Horizontal Gradients of Aerosols and Trace Gases: Insights from MAX-DOAS Measurements in Mainz

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29 Apr, 14:00–15:45 (CEST), Display time Tuesday, 29 Apr, 14:00–18:00 Hall X5, X5.128

Motivation

Horizontal gradients of trace gases and aerosols can have a strong and systematic effect on MAX-DOAS profile retrievals. Here we present and investigate MAX-DOAS measurements in two opposite directions made at the rooftop at the Max Planck Institute for Chemistry in Mainz, Germany from beginning of February to mid March 2025. We compare the derived dSCDs of NO2 and O4 at opposing low elevation angles.

Measurement Setup:

- Location: Max Planck Institute for Chemistry, Mainz, Germany.
- Instrument: Rooftop-mounted MAX-DOAS.
- Observations: Two opposing azimuthal directions (180° apart).

Method:

- Differential Slant Column Densities (dSCDs) at low elevation angles to assess horizontal gradients.
- Influence of wind speed & direction examined.

Calibration

- The correct calibration of the elevation angles is critical for the correct interpretation of the retrieved trace gas DSCDs.
- From horizon scans the accuracy of the elevation calibration was estimated to be better than 0.25°

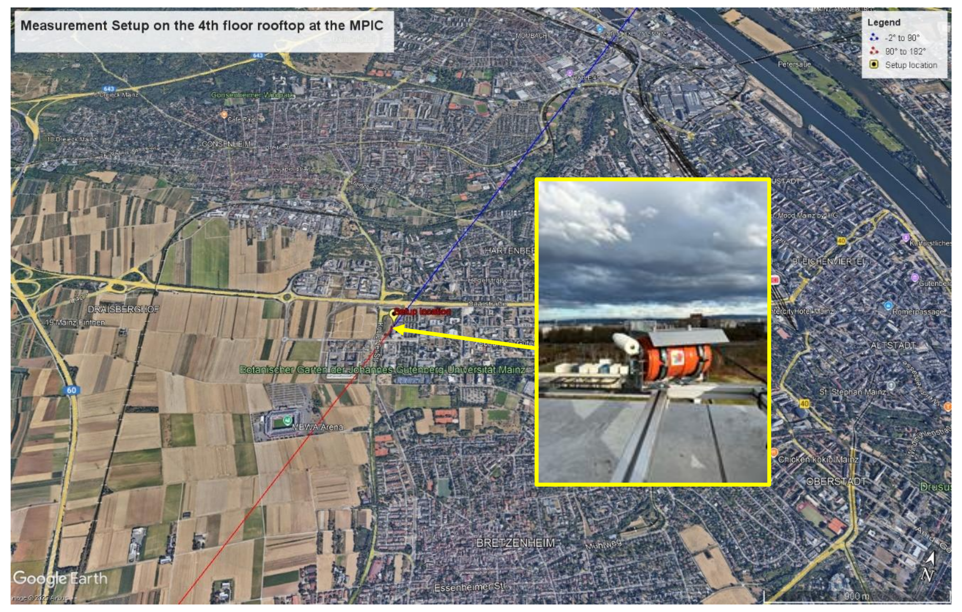

Figure 1: Max Planck Institute for Chemistry, Mainz, Germany, location of instrument and viewing directions. Source: google earth pro

