Influences of meteorological parameters and emission sources upon air pollution in urban areas

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(Source: KIT/IMK-IFU)

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

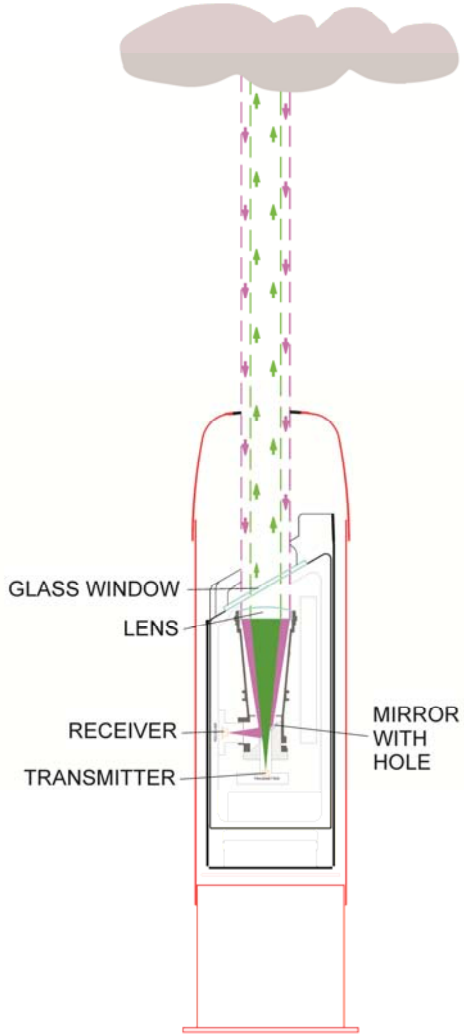
Motivation, objectives

- Local emissions only cannot explain high air pollution episodes in urban areas, especially during cold seasons
- Incomplete understanding of emissions, transport, chemistry – but required for development of emission reduction measures
- Application of source apportionment methods: contributions of different emission sources, also in the surroundings
- Backward trajectory and cluster analyses: long-range transport
- Mixing layer height (MLH) controls vertical space for mixing: influenced by climate change - quality of living in cities

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), 647-658.

Methodology

CL 31 and 51 Ceilometer (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

One-lens design – complete overlapping

Continuous monitoring by uninterrupted remote sensing, limited by fog and rain

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).

Methodology

Radio-Acoustic Sounding System (RASS)

- Profiles of wind speed, wind direction, variance of vertical wind component and of acoustic temperature
- Vertical resolution of 20 m
- Up to a height of 540 m

(Source: KIT/IMK-IFU)

- Threshold of temperature gradient set at 1.0 K/100 m
- All values higher than this threshold taken as range of the upper boundary height of the detected layer

Emeis, S., Schäfer, K., Münkel, C.: Observation of the structure of the urban boundary layer with different ceilometers and validation by RASS data. Meteorologische Zeitschrift 18, 2, 149-154 (2009).

