Influences of meteorological parameters and mixing layer height upon particle size distribution and VOC concentrations in urban areas

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- Motivation, objectives
- Tasks, methodology
- Results
- Conclusions

Motivation, objectives

- Influences of meteorological parameters and atmospheric layering (especially mixing layer height (MLH)) on exchange processes of ground level emissions

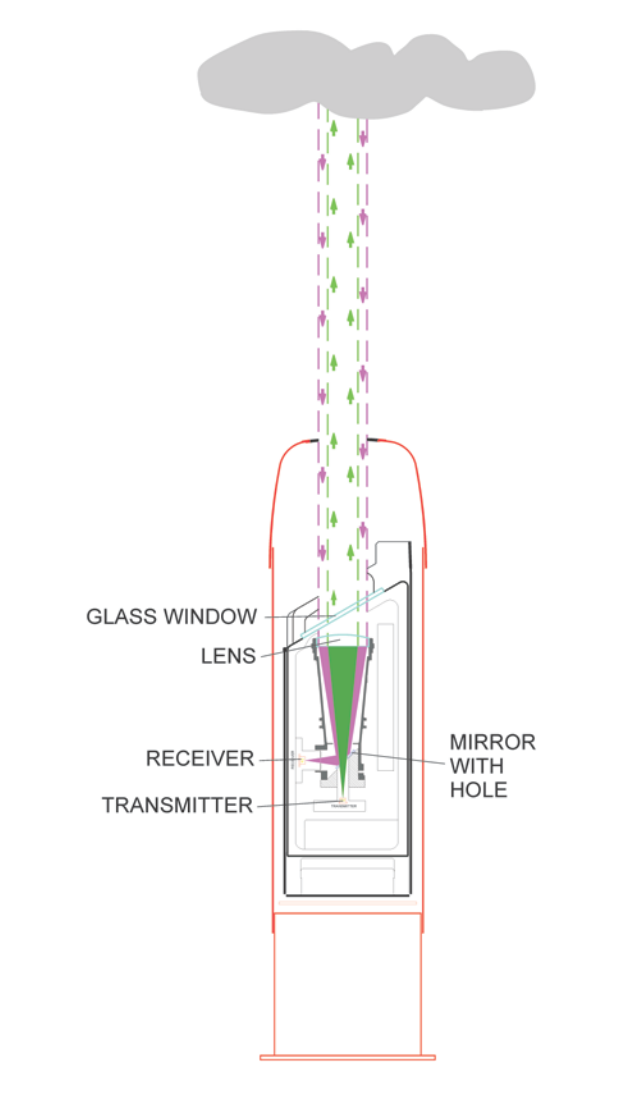
- Application of ceilometer monitoring information for MLH to interpret air pollution near ground

- Measurements at urban background site in Augsburg (particle size distributions) and kerb site in Essen (Benzene, Toluene, Isoprene - VOCs with quite different reactivity)

- Strongest MLH influence: 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, 647 (2006)

CL 31 and 51 ceilometer



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

One-lens design – complete overlapping (Vaisala)

Continuous monitoring by uninterrupted remote sensing

Gradient method for MLH determination

Emeis, S., Schäfer, K.: Remote sensing method to investigate boundary-layer structures relevant to air pollution. Bound-Lay. Meteorol. 121, 377 (2006)

Tasks in Augsburg

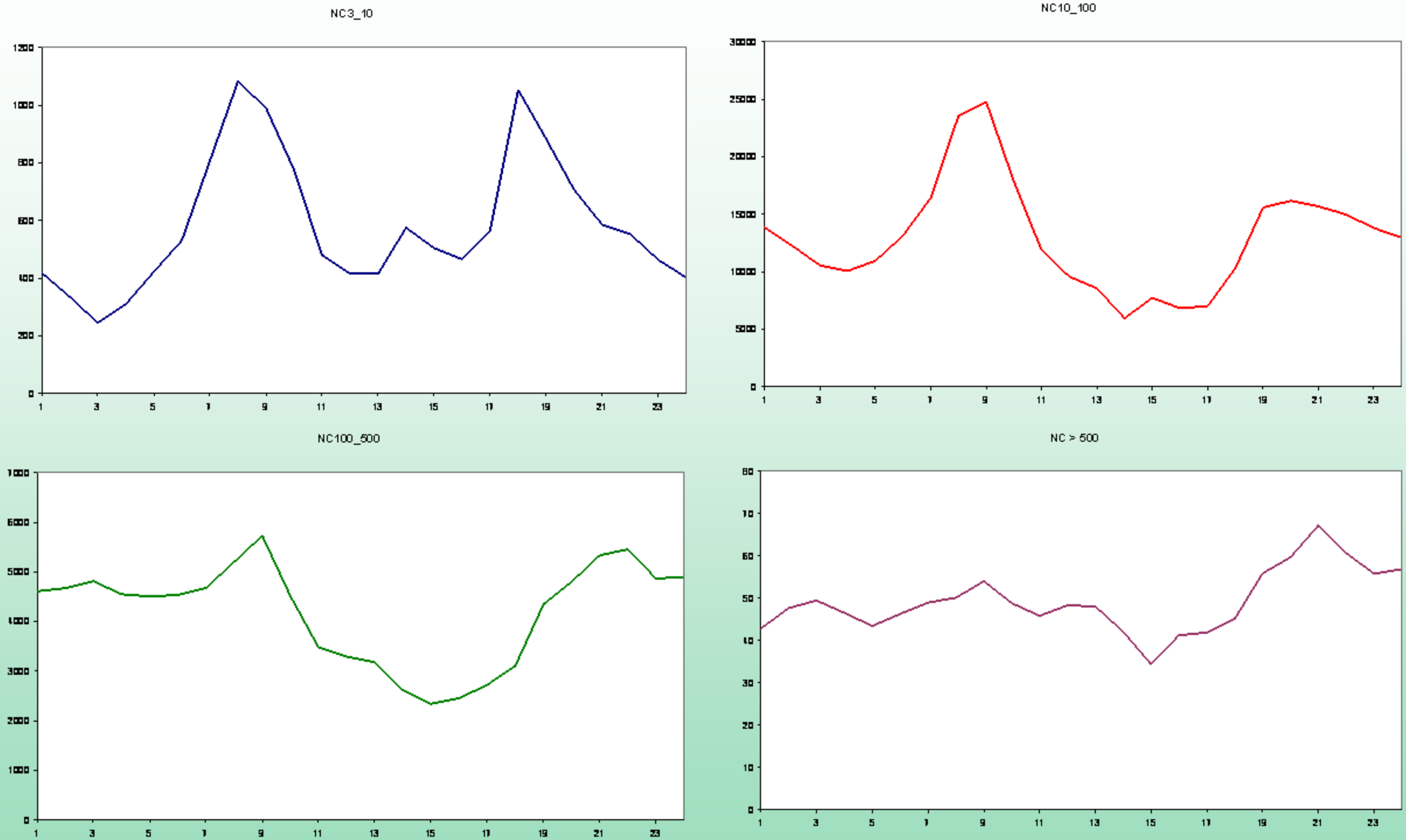
Measurements of meteorological parameters and air pollutant concentrations: 16-23/02/2007, 14-23/02/2008

