Investigating small-scale vertical concentration gradients of formaldehyde and glyoxal above the canopy at the Amazon Tall Tower Observatory (ATTO) using two MAX-DOAS instruments

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A. MEASUREMENT SITE AND PRINCIPLE

ATTO is located in a pristine rain forest in the central Amazon Basin, about 150 km northeast of Manaus/Brazil. In the wet season probed air masses are clean originating from NE directions, while in the dry season E to SE winds can bring air from more urbanised and deforested regions to the site (Andreae et al., 2015).

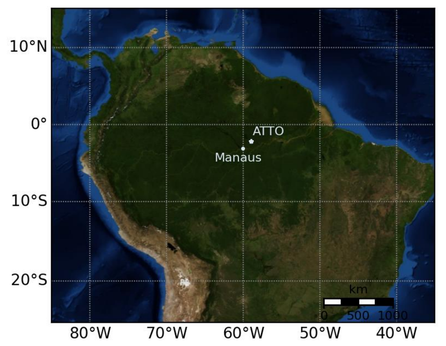

Fig. 1: Location of the ATTO site.

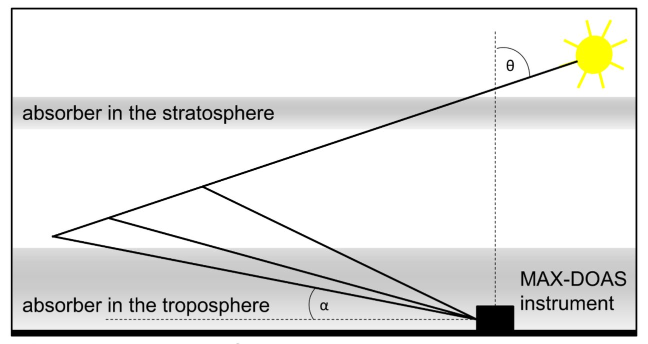

Fig. 2: Sketch of the MAX-DOAS geometry.

In October 2017, a MAX-DOAS instrument was installed at ATTO followed by a second one in March 2019. The instruments were placed on the ATTO tower at altitudes of 80 m and 298 m, i.e, around 40 m and 260 m above the canopy.

Multi AXis-Differential Optical Absorption Spectroscopy (MAX-DOAS) uses trace gas absorptions in spectra of scattered sunlight recorded at different elevations:

- ➔ Vertical concentration profiles of trace gases (e.g. formaldehyde (HCHO), glyoxal or NO_2) and aerosol extinction below ca. 4 km on clear days and integrated properties (vertical column densities/VCDs)
- ➔ High sensitivities (long light paths in the lowest layers)
- ➔ Directly comparing the concentrations* measured at the altitudes of both instruments allows to identify small-scale vertical concentration gradients providing insights into chemical processing of the different species

Fig. 3: MAX-DOAS instrument mounted on the ATTO tower.