Tasks in Augsburg

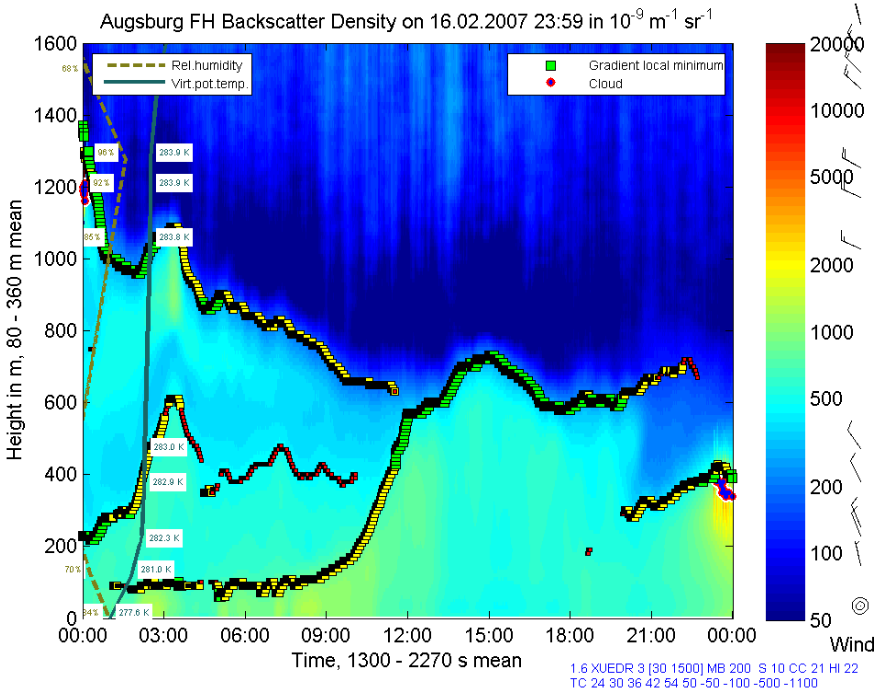
Measurements of meteorological parameters and air pollutant concentrations: 16-23/02/2007, 14-23/02/2008

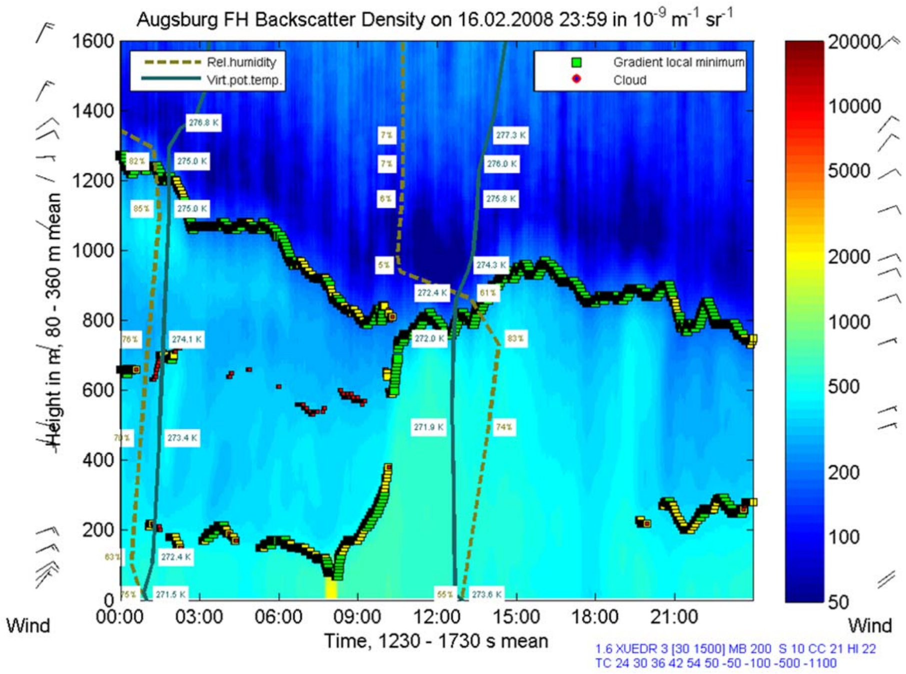
- MLH: Measured by CL31 (*IMK-IFU*), software developed with MATLAB (*Vaisala, IMK-IFU)*; radiosondes *DWD* station Oberschleissheim
- Particle number concentrations (PNC) and mass concentrations (PMC): urban background site (*EPI II; UA, WZU*)
- Meteorological parameters (*LfU; DWD; EPI*)

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).