- MLH: Measured by CL31 (*IMK-IFU*), software developed with MATLAB (*Vaisala, IMK-IFU)*; radiosondes *DWD* station Oberschleissheim
- Particle number concentrations (PNC) and mass concentrations (PMC): urban background site (*HMGU, EPI II; UA, WZU*)
- Meteorological parameters (*LfU; DWD; HMGU, EPI II*)

Correlations of continuous MLH, temperature, wind direction, wind speed and relative humidity data with PNC and PMC of different size fractions, hourly mean data (*IMK-IFU*)

Pitz, M., Birmili, W., Schmid, O., Peters, A., Wichmann, H.E., Cyrys, J.: Quality control and quality assurance for particle size distribution measurements at an urban monitoring station in Augsburg, Germany. J. Environ. Mon. 10(9), 1017-1024 (2008)

Ultra-fine particle measurements in Augsburg



Diurnal pattern of PNC 16-23/02/2007: 3-10 and 10-30 strong variation; 100-500 high night-time values; >500 weak variation

Spearman correlation coefficients R^2 of PNC, PMC with MLH and wind speed

hourly mean, significant >0.24: measurement errors 10 and 15 %

PNC		3 – 10	10 – 30	30 – 50	50 – 100	100 – 500	500 – 1000	1000 – 2500	2500 – 10000
2007	MLH	0.01	0.02	0.06	0.12	0.11	0.03	0.00	0.00
2008	MLH	0.00	0.15	0.24	0.35	0.46	0.19	0.16	0.07
2007	W speed	0.00	0.05	0.14	0.26	0.38	0.20	0.15	0.17
2008	W speed	0.01	0.11	0.23	0.35	0.42	0.10	0.11	0.19
PMC		3 – 10	10 – 30	30 – 50	50 – 100	100 – 500	500 – 1000	1000 – 2500	2500 – 10000
2007	MLH	0.01	0.03	0.07	0.13	0.07	0.02	0.00	0.00
2008	MLH	0.00	0.18	0.25	0.37	0.44	0.18	0.20	0.05
2007	W speed	0.00	0.08	0.19	0.39	0.44	0.22	0.18	0.12
2008	W speed	0.00	0.11	0.20	0.38	0.38	0.04	0.13	0.14

