Vertical structure of the lower-stratospheric bias in ERA5 reanalyses and its relation to mixing processes

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Motivation

- Precise representation of water vapor across the upper troposphere lower stratosphere (UTLS) is crucial for numerical weather prediction

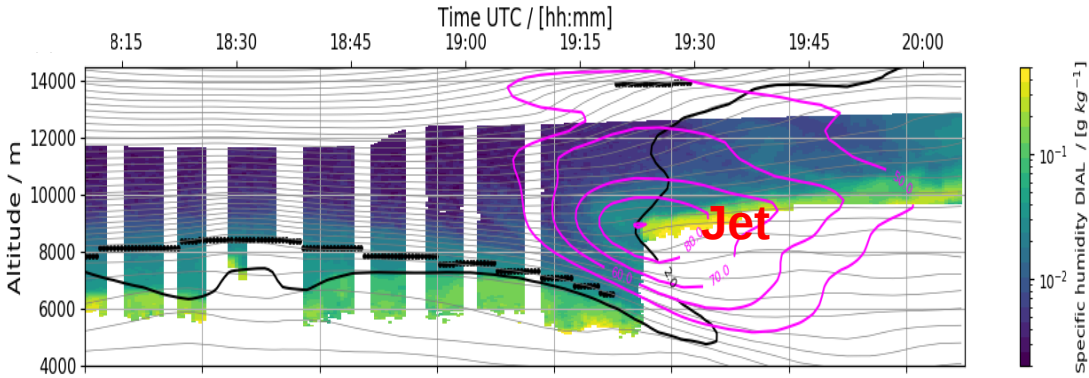
- Moist model bias in the lower stratosphere (>50%) [1-3]
  - Contradictory findings where made about its vertical structure, especially at high altitudes [3]
  - Ongoing discussion of the origin of the bias

Research Questions

I. How is the shape of the vertical structure of the LS moist bias in ERA5, particularly at high altitudes above its maximum?
II. Is there a connection between the vertical structure of the bias and chemically classified UTLS air masses?

Water vapor lidar data set

DIfferential **A**bsorption **L**idar (DIAL)

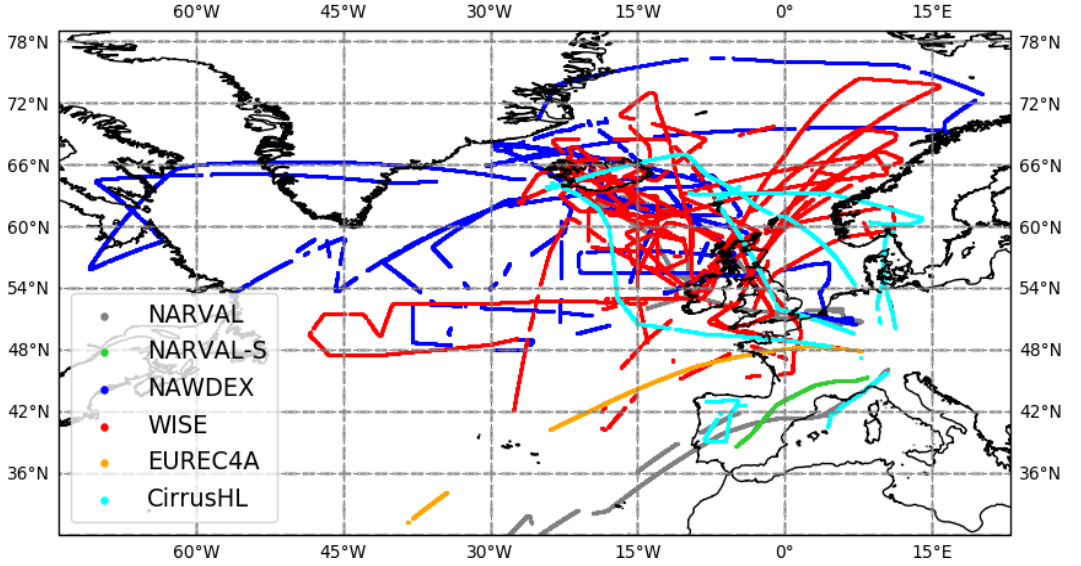


- DIAL onboard the research aircraft HALO
- Humidity profiles are sampled along flight track