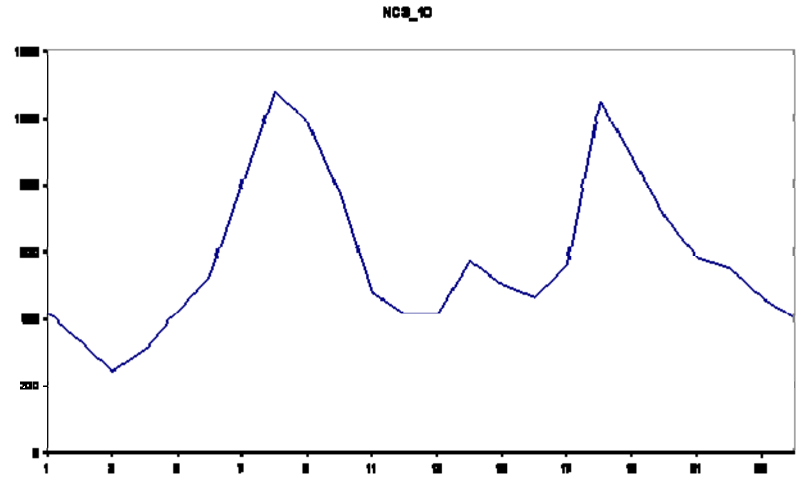
Ceilometer measurements in Augsburg
Radiosonde measurements in Oberschleißheim
(60 km distance)