B. CHARACTERISTICS OF TRACE GAS ABUNDANCES

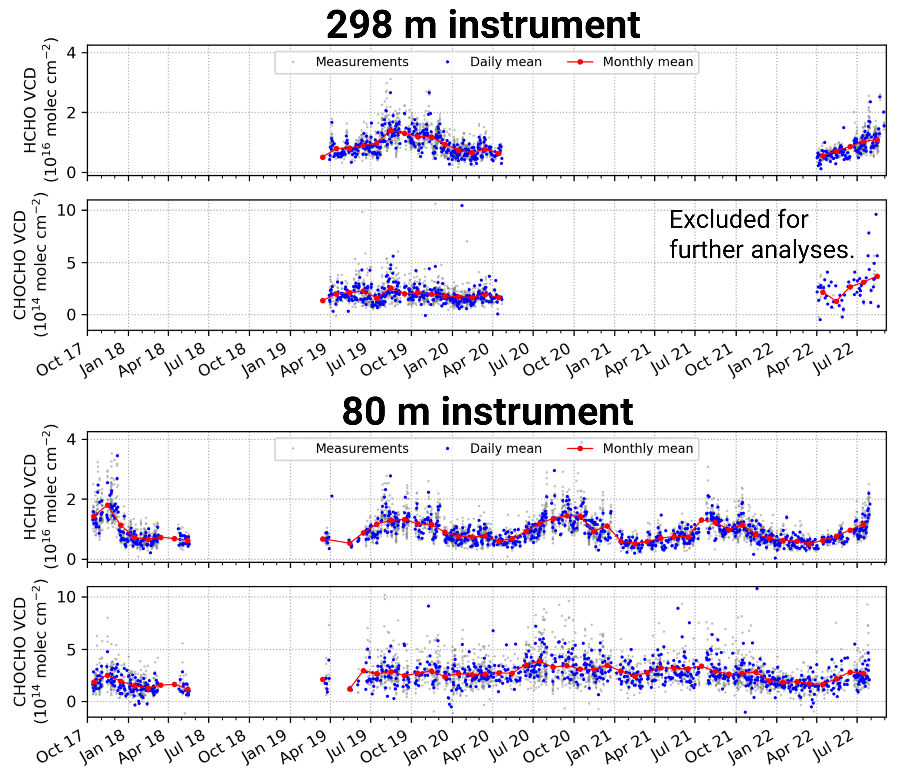

Fig. 4: Time series of formaldehyde and glyoxal VCDs for both instruments.

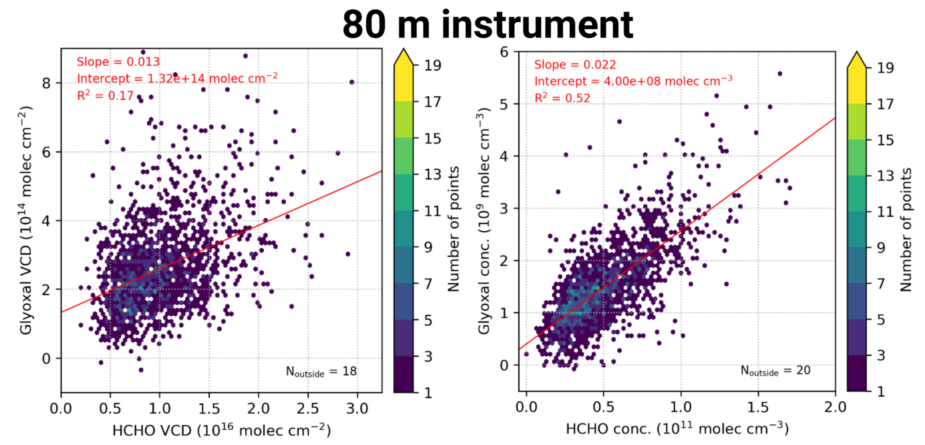

Fig. 5: Correlations of hourly mean HCHO and glyoxal VCDs (left) and concentrations* at instrument altitude (right) for the 80 m instrument.

