Influence of mixing layer height measured by ceilometer upon traffic-related air pollution in urban area

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- Motivation
- Methodology
- Results
- Conclusions

Challenges

- Changing NO_2/NO_x ratios in ambient air
- Threshold exceedances of NO_2, PM_{10}, $PM_{2.5}$ - sustainable reductions, UFP also
- Road traffic is a main source of air pollutants

Objectives

- Influence of meteorological parameters and atmospheric layering (especially MLH) on exchange processes of ground level emissions

- Application of ceilometer monitoring information for MLH to interpret air pollution near ground in Augsburg and Essen

- Measurements of Benzene, Toluene and Isoprene (VOCs with quite different reactivity) in Essen and use of further air pollutant concentration data (NO, NO_2, PM_{10}) in Augsburg and Essen

- Strongest MLH influence: half-hourly-mean or maximum values

Schäfer, K., Emeis, S., Hoffmann, H., Jahn, C.: Influence of mixing layer height upon air pollution in urban and sub-urban area. Meteorol. Z. 15 (2006), 647.

Tasks in Augsburg

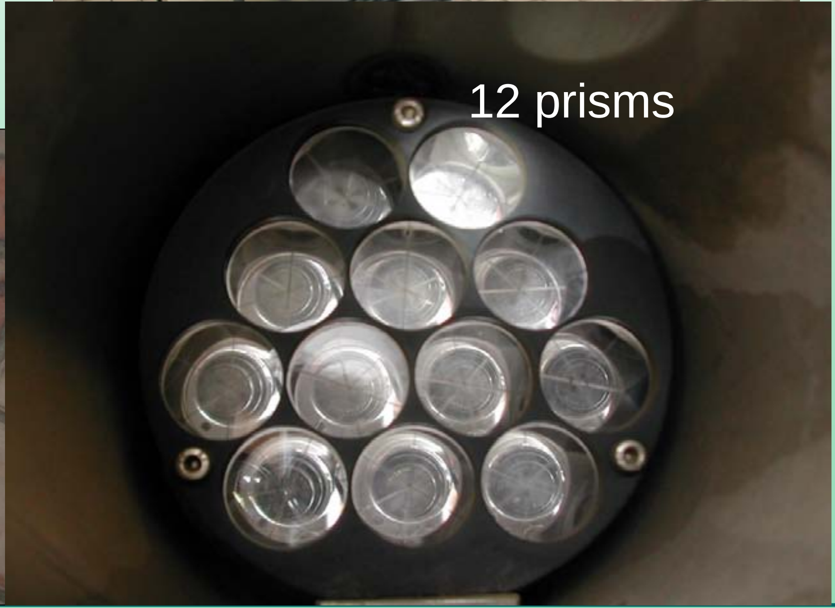
Ambient air concentrations near road traffic

- diurnal variations
- influences from emissions, weather conditions, chemical / photochemical reactions
- gases of interest for secondary aerosol formation (NO, NO_2)

Path-integrated concentrations of NO_2, NO, O_3, HCHO and in situ concentrations of NO_2, NO, O_3

- across / near roads at a crossing in Augsburg 03 – 09/2012
- commercial DOAS (Differential Optical Absorption Spectroscopy) with three retro-reflectors

Methodology: DOAS instrument



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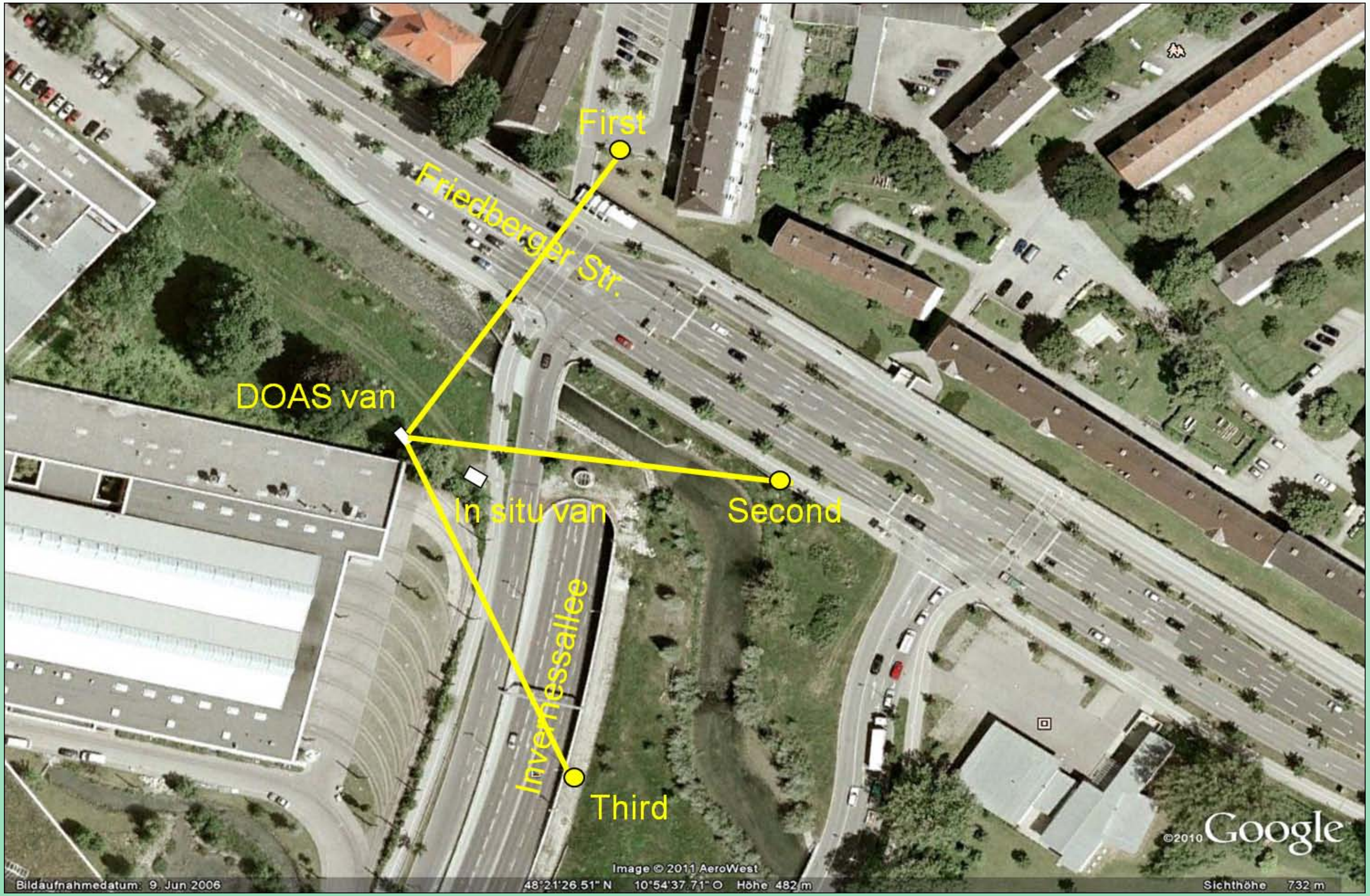
Continuous DOAS measurements in Augsburg March till September 2012



