Tower DOAS off-axis measurements of NO_2 in Vienna

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Motivation

The VINDOBONA project:

- The overall goal of the project is to improve our current knowledge of air pollution in large agglomerations caused by mankind
- The investigation of nitrogen dioxide (NO_2) and aerosol amounts will be based on spectral measurements from two MAX-DOAS instruments located at two different sites with ideal measurement conditions in Vienna, Austria
- The measurements taken at different viewing directions can be used for obtaining both the horizontal and vertical variations of trace gases and aerosols in the troposphere

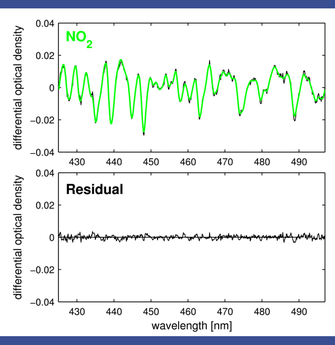
Aims of this study:

- Use an Avantes miniature spectromter and perform off-axis measurements from a rotating tower platform
- These measurements have the potential to provide averaged NO_2 mixing ratios at 160 m altitude

DOAS data analysis

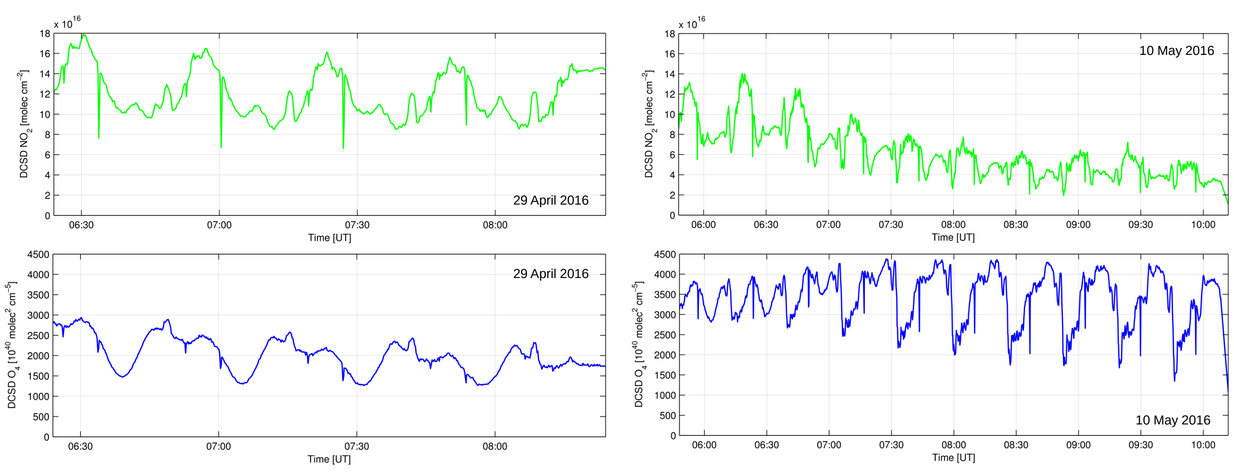
Fit settings:

- Fitting window: 425-497 nm
- Polynomial degree 8
- Single reference zenith-sky measurement
- Cross sections:
  - O_3 (223 K, Serdyuchenko et al., 2014)
  - NO_2 (298 K, Vandaele et al., 1996)
  - O_4 (293 K, Thalman and Volkamer, 2013)
  - H_2O (296 K, Rothmann et al., 2010)
  - Ring (SCIATRAN, Rozanov et al., 2014)



- Examplary fit results of the DOAS analysis for a horizontal spectrum on 29 April 2016 (upper)
- α = 0°, SZA = 66.99°
- Measured under elevated NO_2 (DSCD = 1.46 x 10^{17})
- NO_2 cross section (green) as scaled to NO_2 absorption (black) detected by the instrument
- The residuals are shown in the lower plot