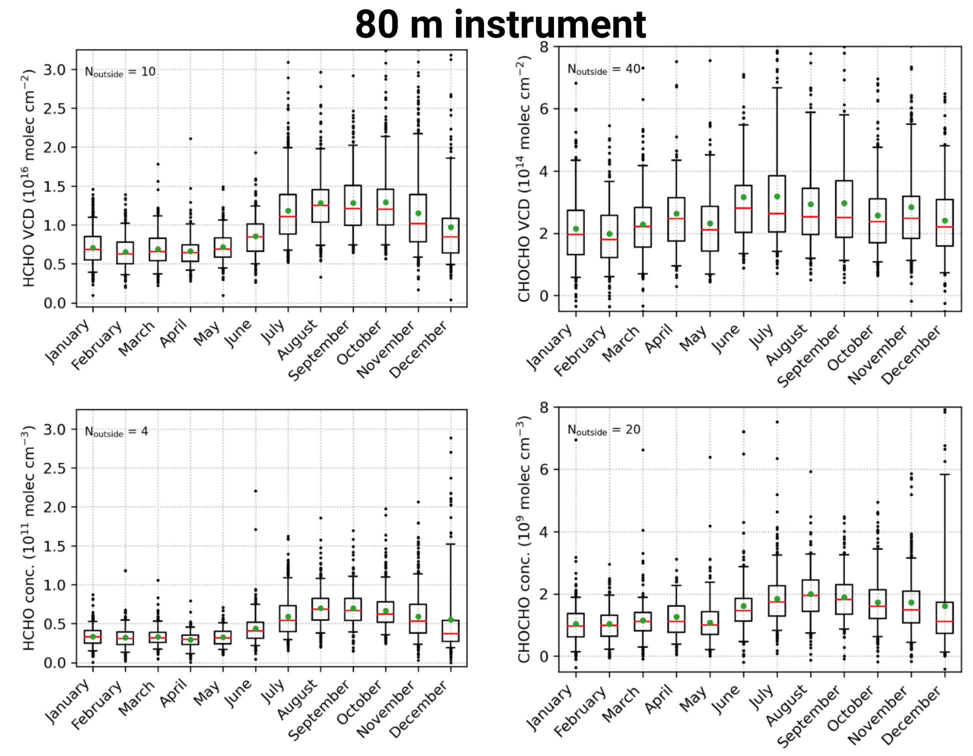

Fig. 6: Monthly box whisker plots of formaldehyde (left) and glyoxal (right) VCDs (upper panels) and concentrations* (lower panels) for the 80 m instrument.

- Abundances of both species show similar seasonal patterns
- Concentrations* correlate well (weaker correlations for VCDs)
- Slopes of linear regressions are 2.2 % and 1.3 % for concentrations and VCDs, respectively
- Similar results for 298 m instrument with slightly worse correlations (not shown)
- ➔ Close relation between both species indicates similar/common sources but different atmospheric processing
- ➔ Different vertical distributions of both species with glyoxal located closer to the ground, while HCHO profiles reach higher

E. PRECURSOR GRADIENTS

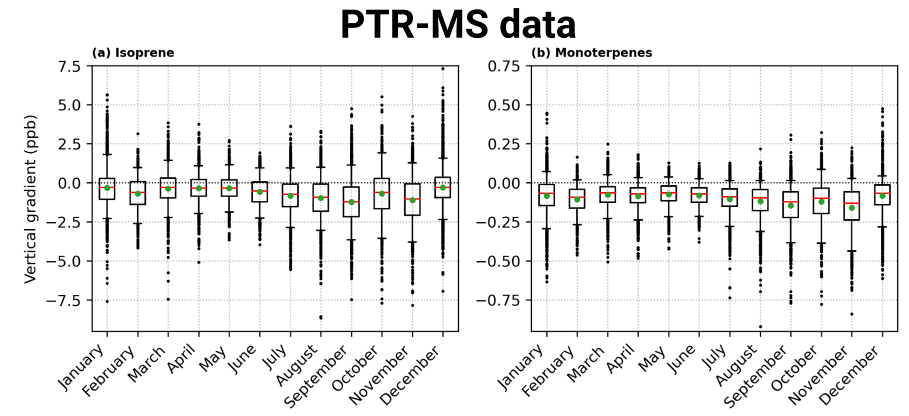

Fig. 9: Vertical gradients of isoprene (left) and monoterpene (right) mixing ratios.

- PTR-MS measurements of isoprene and monoterpenes are performed at altitudes of 80 m, 150 m (not used here) and 320 m
- Isoprene and monoterpenes show decreases in the altitude range between both MAX-DOAS instruments which is (relatively) stronger pronounced for the monoterpenes
- Vertical gradients also exhibit weak but systematic seasonal cycles with stronger gradients in the dry season
- Large scatter related to diel cycles and local meteorology
- Also systematic diel cycles exist (not shown)
- All in all, consistent to formaldehyde and glyoxal concentration* gradients