- Operated in multiple campaigns starting in 2013

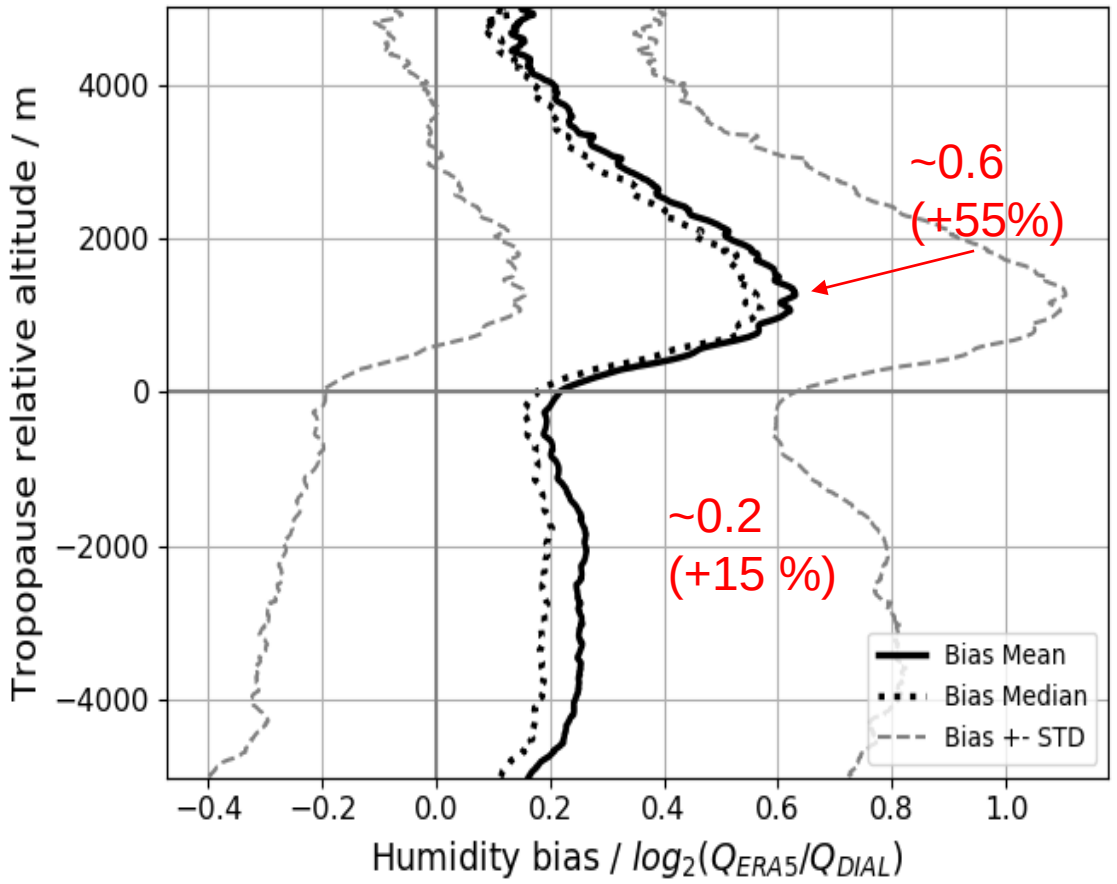
- 41 flights provide more than 31000 profiles
- 4 flights of co-located H_2O and O_3 profile data