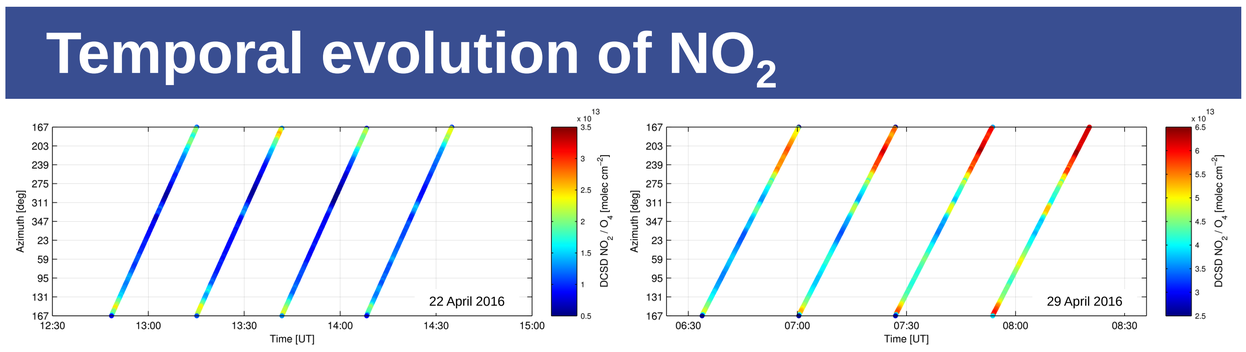
Time series of NO_2 and O_4 columns



- Cloudless, but hazy conditions on 29 April 2016
- Reference zenith-sky measurement was taken afterwards (SZA = 63.48°)
- (Almost) 4 rounds of measurements
- NO_2 (green) and O_4 (blue) columns show variation as a function of azimuth angle

- Broken clouds (not in the field of view) on 10 May 2016
- Reference zenith-sky measurement was taken afterwards (SZA = 45.61°)
- 9 rounds of measurements
- NO_2 (green) and O_4 (blue) columns show (less) variation as a function of azimuth angle

Temporal evolution of NO_2

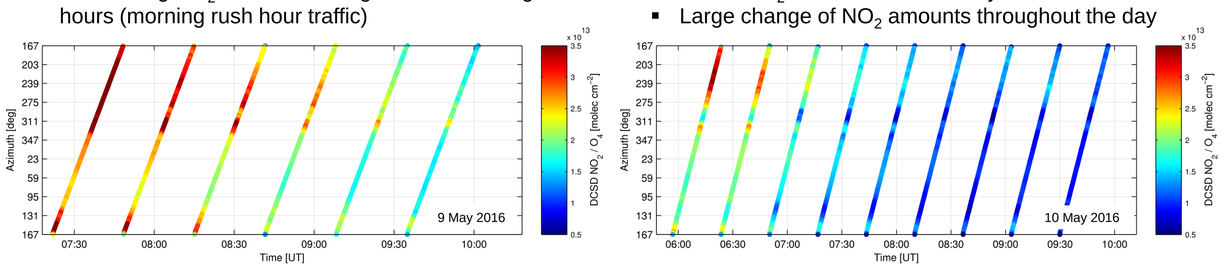


- 22 April 2016 (Friday afternoon)
- Low wind speeds (5-10 km h^{-1})
- Wind direction from north-westerly directions
- NO_2 amounts were highest towards South
- Only slightly changing with time

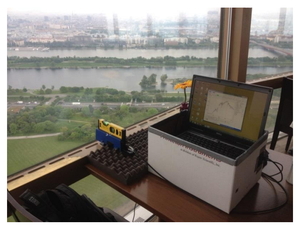
- 29 April (Friday morning)
- (Very) Low wind speeds (less than 5 km h^{-1})
- Wind direction from easterly directions
- NO_2 maximum distribution centered towards southerly directions (factor of 2 when compared to other days)

- 9 May 2016 (Monday morning)
- Relatively high wind speeds (10-15 km h^{-1})
- Wind direction from south-easterly directions
- Decreasing NO_2 amounts throughout the morning hours (morning rush hour traffic)

