MAX-DOAS measurements of NO_2 slant columns in Vienna

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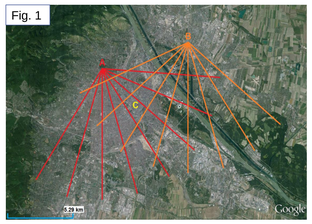
The VINDOBONA project

VIenna horizontal aNd vertical Distribution OBservations Of Nitrogen dioxide and Aerosols (VINDOBONA)

The investigation of nitrogen dioxide (NO_2) and aerosol amounts are based on spectral measurements from two MAX-DOAS instruments located at two different sites in Vienna (Fig. 1).

The MAX-DOAS instrument allows for measurements at different viewing directions and thus, it can be used for obtaining both the horizontal and vertical variations of trace gases and aerosols in the troposphere.

Fig. 1



A … BOKU site
B … VETMED site
C … City of Vienna

As the measurements from the two instruments cover several azimuthal directions with partially overlapping fields of view, these data together with in-situ and car DOAS observations provide a multitude of information on the spatial NO_2 distribution, enabling an attempt to develop a spatially resolved image of air pollution for Vienna using a tomographic imaging approach.

Instrument and site description

2D-MAX-DOAS:

- Acton Standard Series SP-2356 Imaging Spectrograph
- PIX100B-SF-Q-F-A (Detector)
- Dark signal: nightly measurements
- Line shape: HgCd lamp in telescope
- Spectral range: 400-530 nm
- Spectral resolution: 0.85 nm
- Field of view (FOV): ~ 0.8°

VETMED site:

- University of Veterinary Medicine, Veterinärplatz 1, 1210 Vienna, Austria
- 48° 15' 26" N, 16° 25' 54" E
- Altitude: 165 m asl
- The instrument was established in autumn 2016

Fig. 2

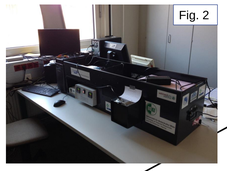


Fig. 3

Fig. 4

Fig. 2: Spectrograph & Detector
Fig. 3: Telescope on pan-tilt-head
Fig. 4: Measuring site (Google Maps)

MAX-DOAS NO_2 retrieval

Fit settings:

- NO_2 and O_4 differential slant column densities (DSCDs) are retrieved in the 425-490 nm wavelength range, taking into account the following cross sections:
  - NO_2 at 298 K (Vandaele et al., 1998)
  - O_3 at 223 K (Serdyuchenko et al., 2014)
  - O_4 at 293 K (Thalman and Volkamer, 2013)
  - H_2O at 296 K (Rothman et al., 2010)
  - Ring (Rozanov et al., 2014)
- Polynomial degree 6, sequential zenith-sky spectra as reference

Example of DOAS fit:

- Examples of DOAS fits for NO_2 and O_4 are shown in Fig. 5 and Fig. 6, respectively, for a horizontal spectrum (elevation angle (α) = 2°) on 21 March 2017
- SZA = 59.89°
- Measured under elevated NO_2 pollution (1.4 x 10^{17} molec cm^{-2})

Fig. 5

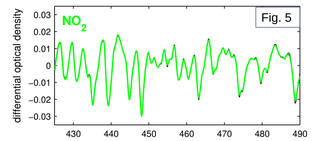
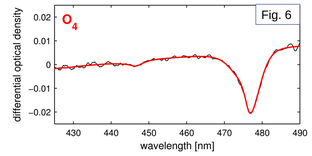


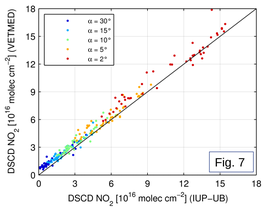
Fig. 6



Comparison with the IUP-UB MAX-DOAS

Comparison results in Bremen:

Fig. 7

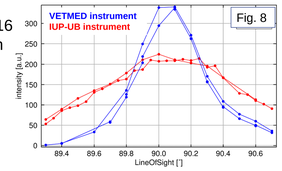


- First test measurements of the VETMED MAX-DOAS instrument were carried out in August 2016 at the IUP in Bremen
- The instrument was set up next to the IUP-UB instrument
- First comparison results show good agreement for NO_2 DSCDs, here for 24 August 2016 (Fig. 7)
- NO_2 DSCDs derived from the VETMED instru. are larger for lower elevation angles (–> different FOV)

Elevation calibration and horizon scan during CINDI-2:

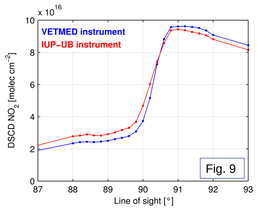
- Elevation calibration using a lamp was performed in the evening of 10 September 2016
- Two scans were performed in elevation direction with both instruments (Fig. 8)
- Valuable information on the characterization of FOV
- FOV of IUB-UB instrument clearly larger in elevation direction –> replacement of lens in the telescope

Fig. 8



http://www.tropomi.eu/science/cindi-2

Fig. 9



- Scan over horizon can be used to estimate FOV and alignment of instrument
- Comparison between IUP-UB and VETMED instruments show similar curves (Fig. 9)
- Better agreement of DSCD NO_2 between the instruments after replacement of lens
- FOV ~ 0.8°