- This data set covers a wide range of synoptic situations and different seasons



The vertical structure of the bias

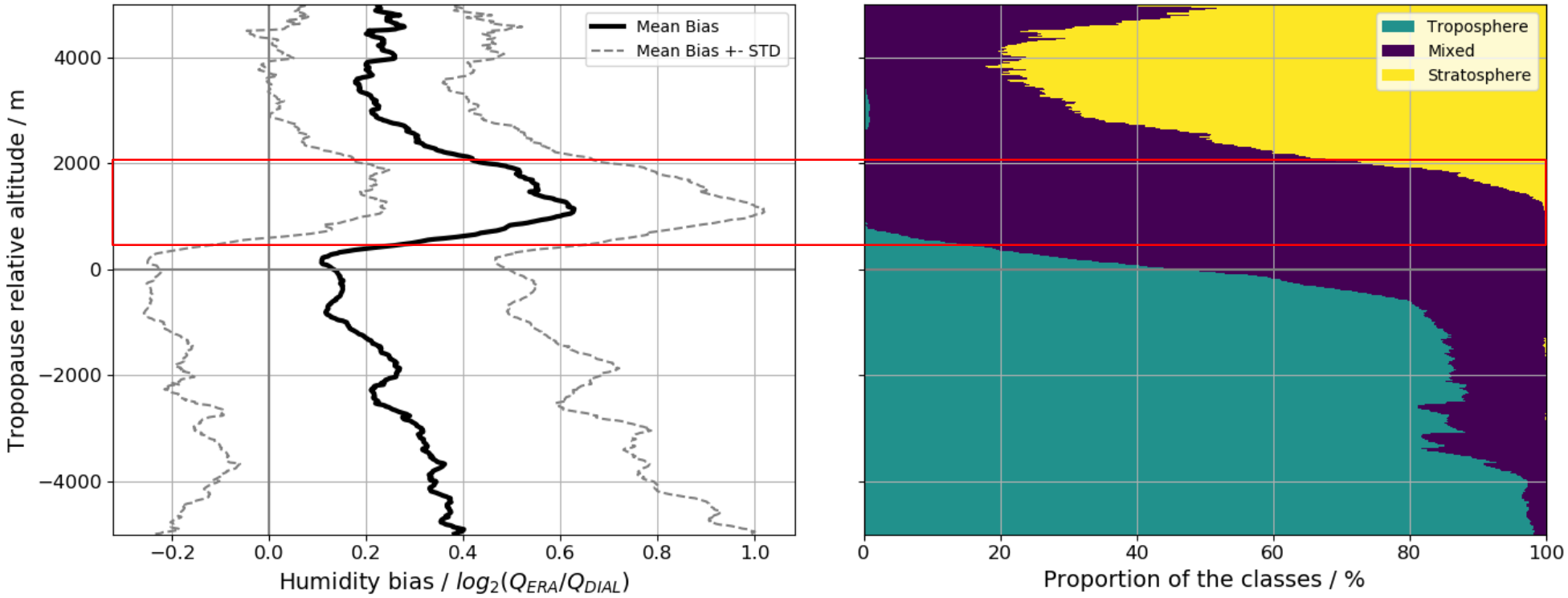
Mean profile of bias in tropopause relative coordinates



- Weak bias in the upper troposphere
- Rapid increase of the bias above the tropopause
- Maximum of +55 % at 1.5 km altitude
- Beyond, decrease of the bias towards 4 km above the thermal tropopause

Relationship between the bias and air masses

- H_2O and O_3 data are used to chemically distinguish tropospheric, stratospheric and mixed air masses [4]



- Bias is strongest in the mixed air layer
- Significant weaker bias for tropospheric or purely stratospheric air

Conclusion

We used a comprehensive data set to study UTLS moisture distribution in ERA5

- ➢High accuracy, high vertical and horizontal resolution
- ➢High data availability across the entire UTLS, also at high altitudes!

1. How is the shape and the variability of the **vertical structure** of the moist bias in ERA5, particularly **at high altitudes in the LS**?
   - ➢Robust evidence of a decrease of the bias beyond its maximum
   - ➢Bias stronger in summer and vertically deeper in trough situations (not shown)

2. Is the vertical structure of the bias related to UTLS air masses?
   - ➢Bias is strongest in the mixing layer, while being week in „purely“ tropospheric/stratospheric air.
   - ➢This is a strong indication that overestimated mixing and transport processes lead to an excessive transport of moisture into the LS and foster the bias

References

[1] Woiwode, W., Dörnbrack, A., Polichtchouk, I., Johansson, S., Harvey, B., Höpfner, M., Ungermann, J., and Friedl-Vallon, F.: Technical note: Lowermost-stratospheric moist bias in ECMWF IFS model diagnosed from airborne GLORIA observations during winter/spring 2016, Atmos. Chem. Phys., 20, 15379–15387, https://doi.org/10.5194/acp-2020-367, 2020.

[2] Dyroff, C., Zahn, A., Christner, E., Forbes, R., Tompkins, A. M., and van Velthoven, P. F. J.: Comparison of ECMWF analysis and forecast humidity data with CARIBIC upper troposphere and lower stratosphere observations, Q. J. Roy. Meteor. Soc., 141, 833–844, https://doi.org/10.1002/qj.2400, 2015.

