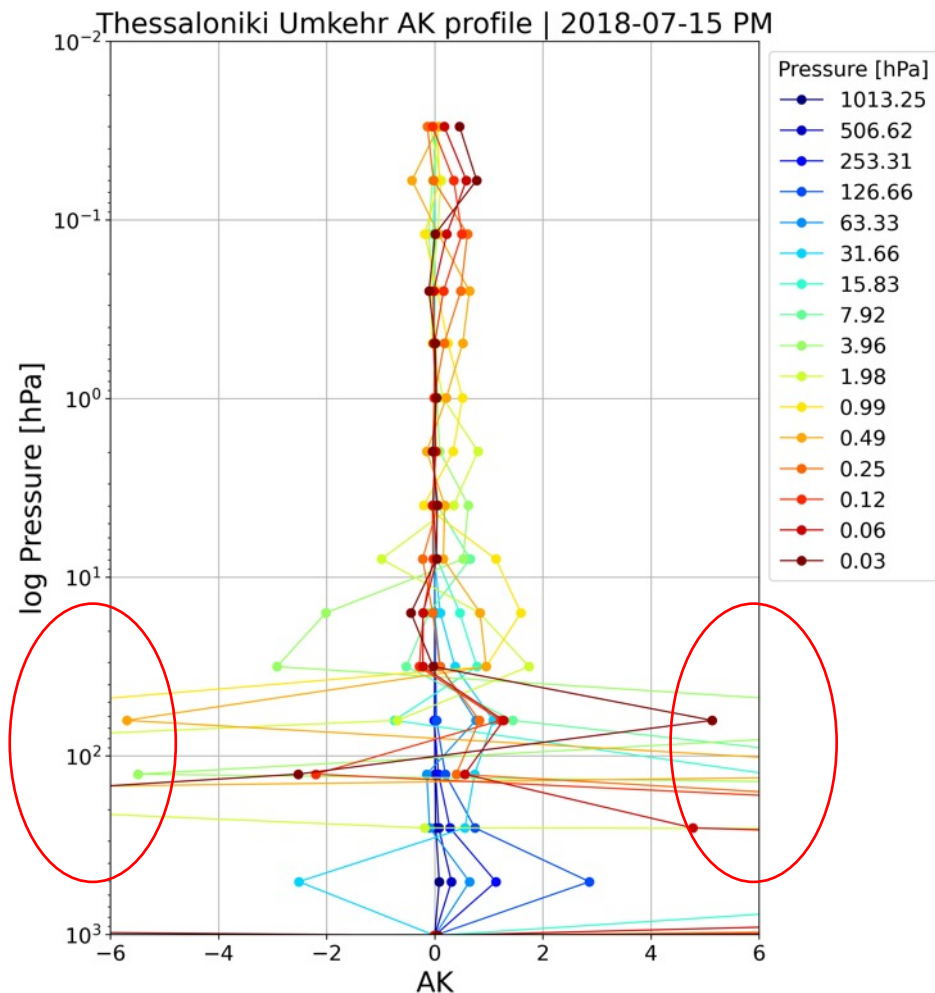
Dobson (left) and Brewer (right) spectrophotometers



# Data usage

- Ground-based ozone profiles (16-layer scheme from the O3BUmkehr algorithm)
  - 4 BREWER ground-based stations
  - 5 DOBSON ground-based stations
  
- Satellite ozone profiles (S5P/TROPOMI, GOME-2 B&C)
  
- The respective ground-based and satellite AK and a-priori profiles
  
- Time period: 2017 – 2022

# Umkehr AK profiles sensitivity study (1)

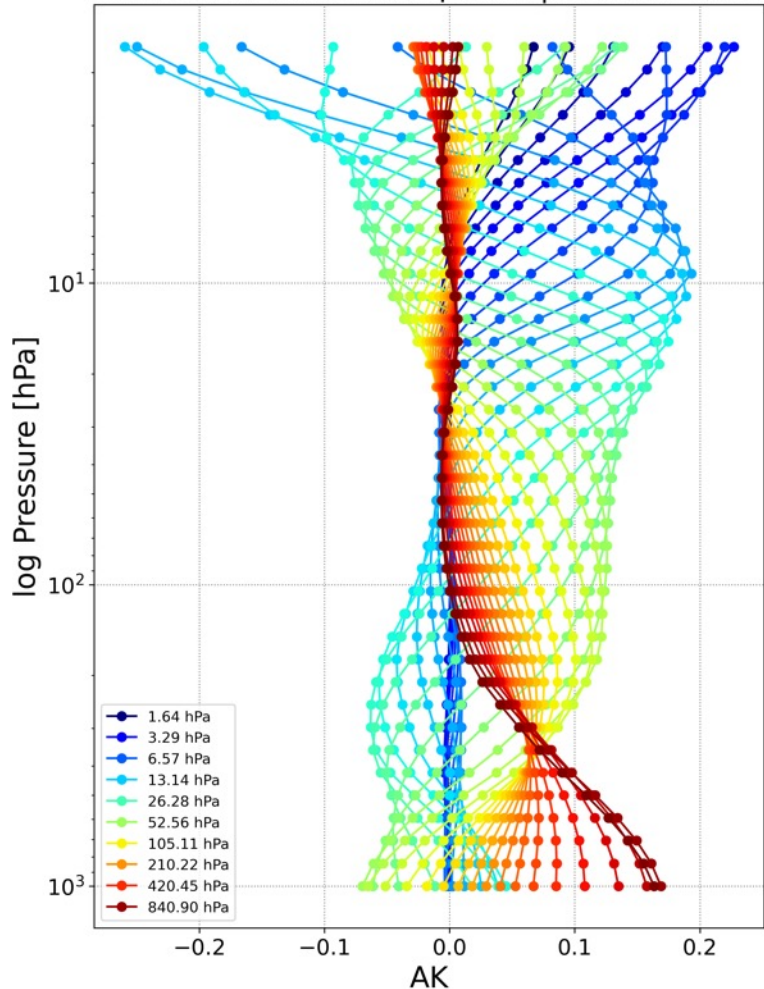


- Extreme high/low values in the BREWER AK profiles
- Use of the 61-layer scheme instead (O3BUmkehr algorithm)

