Horizontal and temporal evolution of tropospheric NO_2 in Vienna as inferred from car DOAS measurements

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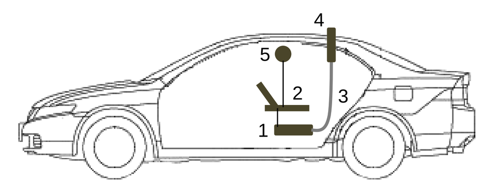
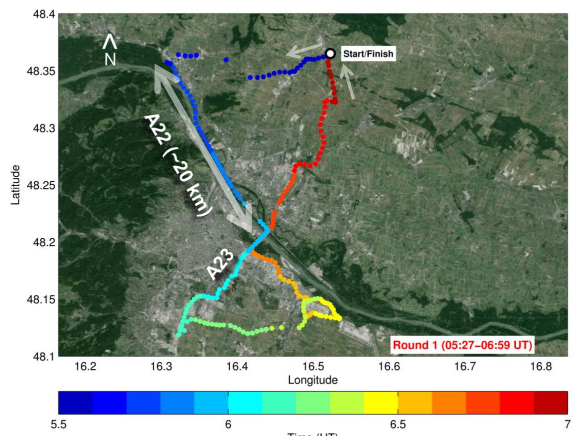
Instrument and car journeys

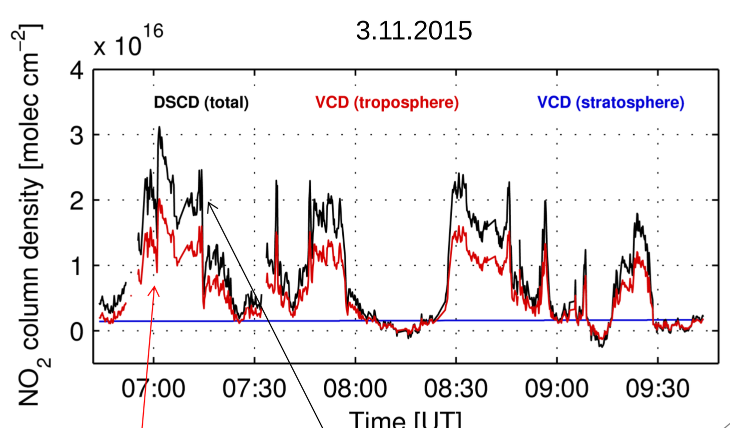
- For the mobile observations of tropospheric NO_2 vertical column densities (VCDs), a simple zenith-sky DOAS (Differential Optical Absorption Spectroscopy) system was implemented
- A cardboard box was built to house an Avantes miniature spectrometer (1) and a notebook (2)
- An optical fibre (3) was connected to the spectrometer and threaded through an aluminium bracket to the outside of the car
- The telescope (4) was directed to the zenith
- The geographical position of the car was recorded by a GPS-mouse (5)