Methodology: ceilometer

CL 31 (Vaisala)

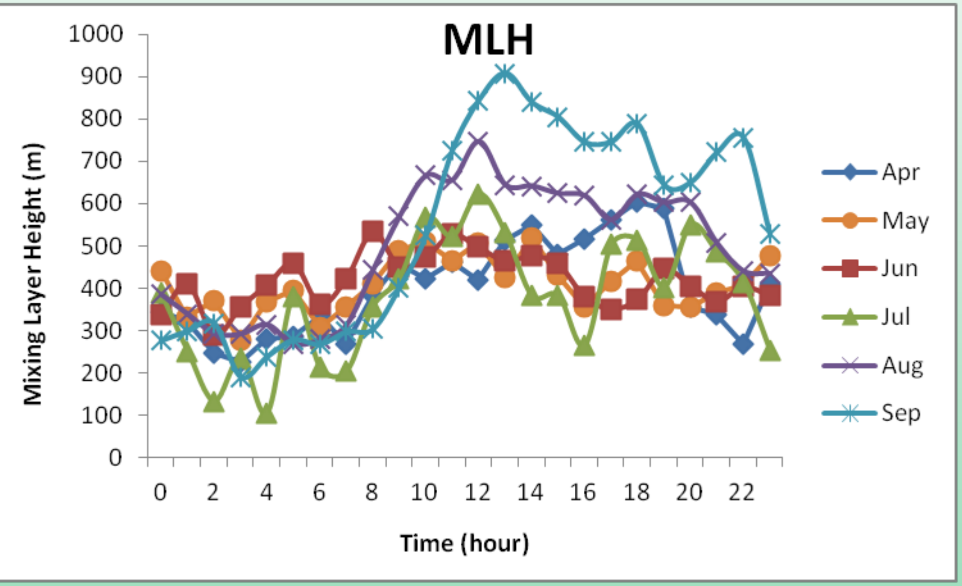
Minimum range resolution	5 m
Typical range resolution for boundary layer	10 m
Backscatter profile range	Up to 7700 m
Range for boundary layer profiling	Up to 3000 m
Laser wavelength	910 nm

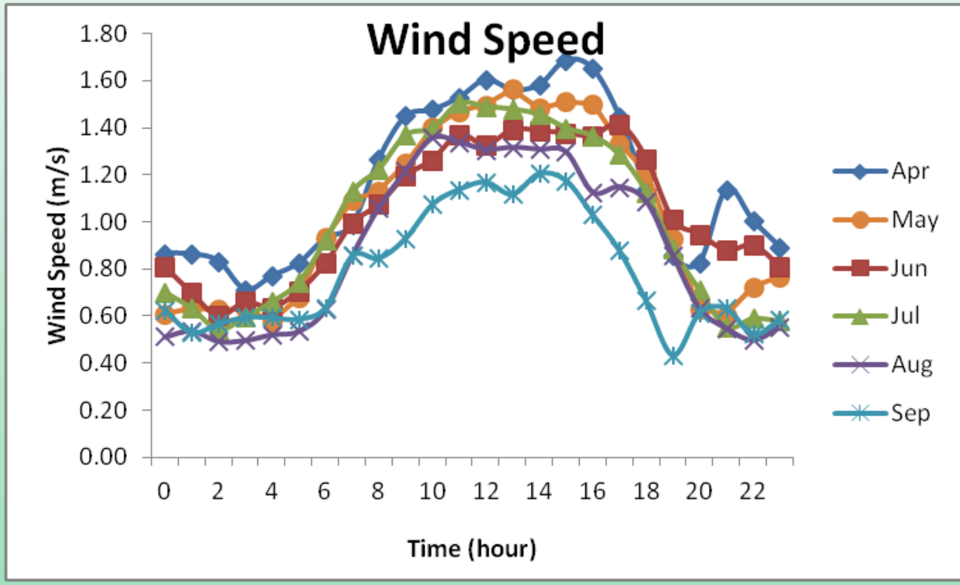
One-lens design – complete overlapping (Vaisala)

