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 tubing assembly (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/late summer 2015 within the metropolitan area of Vienna.
- Each drive spanned about 110 km, lasted about 5 hours (figure at lower right), and included known emission sources as well as a background region (~15 km northeast of Vienna (Still/Pratzer)).

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**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 column densities (DSCDs) of NO$_2$ are shown in the table below.
- The NO$_2$ variation along the A22 motorway is shown for 10 April 2015 (blue) 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.

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**Spatial scale of the NO$_2$ distribution**

- The spatial temporal 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$_2$ 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).
- The correlation coefficient of 0.5 suggests a close linear relationship of VCD vs. in-situ NO$_2$. In that day the magnitude of absolute differences depends on the overall NO$_2$ level of the respective day.

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**Comparison with in-situ NO$_2$**

- Forward and inverse modeling of NO$_2$ via a 2D model can be used to provide a quantitative evaluation of NO$_2$ emissions and transport processes in Vienna.
- Such evaluations will be used for assessing the potential of the VINDOBONA project to provide complementary information about NO$_2$ pollution and transport processes in Vienna.

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**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 concentration distributions 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.