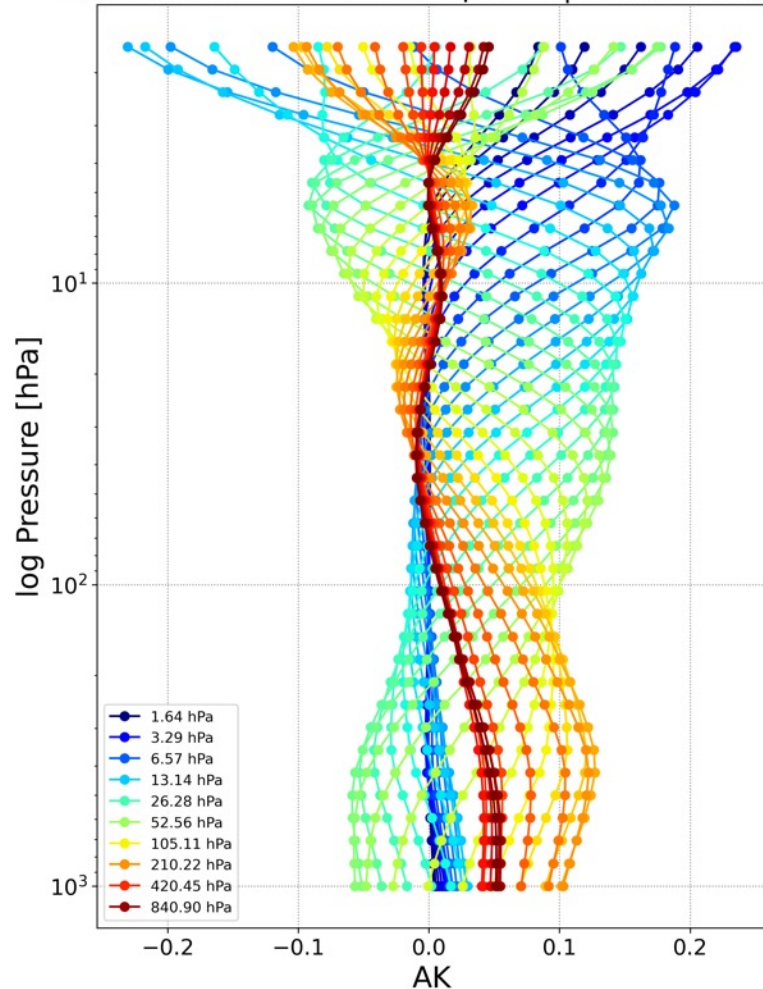


# Umkehr AK profiles sensitivity study (2)

Thessaloniki Umkehr AK profile | 2018-07-15 PM



Hradec Kralove Umkehr AK profile | 2018-05-01 AM



Setup

Instrument, Profile

Instrument number  Station number

Input Data Path

Output Data Path

Spline Interpolation of N-Values  16 Layer Output Density increment [km]  1  2  4 Max. iterations:

320 Ratio  Quality Filter Range  Offset  Slope  Quad.

Brewer temp. circuit  Old  New Wavelength [A.U.] short, long   Temperature coefficients

Total Ozone  Recalculate Total Ozone Standard Lamp R6:  Weighting const.:   
 Read constants from ICF --> Instrument Constant File Name:   
 Correct for ozone weighted mean temperature Surface ozone [D.U.]

Observation Error

Export  Profiles  Observed N - Values  Profiles - Extended output SZA Range k begin min  k end min   
k begin max  k end max   
Max. SZA  Stray Light

Read file with ozone weighted mean temperature   
 Save and apply edited N-Values --> N Folder Path:

O3BUmkehr algorithm – Setup window (available [here](#))

- Use the BREWER AK profiles of the 61-layer scheme and for  $p \geq 2$  hPa
- Similar for the DOBSON stations





# Analysis steps

- Interpolate the satellite profiles to the Umkehr's vertical resolution
- Apply the Umkehr AK to the interpolated satellite ozone profiles

$$\text{sat}_{\text{smoothed}} = \text{Umkehr}_{\text{apriori}} + \text{AK}_{\text{Umkehr}} \times (\text{sat}_{\text{interp}} - \text{Umkehr}_{\text{apriori}})$$

- Calculate the mean percentage difference

$$\left( \frac{\text{sat}_{\text{smoothed}} - \text{Umkehr}}{\frac{\text{sat}_{\text{smoothed}} + \text{Umkehr}}{2}} \right) \cdot 100$$

- Divide the atmosphere into 4 main layers:

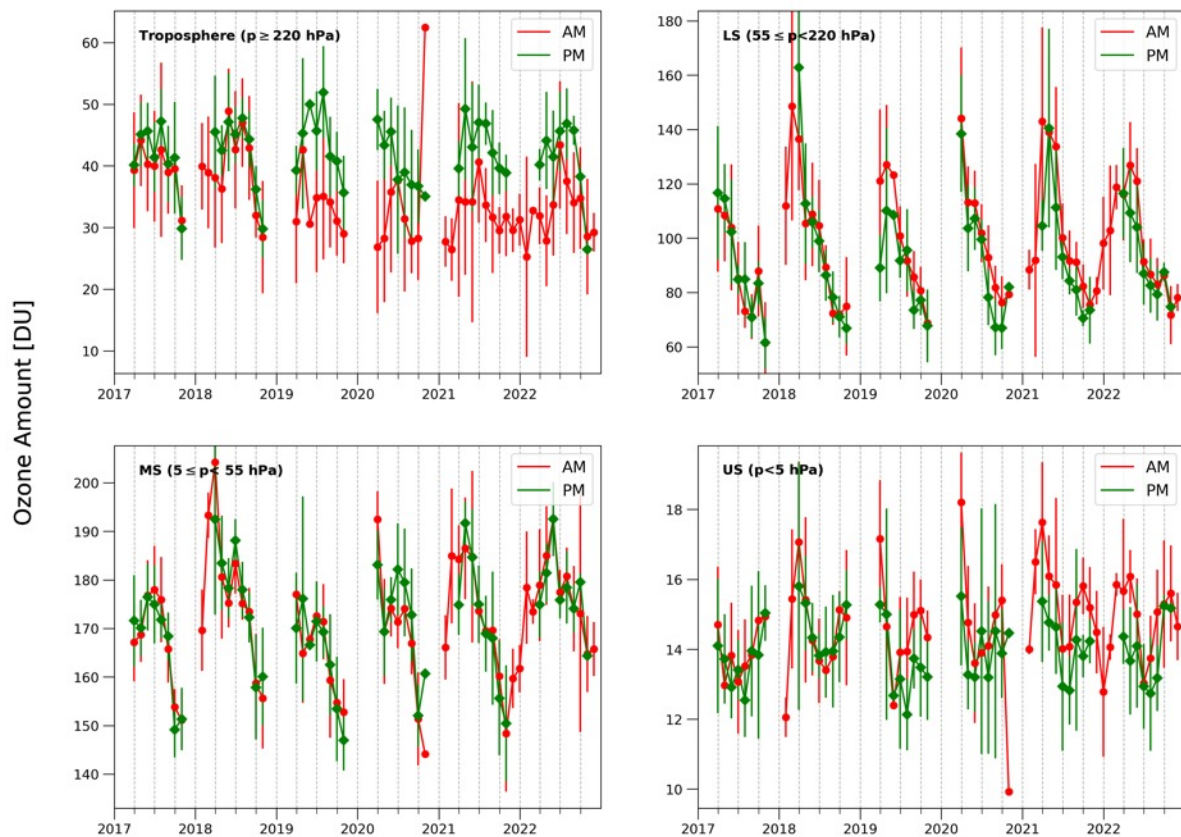
Layers	Boundaries in km	Boundaries in hPa
Troposphere	surface – 11	1013.25 (surface) – 220
Lower Stratosphere (LS)	11 – 20	220 – 55
Main Stratosphere (MS)	20 – 40	55 – 5
Upper Stratosphere (US)	40 – 50	5 – 2