[3] Bland, J., Gray, S., Methven, J., and Forbes, R.: Characterizing extratropical near-tropopause analysis humidity biases and their radiative effects on temperature forecasts, Q. J. R. Meteorol. Soc., 140, 3878-3898, https://doi.org/10.1002/qj.4150, 2021.

[4] Schäfler, A., Fix, A., and Wirth, M.: Mixing at the extratropical tropopause as characterized by collocated airborne H_2O and O_3 lidar observations, Atmos. Chem. Phys., 21, 5217-5234, https://doi.org/10.5194/acp-21-5217-2021, 2021.

Thank you !

This presentation participates in OSPP

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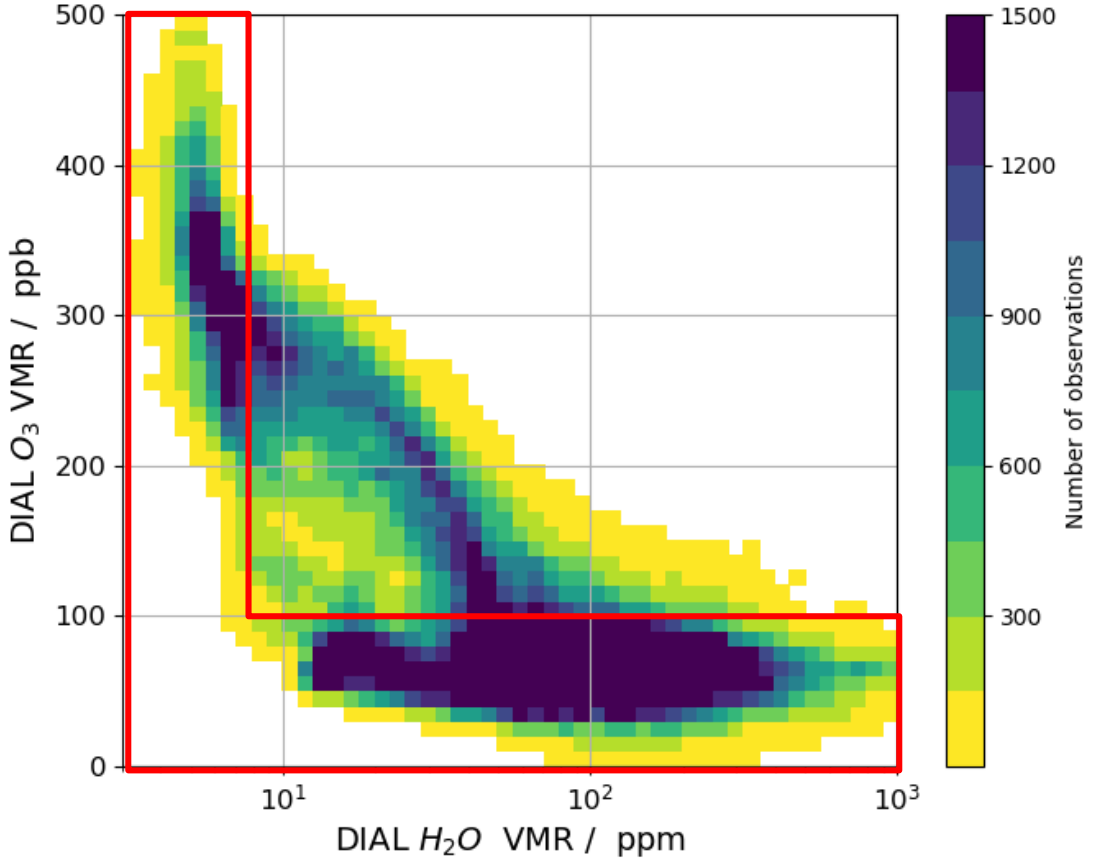
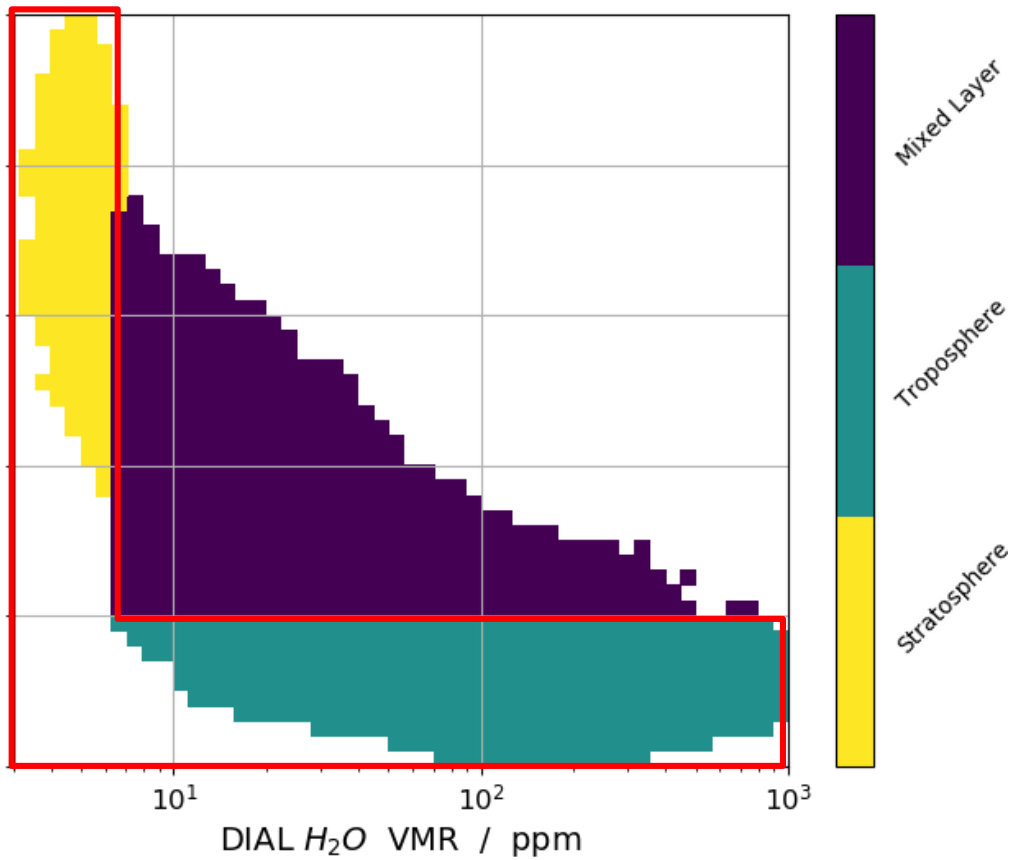
Supplementary Material