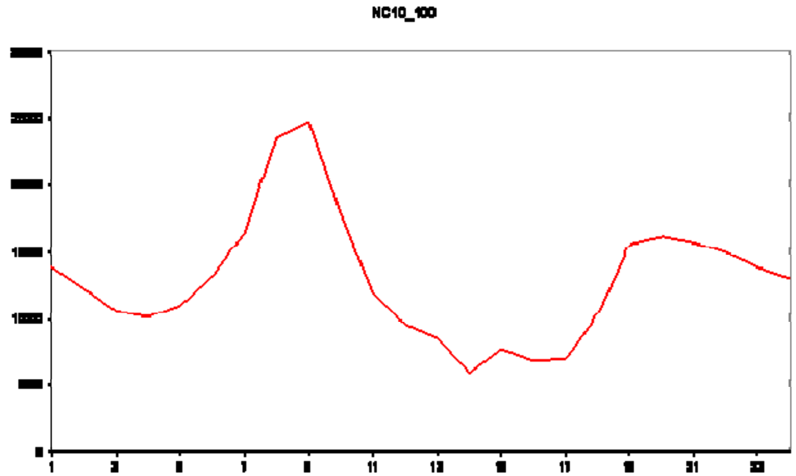


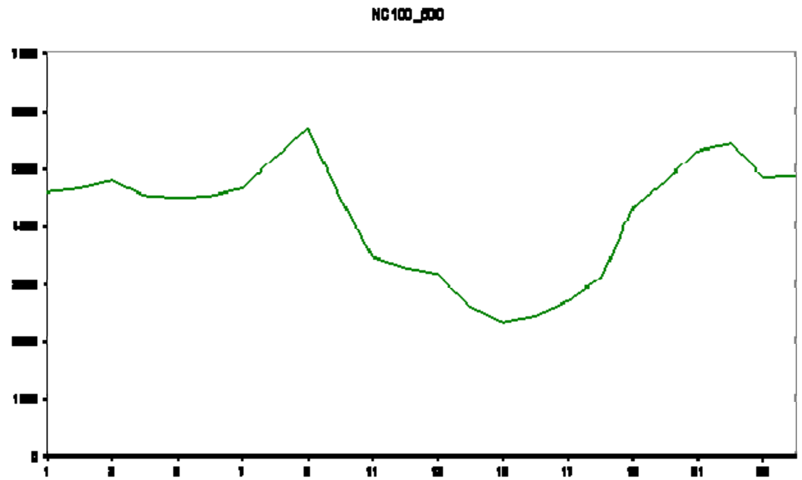


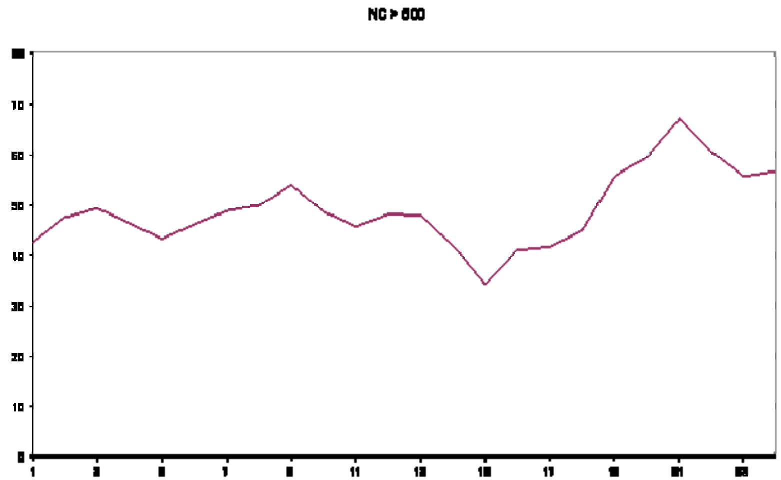
Ultra-fine particle measurements in Augsburg

Diurnal pattern of PNC 16-23/02/2007









Results

- PSD not only influenced by emissions and aerosol formation processes but also by meteorological parameters

- Daily variation of PNC and PMC coupled directly with MLH, wind speeds

- Significant correlation of hourly-mean values of PNC / PMC in size range 100 – 500 nm with MLH (R^2=0.46) and wind speeds (R^2=0.42):

  lower correlation coefficients for particles of bigger as well as smaller size

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)

Tasks in Essen

Measurements 28/12/2011-17/04/2012, VOC 28/02-03/04/2012

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

- NO, NO_2 and PM_{10} concentrations of LANUV Nordrhein-Westfalen: kerb site Gladbecker Str.

Correlations continuous MLH - air pollutants (*UDE, IMK-IFU*)

Wagner, P., Kuttler, W.: Biogenic and anthropogenic isoprene in the near-surface urban atmosphere - A case study in Essen, Germany. Sci. Total Environ., 475, 104–115 (2014).