C. COMPARISON OF THE INSTRUMENTS

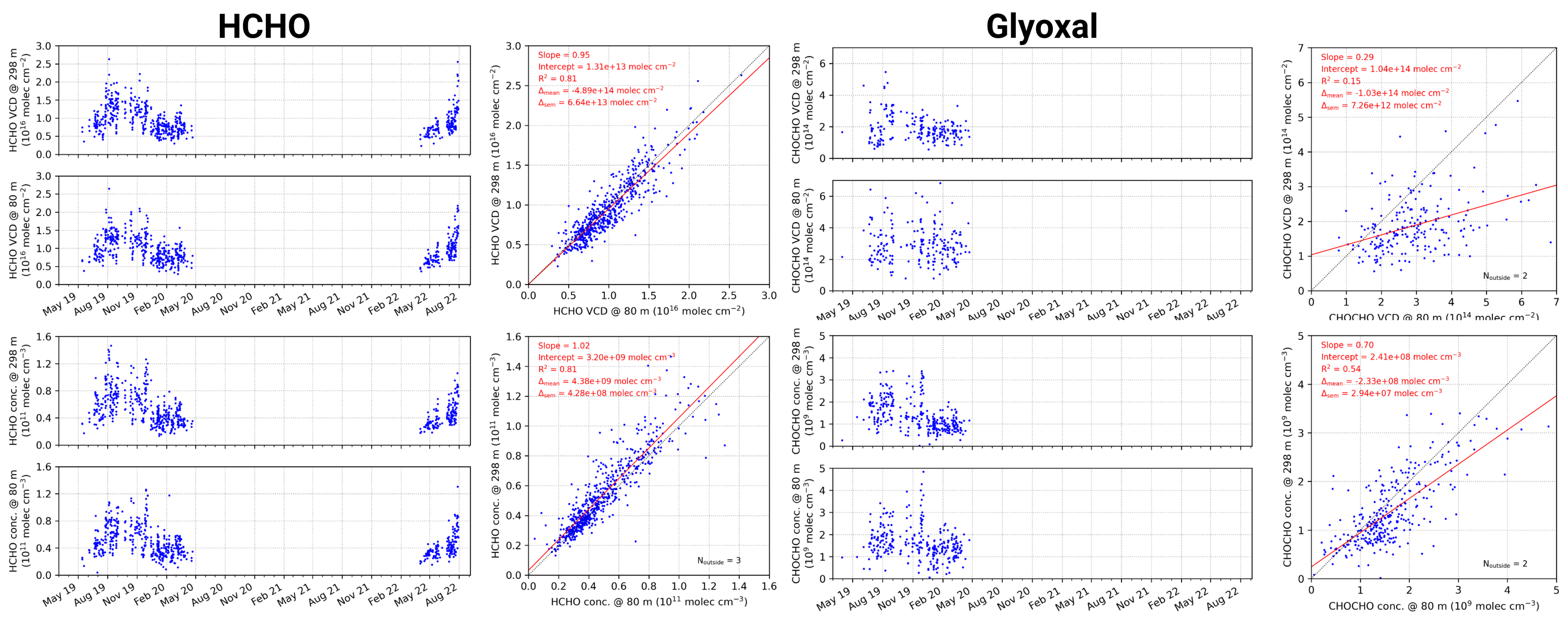

Fig. 7: Comparison of HCHO (left) and glyoxal (right) VCDs (upper panels) and concentrations* (lower panels) obtained for both instruments.

- HCHO results of both instruments agree well
  - VCDs are higher at 80 m, while concentrations* are higher at 298 m
- Glyoxal results differ more between both instruments
  - VCDs are notably lower at 298 m, while better agreement is found for concentrations (still clearly smaller values for 298 m instrument)

➔ HCHO concentrations increase within the lowest 200 m above the canopy, while glyoxal concentrations decrease significantly within this altitude range (probably related to shorter lifetime of glyoxal)