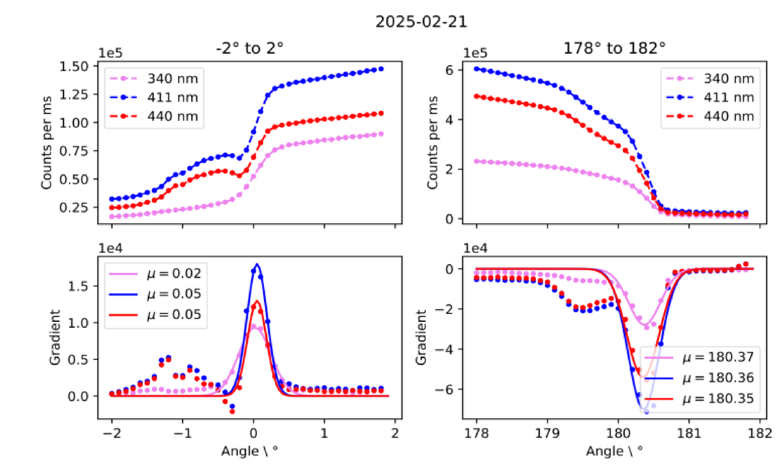

Figure 3: Horizon scans in both azimuth directions

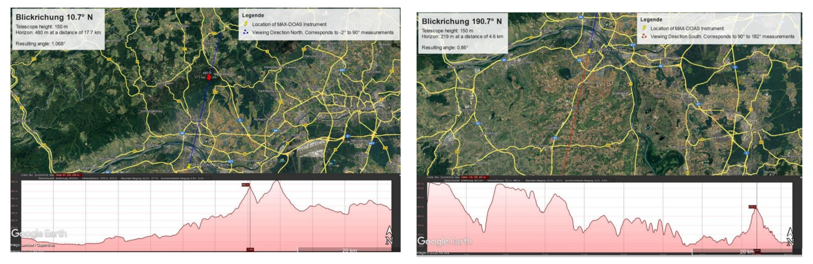

Figure 4: Topography in both viewing directions. (created from google earth pro)

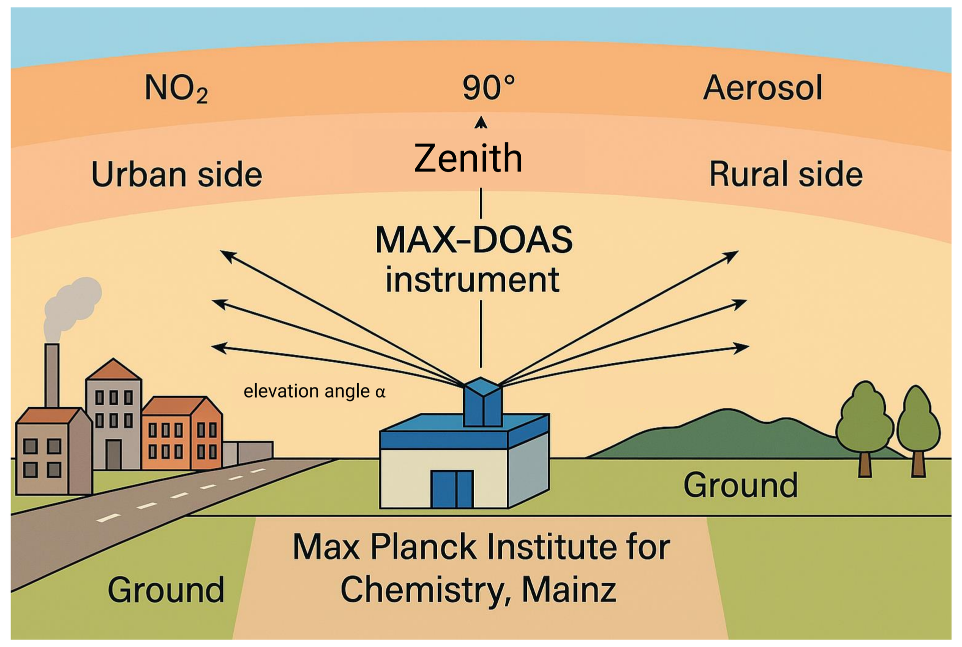

Figure 2: schematic of measurement field. adapted from OpenAI. ChatGPT, 24 Apr. 2025

Results

The figures below show results for two selected days. Both days were mostly clear sky days. On 1 February (left), almost no difference between the NO2 dSCDs in both opposite viewing directions is found. On that days a rather strong wind blew from the north-east. Thus, emissions rather homogenously distributed. On 3 March (right), almost no difference between the NO2 dSCDs in both opposite viewing directions is found. On that days a slow wind blew from the west. Thus, strong gradients could establish. Systematic differences are also found for the O4 dSCDs, which are mainly caused by the different scattering angles for both azimuth directions.