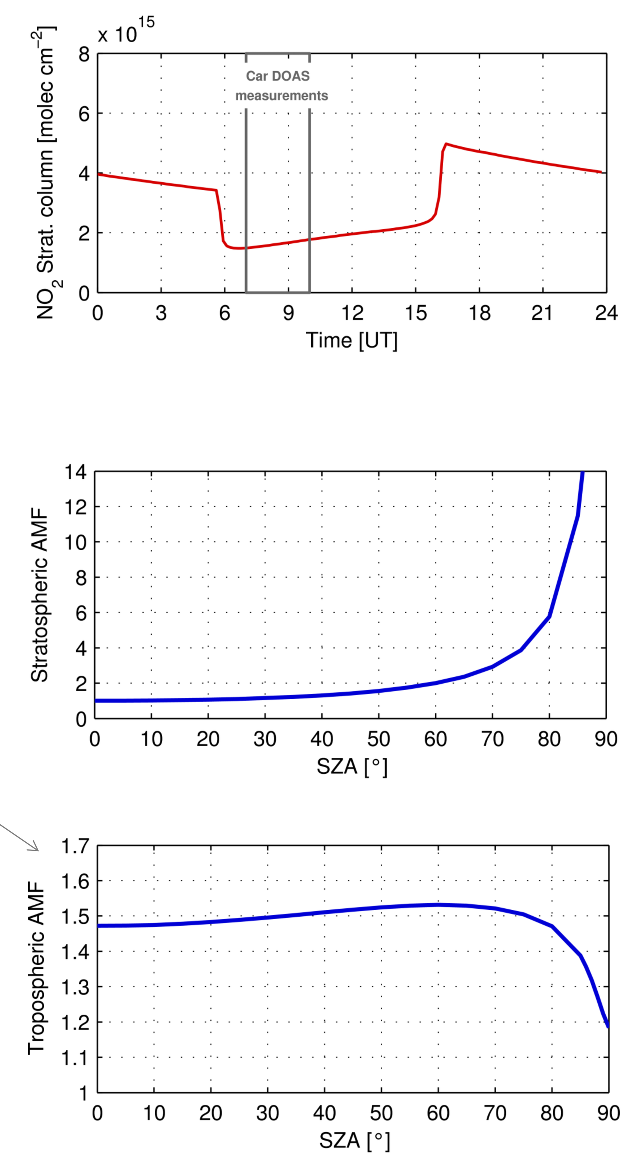


- A total of twenty identical car rides were performed on nine days in spring/fall 2015 within the metropolitan area of Vienna
- Each drive spanned about 110 km, lasted about 1.5 hours (figure at lower right), and included known emission sources as well as a background region ~15 km northeast of Vienna (Start/Finish)

Tropospheric NO_2 VCDs



$$VCD_{tropo} = \frac{DSCD_{meas} + SCD_{ref} - VCD_{strato} * AMF_{strato}}{AMF_{tropo}}$$

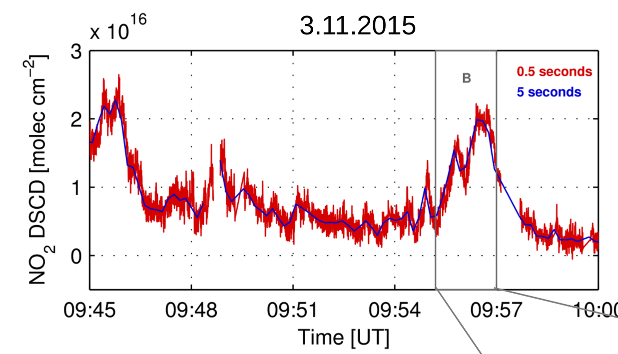


- Tropospheric NO_2 VCDs (also referred to as VCD_{tropo}) from the zenith-sky car DOAS measurements are based on the formula given above
- The stratospheric correction is based on stratospheric NO_2 fields as simulated by the Bremen 3d CTM (B3dCTM) and scaled to satellite observations from the GOME-2 instrument over a selected region in the Pacific (180°-140°W, 48°-48.5°N)
- Stratospheric and tropospheric airmass factors (AMFs) are calculated by using the SCIATRAN radiative transfer model (here for a wavelength of 450 nm)
- SCD_{ref} is estimated from GOME-2 measurements

DOAS analysis and temporal resolution

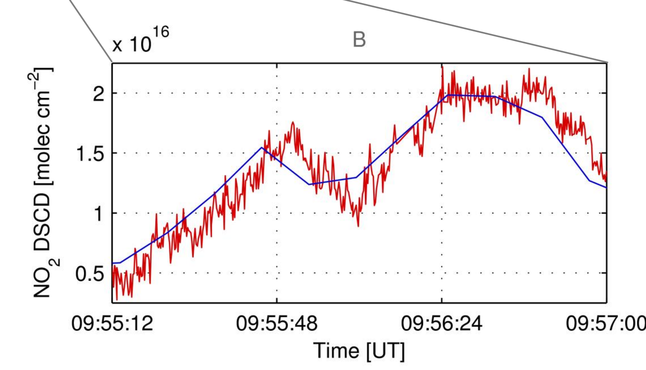
- The spectral measurements obtained during the individual car journeys are analyzed using the DOAS technique
- Settings used for the analysis of spectra to produce differential slant column densities (DSCDs) of NO_2 are shown in the table below