Daytime correlation coefficients smaller than during night-time

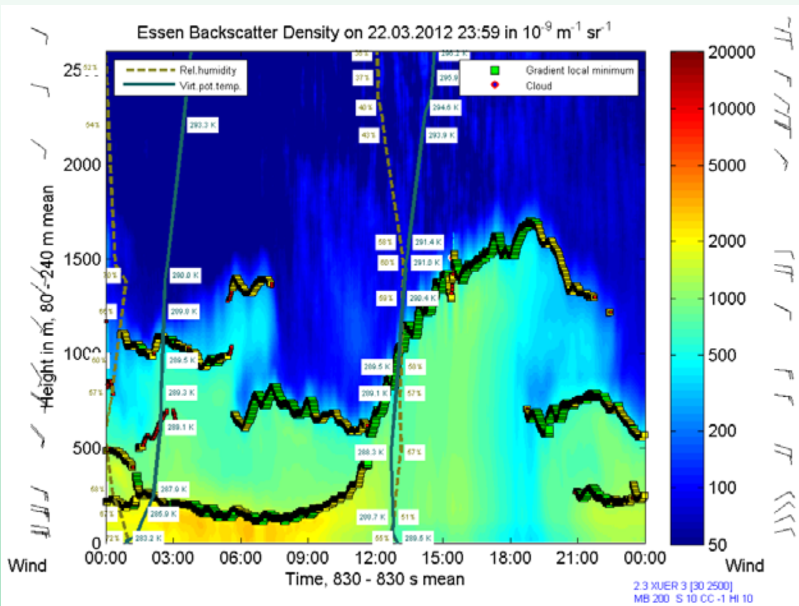
Tasks in Essen

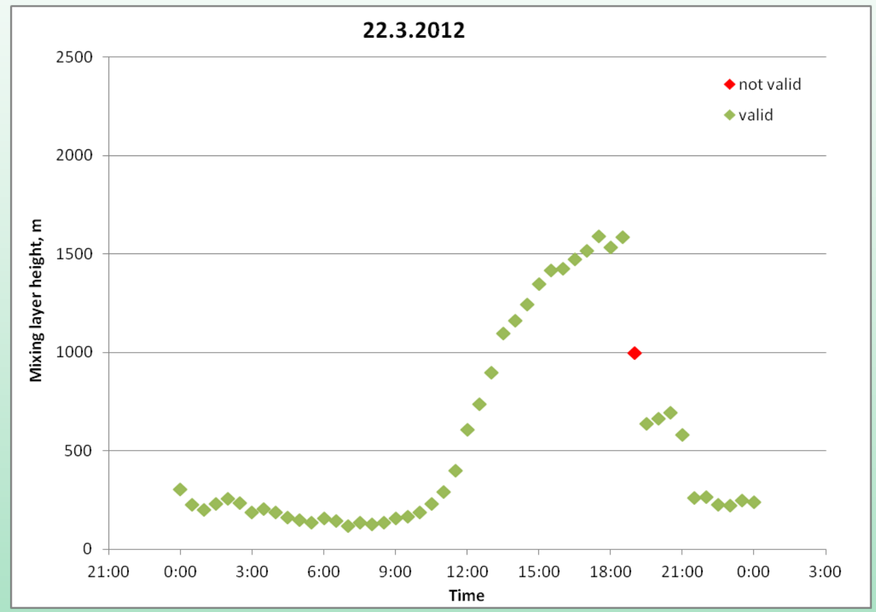
Measurements of meteorological parameters and air pollutant concentrations: 28/12/2011-17/04/2012, VOC 28/02-28/03/2012

- MLH: Measured by CL51 at *UDE* Campus Essen, software developed with MATLAB (*Vaisala, IMK-IFU)*, radiosondes *DWD* station Essen
- VOC concentrations: 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 data with air pollutant concentrations (*UDE, IMK-IFU*)

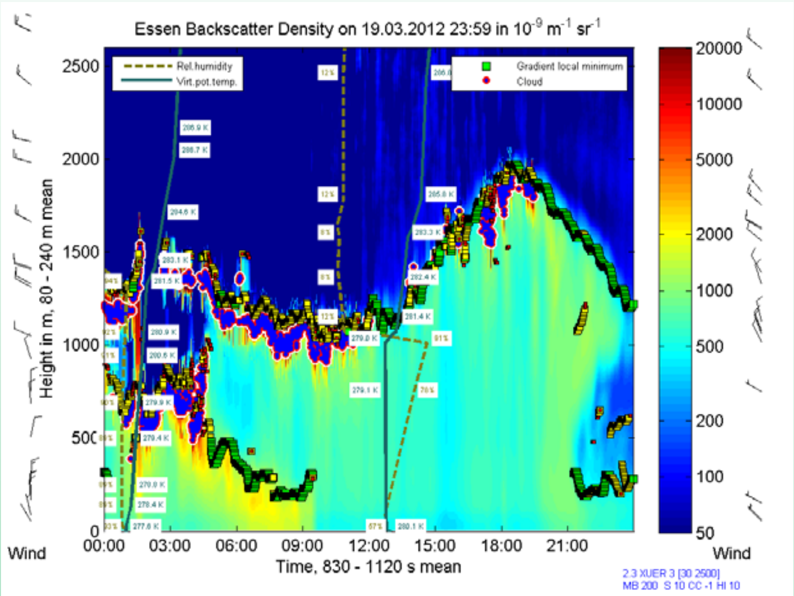
Ceilometer and radiosonde measurements in Essen

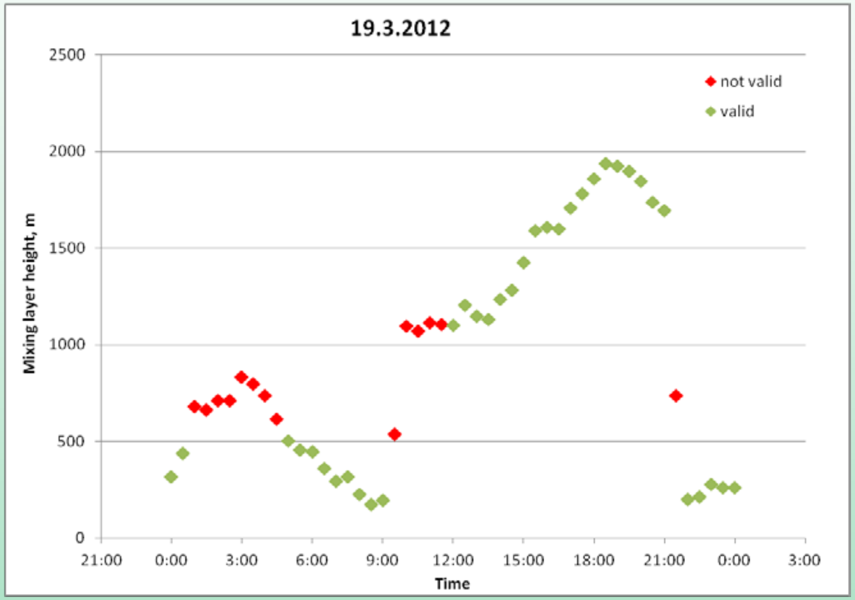




Residual layer during late night, increasing MLH during day-time, formation of a near surface layer during evening

Ceilometer and radiosonde measurements in Essen





Time frames with low clouds excluded,

cloud upper boundary is layer upper boundary 17:00 - 20:00,

no time periods with high variability of MLH considered (e.g. abrupt rise due to solar heating, formation of nocturnal inversion)

Methodology

- MLH: classification scheme of Sturges: $K = 1 + 3.32 \log N$, where K number of classes and N total number of observations