# Updated Umkehr ozone profiles timeseries

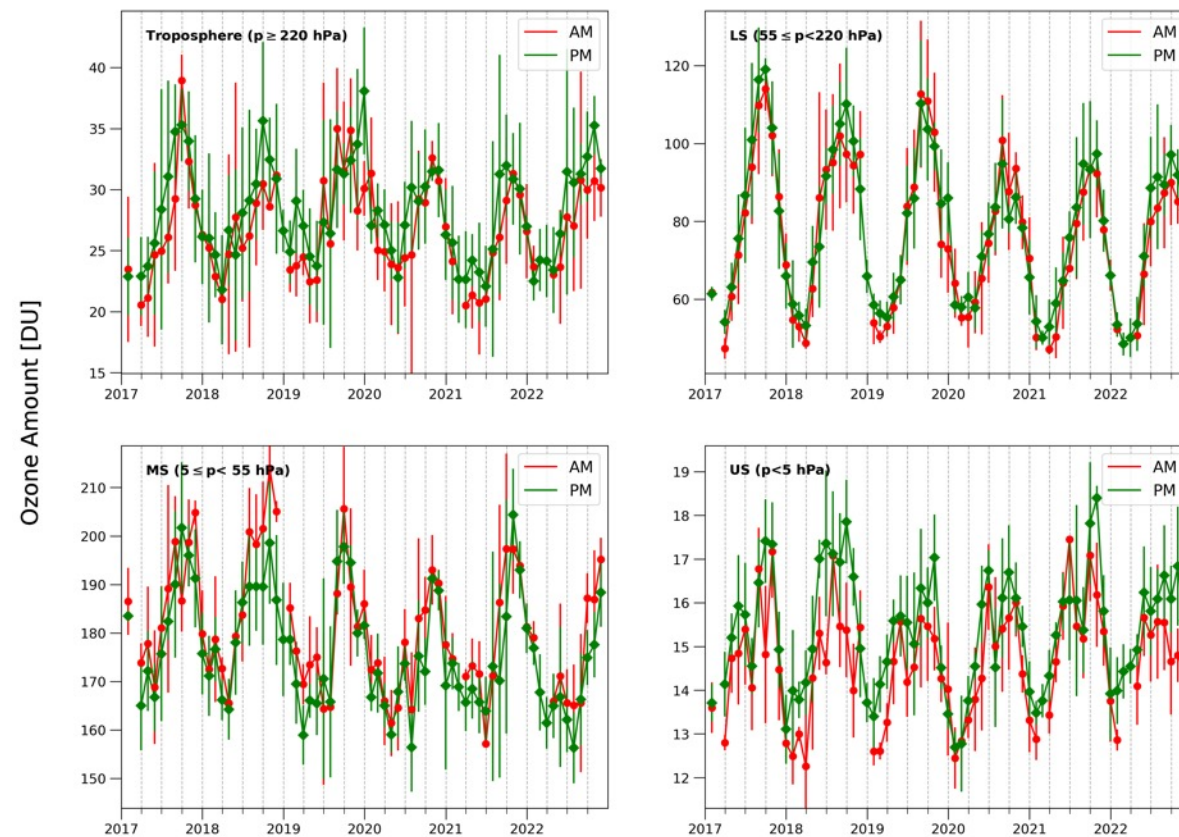
## ➤ BREWER

Hradec Kralove - Monthly average



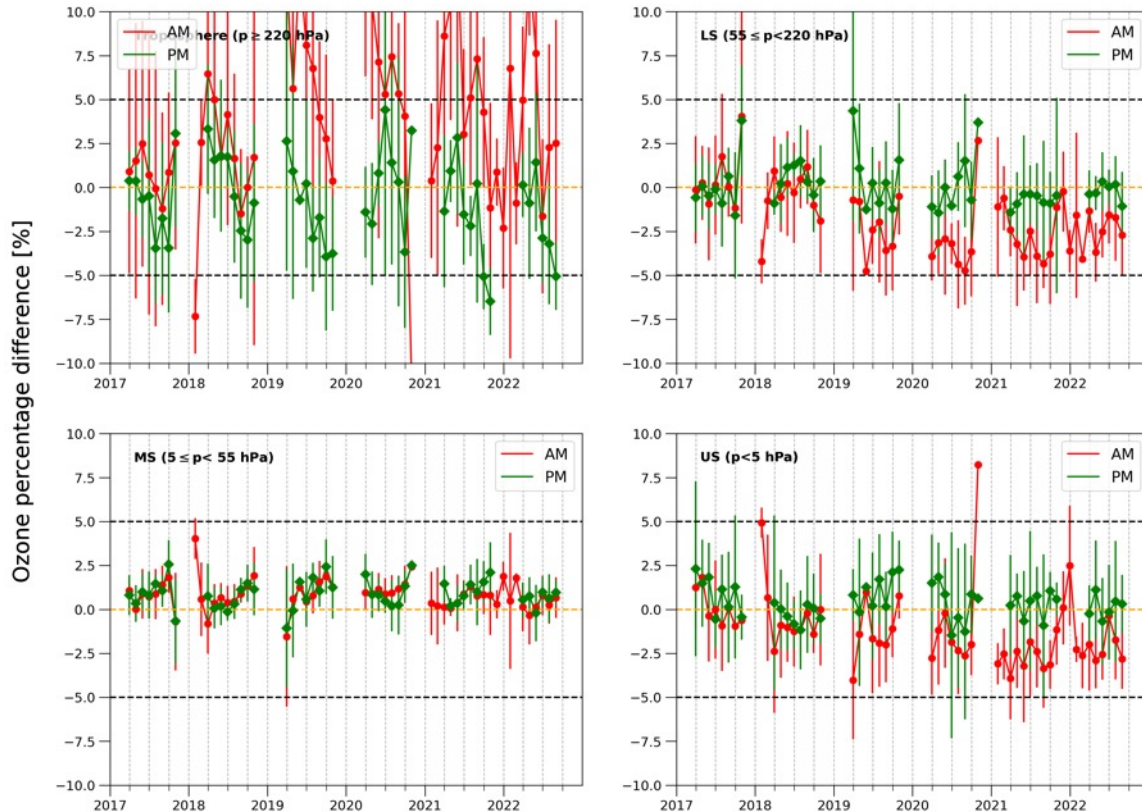
## ➤ DOBSON

Lauder - Monthly average

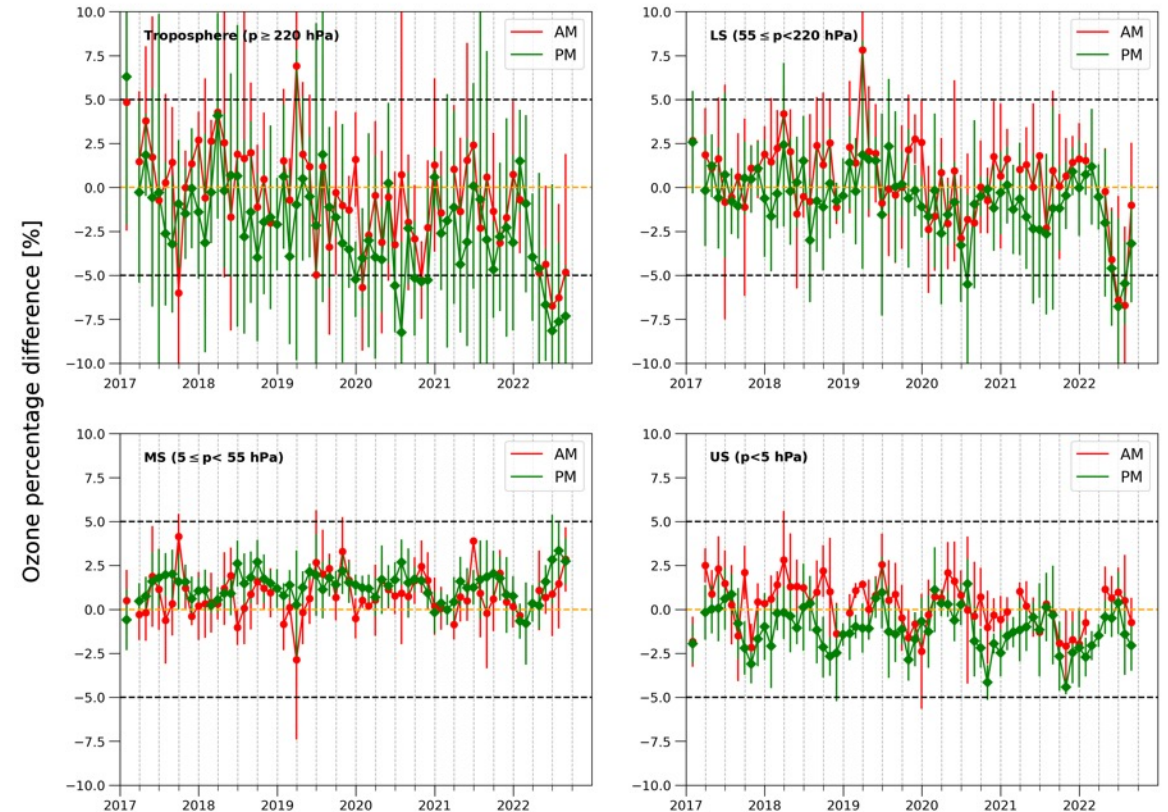