Fit parameter	Selection/Source
Spectral range	425-490 nm
Polynomial degree	3
Wavelength calibration	Solar atlas
Reference	Noontime spectrum
Cross section	**Temperature**
O_3	223 K
NO_2	298 K
O_4	296 K
H_2O	273 K
Ring	-



- In some cases, there is more information given in the data with higher temporal resolution (0.5 seconds)
- However, 5 seconds appears to be a good compromise

- The temporal resolution of the measurements was initially set to 0.5 seconds
- Spectra are averaged over 5 seconds, which correspond to a traveled distance of about 100 m

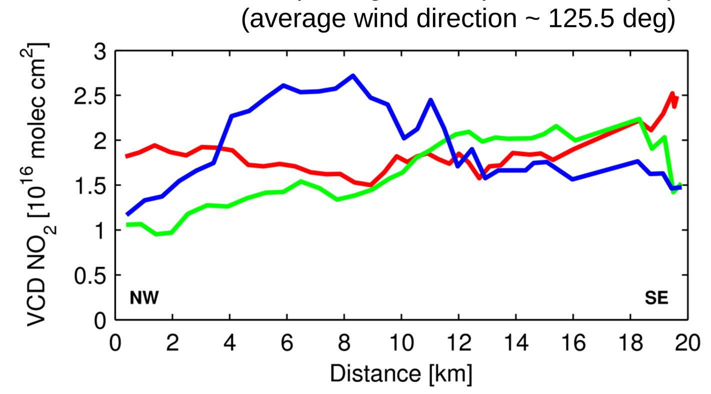


Temporal evolution of tropospheric NO_2

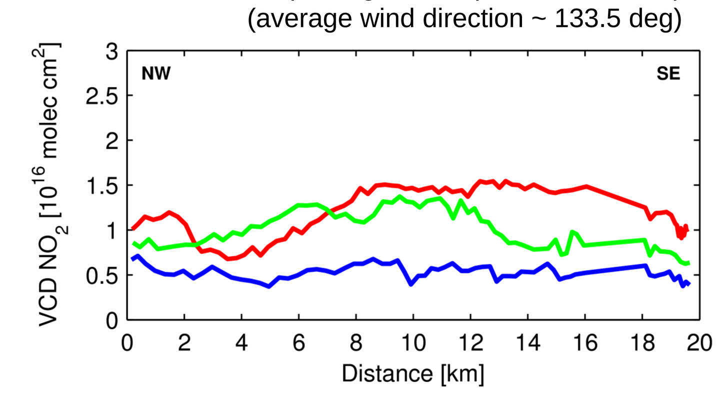
- The small-scale transport of NO_2 is evaluated along the Donauufer motorway (A22) in more detail. The A22 motorway is one of the busiest roads in Vienna, in particular in the south-eastern area, where many commuters take the Südosttangente motorway (A23) at the motorway junction Kaisermühlen
- The A23 is in fact the busiest road in Austria having about 180,000 cars driving every day on average

- The NO_2 variation along the A22 motorway is shown for 10 April 2015 (left) and 2 October 2015 (right) as a function of cumulative distance
- A clear shift of NO_2 pollution from South-East to North-West is observed on 10 April
- Highest NO_2 amounts during the first, second, and third drive of that day are located around 19, 14, and 7 km away from the starting point in the North-West, respectively

10.4.2015 (average wind speed ~ 5 km h[-1]) (average wind direction ~ 125.5 deg)