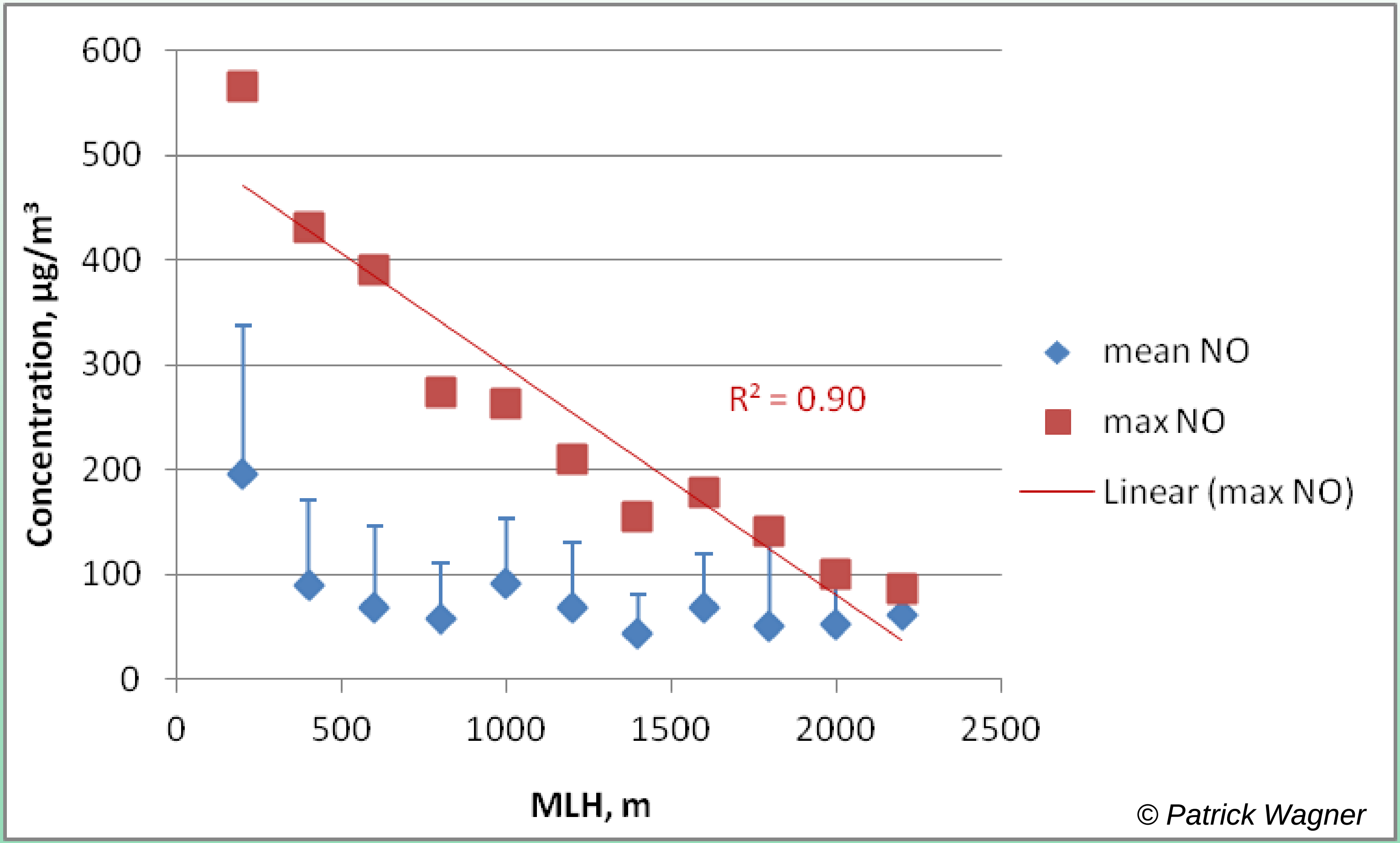
- 11 classes and a class width of 200 m intervals of MLH

  (200 m – 2200 m) instead of original 10 m intervals used for correlation analyses (i.e. mean and maximum concentrations determined for each MLH class)