➤ Timeseries of the mean percentage differences in monthly basis

Hradec Kralove - Monthly percentage differences | GOME2B-Umkehr

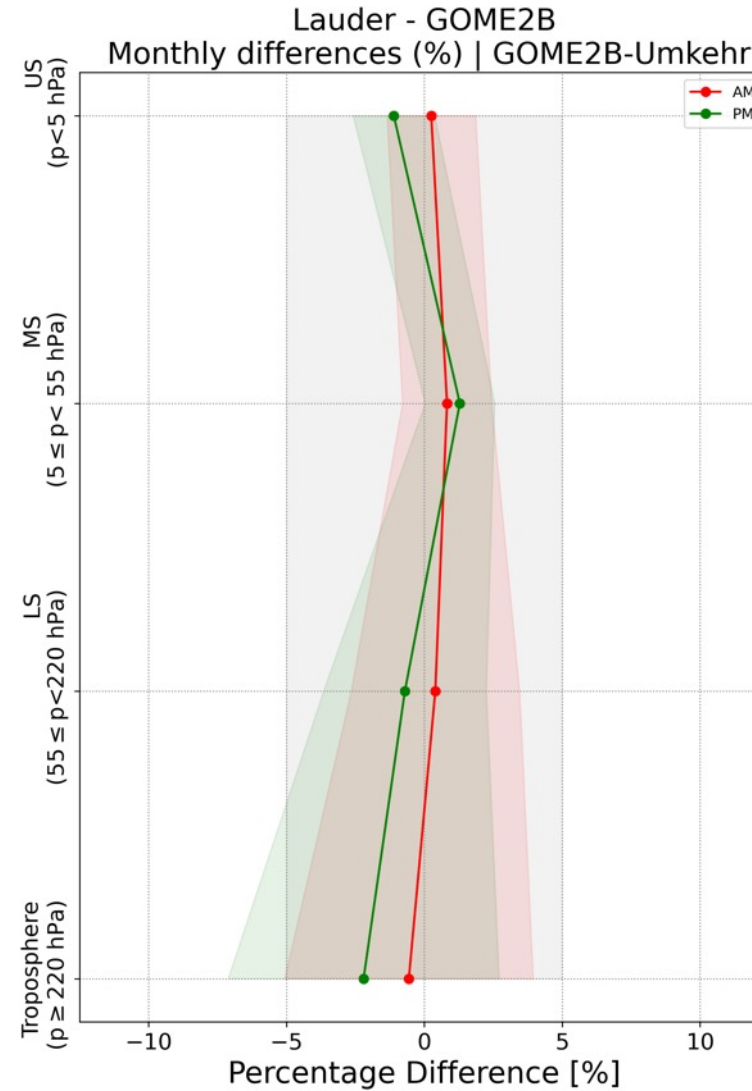
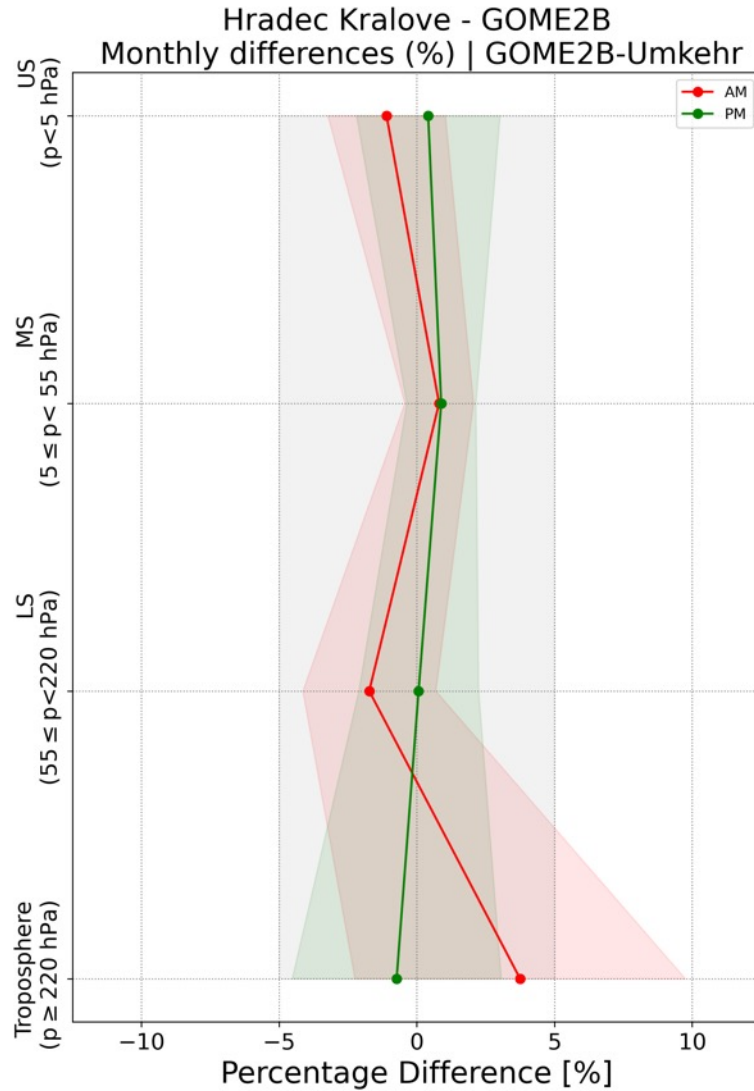