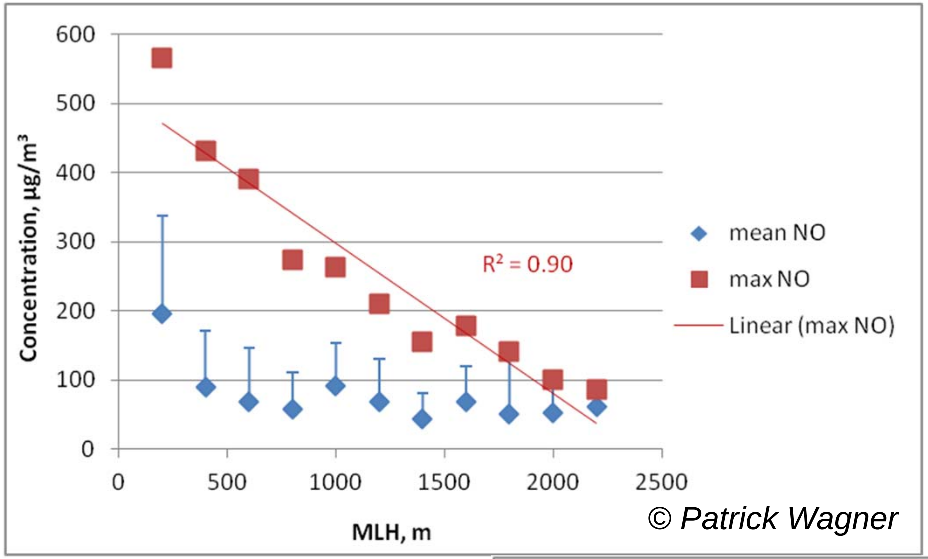
Methodology

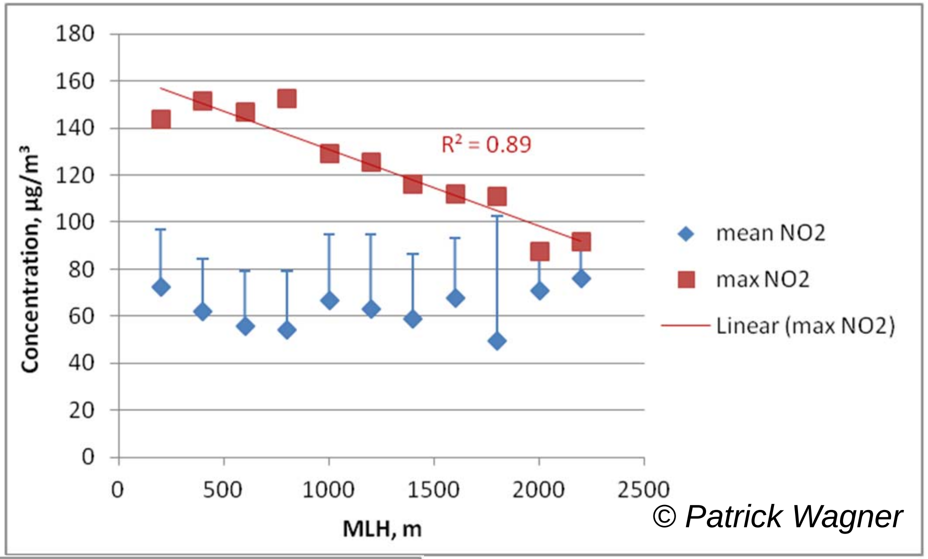
- MLH: statistical classification scheme of Sturges:
  $K = 1 + 3.32 \log N$, K number of classes, N number of data

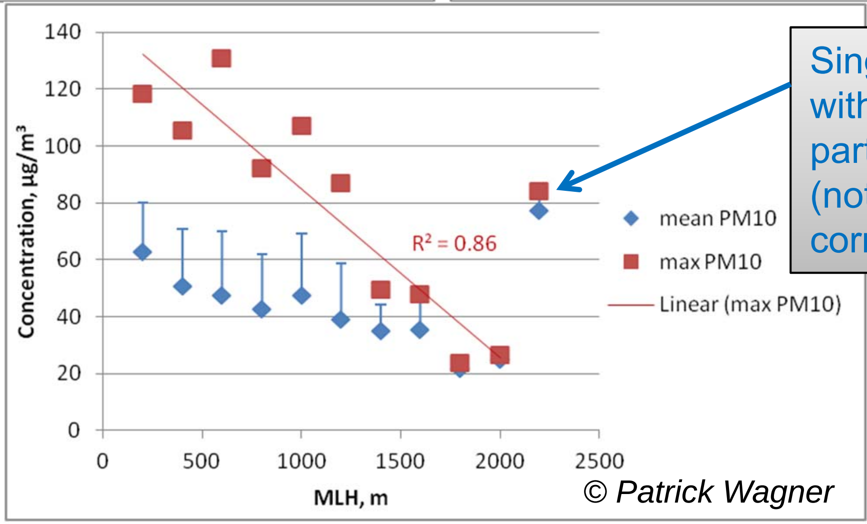
- 11 classes and a class width of 200 m intervals of MLH (200 m – 2200 m) instead of original 10 m intervals