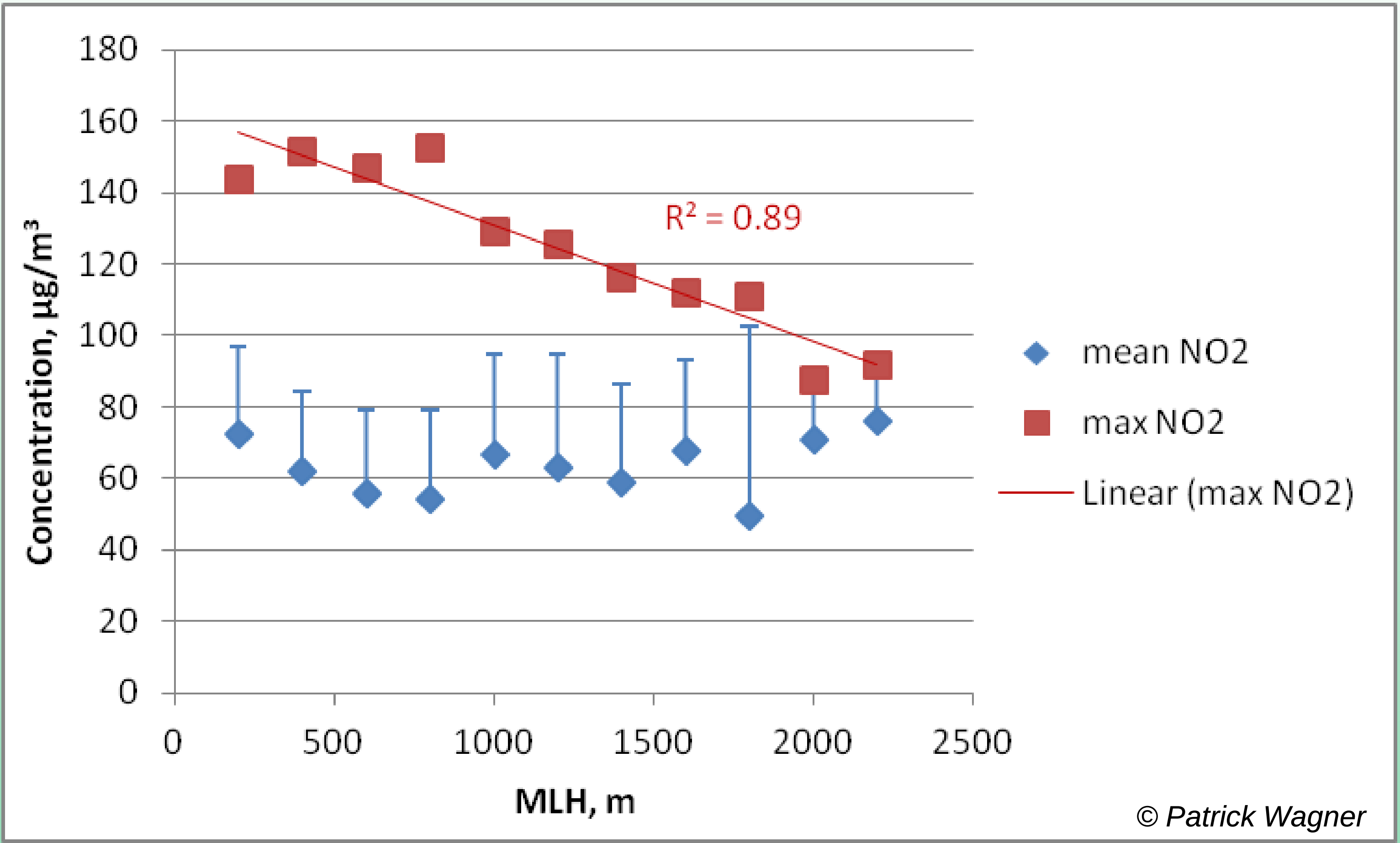
- Benzene, Toluene, Isoprene concentrations: every half hour by gas-chromatograph GC955 from Synspec b.v. during 20 min

- Enriched on Tenax GR before analyzed by GC-PID system

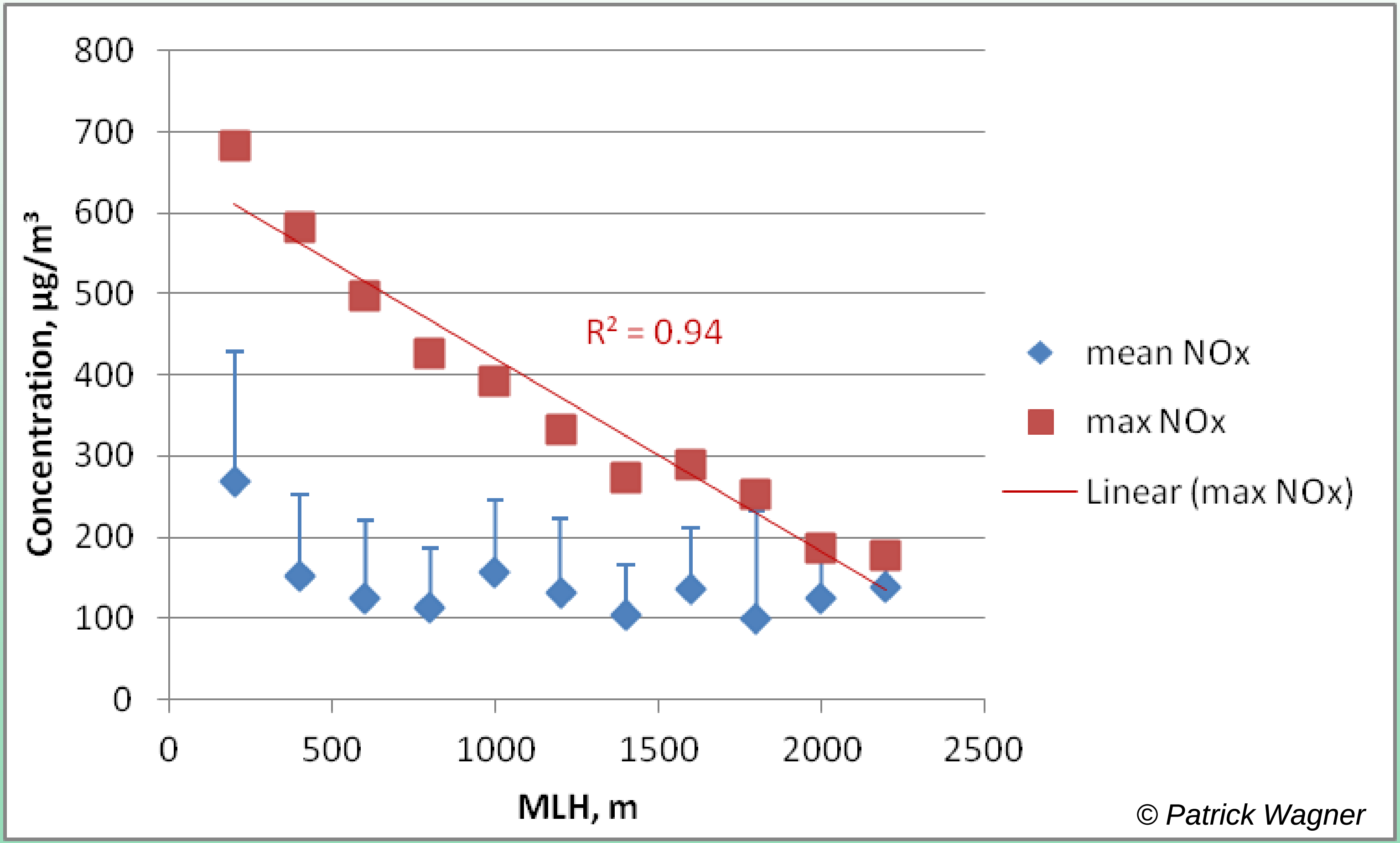
Correlation of NO concentrations with mixing layer height (Essen, Gladbecker Str.)