2.10.2015 (average wind speed ~ 11 km h[-1]) (average wind direction ~ 133.5 deg)



VINDOBONA project – Overview

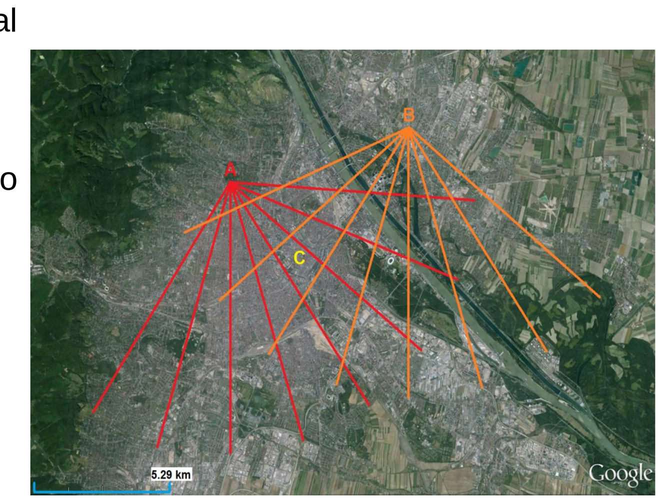
VIenna horizontal aNd vertical Distribution OBservations Of Nitrogen dioxide and Aerosols (VINDOBONA)

The investigation of nitrogen dioxide (NO_2) and aerosol amounts will be based on spectral measurements from two Multi AXis Differential Optical Absorption Spectroscopy (MAX-DOAS) instruments located at two different sites with ideal measurement conditions in Vienna, Austria

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

Visit our website at:

www.DOAS-VINDOBONA.at



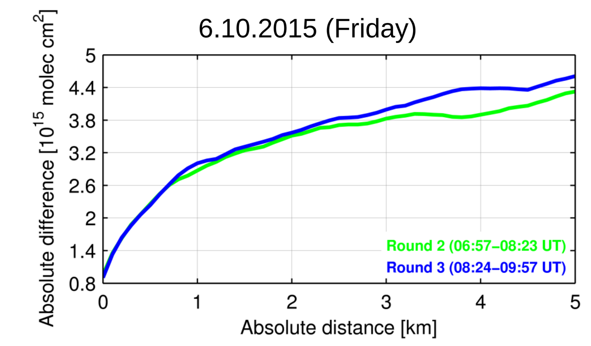
A BOKU site
B VETMED site
C City of Vienna

The overall goal of the proposed project is to improve our current knowledge of air pollution in large agglomerations caused by mankind

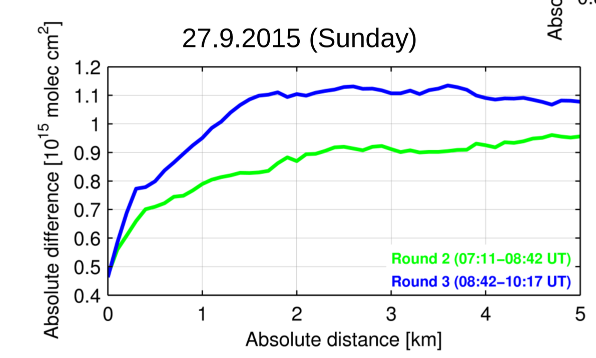
As the measurements from the two instruments will cover several azimuthal directions with partially overlapping fields of view, these data together with in-situ and car DOAS observations provide a multitude of information on the spatial NO_2 distribution, enabling an attempt to develop a spatially resolved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

