Investigation of air quality by particulate, meteorological and traffic emission measurements in Beijing

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- Strategic background
- Process studies
  - Methodology
  - Influences upon air pollution
- Future work and perspectives

Strategic background

Strategic topics

- Knowledge about the interaction of climate, biosphere, ecosystems and human activities
- Aerosol research (fine / ultra-fine particles) – loads / composition / formation / sources
- Process studies of air pollution relevant for health protection and legislation (NO_2, PM_{10}, $PM_{2.5}$)

Influences of regional climate change
(T, RH, wind, prec., rad., MLH)

Changing surface fluxes

Transport, Chemistry →

← Emission rates

Changing ambient air concentrations

Differences of scales in space and time

Process studies

Methodology

Problems

Although a lot of measures for
• emission reduction (health protection) and
• efficient energy consumption (climate protection)
in the traffic and industrial sector have been realised so far, the following problems remain:

High amount of ultrafine particles in urban background
NO_2/NO_x ratio in ambient air continuously increasing

How to reduce NO_2 and PM_{10} in a sustainable way?

Threshold values acceptable for health protection?

Solutions

Investigation of processes leading to high air pollution by application of remote sensing methods and modelling techniques

Study of the interactions between urban areas and its surroundings

Determination of emission source strengths for modelling: Gaps; Hot spots

Validation of air quality modelling:
Validation strategies; Data requirements

Scientific questions

- Which regional meteorological situations (transport and exchange conditions),
- which secondary aerosol formation processes and
- which emission processes

cause high air pollutant (mainly PM, NO_2) exposures?

In particular:

- Local wind systems and secondary circulation systems
- MLH: spatial variation of air pollutants, long-term study
- Urban area – surroundings interactions

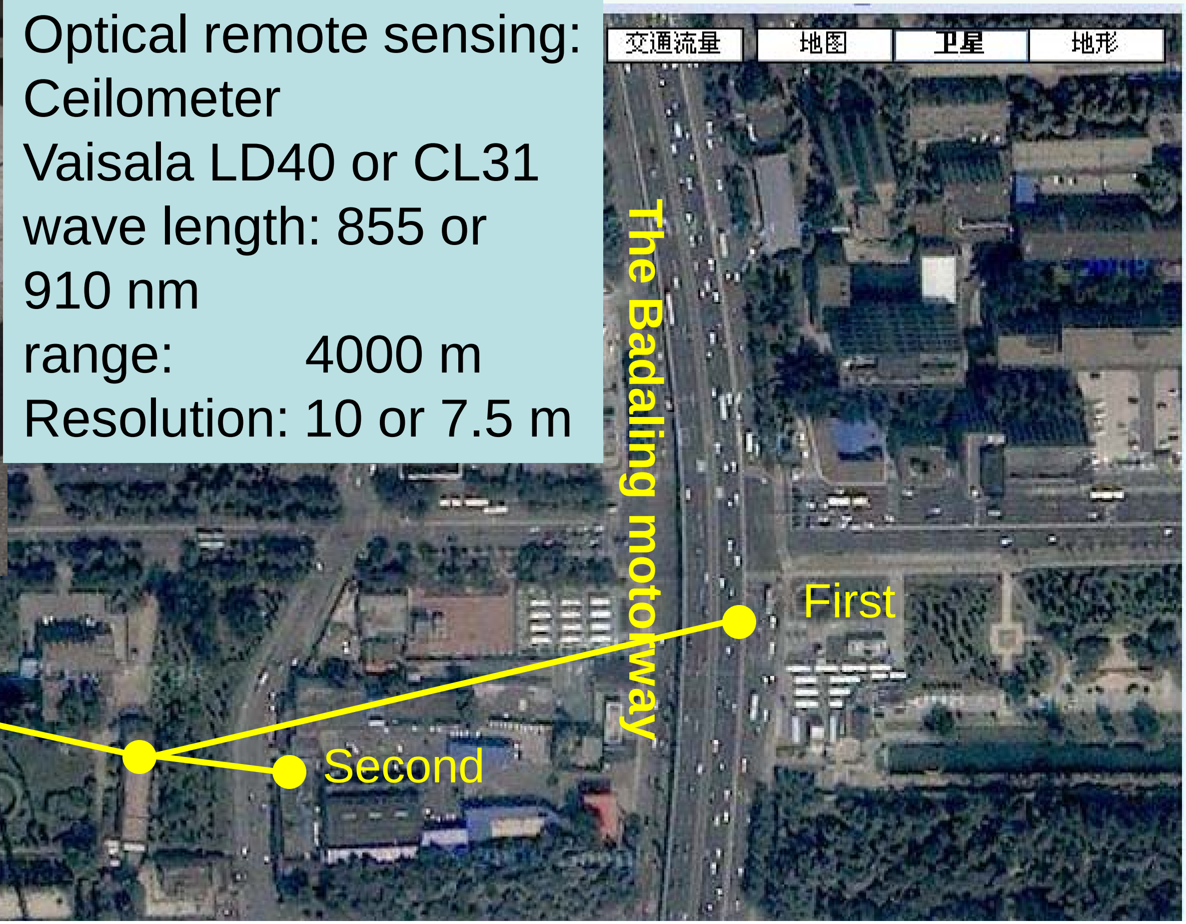
Schäfer, K., Emeis, S., Hoffmann, H., Jahn, C.: Influence of mixing layer height upon air pollution in urban and sub-urban area. Meteorol. Z. 15 (2006), 647-658.

Wiegner, M., Emeis, S., Freudenthaler, V., Heese, B., Junkermann, W., Münkel, C., Schäfer, K., Seefeldner, M., Vogt, S.: Mixing Layer Height over Munich, Germany: Variability and comparisons of different methodologies. Journal of Geophysical Research - Atmospheres, 111 (2006), D13201.

Beijing

Measurement sites: LAPC tower, ceilometer, DOAS February 2009 until July 2009

Optical remote sensing:
Ceilometer
Vaisala LD40 or CL31
wave length: 855 or 910 nm
range: 4000 m
Resolution: 10 or 7.5 m



Münkel, C., "Mixing height determination with lidar ceilometers - results from Helsinki Testbed," Meteorol. Z. 16, 451-459 (2007).