Continuous monitoring by uninterrupted remote sensing

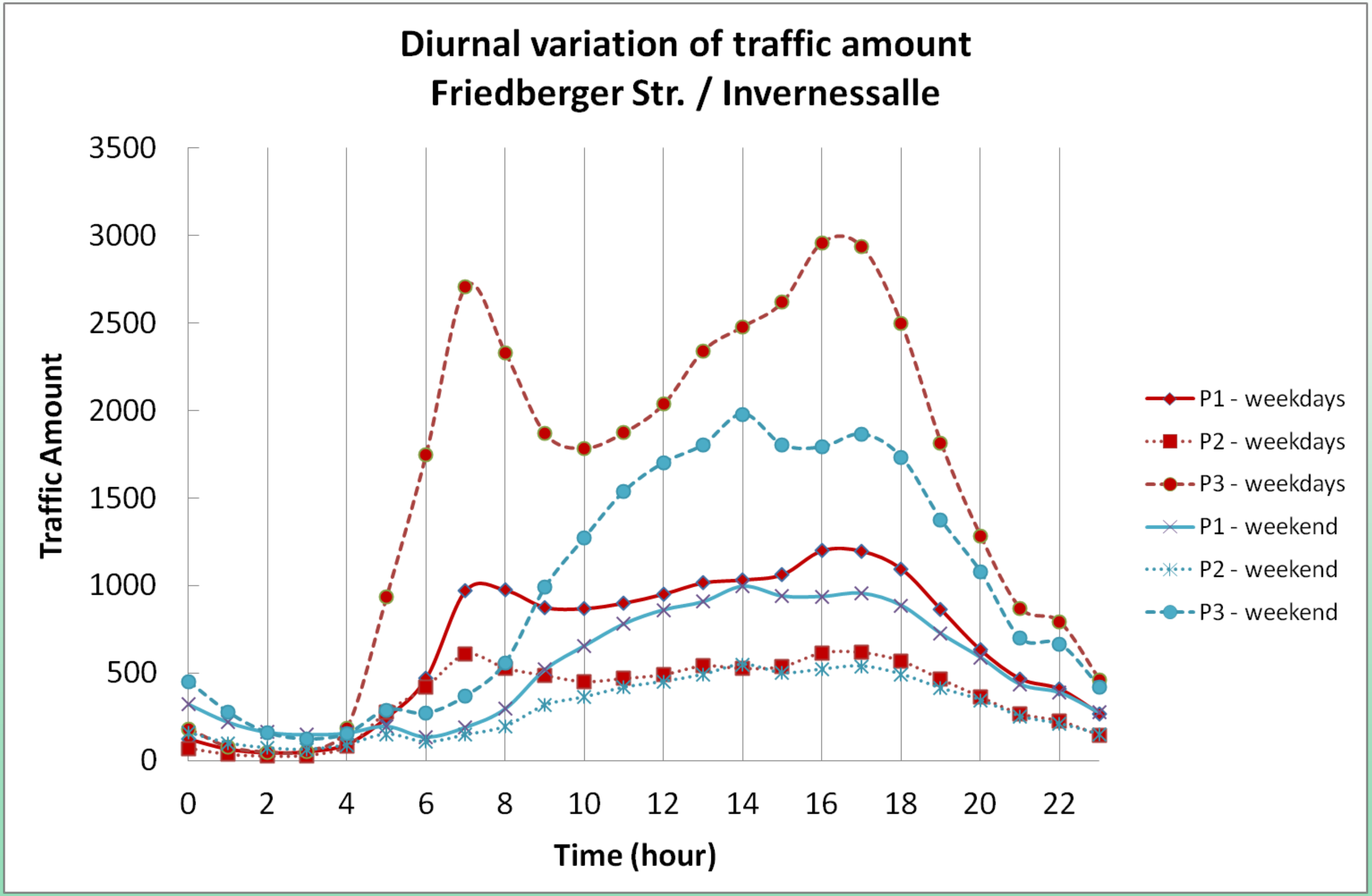
Gradient method for MLH determination

MLH from ceilometer
wind speed from weather station

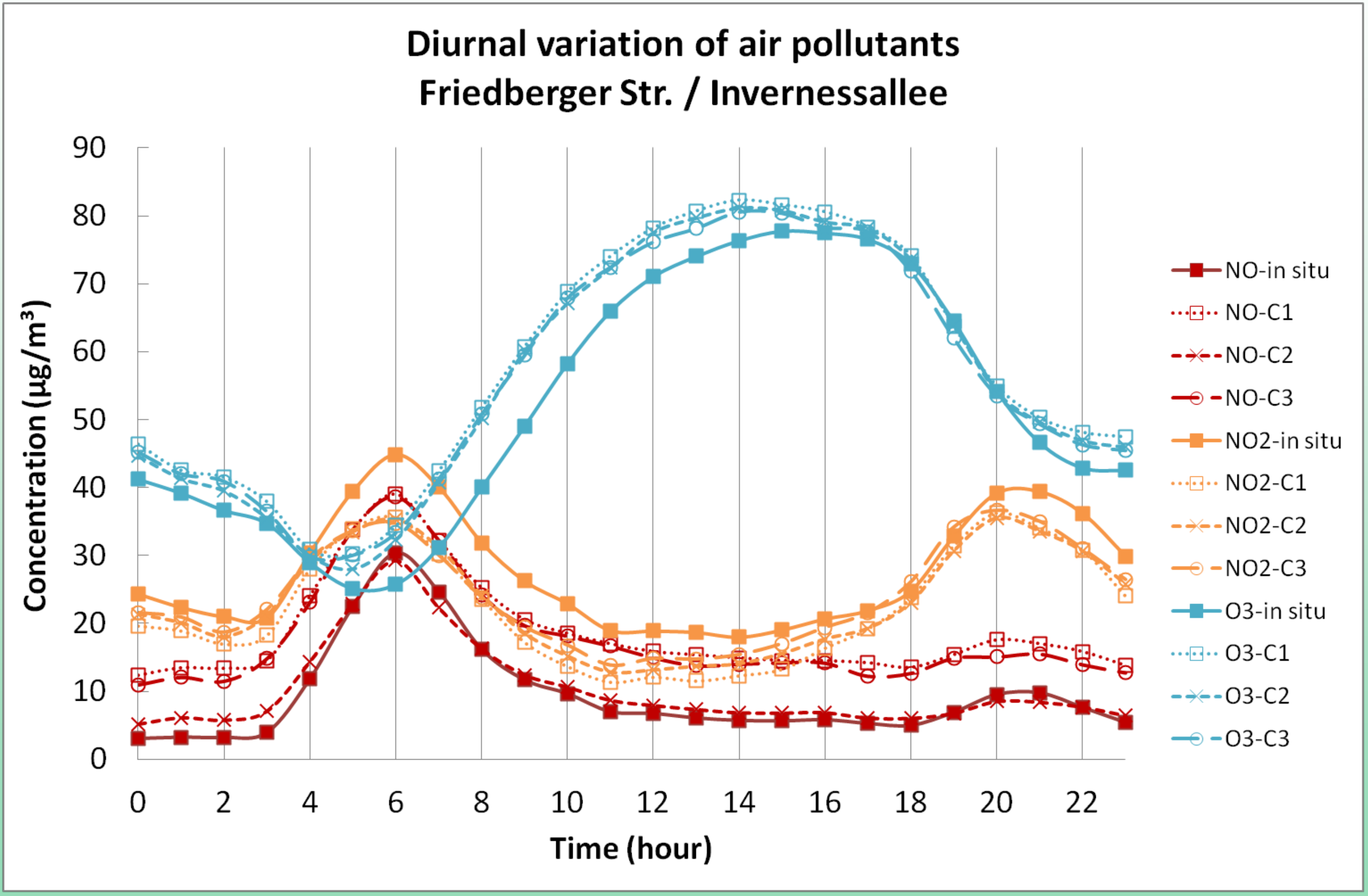




Road traffic at the three paths, 10/2011 - 09/2012



Concentrations at three paths and in situ



Conclusions

- Path-integrated measurements and high temporal resolution of the DOAS system satisfy the task of long-term and multiple-compound monitoring of traffic emissions

- Diurnal patterns of NO and NO_2 are mainly caused by traffic emissions

- Local convection affect both the spatial and temporal variation of NO and NO_2

- Concentration ratios path-integrated / in situ smallest for O_3 and highest for NO and NO_2 - differences caused by local convection, emissions and chemistry

Tasks in Essen

Measurements of meteorological parameters and air pollutant concentrations: 28/12/2011-17/04/2012, VOC 28/02-28/03/2012

- MLH: Software developed with MATLAB (*Vaisala, IMK-IFU)* for CL51 at *UDE* Campus Essen, radiosondes *DWD* station Essen

- Benzene, Toluene, Isoprene concentrations: every half hour by gas-chromatograph GC955 from Synspec b.v. during 20 min, enriched on Tenax GR, kerb site Gladbecker Str. *(UDE)*

- NO, NO_x and PM_{10} concentrations of LANUV Nordrhein-Westfalen (LANUV): kerb site Gladbecker Str.