(Preliminary) Measurement directions

- After the set up of the instrument in the end of November / beginning of December 2016, six viewing directions were selected (Fig. 10)
- Currently, measurements are obtained in viewing directions A (azimuth = 0°), B (azimuth = 90°), and F (azimuth = 300°)
- Elevation angle sequence: 0°, 1°, 2°, 3°, 4°, 5°, 15°, 30°, 90°
- Viewing directions will be modified soon (second instrument)
- First O_4 (upper panel) and NO_2 (lower panel) DSCDs at the VETMED site are shown in Fig. 11 and 12 (including C, D, and S) and in Fig. 13 and 14 (only A, B, and F)

Fig. 10

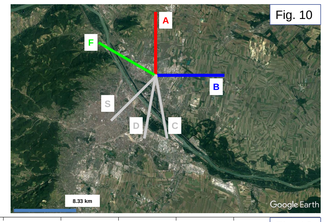
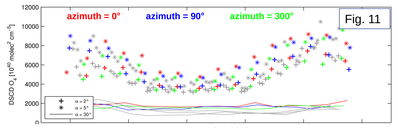


Fig. 11



4 December 2016

Fig. 12

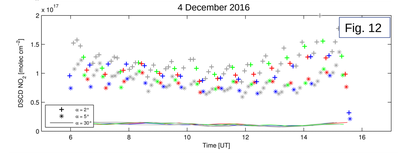
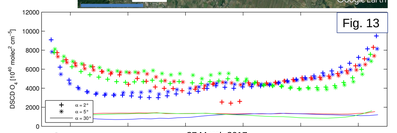
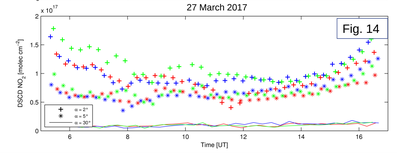


Fig. 13



27 March 2017

Fig. 14



Diurnal NO_2 cycles on weekdays/weekends

Fig. 15

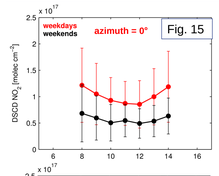


Fig. 16

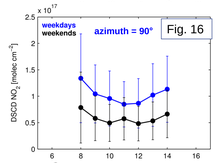
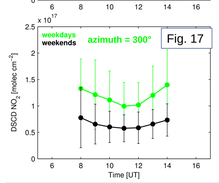


Fig. 17



- Diurnal NO_2 cycles were derived from the 2° elevation angle MAX-DOAS measurements for January (Fig. 15-17) and March (Fig. 18-20)
- The diurnal cycles were obtained for the viewing directions A (red), B (blue), and F (green)
- Data of 20 days in (January) and 28 days (March) were averaged; the error bars represent the standard deviation
- There are two NO_2 maxima during daytime – one in the morning and one in the evening
- While the diurnal cycles are similar for all viewing directions, the order of magnitude is lower for the A and B directions (rather remote areas)
- The NO_2 maxima are more pronounced on weekdays (–> rush hour traffic)
- Averaged NO_2 levels are clearly lower on weekends (< 1 x 10^{17} molec cm^{-2}) than on weekdays (> 1 x 10^{17} molec cm^{-2})
- In January, the peak of rush hour traffic occurs before/after observations

Fig. 18

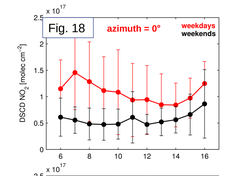


Fig. 19

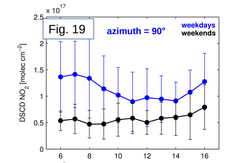
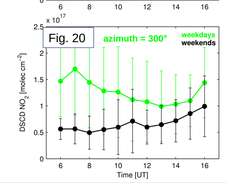


Fig. 20



Comparison with in-situ measurements

Fig. 21

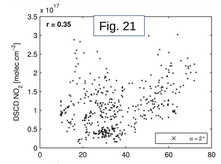
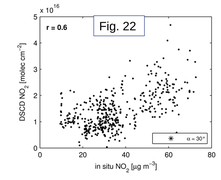


Fig. 22



- Averaged NO_2 concentrations from three in-situ ground stations located within the viewing direction F (see Fig. 10) are compared with NO_2 DSCDs at different elevation angles
- The comparison results are presented for January (Fig. 21 and 22) and March (Fig. 23 and 24)
- We note that the data are preliminary and unfiltered
- Highest correlation between the two data sets is found for α = 2° in March
- The agreement between NO_2 concentrations at the ground level and NO_2 DSCDs obtained at α = 30° is less strong

Fig. 23

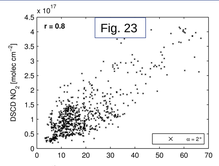
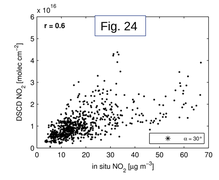


Fig. 24



Summary and outlook

- The assembly and testing phase of two MAX-DOAS systems were conducted at the IUP-UB as a first step of the project VINDOBONA
- One of the two MAX-DOAS systems successfully took part in the CINDI-2 intercomparison campaign in September 2016
- After the campaign, this system was transferred to Vienna and set up at the VETMED site, which is located northeast of the city center
- Measurements at predetermined viewing directions started at the beginning of December 2016
- First analyses of the four-months data (December until March) indicate diurnal NO_2 cycles with two maxima and a clear difference between NO_2 pollution on weekdays and weekends
- The comparison of NO_2 DSCDs and ground-based in situ concentrations reveal good correlation, although data are preliminary and unfiltered
- As a next step, the second MAX-DOAS system will be set up at the BOKU site, which is located northwest of the city center and about 7.75 km away from the VETMED site

Acknowledgements

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Selected References

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Universität Bremen

DFG Deutsche Forschungsgemeinschaft

vetmeduni vienna

FWF Der Wissenschaftsfonds.

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