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

Beijing

Measurement sites: LAPC tower, DOAS from 13 July 2009 on

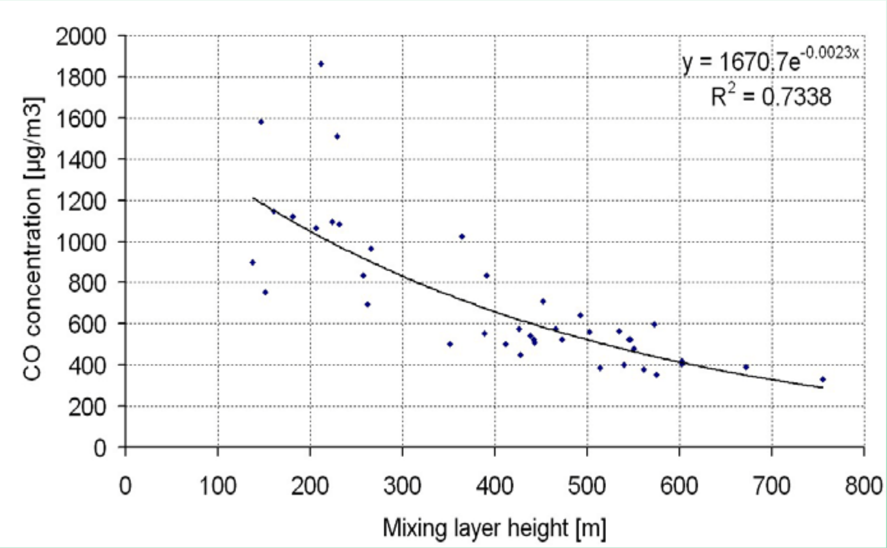
Schäfer, K., Vergeiner, J. Emeis, S., Wittig, J., Hoffmann, M., Obleitner, F., Suppan, P.: Atmospheric influences and local variability of air pollution close to a motorway in an Alpine valley during winter. Meteorologische Zeitschrift, 17, 3, 297-309 (2008)

Process studies

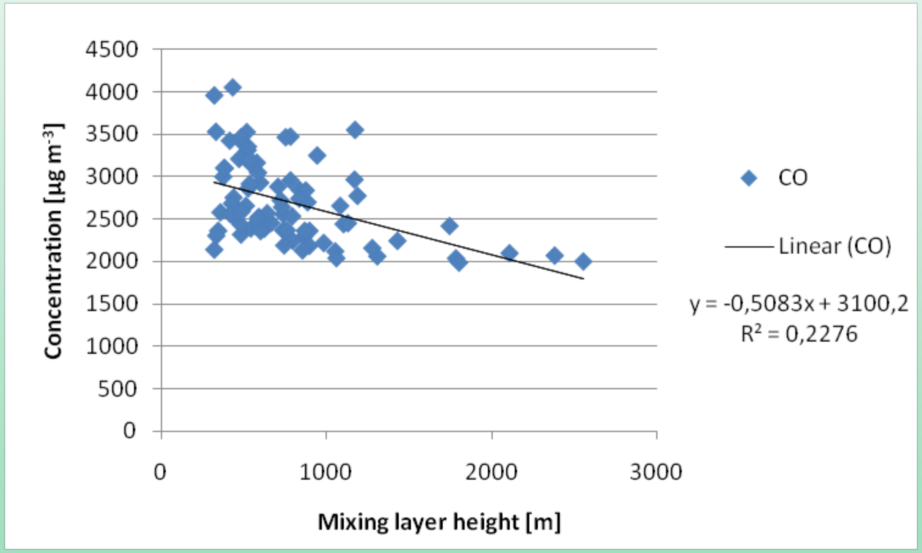
Influences upon air pollution

Correlation of air pollutant CO with MLH

Urban stations Munich
10 – 29 May 2003 and
27 Nov. – 19 Dec. 2003



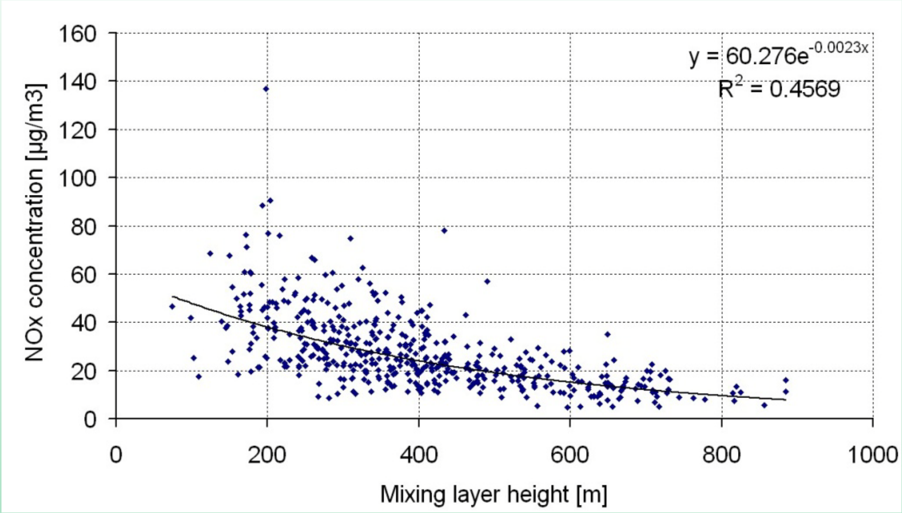
Mexico City International
Airport
12 – 16 April 2006



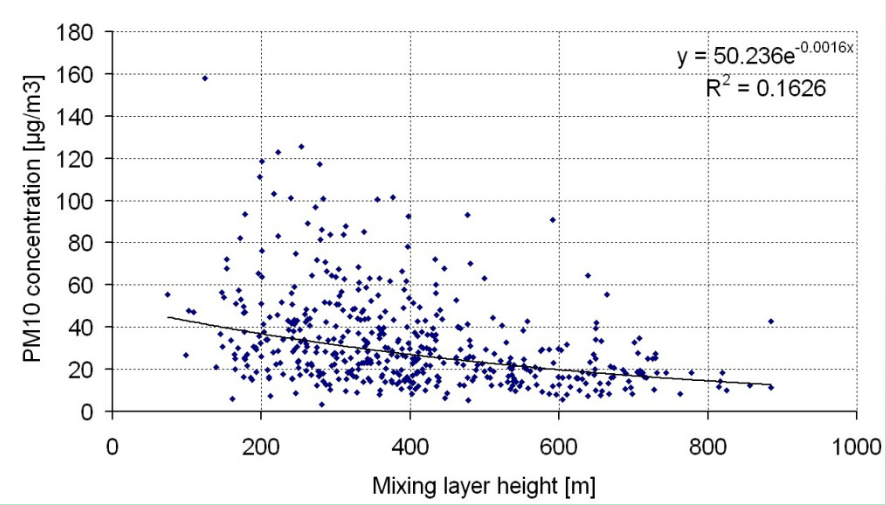
Schäfer, K., S. Emeis, H. Hoffmann, C. Jahn: Influence of mixing layer height upon air pollution in urban and sub-urban areas. Meteorol. Z., 15, 647-658 (2006).

Correlation of air pollutants (roof station Hannover) with MLH

October 2001 - April 2003



NO_x



PM_{10}

Schäfer, K., Emeis, S., Hoffmann, H., Jahn, C., Müller, W., Heits, B., Haase, D., Drunkenmölle, W.-D., Bächlin, W., Schlünzen, H., Leitl, B., Pascheke, F., Schatzmann, M.: Field measurements within a quarter of a city including a street canyon to produce a validation data set. International Journal of Environment and Pollution, 25, 1/2/3/4, 201-216, (2005).