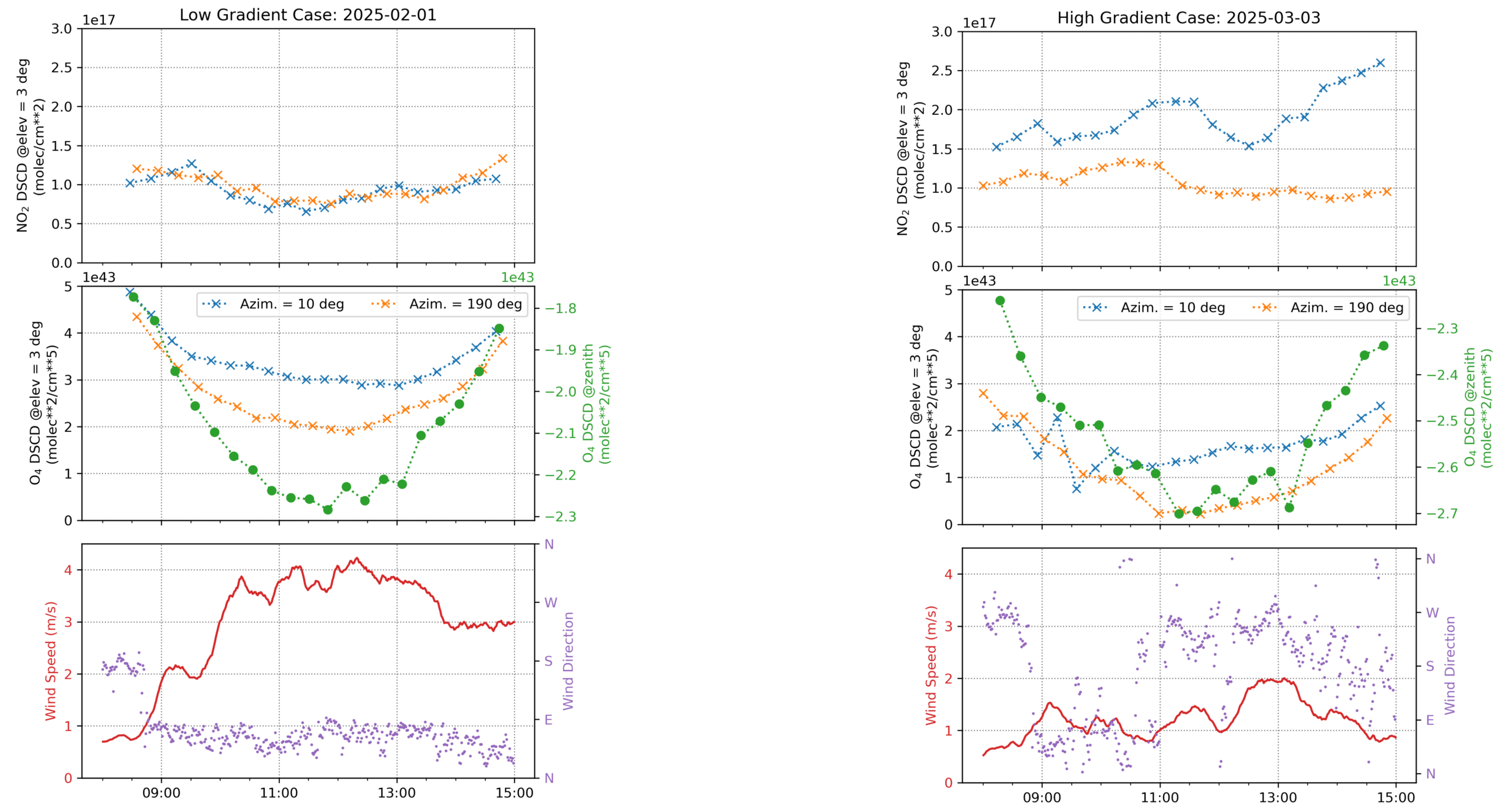

Figure 5: Comparison of the low and high gradient measuerment days and Interpretation of wind effect on the dSCDs .

The figures below show results for the whole measurement period. Left the average diurnal variation is shown. A systematic difference between the NO2 dSCDs in both azimuth directions is found indicating persistent gradients, maily caused by the main wind direction from the east. The right figure showns the daily average dSCDs. In general, smaller NO2 gradients are found for days with high wind speed (e.g. indicated by the red rectangle).

