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Mobile spectroscopic real-time monitoring of NO_2 for pollution maps of Zurich

Empa
Materials Science and Technology

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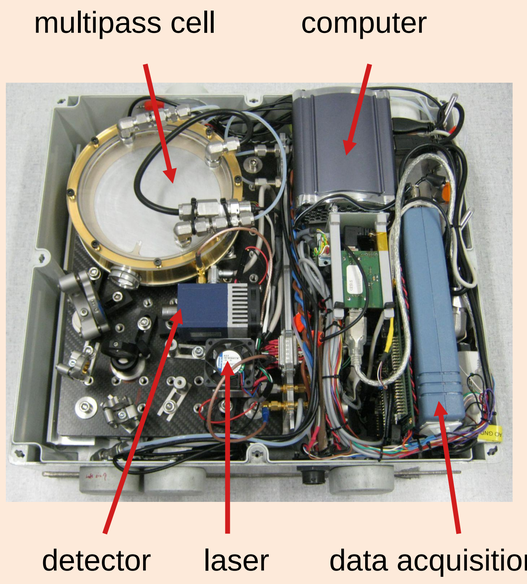
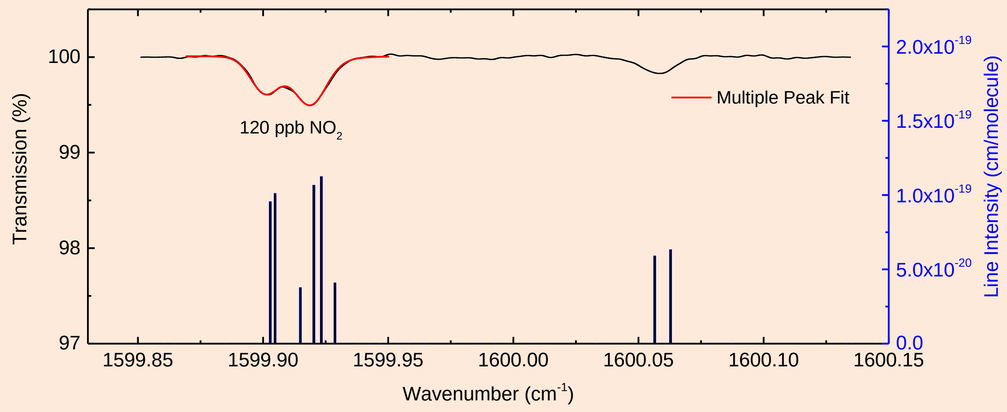
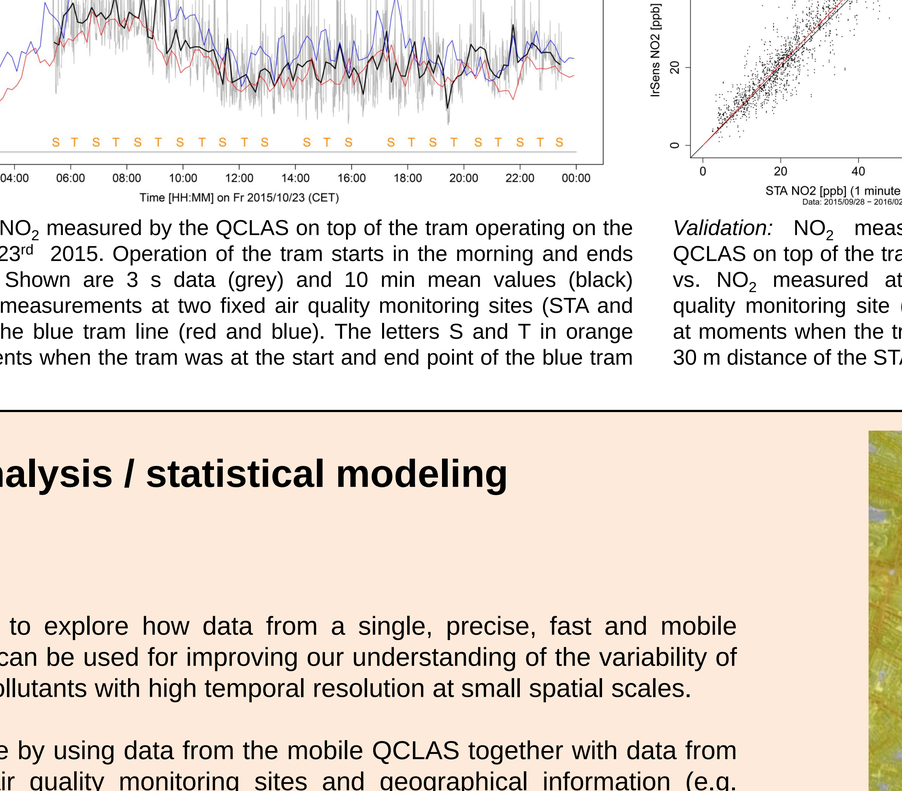
Compact Quantum Cascade Laser Absorption Spectrometer (QCLAS) for NO_2