- Mean and maximum concentration determined for each MLH class

Correlations

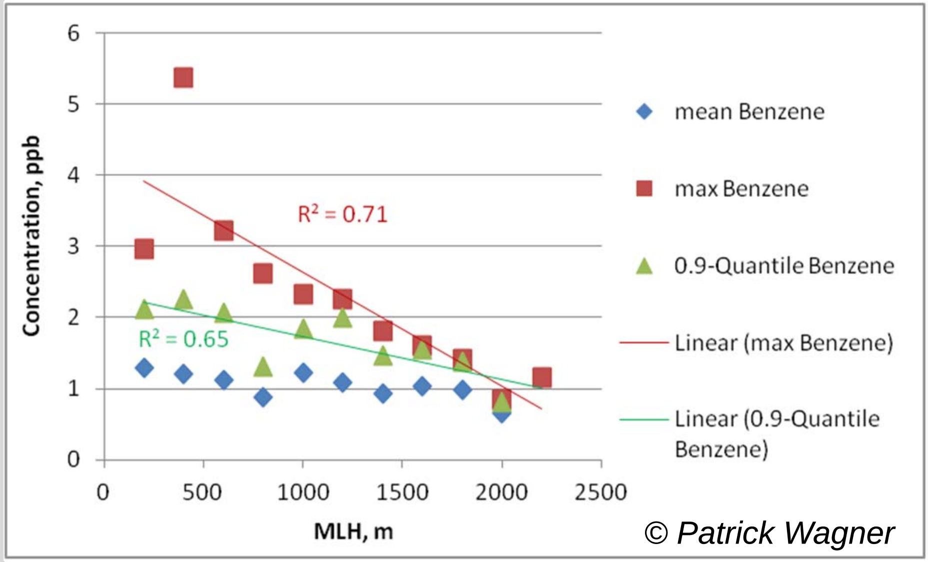


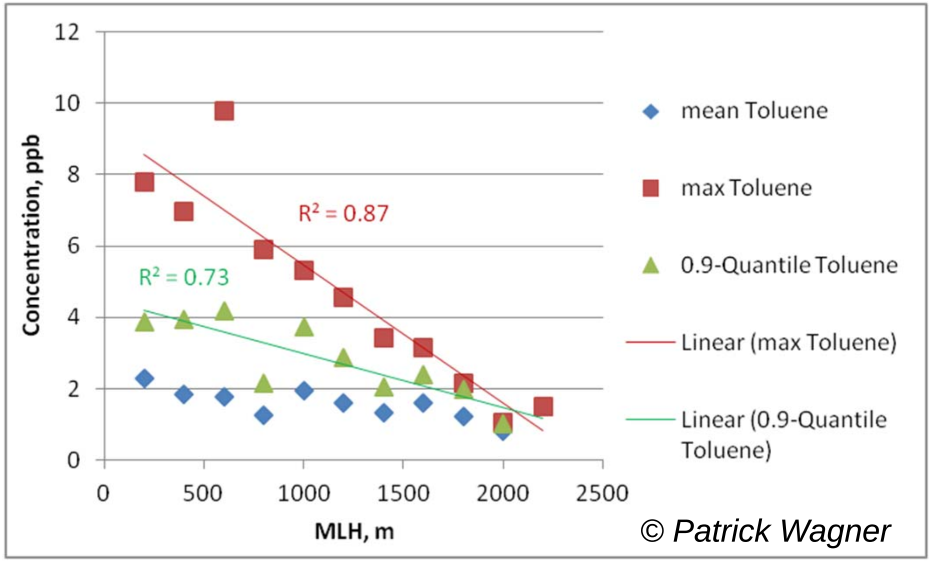


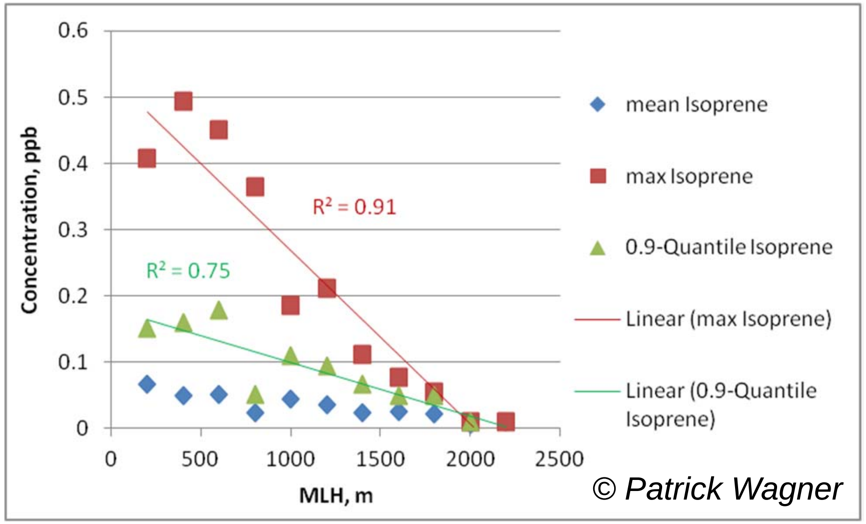


Single day event with overall high particle concentrations (not included in correlation)

Correlations







Conclusions

- Maximum concentrations affected strongly by MLH and atmospheric stability
- Best correlation results for 200 m intervals of MLH
- Higher correlation coefficients of maximum NO, NO_2, PM_{10}, Benzene, Toluene, Isoprene concentrations in street canyon with MLH than for mean concentrations in urban and rural background with MLH (Munich, Hannover, Augsburg, Budapest, Athens)

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, 141-163, (2007).
Schnelle-Kreis, J., Orasche, J., Abbaszade, G., Schäfer, K., Harlos, D.P., Hansen, A.D.A., Zimmermann, R.: Application of direct thermal desorption gas chromatography time-of-flight mass spectrometry for determination of non-polar organics in low volume samples from ambient particulate matter and personal samplers. Anal. Bioanal. Chem., 401, 3083–3094 (2011).