Spatial scale of the NO_2 distribution

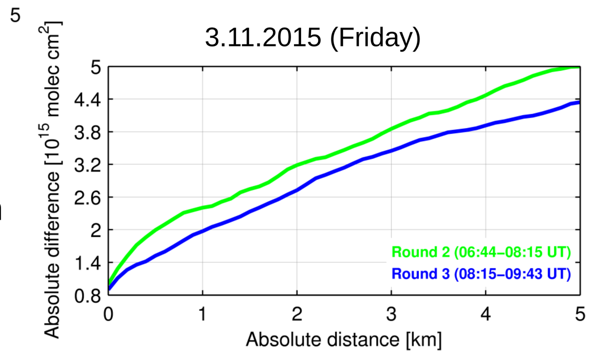
- Measurements of NO_2 DSCDs (0.5 sec) are averaged over spatial distance bins of 100 m
- Absolute NO_2 differences are computed to all other points within 5 km



- The magnitude of absolute differences depends on the overall NO_2 level of the respective days
- In general, the shape of the curves between the individual car journeys is quite similar



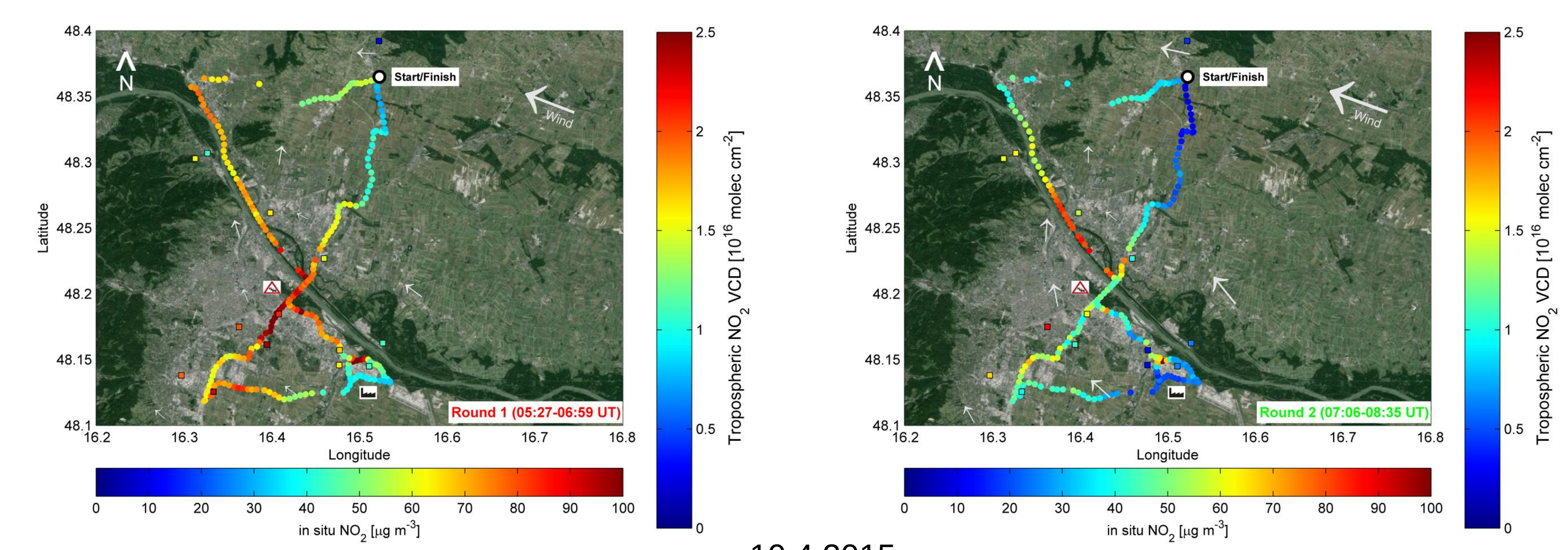
- There is no clear picture found for the spatial scale of NO_2 distribution
- However, a sharp increase in the NO_2 difference is evident within the first kilometer for most cases