Lauder - Monthly percentage differences | GOME2B-Umkehr



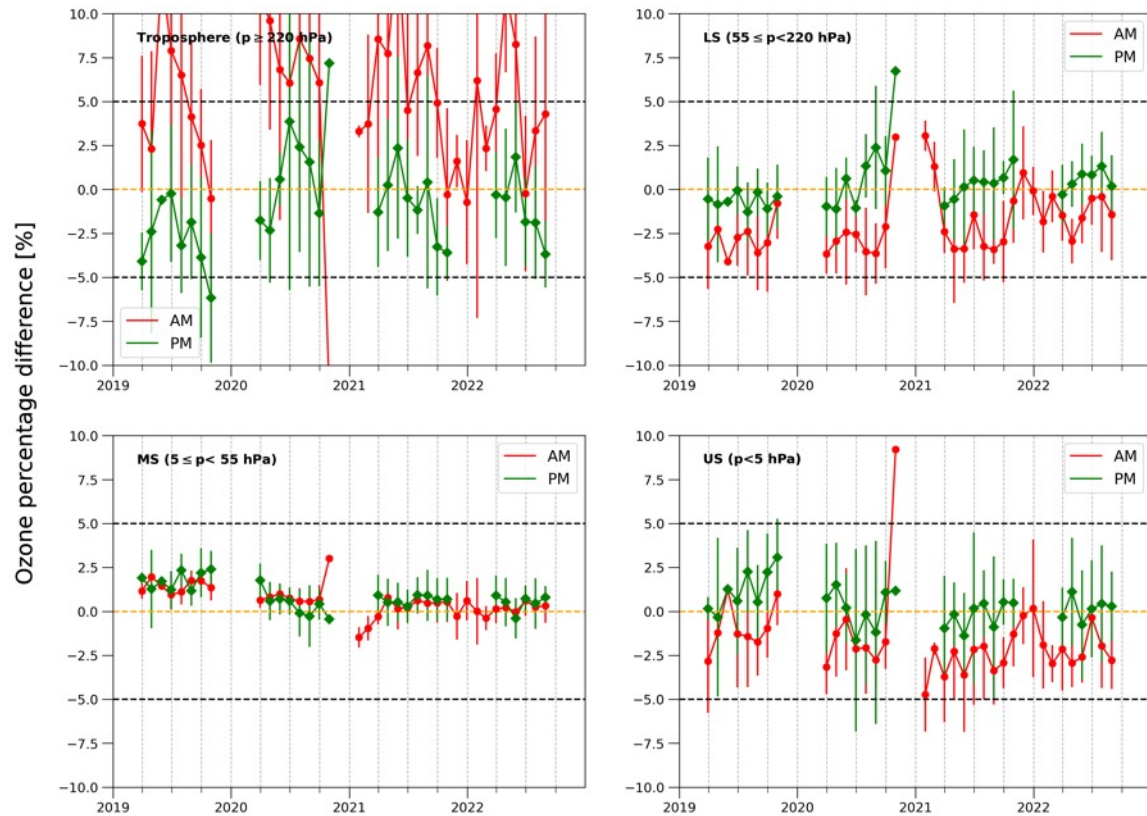
# Comparison results (GOME-2B/ground-based) (2)