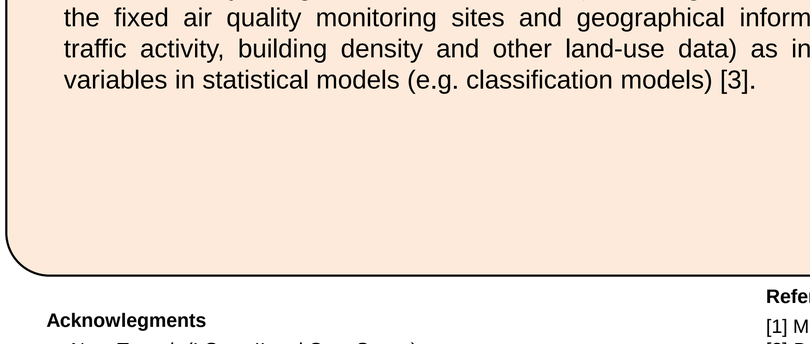


- Quantum cascade laser emitting at 1600 cm^{-1} probes absorption of NO_2
- Air cylindrical multipass cell with 12 m optical path length is used to enhance the absorption signal of NO_2 in air [1]
- NO_2 concentration is determined by fitting the transmission profile using pressure, optical path length and line intensity parameters
- Measurements are performed at 3 kHz sampling rate and aggregated to 3 second values
- A drift correction is realized by repeated measurement of NO_2-free (zero) air
- Instrument dimensions: 40 × 36 × 15 cm

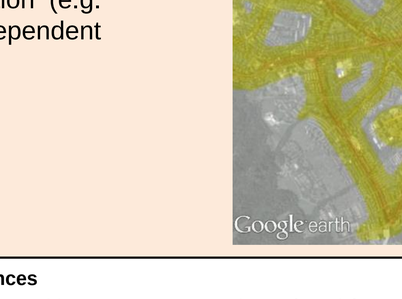


Measured NO_2 absorption spectrum at a pressure of 100 hPa and the corresponding line intensities obtained from the HITRAN database.





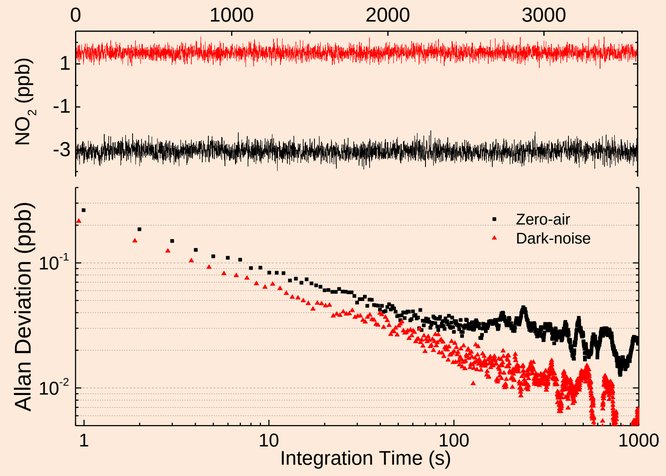
Mobile operation: NO_2 measured by the QCLAS on top of the tram operating on the blue line on Oct. 23rd 2015. Operation of the tram starts in the morning and ends around midnight. Shown are 3 s data (grey) and 10 min mean values (black) together with the measurements at two fixed air quality monitoring sites (STA and SCH) located at the blue tram line (red and blue). The letters S and T in orange indicate the moments when the tram was at the start and end point of the blue tram line.