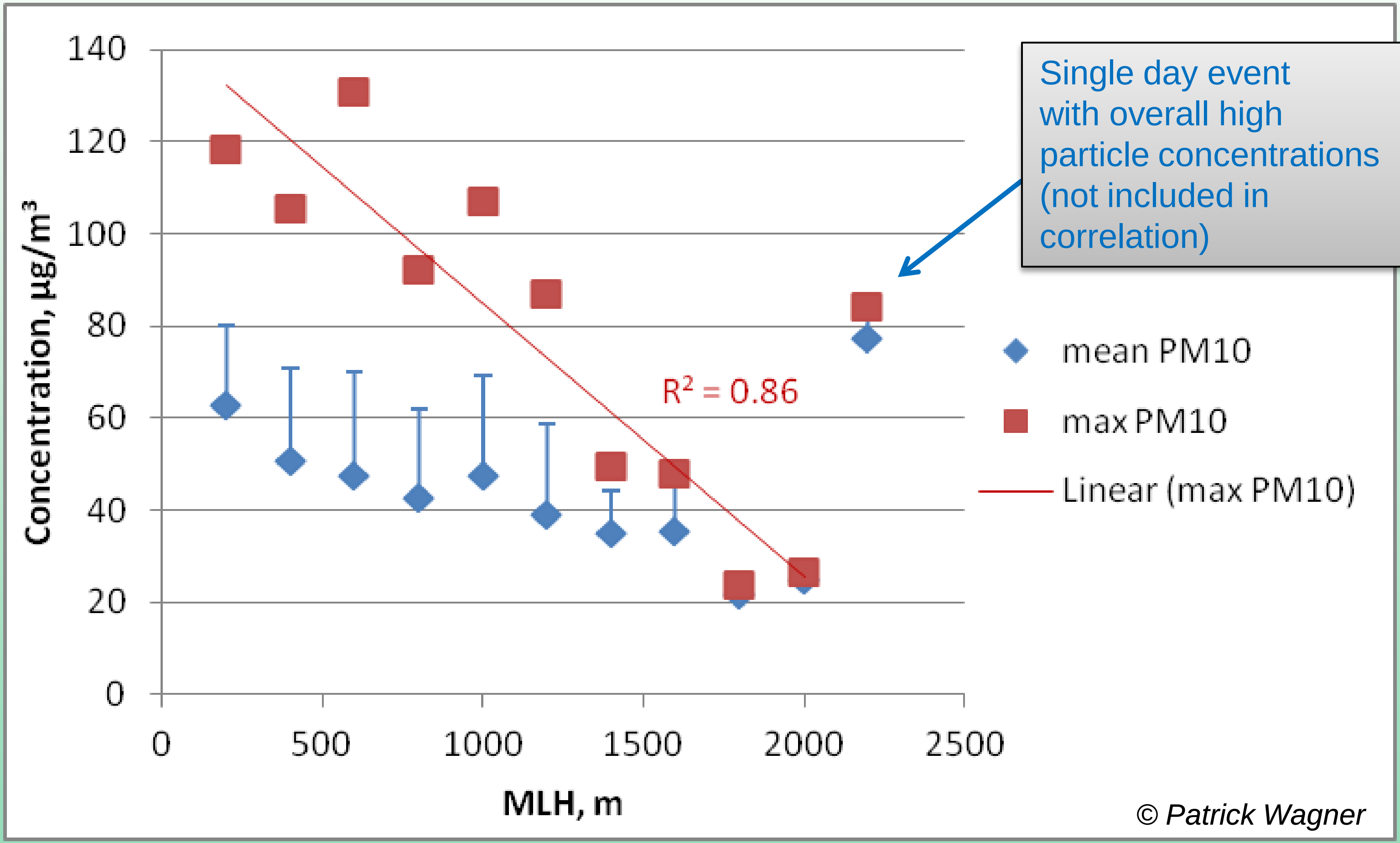
Correlation of NO_2 concentrations with mixing layer height (Essen, Gladbecker Str.)