➤ Profiles of the mean percentage differences in monthly basis

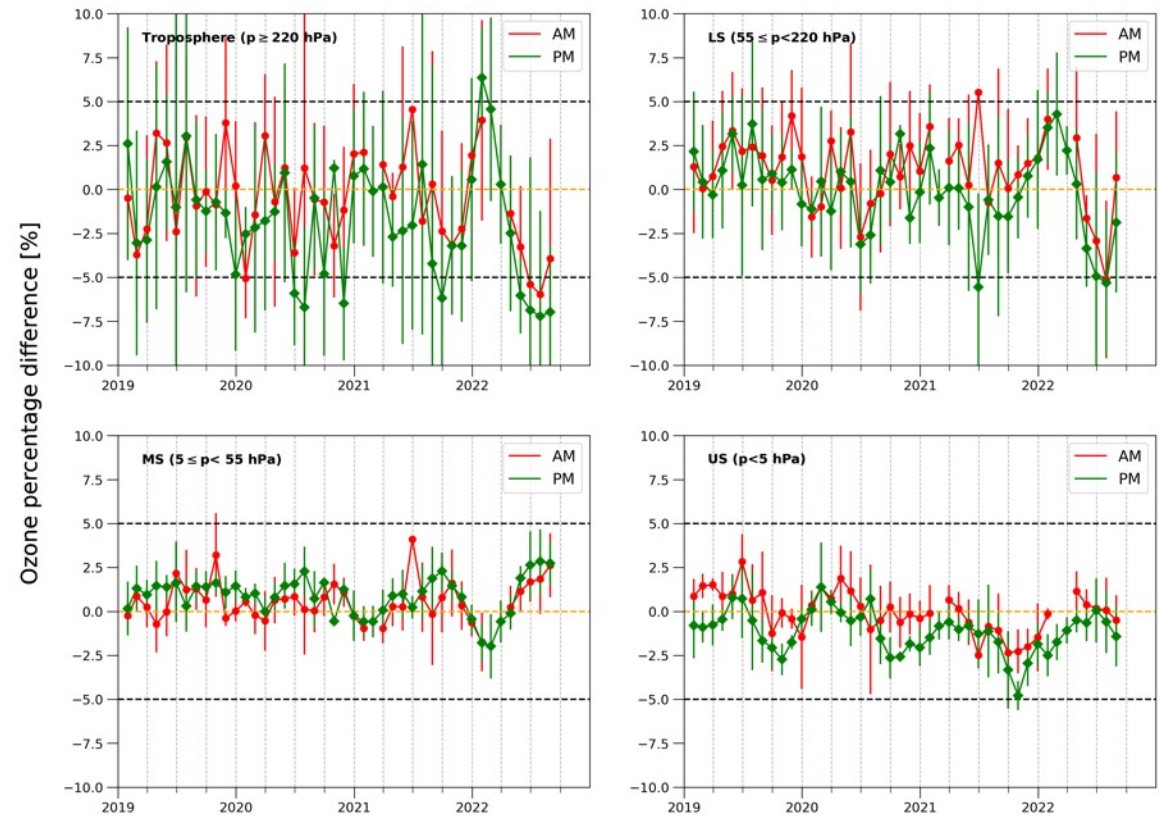


➤ Timeseries of the mean percentage differences in monthly basis

Hradec Kralove - Monthly percentage differences | GOME2C-Umkehr

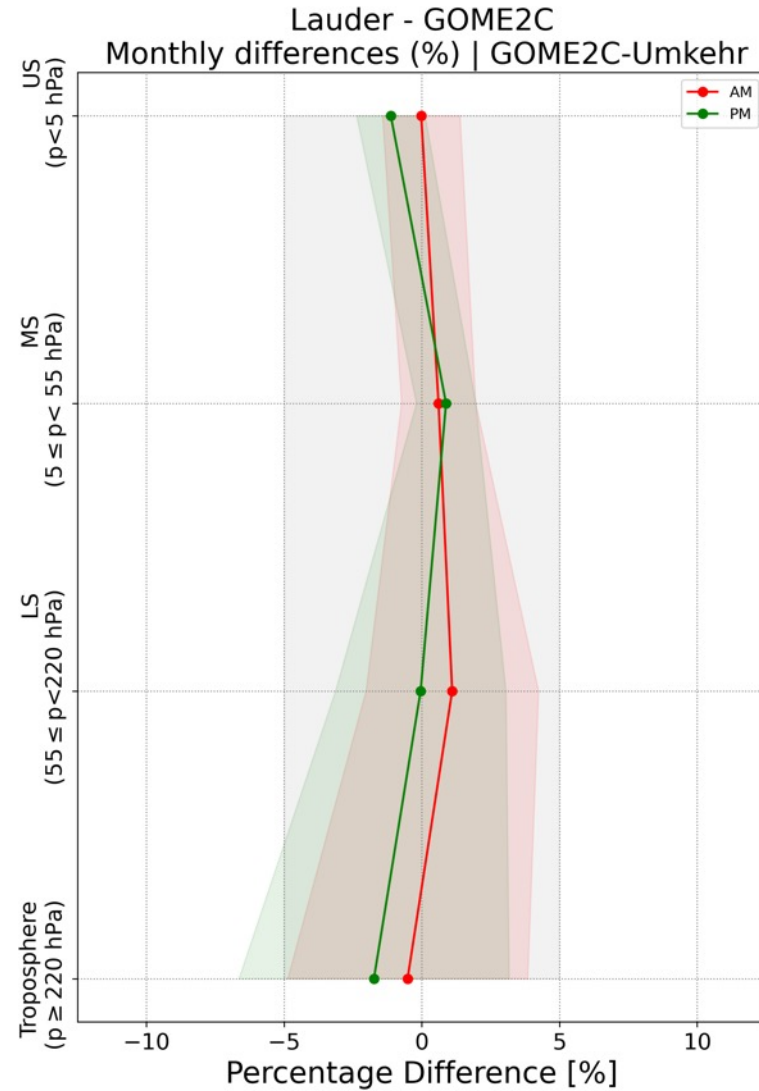
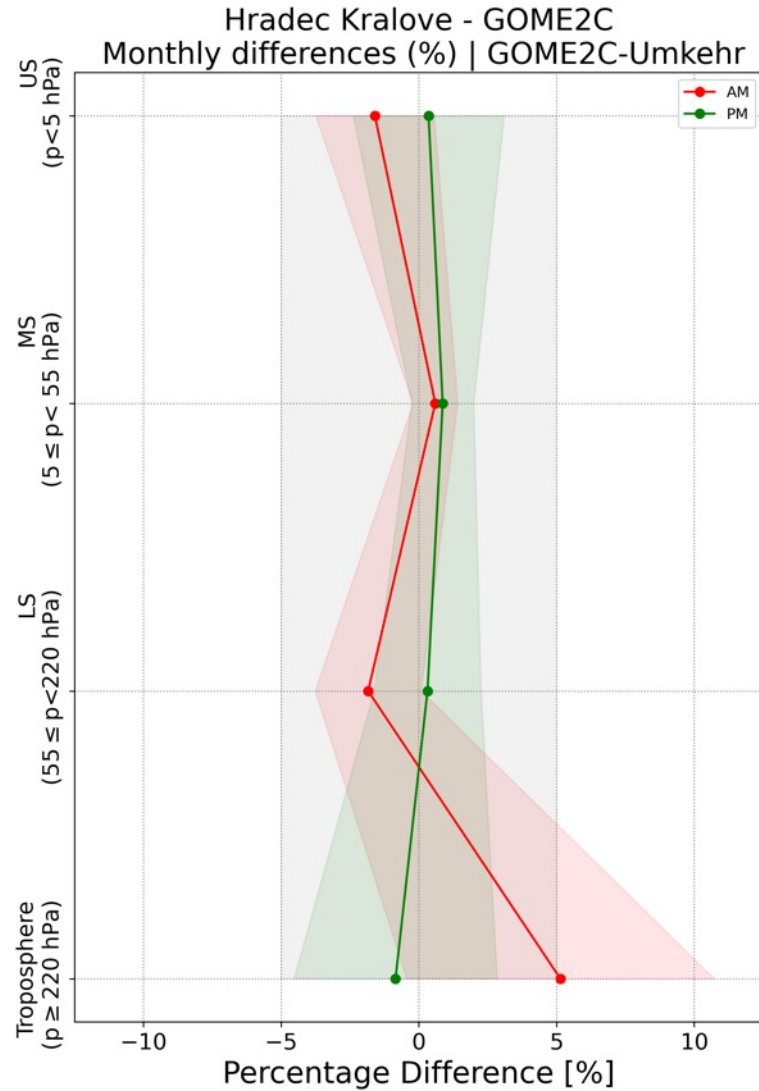