Correlations of continuous MLH with air pollutant (*UDE, IMK-IFU*)

Methodology: ceilometer

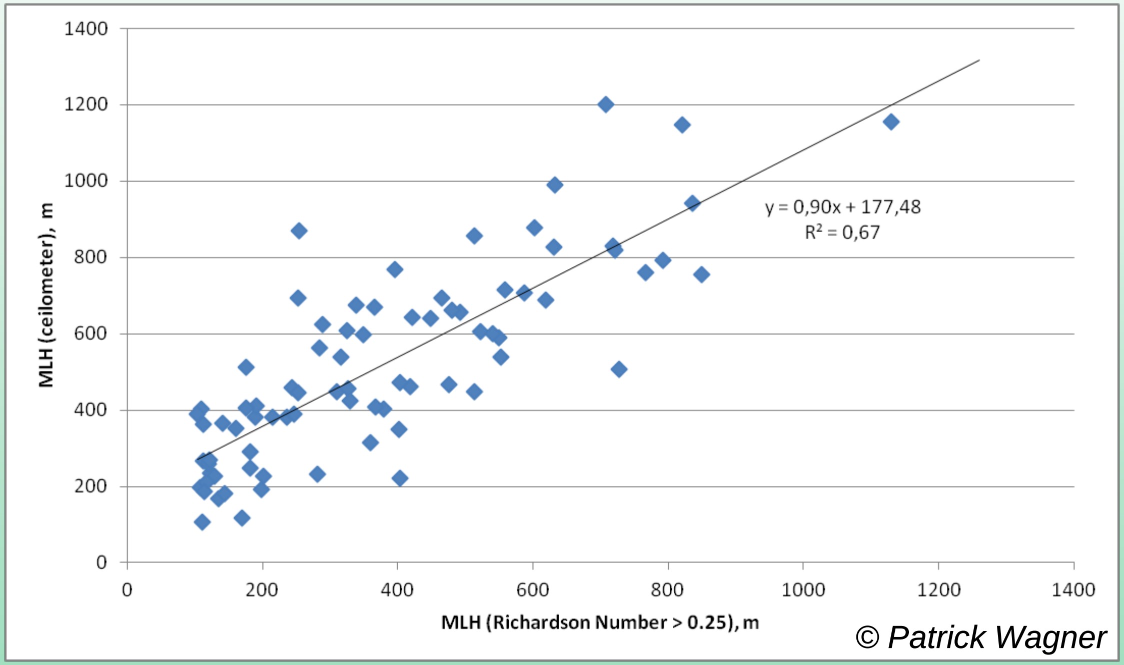
CL 51 (Vaisala)

Typical range resolution for boundary layer	10 m
Backscatter profile range	Up to 15000 m
Range for boundary layer profiling	Up to 4000 m
Laser wavelength	910 nm

Methodology

- MLH: classification scheme of Sturges: $K = 1 + 3.32 \log N$, where K number of classes and N total number of observations
- 11 classes and a class width of 200 m intervals of MLH (200 m – 2200 m) instead of original 10 m intervals used for correlation analyses
- Time frames with low clouds excluded, cloud upper boundary taken as layer upper boundary from about 17:00 till 20:00
- No time periods with high variability of MLH (e.g. abrupt rise due to solar heating, formation of nocturnal inversion)