Tasks for evaluations in Beijing

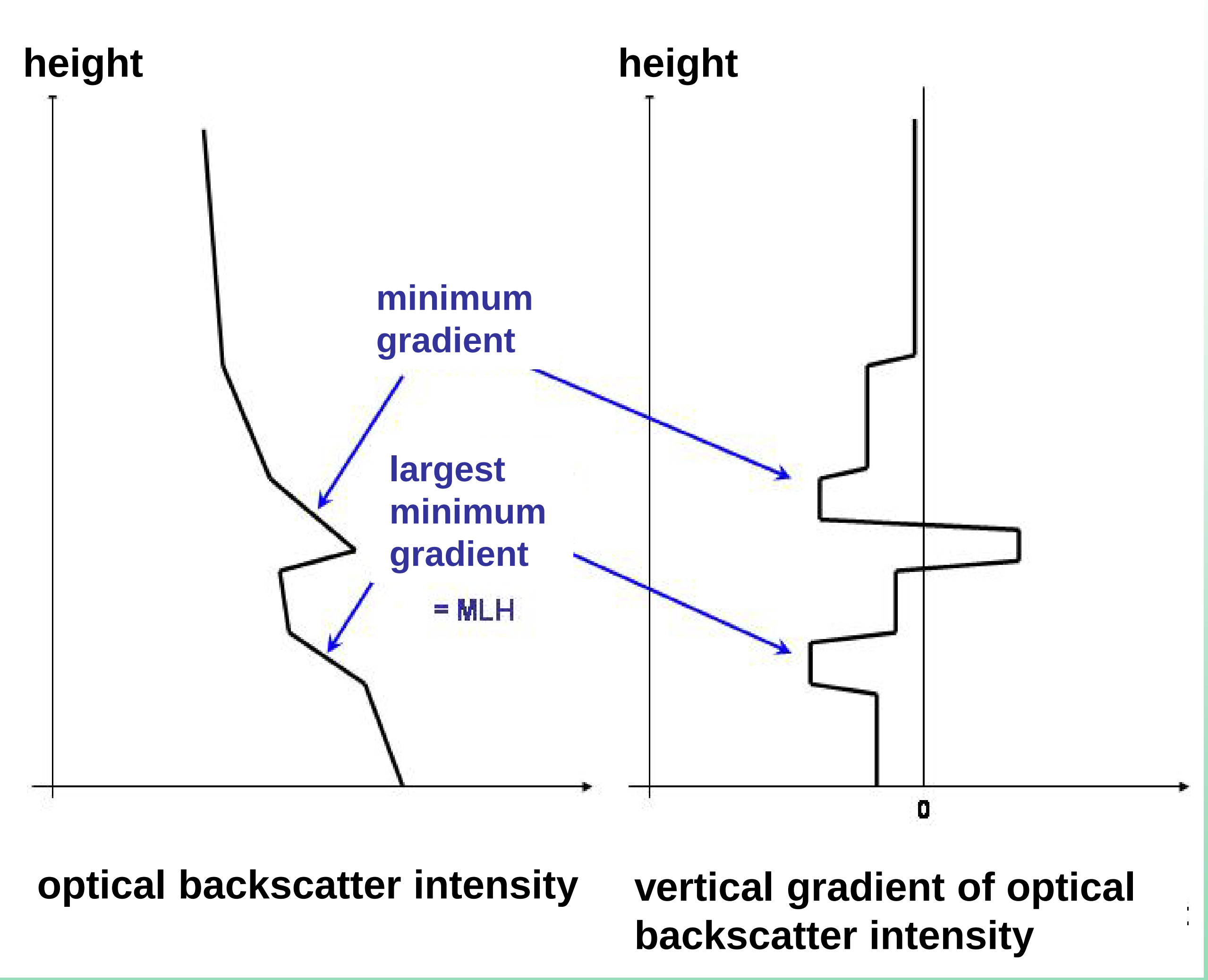
Analyses of height dependent particulate loads

- $PM_{2.5}$ and PM_{10} concentrations, sampled actively at CRAES, LAPC and CUMTB and in 80 m altitude at 325 m LAPC tower by mini-volume sampler and TEOM (KIT/IMG, KIT/IGG, CUMTB, LAPC)
- Analyses of quartz fibre filters by ICP-MS for trace elements and main elements (KIT/IMG, KIT/IGG)
- Continuous MLH ceilometer measurements (KIT/IMK-IFU, Vaisala, LAPC)
- Meteorological monitoring at 325 m LAPC tower (LAPC)
- Path-averaged concentrations of air pollutants NO_2 (SO_2, O_3, Benzene / Toluene, Xylene, NO, NH_3, HCHO) near and across a motorway: DOAS (at LAPC building, three retroreflectors, automatic operation) (KIT/IMK-IFU, LAPC)

Evaluations in Beijing

Algorithms to detect MLH from ceilometer data

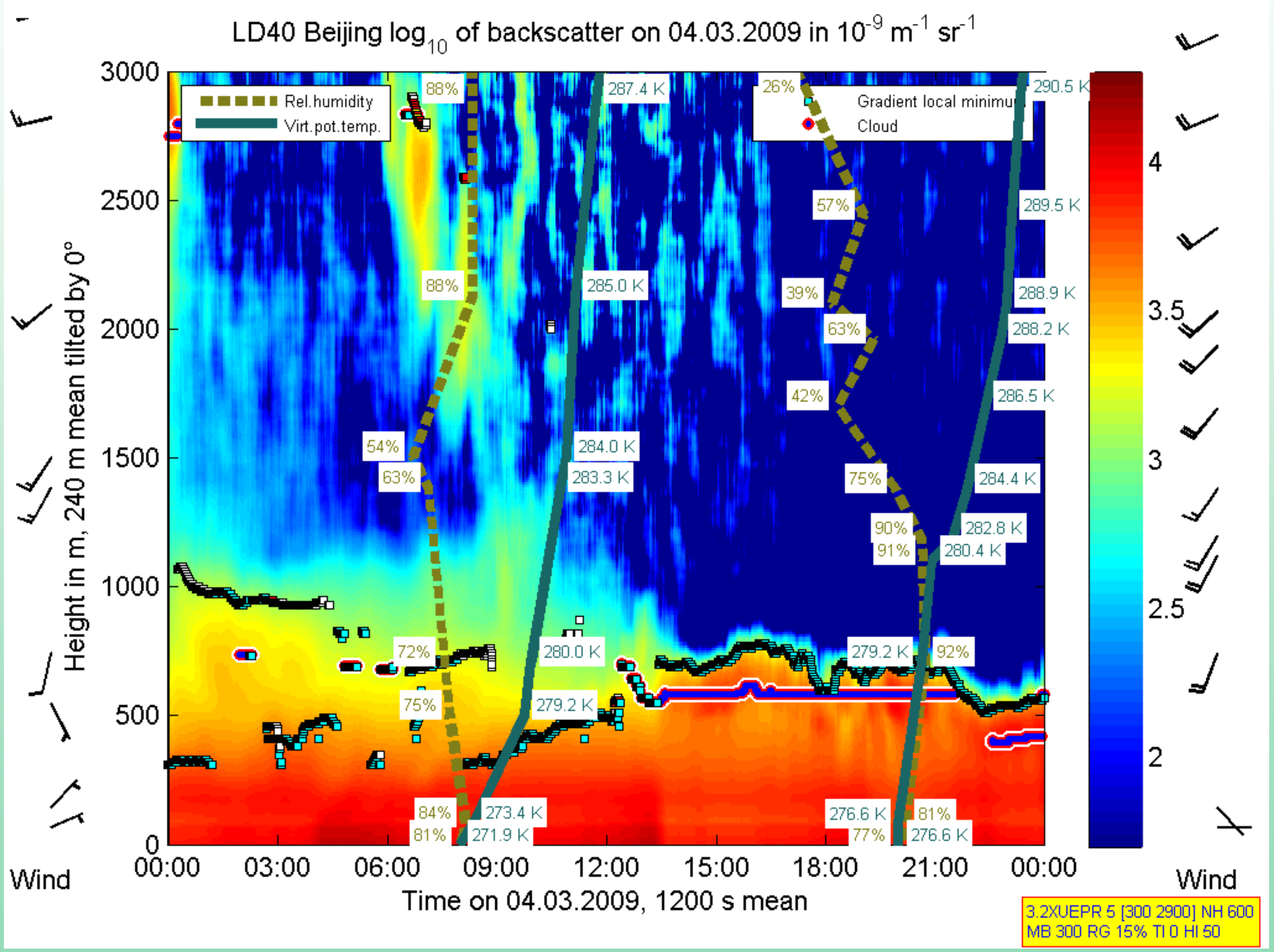
Criterion:
minimal vertical gradient of backscatter intensity (the most negative gradient)