Helmis, C. G., Sgouros, G., Flocas, H., Schäfer, K., Jahn, C., Hoffmann, M., Heyder, C., Kurtenbach, R., Niedojadlo, A., Wiesen, P., O'Connor, M., Anamaterou, E.: The role of meteorology on the background air quality at the Athens International Airport. Atmos. Environ., 45, 5561-5571 (2011).

Tasks in Beijing

$PM_{2.5}$ filter sampling by 2 HVS DHA80, 500 l min^{-1} *(IMK-IFU)*

06/10 – 06/2011 at CUGB, since 04/2013 at IAP

Meteorological, MLH data: *ZBAA, IAP, IMK-IFU*

(Source: KIT/IMK-IFU)

Methodology

- Filters: Quartz fibre filters (Ø 150 mm)

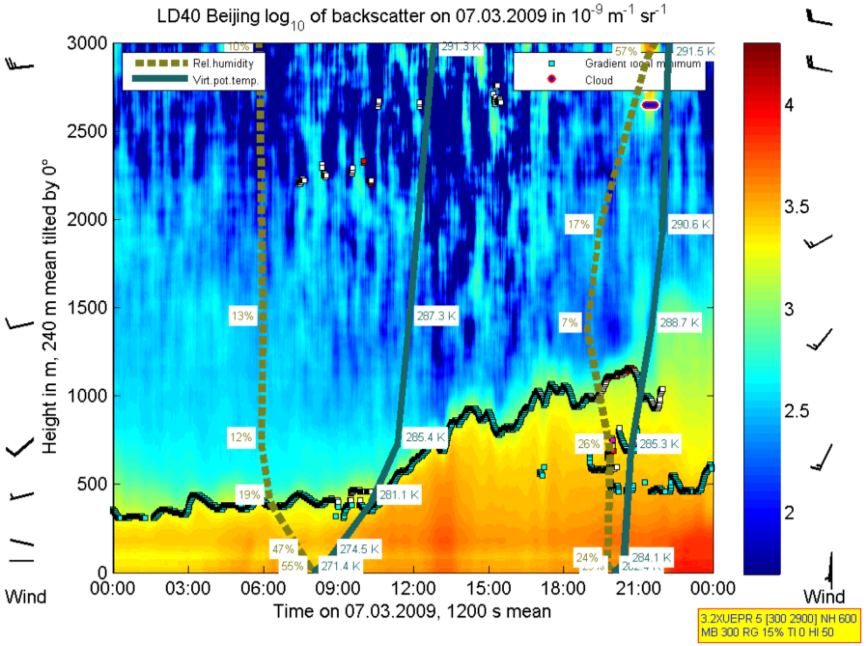
- Sampling time: 24 h (00:00-24:00); 4 h (some haze episodes)
  - <u>Sampler A</u>
    - Organics: Gas chromatography-mass spectrometry *(CMA)*
    - EC/OC: Thermal/optical carbon analyser *(U Rostock, IAP)*
    - Ions: Ion chromatography, continuous flow analyser *(CMA, IAP)*
  - <u>Sampler B</u>
    - Mass concentration: Gravimetric determination *(IMK-IFU)*, TEOM (Tapered element oscillating microbalance) *(IAP)*
    - Elements: Polarized energy dispersive X-ray fluorescence *(IGG)* Inductively coupled plasma mass spectrometry *(IGG, IAP)*