Comparison of mixing layer height measurements from ceilometer and radiosonde



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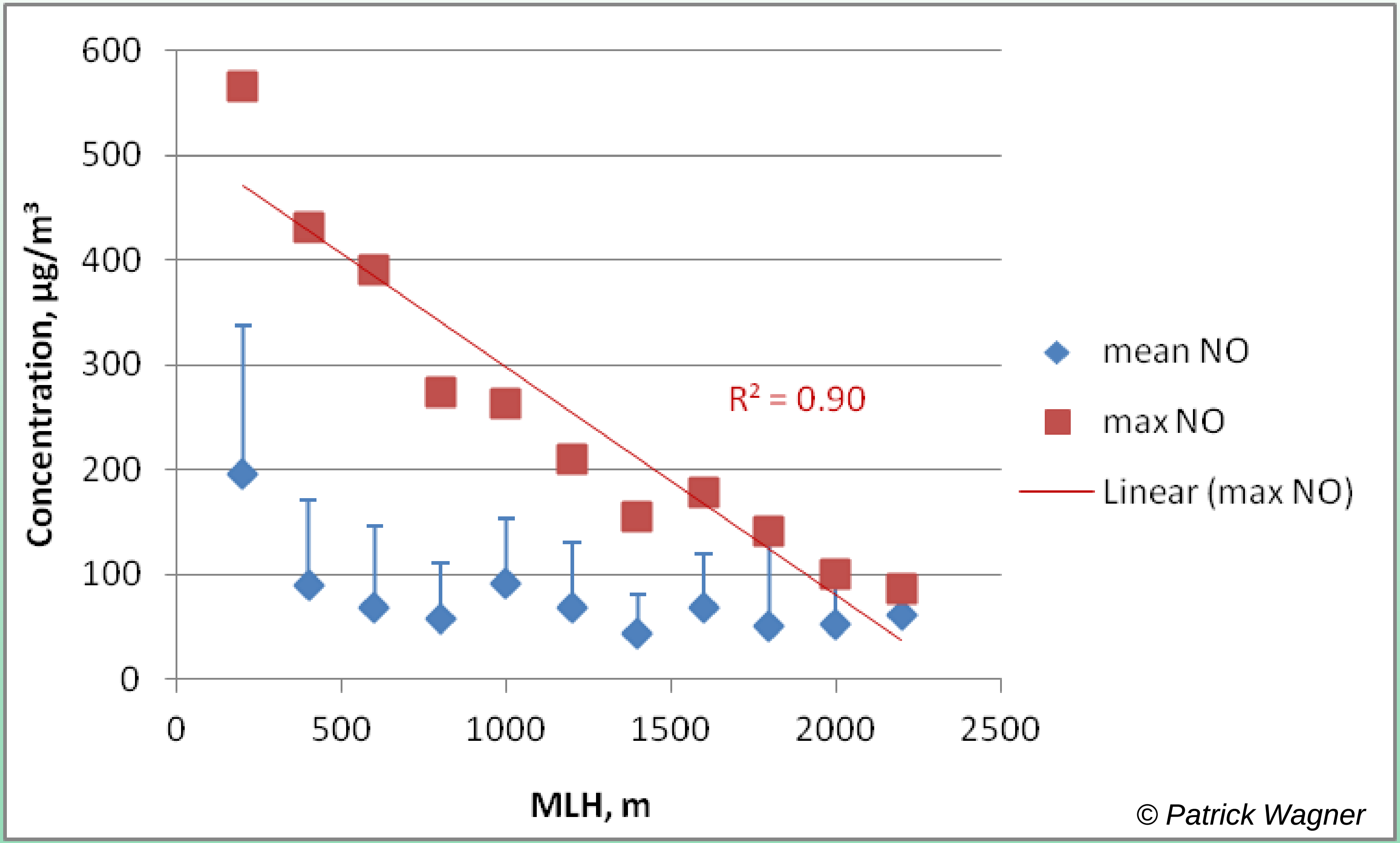
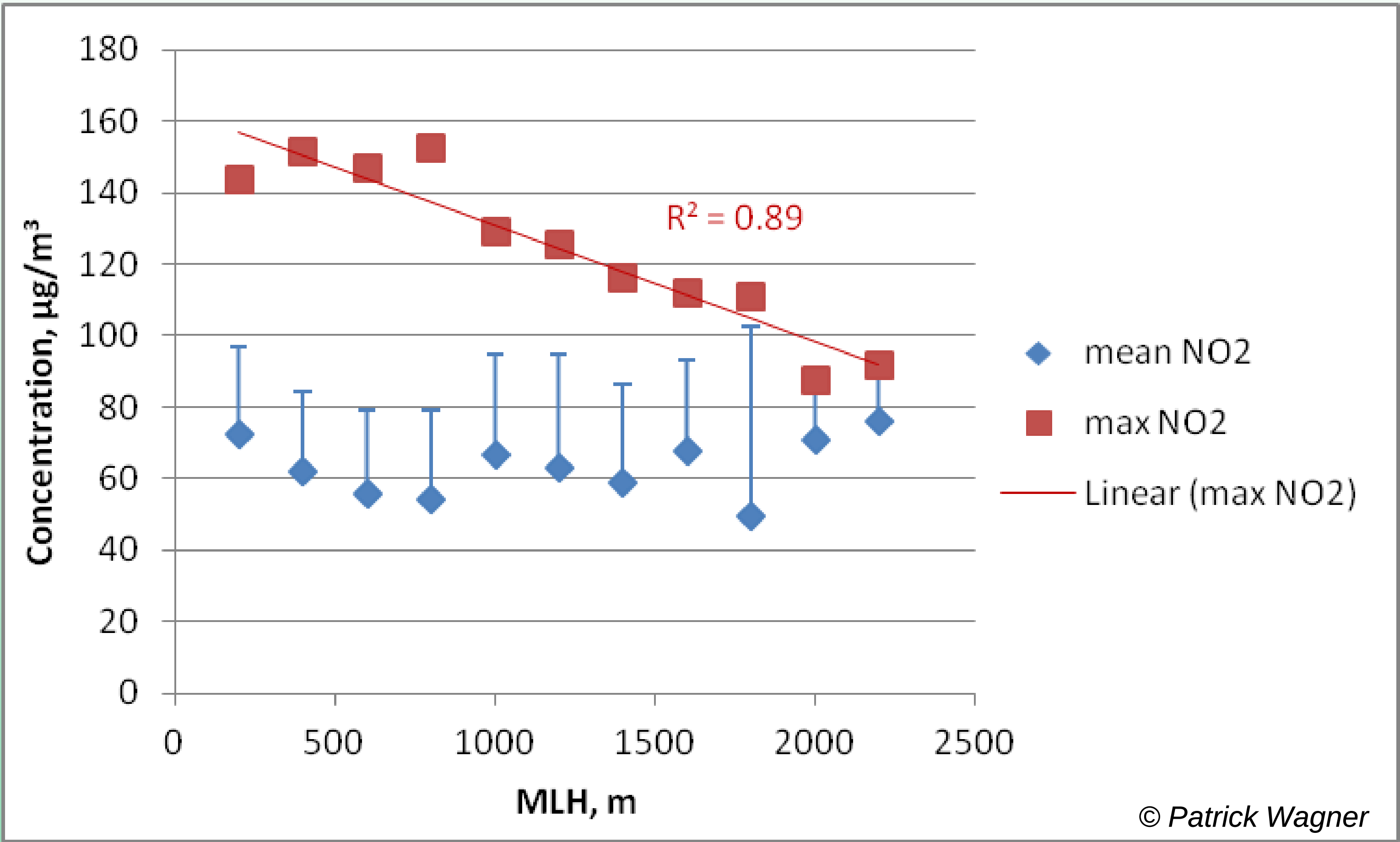
Deviations might be caused by:

1. Complex particle gradient structure affecting ceilometer MLH retrieval
2. Short-term stable layers affecting radiosonde measurements (threshold $Ri_c = 0.25$ used for MLH determination)
3. Urban heat island (city centre: ceilometer; suburban site: radiosonde)