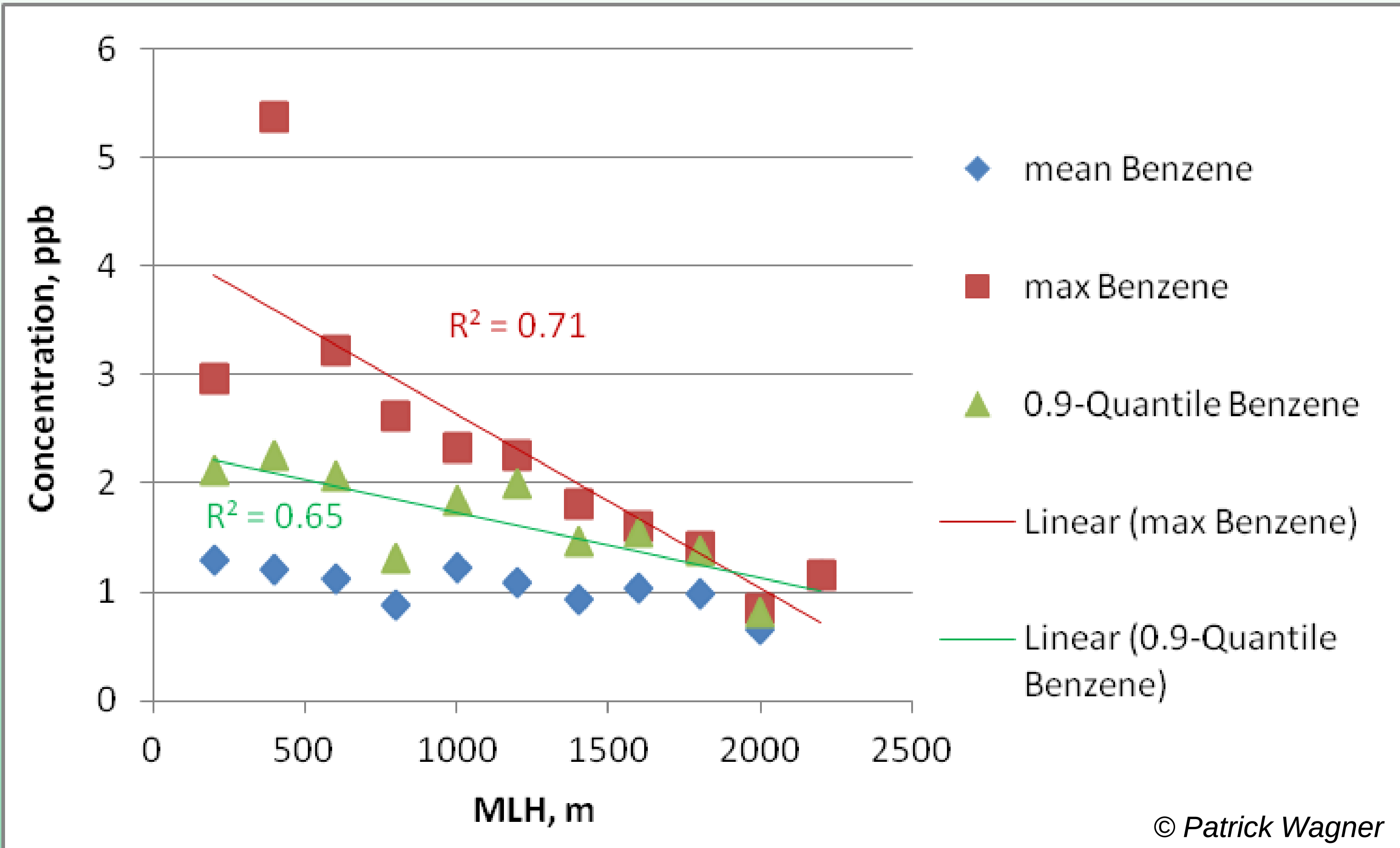
Correlation of NO_x concentrations with mixing layer height (Essen, Gladbecker Str.)



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



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



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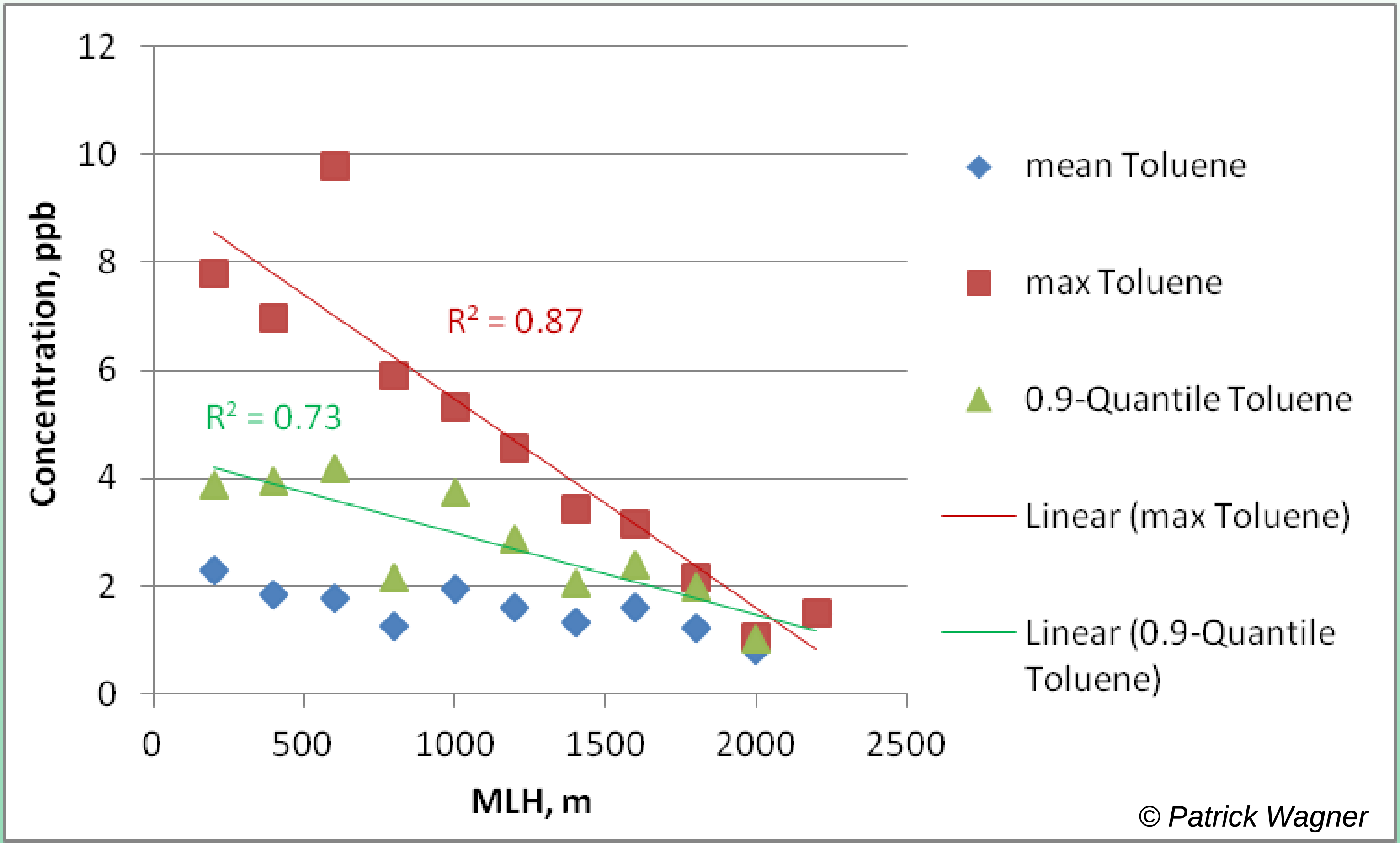
Correlation of Toluene concentrations with mixing layer height (Essen, Gladbecker Str.)