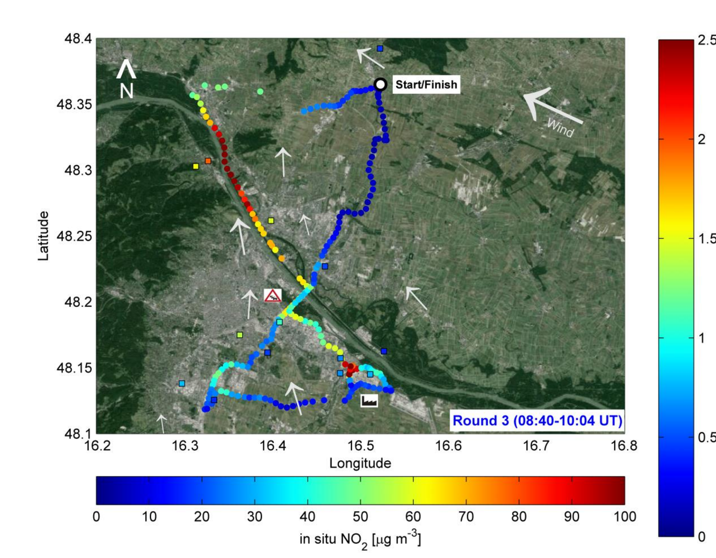


Comparison with in-situ NO_2

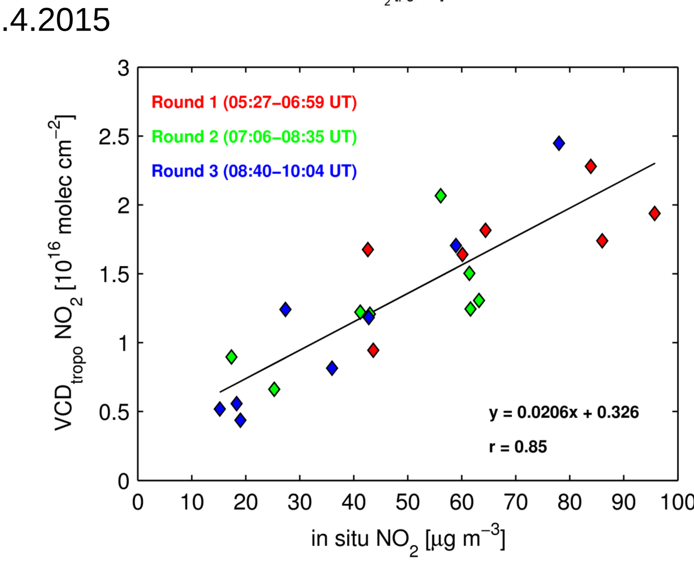
- The spatiotemporal evolution of NO_2 on 10 April 2015 in Vienna based on car DOAS (dots) and in situ measurements (squares) is shown below
- A large proportion of observed NO_2 amounts might be produced from traffic emissions of NO_x during the morning rush hour (in particular along the A23)

- During the time period of about 3 hours, NO_2 from rush hour traffic is transported over a distance between 10 and 15 km, which is in good agreement with average wind speed on that day (~5 km h[-1])
- The correlation coefficient of 0.85 suggests a close linear relationship of VCD vs. in-situ NO_2 on that day





10.4.2015



Summary and outlook

- A total of twenty identical car rides were performed in April, September, October, and November 2015 in order to collect high resolved spectral measurements for the retrieval of tropospheric NO_2 columns
- Although the information content is better for the high-resolved measurements in some cases, 5 seconds averages appear to be a good compromise
- The evaluation of NO_2 DSCDs shows that the absolute NO_2 difference increases with increasing distance (in particular for the first kilometer)
- Under low wind speed conditions, a small-scale transport event of NO_2 could be observed along the A22 motorway, which is in good agreement with surface concentrations from in-situ instruments
- Within the VINDOBONA project, measurements from two MAX-DOAS instruments will be collected and thus, a multitude of information will enable further research on the spatial NO_2 distribution in Vienna

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Selected References

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