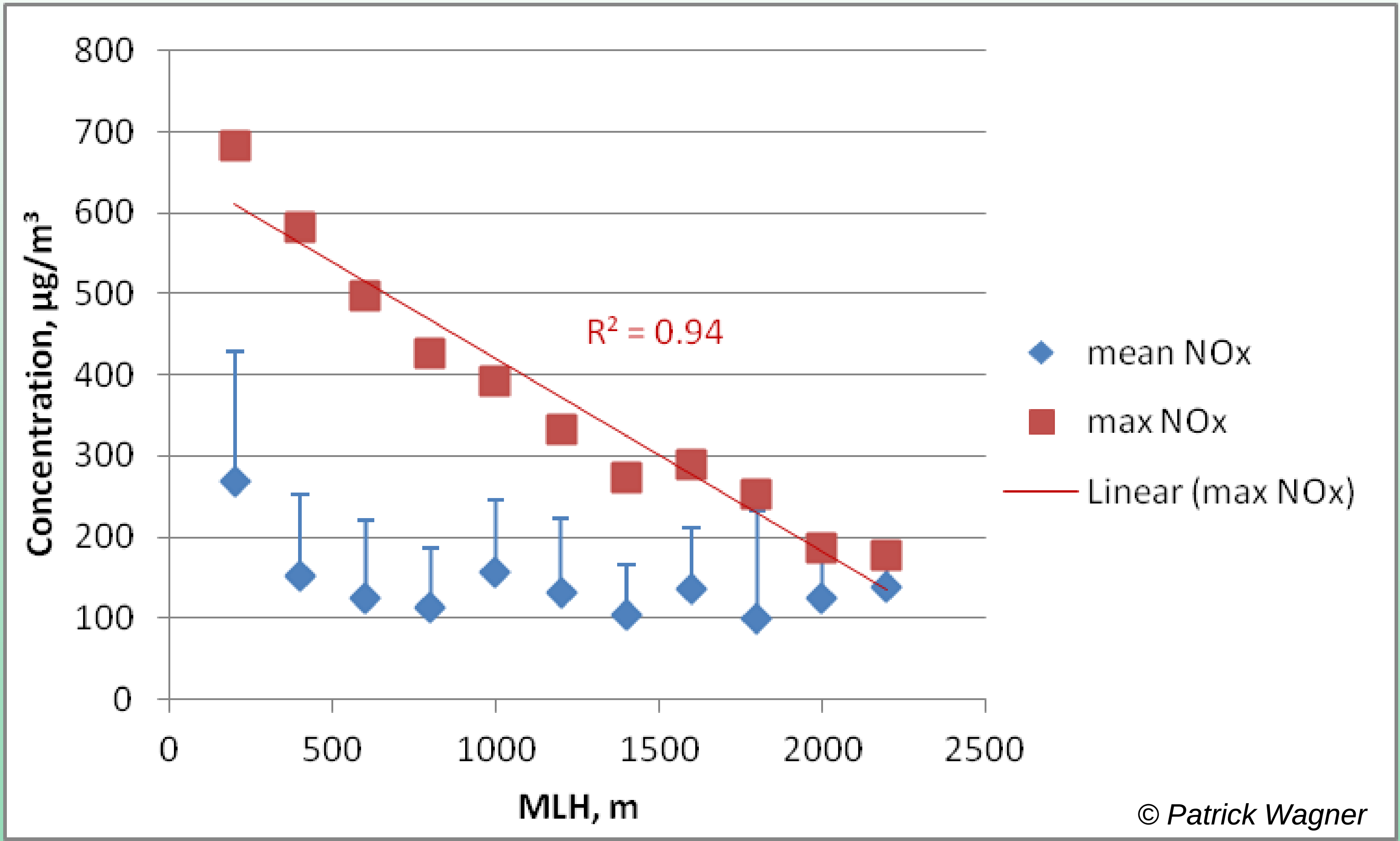
Correlation of NO concentrations with mixing layer height (Essen, Gladbecker Str.)



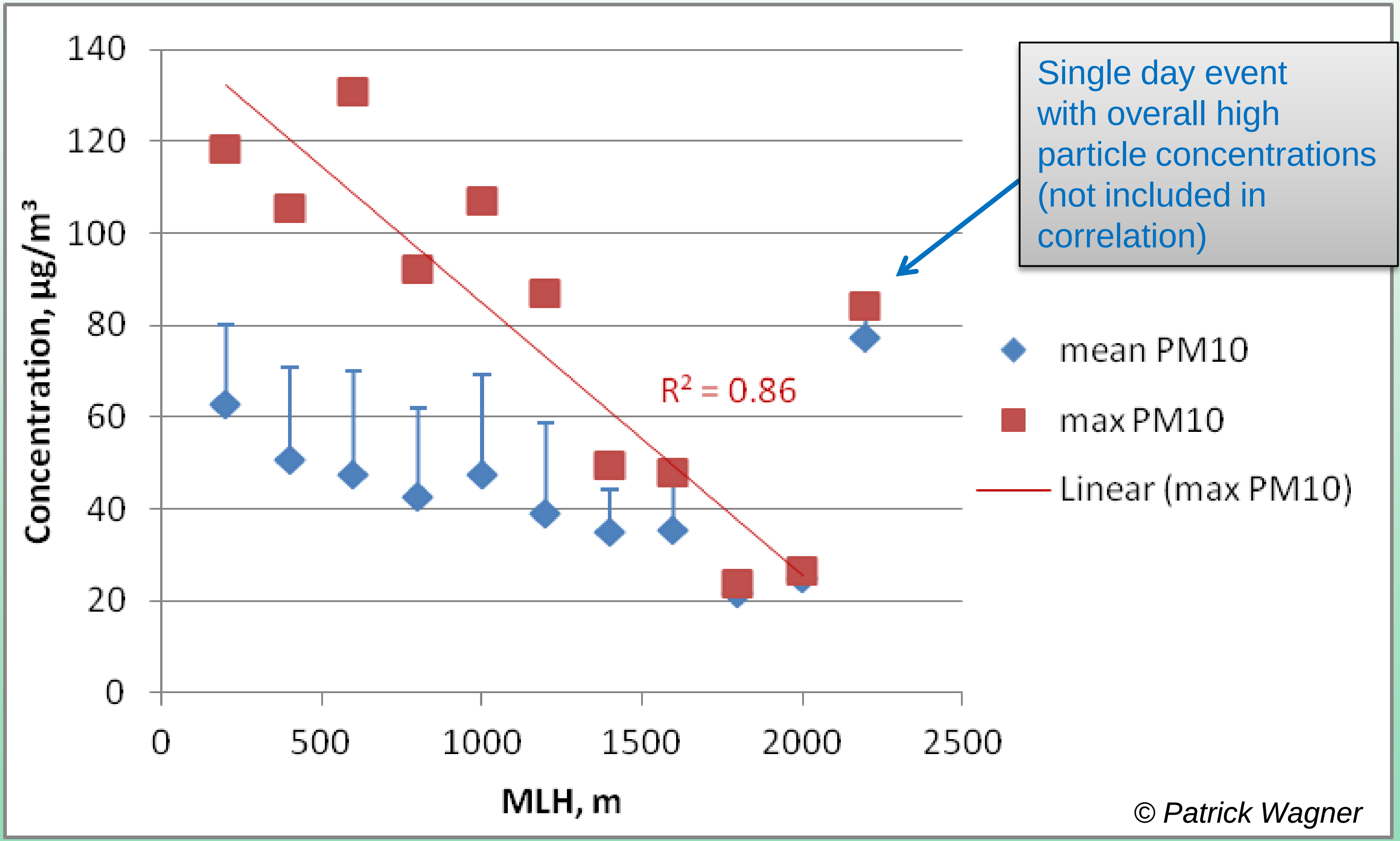
Correlation of NO_2 concentrations with mixing layer height (Essen, Gladbecker Str.)