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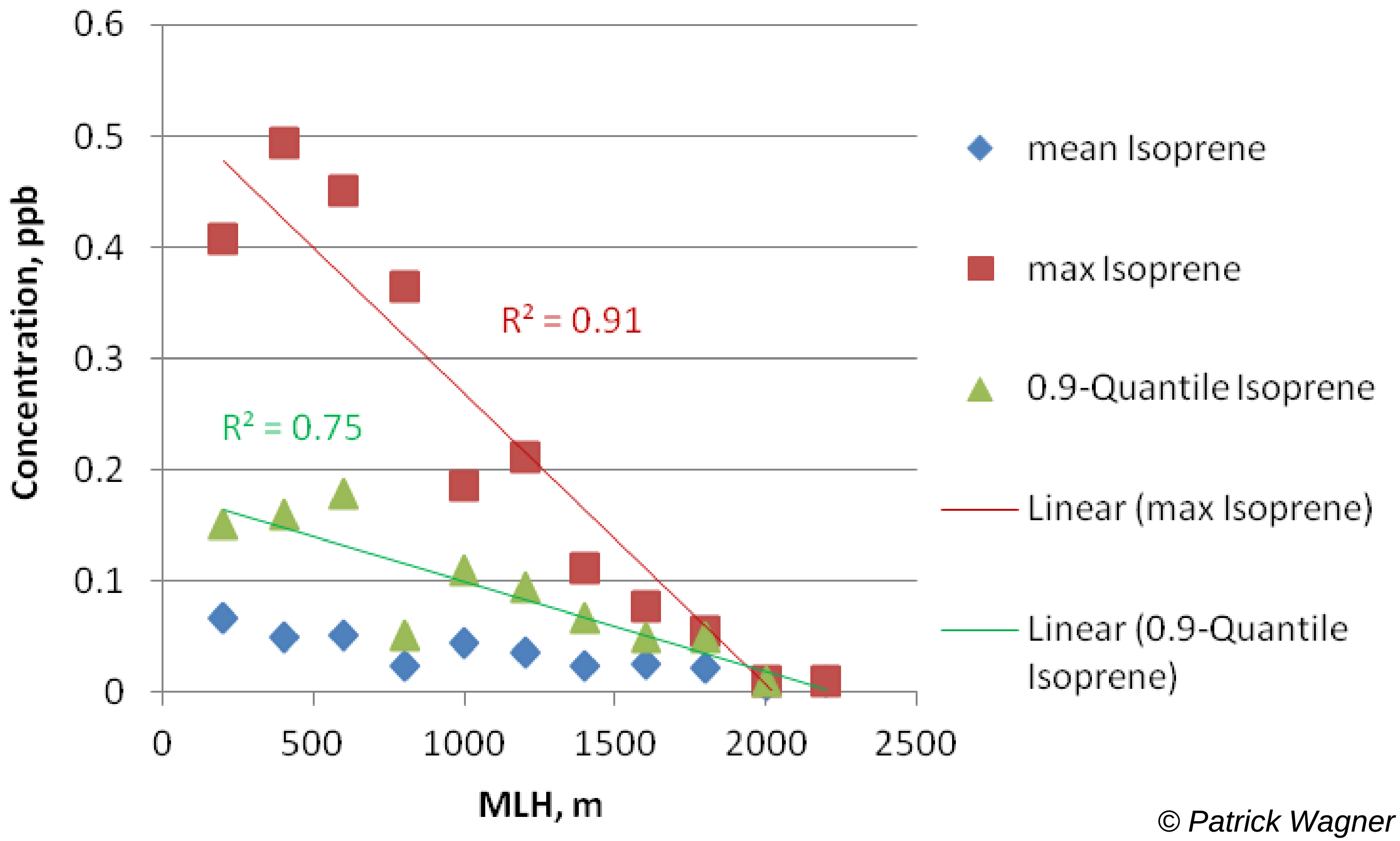
Correlation of Isoprene concentrations with mixing layer height (Essen, Gladbecker Str.)



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Conclusions

- Surface emissions - main sources of UFP in the atmosphere
  - Accumulation, coagulation and nucleation form very rapidly coarser particles
  - Larger particles (e.g. particle size range 500 - 1000 nm) influenced by formation of secondary particles
- MLH influence upon PMC significant also (as for $PM_{2.5}$, PM_{10})
  - 80 % of PNC represented by size fractions up to 100 nm
  - 70 % of PMC in size fraction 100 – 500 nm

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. Meteorol. Z. 21, 1, 47-57 (2011)

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. Sci. Total Environ. 383, 1-3, 141-163 (2007)

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Thank you very much for your attention

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