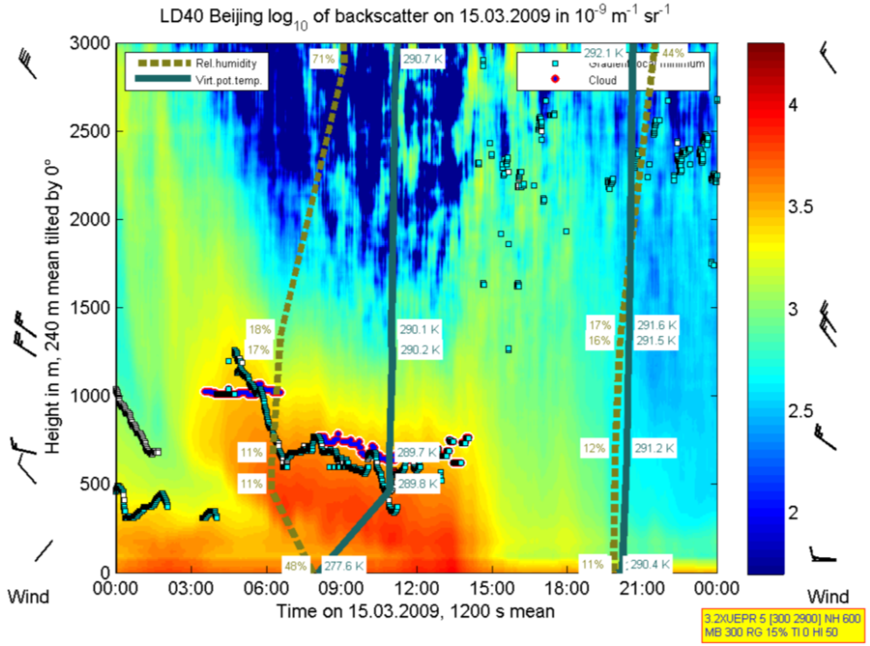
Evaluations in Beijing

Karlsruhe Institute of Technology

Higher particulate loads during winds from South-West

Desert dust clouds, winds from West, dry air





MLH > 1000 m: often multiple layering, < 1000 m: often one layer

High $PM_{2.5}$ load (40 – 140 µg/m³): MLH much lower than 1000 m

Meteorological influences

- RH: ↑ PM mass concentration
- WS: ↑ dilution of pollutants
- MLH: ↑ dilution of pollutants - widespread area sources
- WD: transport of pollution from local and regional sources

→ Haze days: high RH/low MLH, stagnant weather conditions with low air mass exchange, highest Zn, As and Pb from anthropogenic activities

→ Dust days: high wind speed, highest Fe, Ti and Ba from mineral dust

Visibility: negative correlated with RH and anthropogenic compounds, especially NO_3^-, SO_4^{2-}, and NH_4^+

(Source: KIT/IMK-IFU)