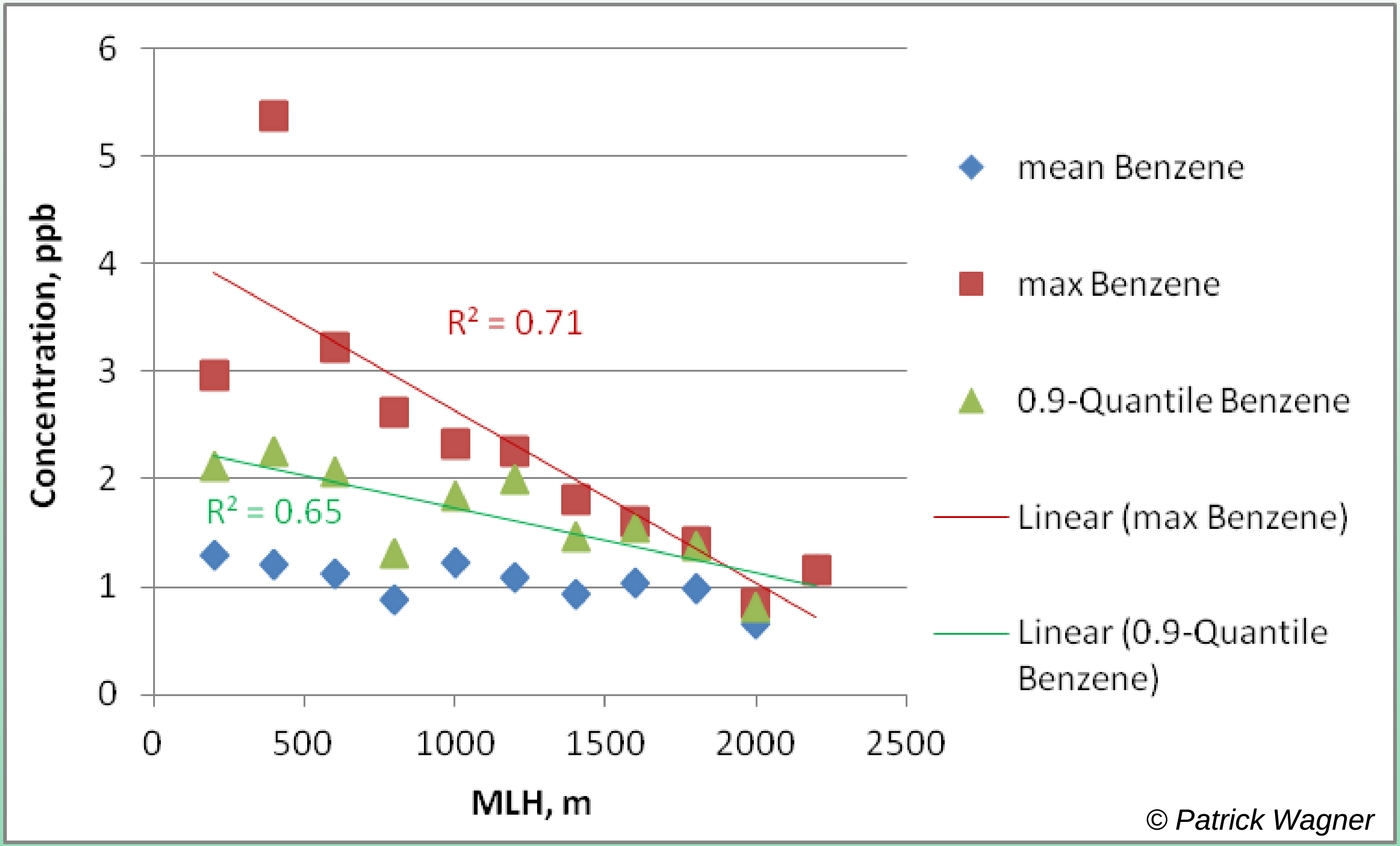
Correlation of NO_x concentrations with mixing layer height (Essen, Gladbecker Str.)



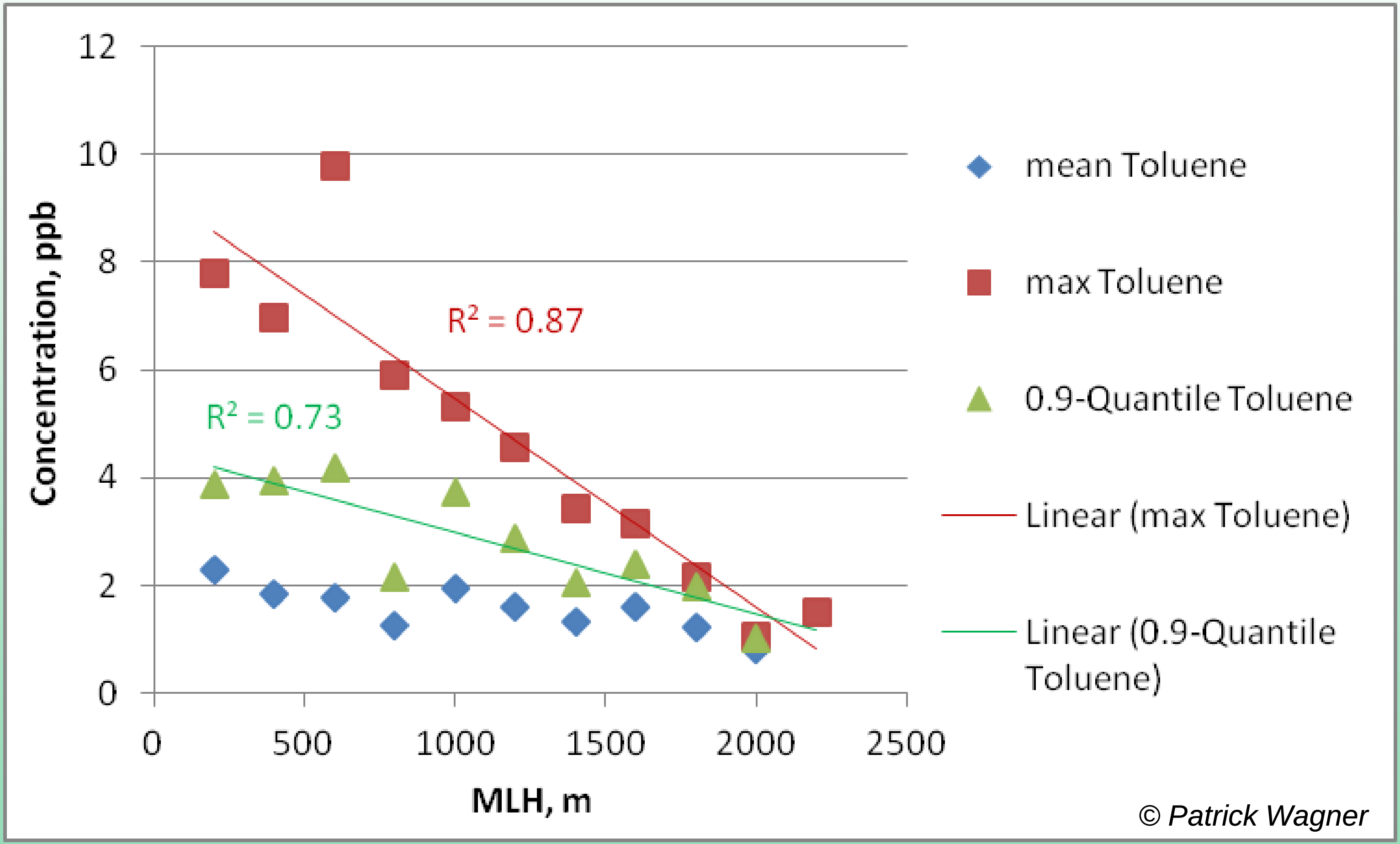
Correlation of PM_{10} concentrations with mixing layer height (Essen, Gladbecker Str.)