Lauder - Monthly percentage differences | GOME2C-Umkehr



# Comparison results (GOME-2C/ground-based) (2)

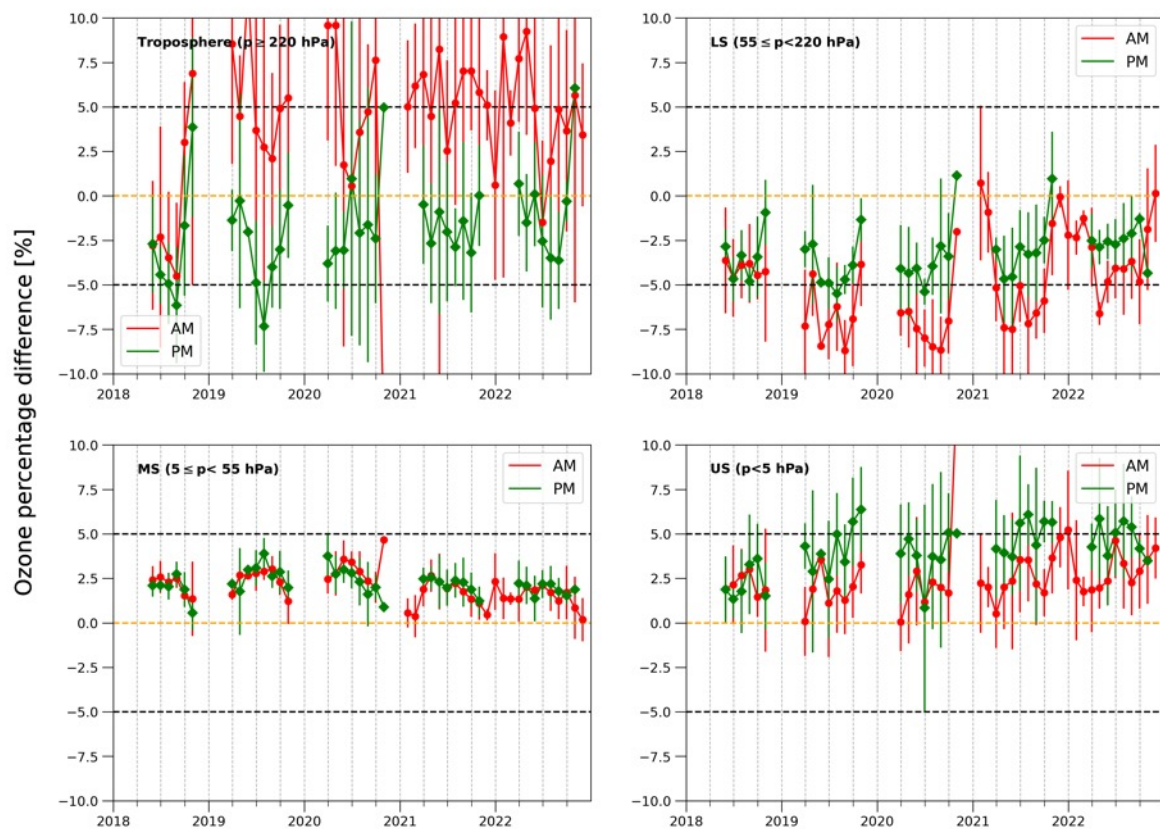
- Profiles of the mean percentage differences in monthly basis



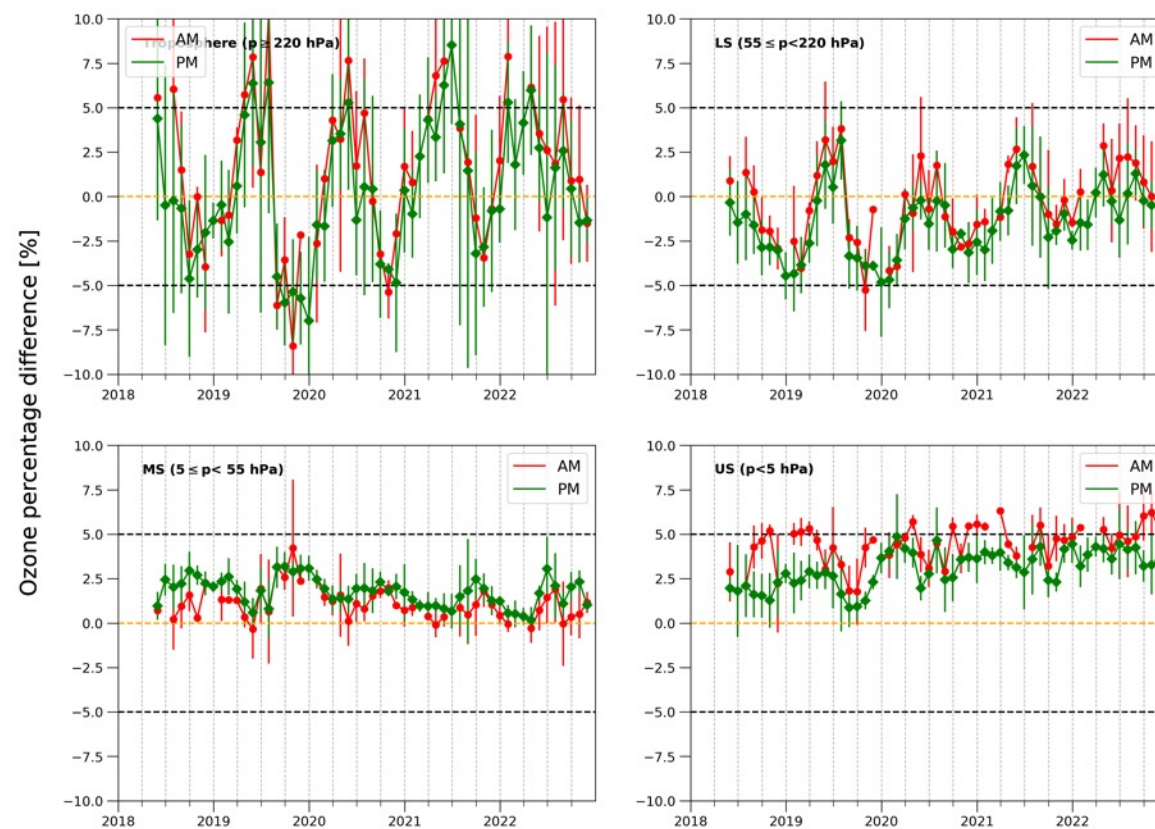
# Comparison results (S5P/ground-based) (1)