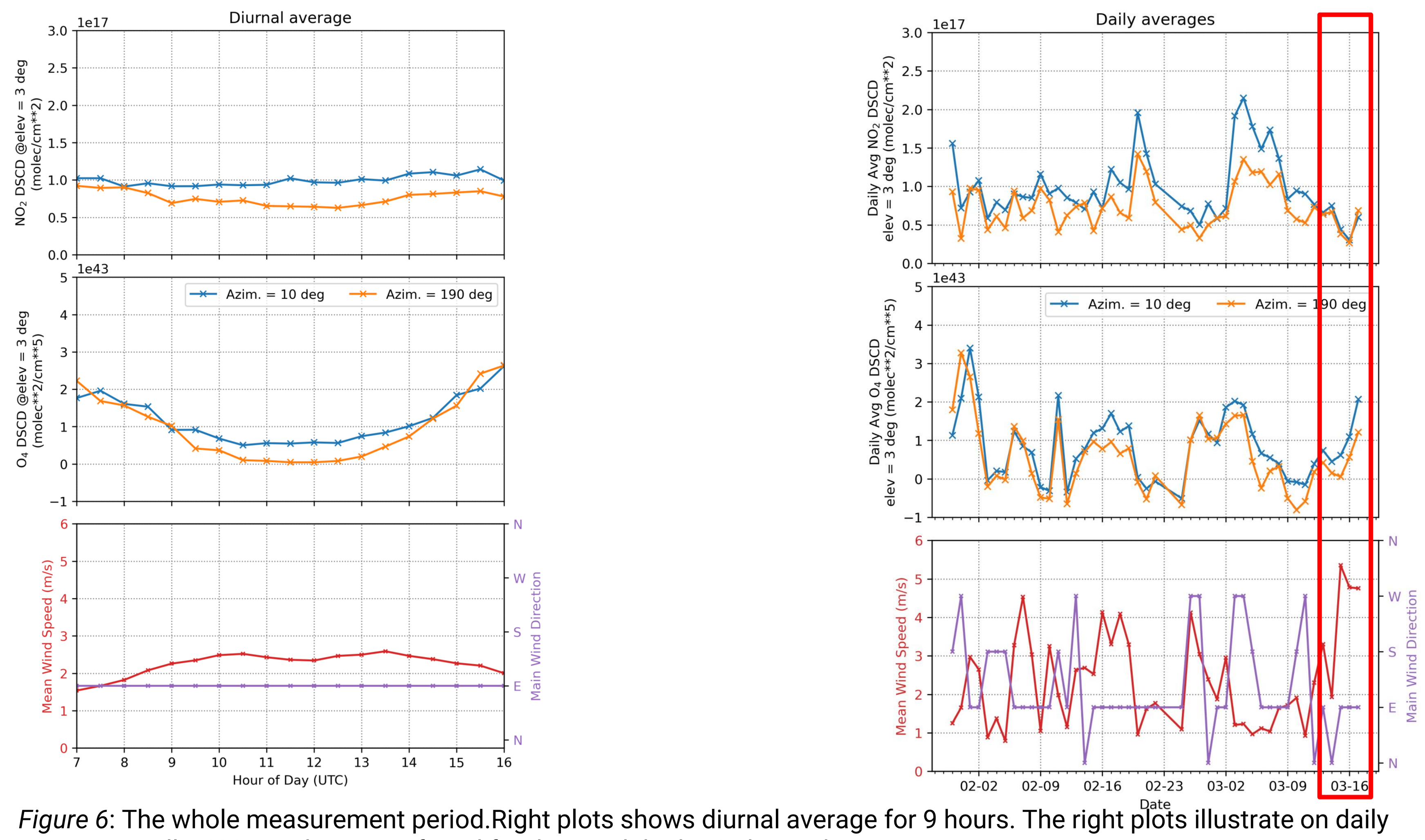

Figure 6: The whole measurement period.Right plots shows diurnal average for 9 hours. The right plots illustrate on daily average smaller NO_2 gradients are found for days with high wind speed.

Conclusions

- During the measurement period often systematic differences between the NO2 dSCDs in both azimuth directions were found
- For days with high wind speeds usually the differences are small /and vice versa)
- Also for O4 usually differences between the dSCDs in both azimuth directions were found indicating differences in the radiative transfer (different scattering angles) for both viewing directions.

Outlook

- More quantitative analysis of the obtained results and comparison with radiative transfer simulations
- More detailed analysis of the relationship between the observed gradients and the wind fields.
- Connection of the horizontal gradients with the temporal variation (measured in zenith direction) using wind fields.
- Application of (1D) profile retrievals to both viewing directions and comparison of the results for days with strong and weak gradients.
- Quantification of the errors caused by the horizontal gradients and development of possible corrections.
- Validation tropospheric NO2 VCDs observed by satellites

Sharing is encouraged

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- **REFERENCES**:
- Wang, Y., et al. (2020). Quantification of NO_2 from MAX-DOAS: A case study. Atmospheric Environment, 224, 117311.https://doi.org/10.1016/j.atmosenv.2020.117311. https://doi.org/10.1016/j.atmosenv.2020.117311
- Lauster, B., Dörner, S., Beirle, S., Donner, S., Gromov, S., Uhlmannsiek, K., & Wagner, T. (2023). Estimating real driving emissions from multi-axis differential optical absorption spectroscopy (MAX-DOAS) measurements at the A60 motorway near Mainz, Germany. Atmospheric Measurement Techniques, 16, 1234–1250. https://doi.org/10.xxxx/amt-2023-xxx
- Johannes Gutenberg University Mainz. (2025). Meteorological data and support for atmospheric observations. Institute of Atmospheric Physics. https://www.uni-mainz.de
- Deutscher Wetterdienst (DWD). (2025). Meteorological Data Archive. Retrieved from https://www.dwd.de.
- Timeanddate.com. (2025). Weather archive for Mainz, February 2025. Retrieved April 2025, from https://www.timeanddate.com/weather/germany/mainz/historic?month=2&year=2025