Emeis, S., Schäfer, K., Münkel, C.: Surface-based remote sensing of the mixing-layer height – a review. Meteorologische Zeitschrift 15, 5, 621-630 (2008); DOI: 10.1127/0941-2948/2008/0312.

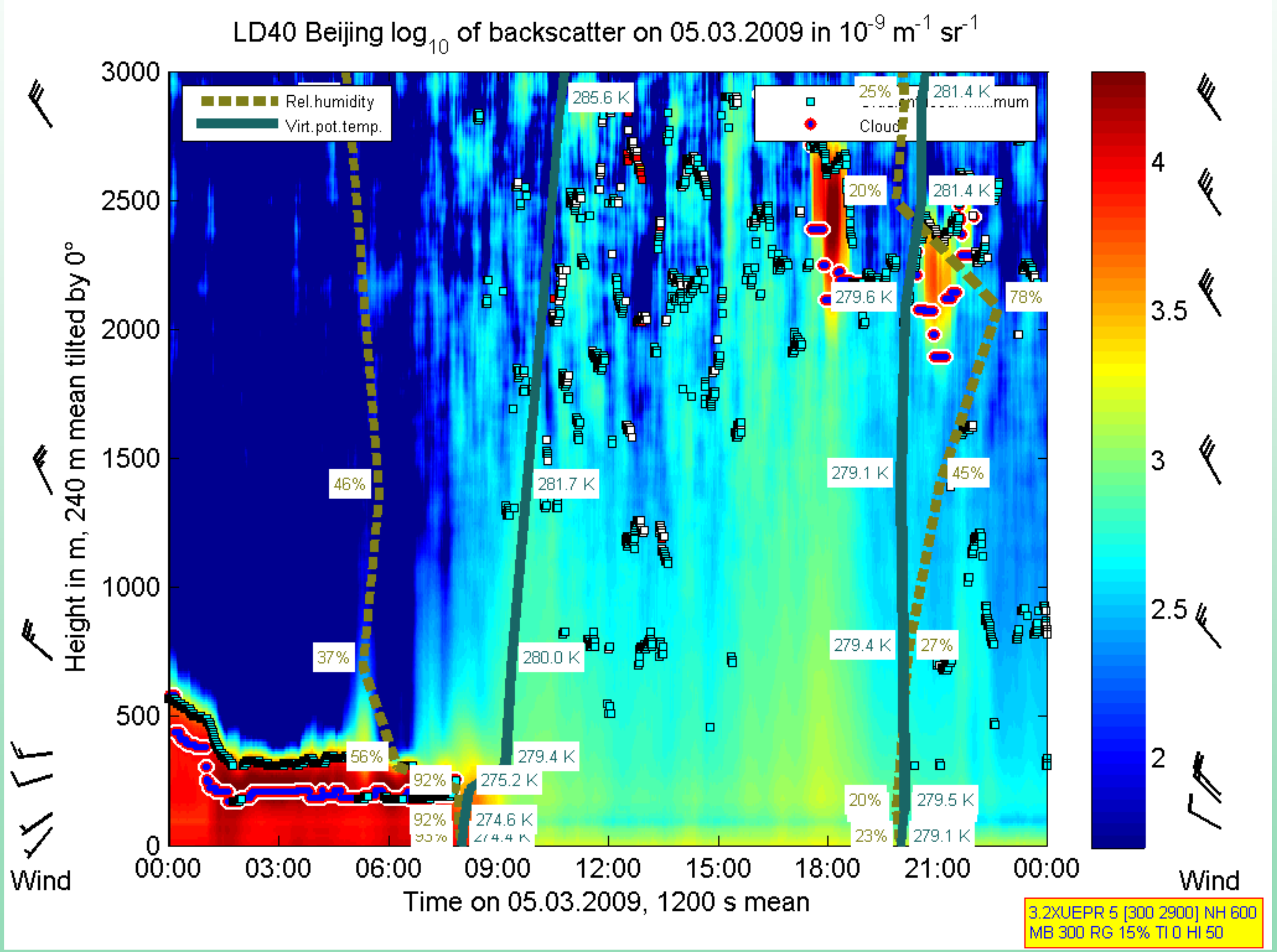
Evaluations in Beijing

High particulate load and low mixing layer height

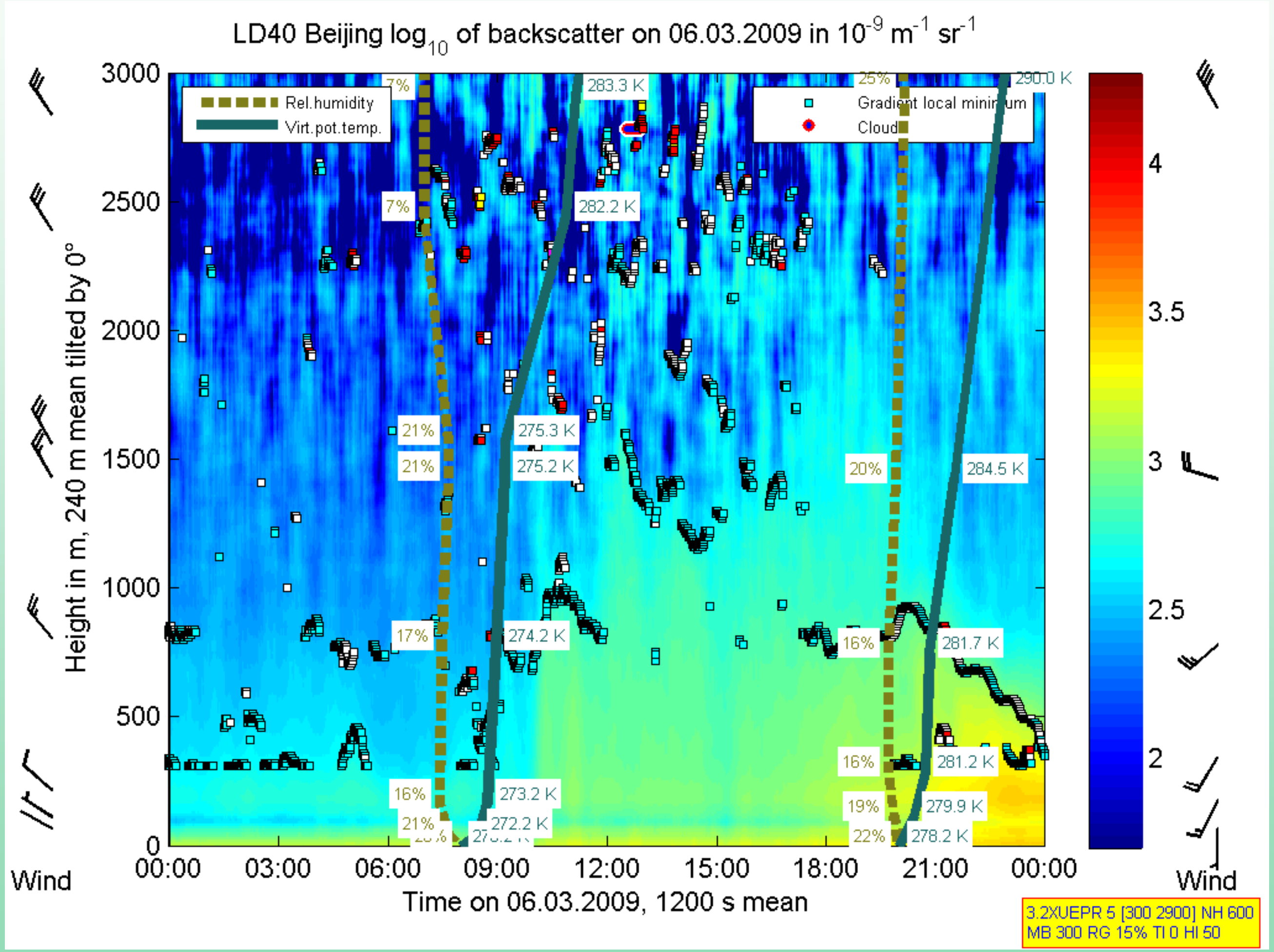


Evaluations in Beijing

Low particulate load and winds from West / North-West, after fog in the morning with winds from South-West