## ➤ Timeseries of the mean percentage differences in monthly basis

Hradec Kralove - Monthly percentage differences | S5P-Umkehr

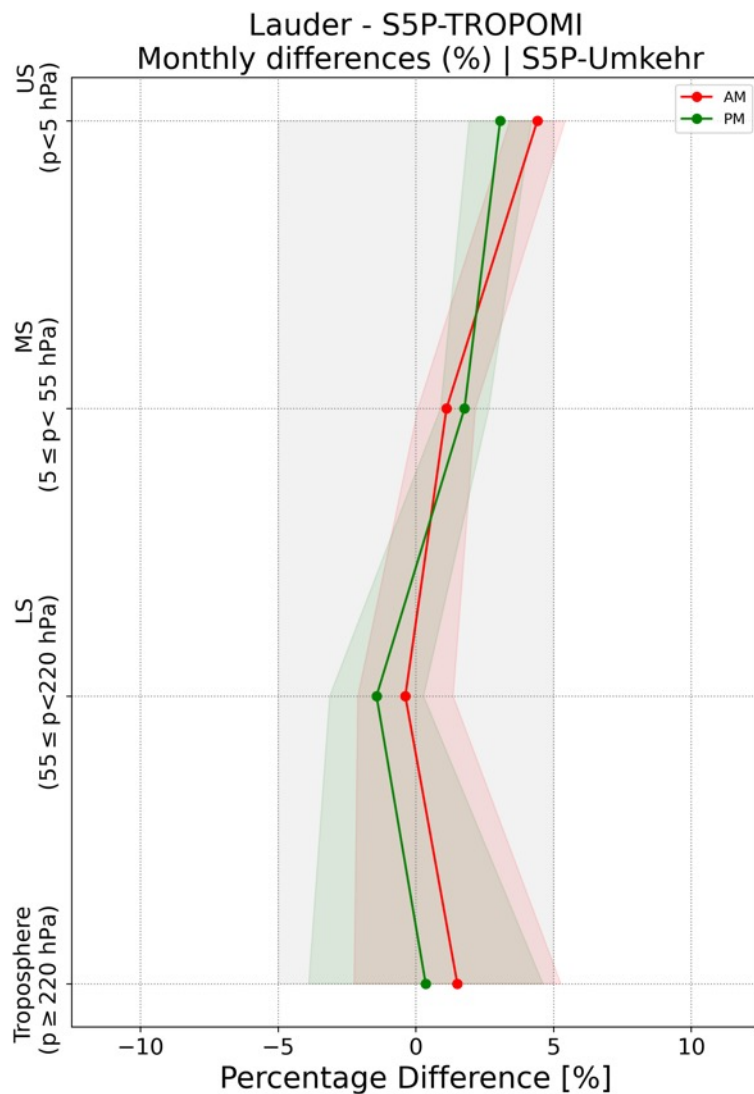
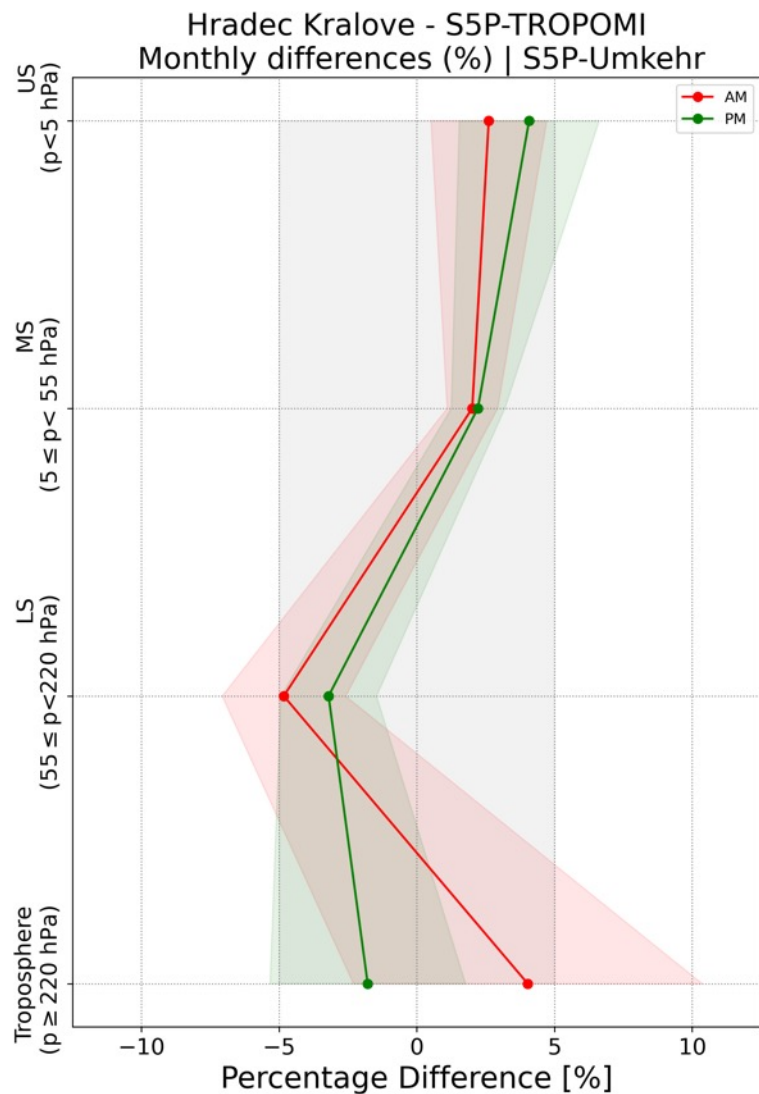


Lauder - Monthly percentage differences | S5P-Umkehr



# Comparison results (S5P/ground-based) (2)

## ➤ Profiles of the mean percentage differences in monthly basis







# Conclusions

- Timeseries of the mean percentage differences
  - high variation in Troposphere
  - good agreement (within  $\pm 5\%$ ) in the other three layers (mostly in Main Stratosphere)
  
- Good agreement (within  $\pm 5\%$ ) for the mean percentage differences between the Umkehr and the satellite profiles
  
- **Overall**, the re-evaluated Umkehr ozone profiles from Dobson and Brewer instruments can be utilized as fiducial measurements for the validation of various satellite ozone profile products



Thank you for your attention!!

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