H_2O and O_3 observations in Tracer-Tracer space

Histogram of observations



Air mass classification



- Tracer-Tracer distribution would provide L-shape in „non-mixed“ UTLS
- Classification of three air masses following Schäfler et al. (2021)

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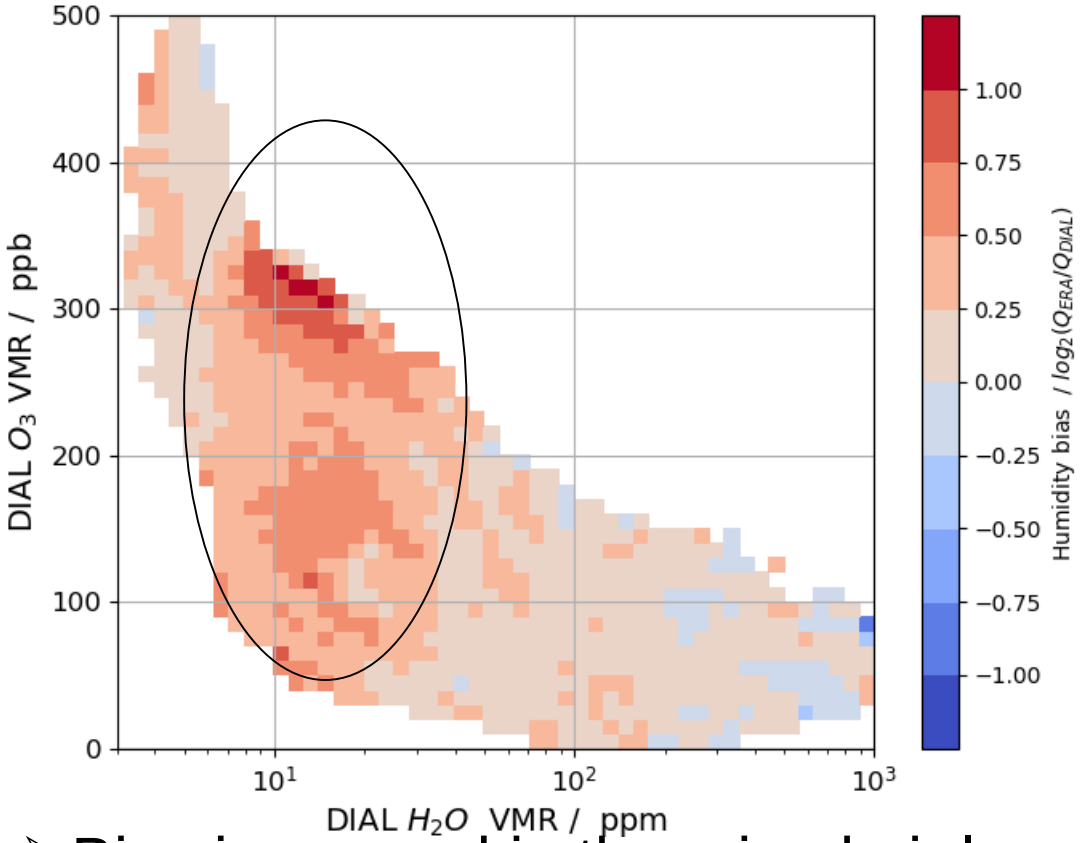
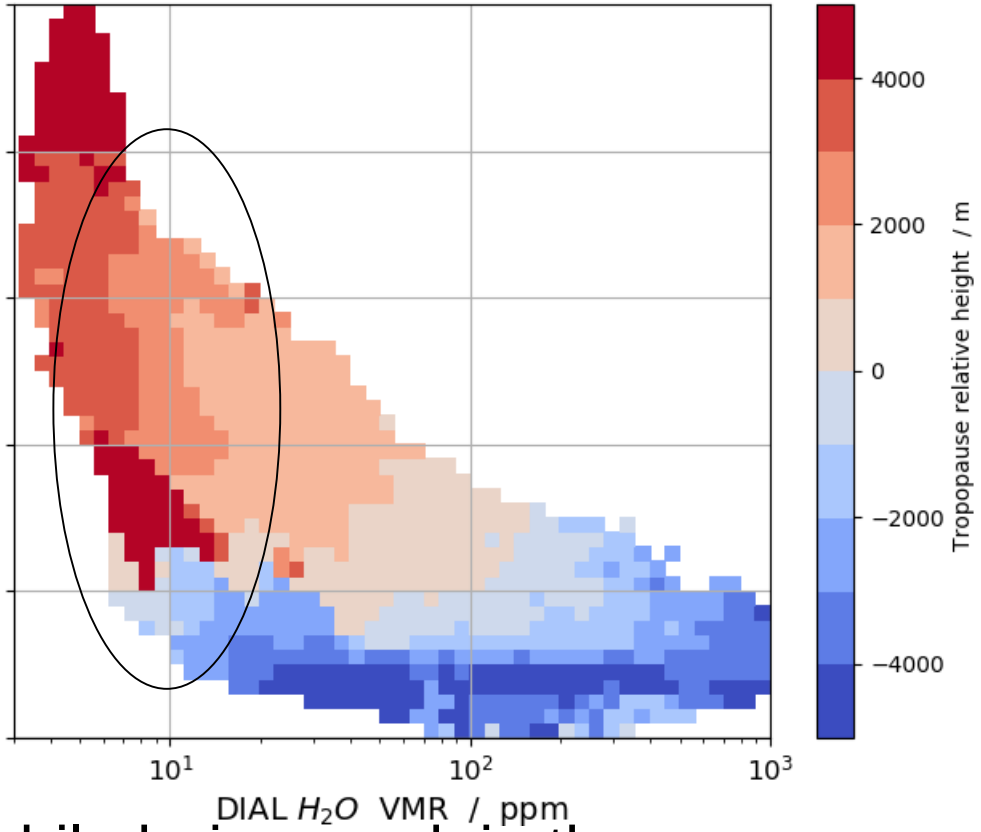
Appendix

Connection of the bias and UTLS air masses

Bin-average bias



Bin-average TP-relative altitude



- Bias increased in the mixed air layer while being week in the tropospheric/stratospheric air masses