- 10 May 2016 (Tuesday morning)
- Relatively high wind speeds (up to 20 km h^{-1})
- Wind from south-easterly directions
- Lower NO_2 amounts than the day before
- Large change of NO_2 amounts throughout the day



Set-up of tower DOAS measurements

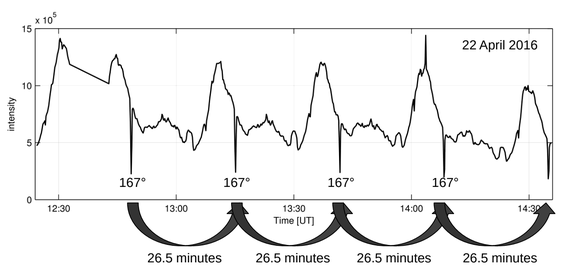


Donauturm Wien

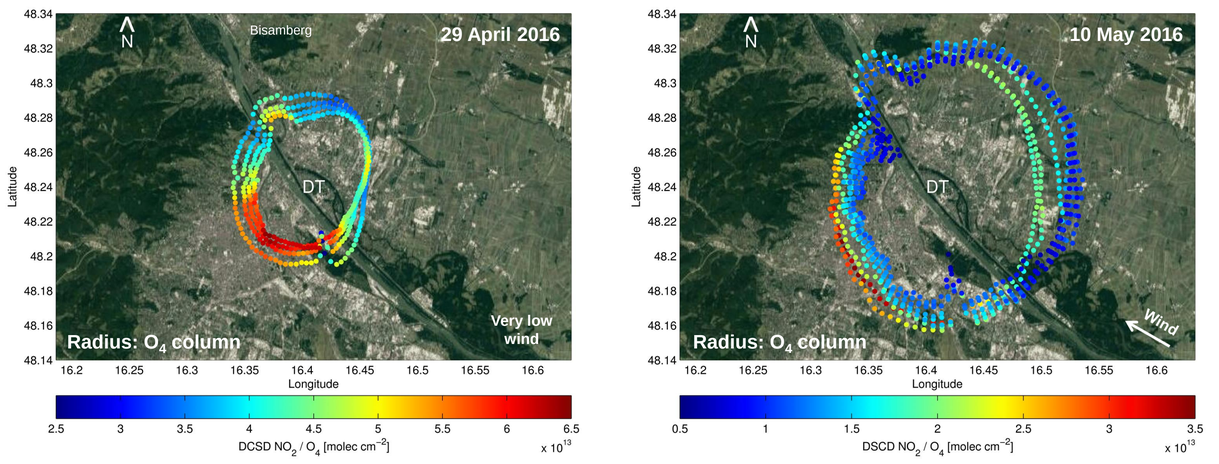
- Kaffeehaus at 160 m above ground
- 360° rotation (anti-clockwise) every 26.5 minutes
- DOAS measurements at 0° elevation (off-axis) through a glass window (no UV)
- Reference zenith-sky measurement from the open terrace afterwards
- More than thirty rounds on five days in spring 2016 were performed

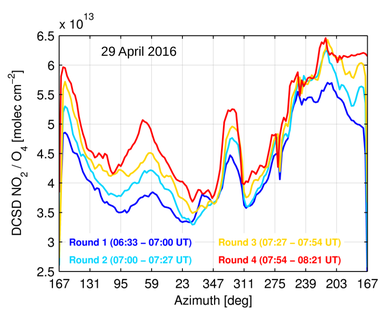
Determination of azimuthal viewing directions:

- Donauturm does not provide information on position
- GPS mouse was unable to reliably determine position
- DC Tower (220 m) comes into field of view once every rotation –> signal loss
- Position of DC Tower from Donauturm is 167°