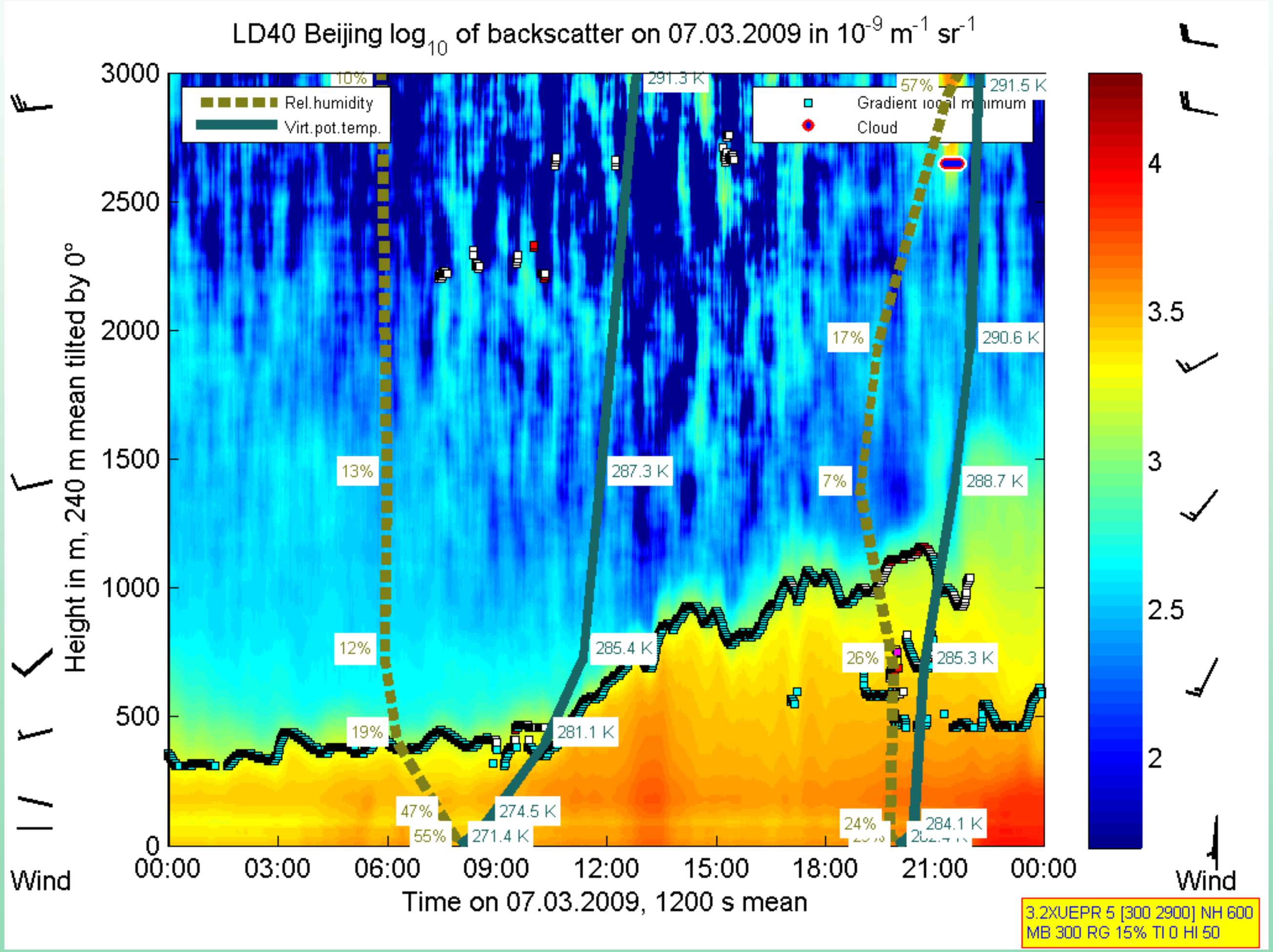


Higher particulate loads during winds from South-West



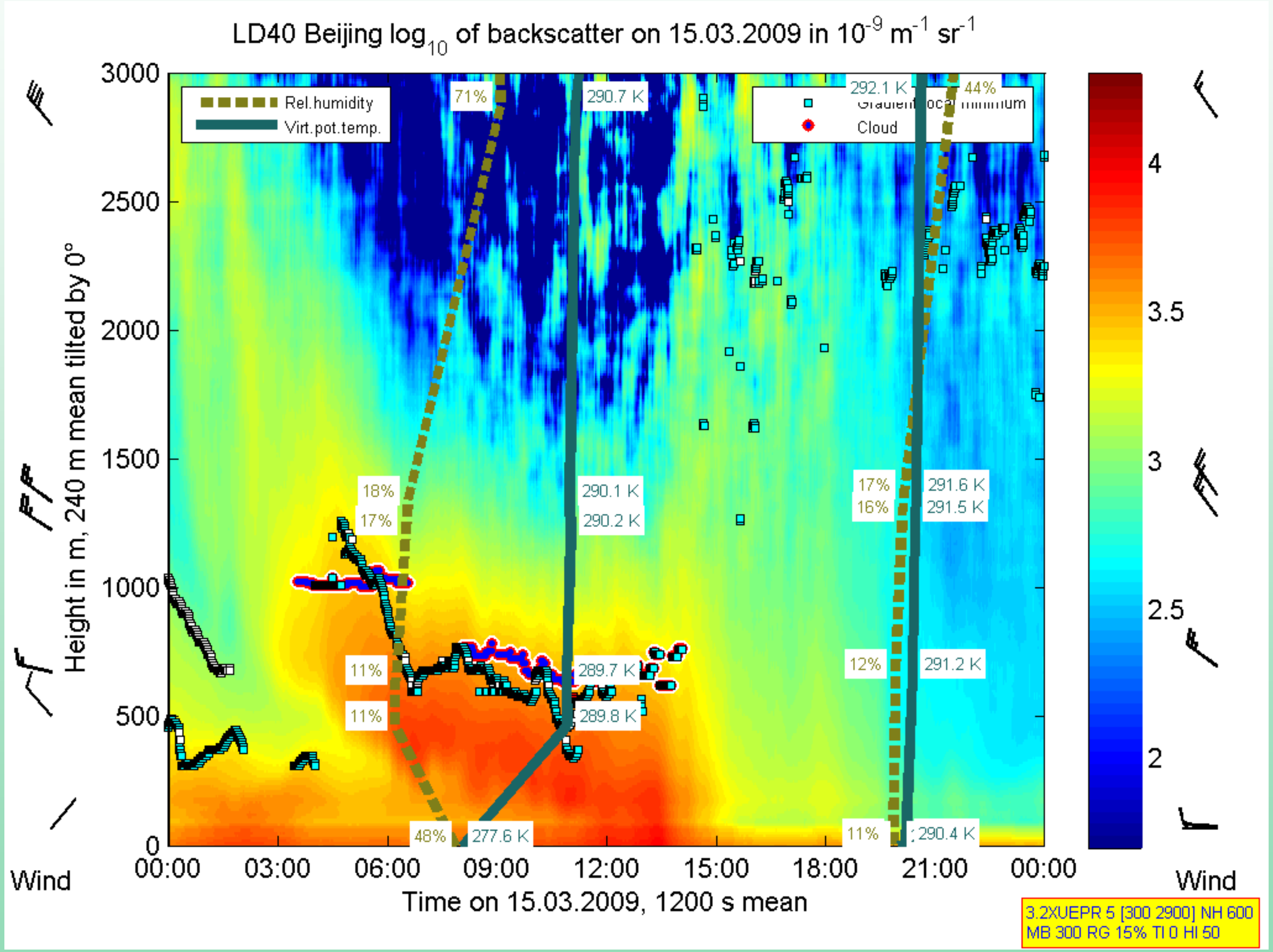
Evaluations in Beijing

Higher particulate loads during winds from South-West

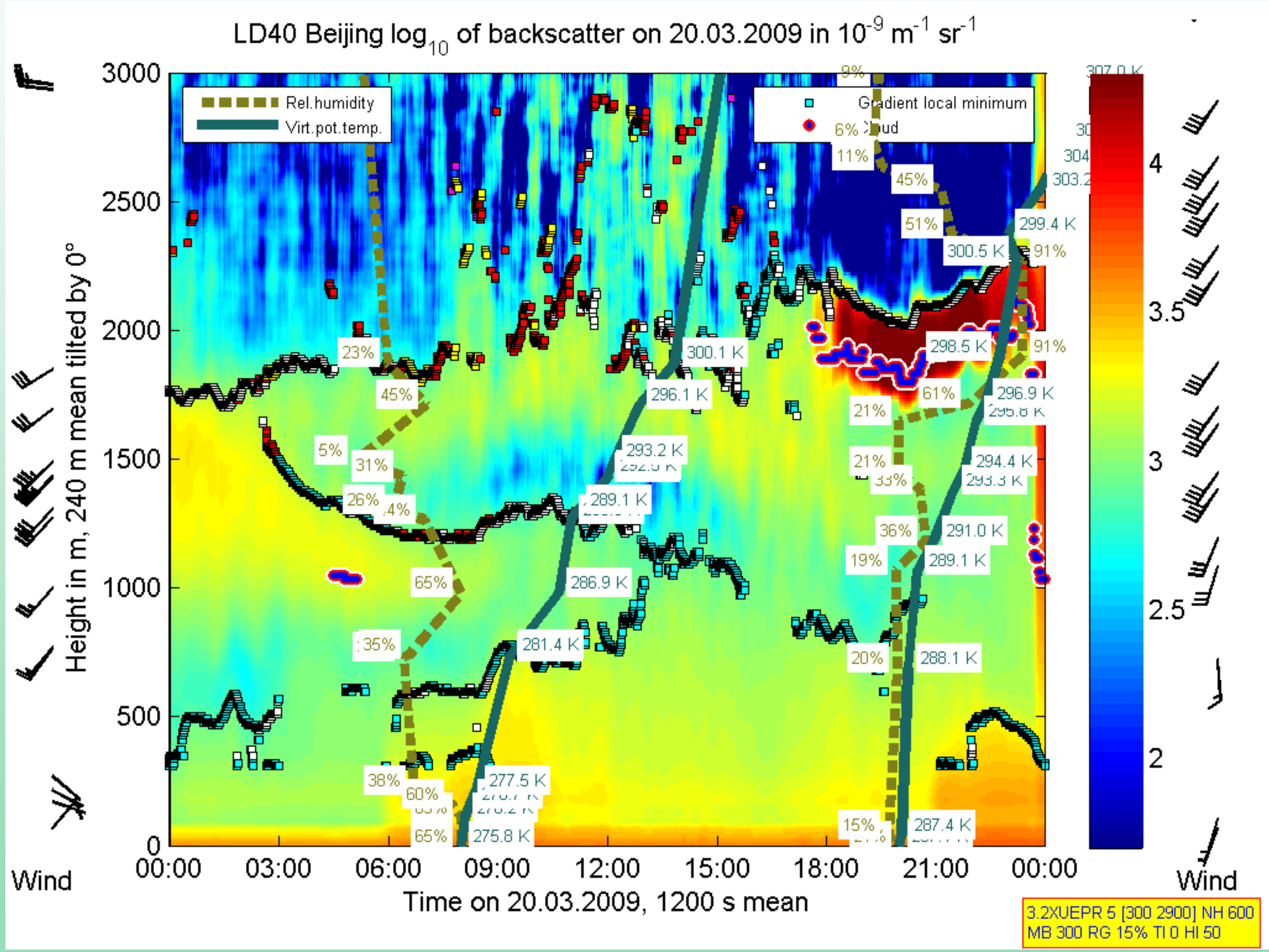


Evaluations in Beijing

Desert dust clouds, winds from West, dry air

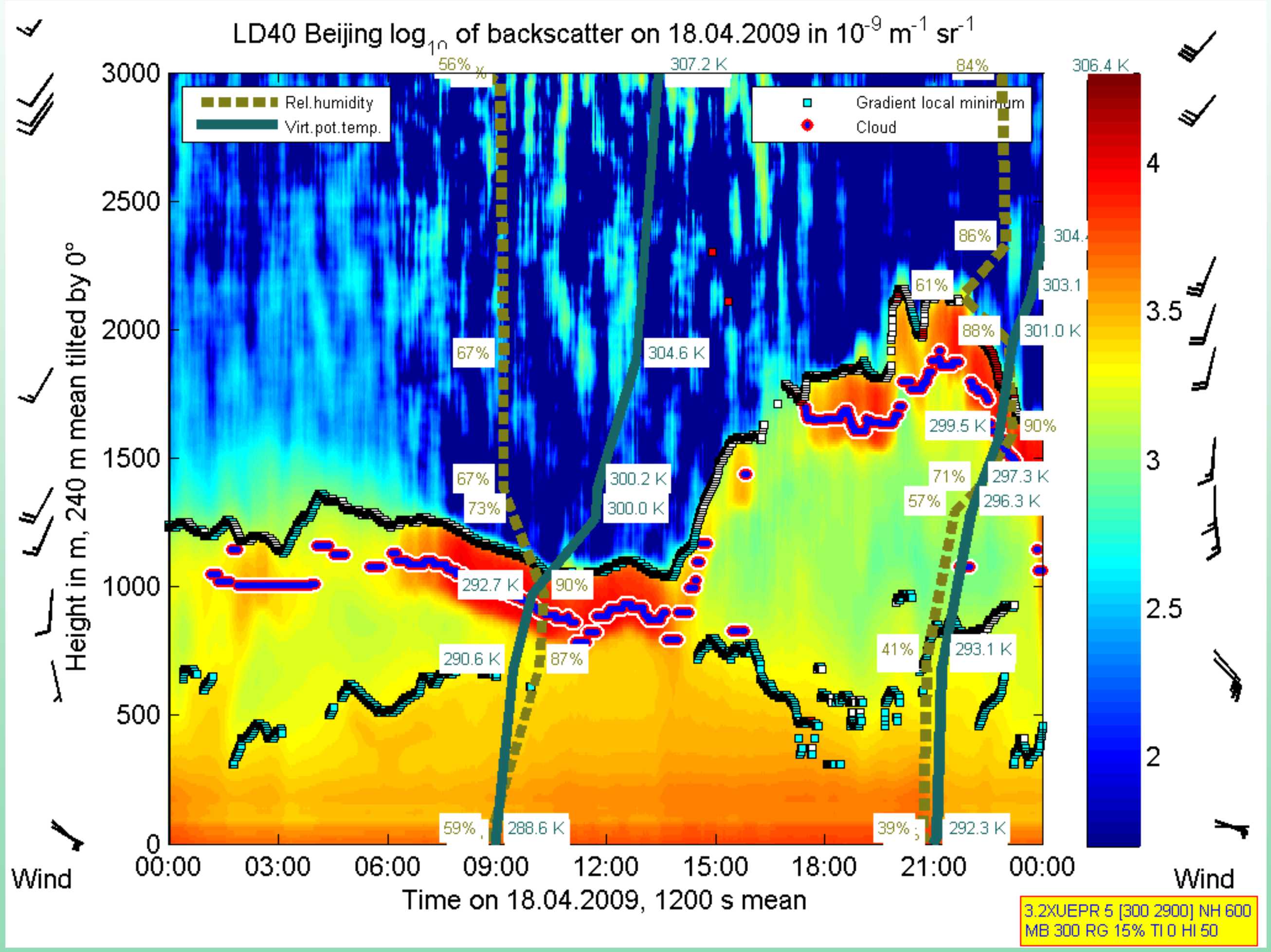


Multiple layering of the lower atmosphere