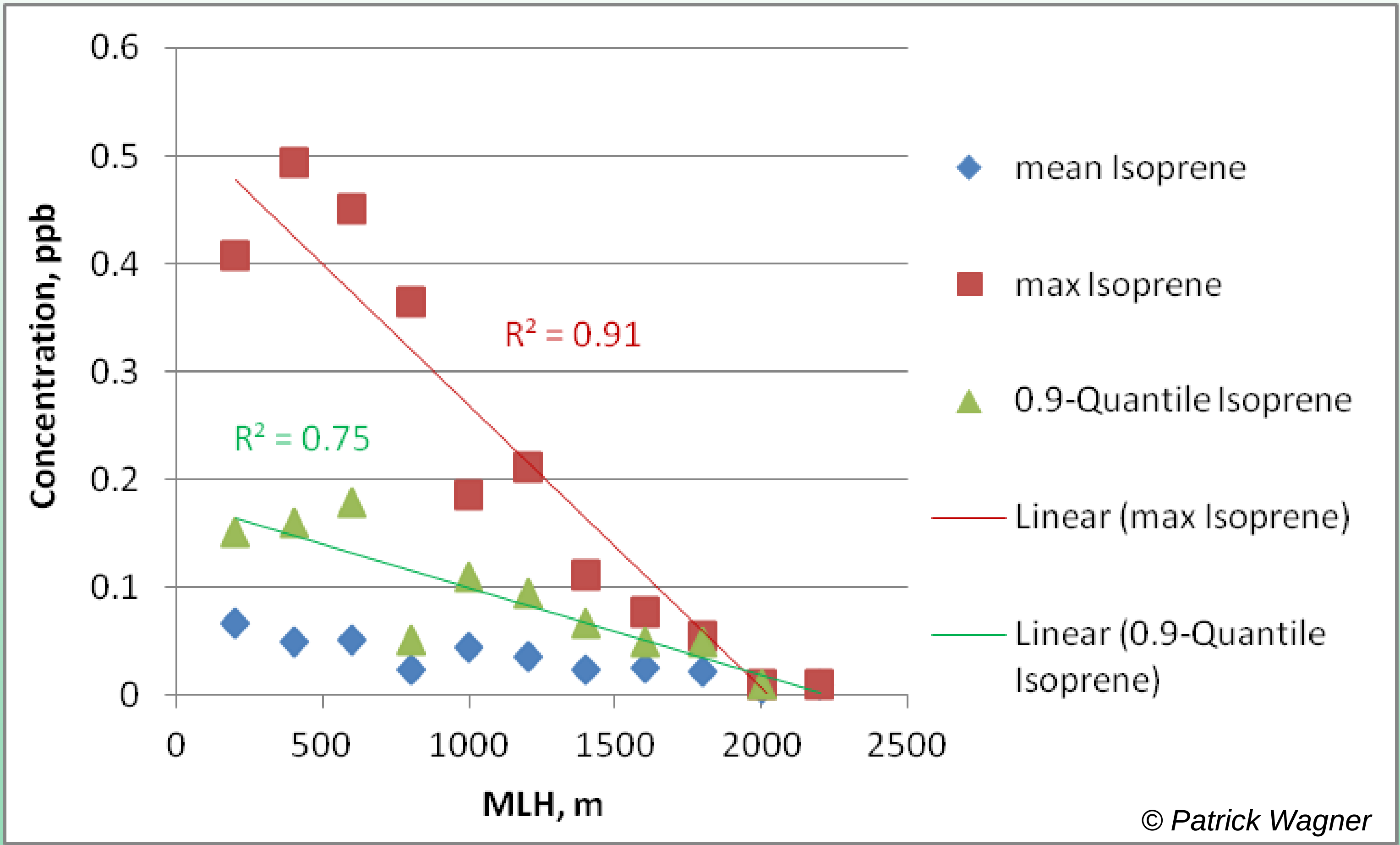
Correlation of Benzene concentrations with mixing layer height (Essen, Gladbecker Str.)



Correlation of Toluene concentrations with mixing layer height (Essen, Gladbecker Str.)



Correlation of Isoprene concentrations with mixing layer height (Essen, Gladbecker Str.)



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Conclusions

- Mainly maximum concentration of pollutant at kerb site affected by MLH
- Best results for 200 m intervals of MLH
- Important part of variance of observed maximum NO, NO_2, PM_{10}, Benzene, Toluene, Isoprene concentrations in street canyon in Essen caused by MLH - as for mean concentrations in urban and rural background (Munich, Hannover, Augsburg, Budapest)

Alföldy, B., Osán, J., Tóth, Z., Török, S., Harbusch, A., Jahn, C., Emeis, S., Schäfer, K.: Aerosol optical depth, aerosol composition and air pollution during summer and winter conditions in Budapest. Science of the Total Environment 383, 1-3 (2007), 141-163, doi: 10.1016/j.scitotenv.2007.04.037.

Schäfer, K.; Emeis, S.; Schrader, S.; Török, S.; Alföldy, B.; Osan, J.; Pitz, M.; Münkel, C.; Cyrys, J.; Peters, A.; Saragiannis, D.; Suppan, P.: A measurement based analysis of the spatial distribution, temporal variation and chemical composition of particulate matter in Munich and Augsburg. Meteorologische Zeitschrift, 21, 1, 47-57 (2011); DOI 10.1127/0941-2948/2011/0498.

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Thank you very much for your attention