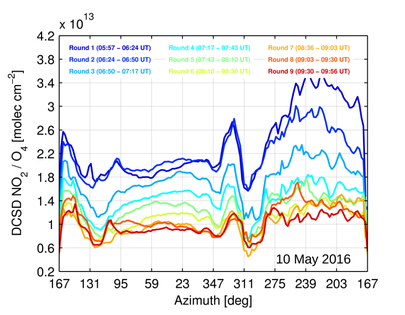


Geographical distribution of NO_2





- Normalization with O_4 does not change the angle distribution of NO_2 very much
- Either light path effects are not so important or normalization with O_4 does not work so well under these conditions
- Higher NO_2 and lower O_4 on 29 April --> much higher NO_2 / O_4
- Highest NO_2 / O_4 values are found over industry and heavy traffic roads
- Very smooth behaviour in space & time
- Average over long light path in 160 m altitude



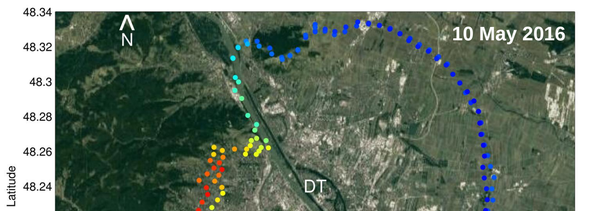
Estimates of averaged NO_2 mixing ratios

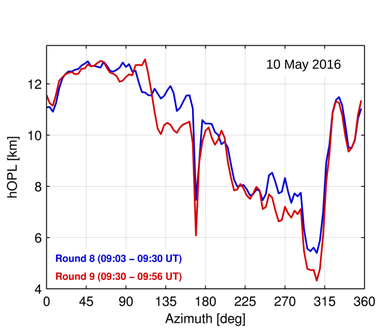
The mountain MAX-DOAS approach:

- Assumption that the signal for horizontal measurements (α = 0°) is dominated by the horizontal part of the light path after the last scattering event

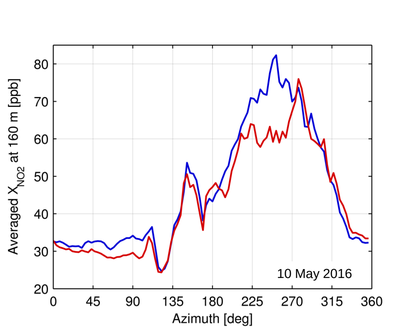
$$X_{NO_2} = \left(\frac{DSCD\ (NO_2, 0°) - DSCD\ (NO_2, 90°)}{hOPL} \right) / n_{air}$$

- Were X_{NO2} is the mean mixing ratio of NO_2, *hOPL* the horizontal optical path length, and n_{air} the number density of air, which can be calculated by using the ideal gas law
- For the measurements from Donauturm we make the following two assumptions:
  (1) Bisamberg comes into field of view
  --> position from Donauturm is 345°(nearly North)
  --> the hill limits the hOPL (--> 9.5 km) under clear sky conditions / good visibility (e.g. 10 May 2016)
  --> use this distance as normalization value
  (2) For the (polluted) urban environment, DSCD NO_2 at 90° can be neglected (error of the order of <10%)





- Estimation of hOPL is shown as a function of azimuth angle (left figure)
- hOPL varies between 4.5 and 13 km
- Lowest hOPLs are found in the North-West of Donauturm --> hills with up to 542 m altitude
- Highest hOPLs are found towards the rural area in the North-East of DT
- Averaged X_{NO2} as a function of azimuth angle is shown in the right figure



References & Acknowledgements

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Summary & Outlook

- Measurements went well and simple
- Donauturm personnel was very helpful
- Reference zenith-sky measurement was only taken once (outside) after off-axis measurements (inside)
- Long-term deployment of instrument was not yet discussed
- More reference zenith-sky measurements are needed for better quantification of NO_2 amounts
- Added value of these observations will be important when having both MAX-DOAS instruments and Car DOAS measurements operating at the same time (VINDOBONA project)
- Measurements from Donauturm have potential to provide averaged NO_2 mixing ratios at about 160 m altitude for all directions
- In this study, NO_2 mixing ratios are obtained for two single rounds (close to the reference measurement) on a day with good visibility

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http://www.doas-vindobona.at/

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