Evaluations in Beijing

Multiple layering of the lower atmosphere



Evaluations in Beijing

Results for MLH monitoring

Strong diurnal variation and from day to day during convective conditions

Low altitude variation during stable conditions

Several layers or lifted inversions are possible

During early afternoon the surface-based inversion can be broken up by sunshine

Strong coupling of changes in the vertical profile of relative humidity and virtual potential temperature with minimum of backscatter intensity gradient

Wind influences upon air pollution in Beijing

During winds from westerly directions relative dry and clean air

Sometimes particulate clouds from desert regions are transported to Beijing

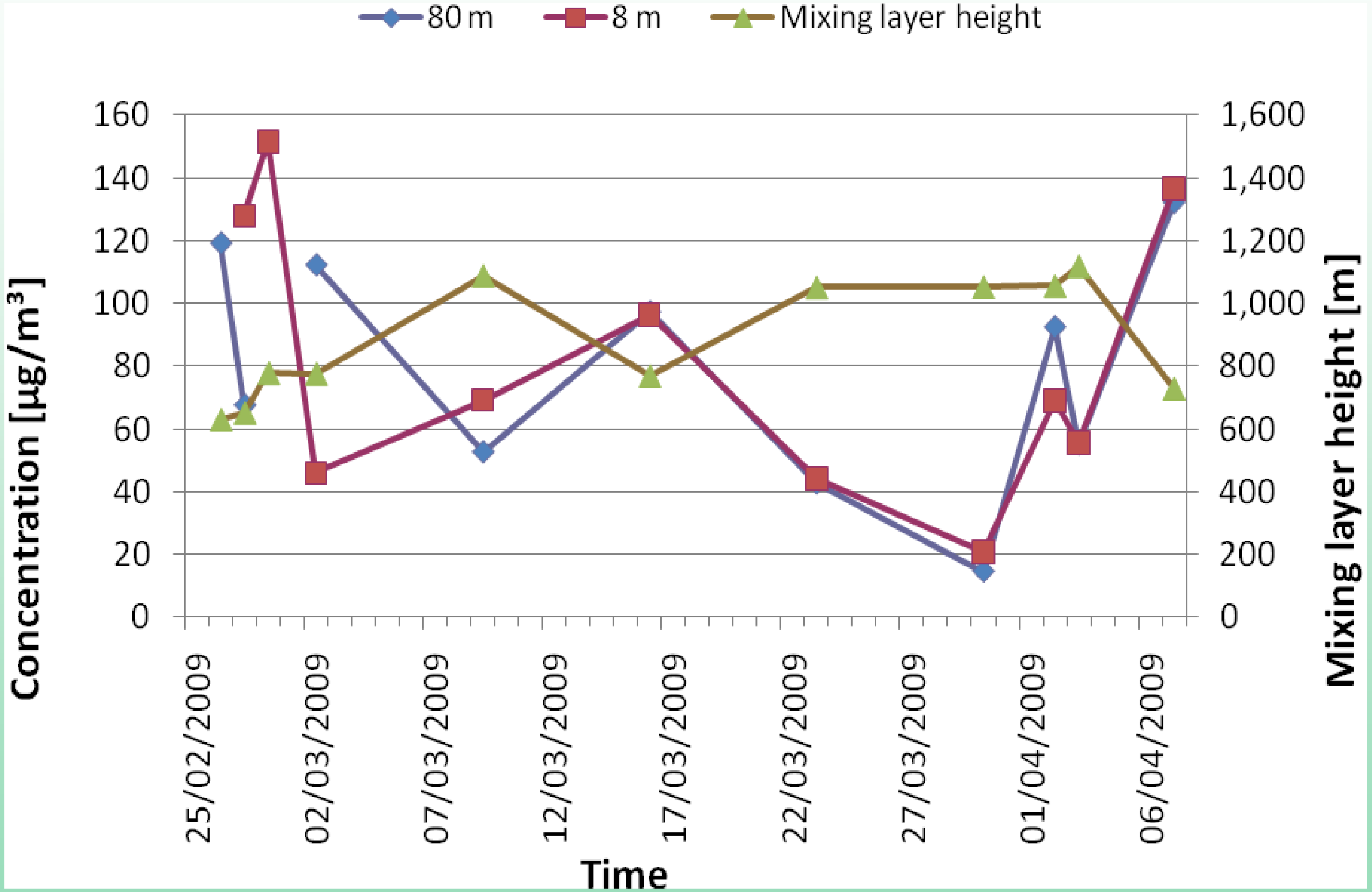
During winds from other directions, especially from the ocean, high relative humidity