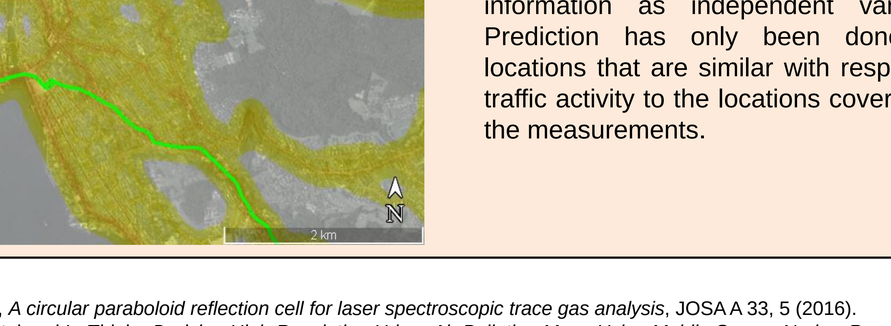


Validation: NO_2 measured by the QCLAS on top of the tram (3 s values) vs. NO_2 measured at the STA air quality monitoring site (1 min values) at moments when the tram was within 30 m distance of the STA site.

Instrument performance

Allan deviation plot of NO_2 measured by the QCLAS. At 1 s integration time the precision is 0.3 ppb. The best *precision* of 30 ppt is reached after ~100 s integration time. The precision is limited by the dark noise of the detector and the electronics.



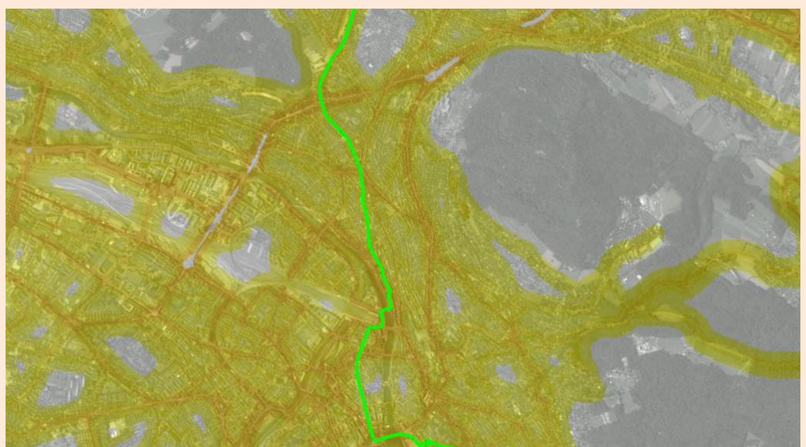


Comparison of QCLAS with a standard instrument (CLD) at a NABEL air quality monitoring station yields an *accuracy* of the QCLAS of better than 1 ppb.

Data analysis / statistical modeling

Our aim is to explore how data from a single, precise, fast and mobile instrument can be used for improving our understanding of the variability of urban air pollutants with high temporal resolution at small spatial scales.

This is done by using data from the mobile QCLAS together with data from the fixed air quality monitoring sites and geographical information (e.g. traffic activity, building density and other land-use data) as independent variables in statistical models (e.g. classification models) [3].



Illustrative example for mapping of NO_2 in Zurich based on QCLAS data measured on top of the tram operating on the green line on Dec. 21st 2015 from 13:00h to 14:00h.

Hourly NO_2 is spatially predicted using a classification model with traffic information as independent variable. Prediction has only been done for locations that are similar with respect to traffic activity to the locations covered by the measurements.

Acknowlegments

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References

[1] M. Mangold, B. Tuzson, M. Hundt, J. Jágerská, H. Looser, L. Emmenegger, *A circular paraboloid reflection cell for laser spectroscopic trace gas analysis*, JOSA A 33, 5 (2016).
[2] D. Hasenfratz, O. Saukh, Ch. Walser, Ch. Hueglin, M. Fierz, T. Arn, J. Beutel and L. Thiele, *Deriving High-Resolution Urban Air Pollution Maps Using Mobile Sensor Nodes*, Pervasive and Mobile Computing 16, 268-285 (2014).
[3] M. Müller, D. Hasenfratz, O. Saukh, M. Fierz, Ch. Hüglin, *Statistical modelling of particle number concentration in Zurich at high spatio-temporal resolution utilizing data from a mobile sensor network*, Atmospheric Environment 126, 171-181 (2016).