D. SEASONAL CYCLES OF VERTICAL GRADIENTS

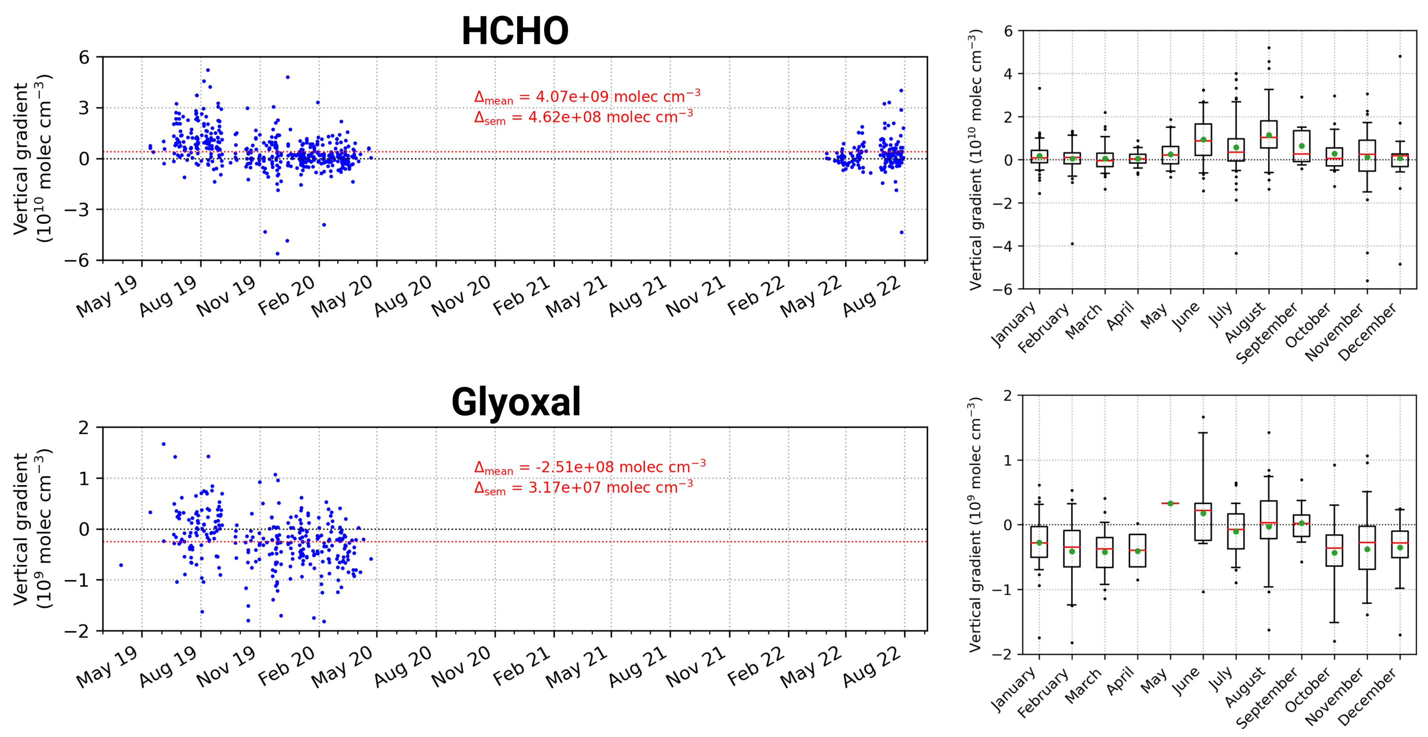

Fig. 8: Time series and average seasonal patterns of the small-scale vertical gradients of formaldehyde (upper panels) and glyoxal (lower panels).

- Gradients (differences 320 m – 80 m) of hourly mean concentrations* confirm findings from box C
  - Positive vs. negative gradients for HCHO and glyoxal, respectively
- Vertical concentration gradients show systematic seasonal variations
  - Largest HCHO increase in the lowest layer during wet to dry transition and early dry season
  - Smallest decrease of glyoxal in the same period

F. CONCLUSION AND OUTLOOK

- HCHO, glyoxal and other species (e.g. NO_2) were successfully retrieved from MAX-DOAS measurements at ATTO
- Generally, glyoxal profiles are notably shallower than HCHO profiles
- Direct comparison of the results of both instruments yields small-scale vertical gradients (~ 200 m)
  - Insights into production and degradation mechanisms of HCHO and glyoxal
  - HCHO is net formed within the lowest 200 m above the canopy, while glyoxal is net degraded
- Systematic seasonal cycles of the small-scale vertical gradients of HCHO, glyoxal and their precursor species are found
- Outlook:
  - Extend time series and investigate further dependencies, e.g., the influence of meteorological parameters
  - Investigate link between vertical gradients of HCHO, glyoxal and their precursors, i.e., isoprene and monoterpenes
  - Model comparison

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Link to abstract and digital version of the poster

*The term "concentrations" refers to the mean concentration between 0 and 400 m above instrument altitude.

REFERENCES: *Andreae et al., 2015. The Amazon Tall Tower Observatory (ATTO): overview of pilot measurements on ecosystem ecology, meteorology, trace gases, and aerosols. ACP 15, 10723-10776.*
Beirle et al., 2019. The Mainz profile algorithm (MAPA). AMT, 12. 1785 – 1806.

Acknowledgements: *The ATTO site is operated and managed by INPA and MPG. The authors also acknowledge the whole ATTO team for maintenance and operation of the ATTO site and its infrastructure.*