Higher particulate loads during winds from south-westerly directions

Evaluations in Beijing

Concentrations of $PM_{2.5}$ in 8 m and 80 m height as well as MLH

- Quartz fibre filters (25 mm or 50 mm in diameter)
- Mini Volume Sampler (Leckel GmbH, Berlin)
- Pump rate 200 l/h
- Weighing procedures at the KIT/IMG
- Correlations $R^2 \sim 0.4$



Norra, S., Hundt, B., Stüben, D., Cen, K., Liu, C., Dietze, V., Schultz, E., „Size, morphological and chemical characterization of aerosols polluting the Beijing atmosphere in January/February 2005." In: Morrison, G.M.; Rauch, S. (Eds.): Highway and Urban Environment, Springer, Berlin (2007)

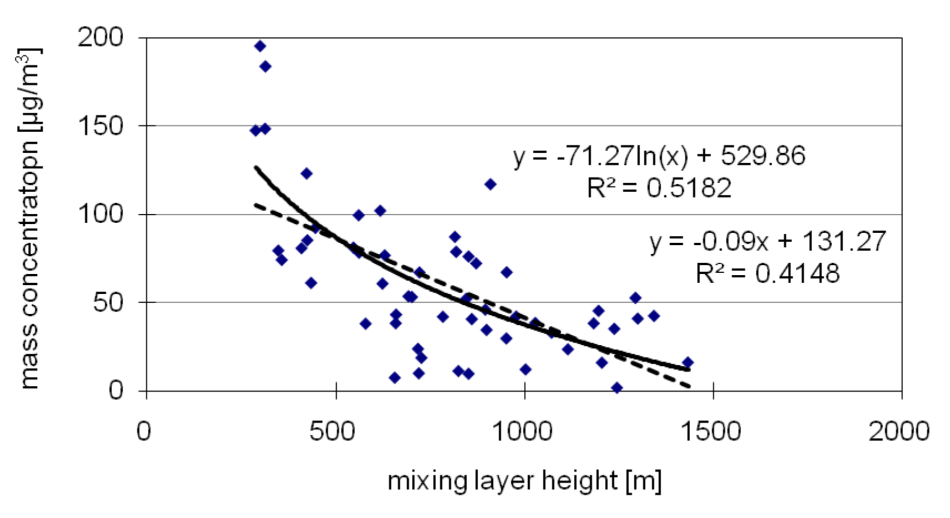
Evaluations in Beijing

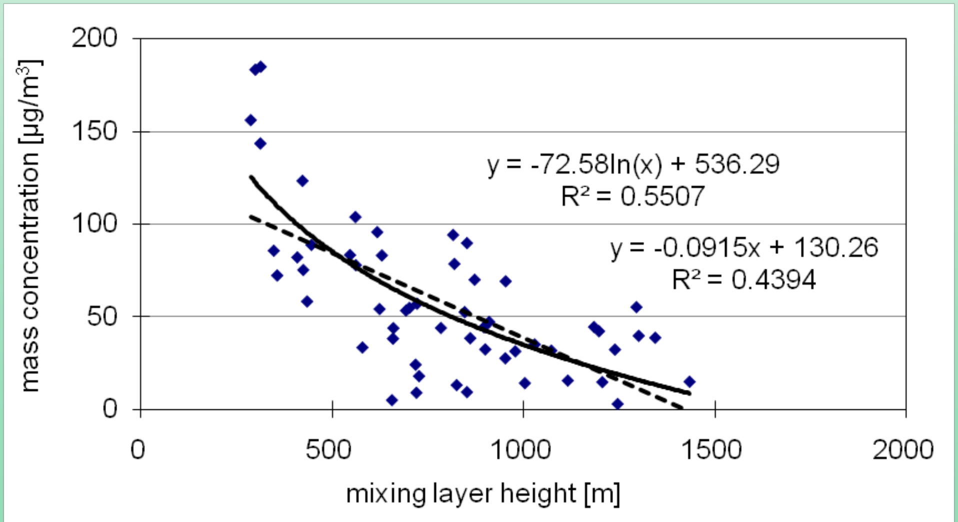
Concentrations of $PM_{2.5}$ in 8 m and 80 m height as well as MLH

Daily mean:

TEOM at
8 m height
(above) and
80 m height
(below)

MLH by
ceilometers
(up to 1500 m)





Evaluations in Beijing

High $PM_{2.5}$ load (40 – 140 µg/m^3) near the surface is coupled with MLH much lower than 1000 m

If planetary boundary layer higher than 1000 m often a multiple layering of the boundary layer is observed

Influence of MLH upon the variance of the observed $PM_{2.5}$ concentrations is significant, also from hourly-mean TEOM data in both heights (R^2 ~ 0.2)

Logarithmic regression provides better correlations than linear i.e. PBL is well mixed

Evaluations in Beijing

Influence of MLH upon the Cu and Zn mass concentrations is significant
i.e. if the origin of the elements is
• the soil this source dominates the concentrations (Al, K and Ca no MLH influence),
• the traffic and the industry the air transport dominates (no MLH influence in higher altitudes) and
• a widespread area source the MLH dominates (Cu, Zn)

Influence of MLH upon NO_2 and SO_2 concentrations from DOAS is relevant (not for NO – traffic emissions are dominant)

Future work and perspectives

Beijing

Source apportionment for PM (PhD student Rong-rong Shen)

- PM_{10} filter samples from January 2008 – August 2009: CUMTB
- $PM_{2.5}$ filter sampling with 2 high-volume samplers from June 2010 on: CUMTB, CUGB
- PM composition (organics, elements, ^{13}C) from filter samples (April – August 2009, June 2010 – June 2011) in cooperation with HMGU, DWD, KIT/IMG, KIT/IGG, University of Rostock

Model evaluation on the basis of traffic emission and particulate measurements as well as MLH investigations: interpretation with in situ concentrations, meteorological data, ceilometer data - MLH (PhD student Hong Ling)

Beijing

Beijing

Application of satellite-based remote sensing data systems (2005 up to now AOD, PM concentrations, MLH) and coupling with numerical modelling (PhD student Stefanie Schrader)

Application of inverse dispersion modelling methods to determine emission source strengths

Co-operation with epidemiological studies: PM composition, NO_2, O_3, BTX, SO_2

PhD works within the frame of CSC-Helmholtz program

Co-operations

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