Meteorological influences and role of emissions within the context of air quality in Beijing

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INSTITUTE FOR METEOROLOGY AND CLIMATE RESEARCH, ATMOSPHERIC ENVIRONMENTAL RESEARCH (IMK-IFU)

- Problems
- Scientific questions
- Process studies
  - Influences upon air pollution
  - Source apportionment
  - Spatial distribution of PM
- Future work and perspectives

Problems

Climate protection or improvement of air quality / health protection? Or both?

Decisions for emission reduction measures

- Gasoline or Diesel motor: PM, NO_2, NH_3 emissions
- Aircraft: VOC, CO, NO_x emissions and contrails
- Odour and noise emissions or GHG emissions

Problems

- Changing NO_2/NO_x ratios in ambient air
- Threshold exceedances - sustainable reduction of NO_2, PM_{10}
- Load, character and sources of ultrafine particles in urban background
- Air pollutants and health impact
  - Which pollutants are relevant?
  - Which concentrations/exposures influence health impacts?

Scientific questions for air quality in Beijing

Origin of frequently occurring air pollution events

Origin of pollutants and especially PM - urban agglomerations are one of the most important sources for PM

Local and regional wind systems - can bring fresh air masses and limit air pollution

Aeolian mineral dust originated from West and Northwest during storm events – can carry pollutants and nutrients

Role of mixing layer height - mountains are West to North

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Process studies

Influences upon air pollution

Influence of MLH upon air pollution in urban and sub-urban area

Hannover, Munich, Augsburg, Budapest, Zurich Airport, Mexico City International Airport, Athens International Airport, Paris CDG, Beijing

- Correlation with MLH smallest inside street canyons
- Correlation with MLH larger in winter than in summer
- Influences of MLH upon CO, NO_2 and PM_{10} concentrations in the order of 20 %, up to 50 %

➔therefore better MLH determination necessary

➔deployment of ceilometers for continuous operation

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).

Wind influences upon air pollution

- Under strong background flows:
  reduced concentrations for all pollutants without distinct maxima and minima of diurnal cycle

- Under the development of local flows:
  high concentrations of air pollutants

- Influences of wind speed upon CO, NO_2 and PM_{10} concentrations in the order of 20 %

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, 647-658 (2006).

Dandou, A., Tombrou, M., Schäfer, K., Emeis, S., Protonotariou, A.P., Bossioli, E., Soulakellis, N. Suppan, P.: A comparison between modelled and measured mixing layer height over Munich. Boundary-Layer Meteorology 131, 425–440 (2009).

Air quality studies in Beijing

Continuous determination of mixing layer height (MLH) by ceilometer since February 2009 (LAPC, KIT/IMK-IFU)

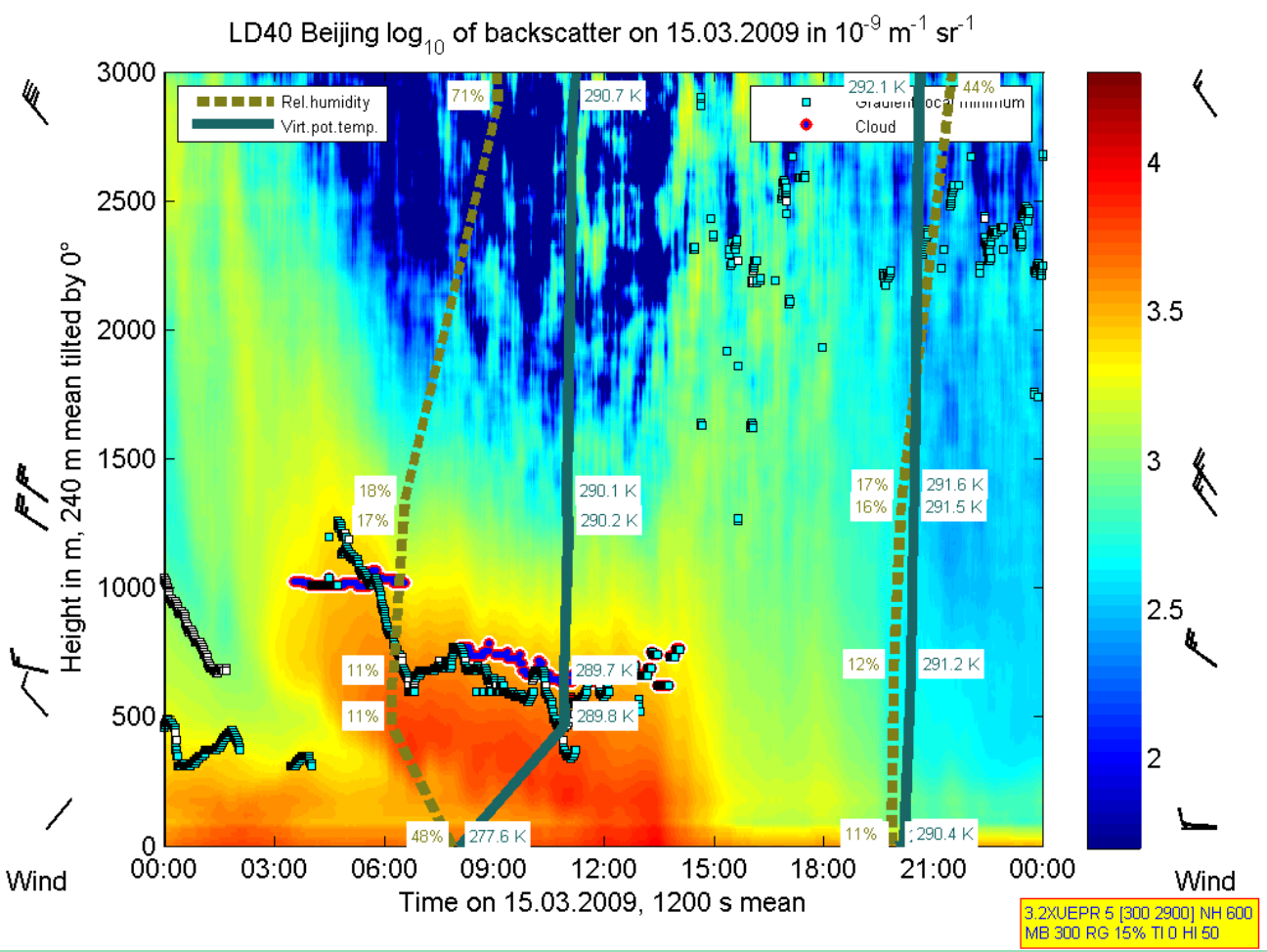
Limits the vertical distribution of emitted air pollutants with consequences for dilution and transport

Essential for the determination of speed and range of vertical dispersion

Influenced by future climate change and thus important for quality of living in large cities

Air quality studies in Beijing

Dust clouds, winds from West, dry air



Air quality studies in Beijing

Path-averaged concentrations of air pollutants NO_2, SO_2, O_3, (Benzene / Toluene, Xylene, NO, NH_3, HCHO) near / across a motorway April 09 – March 11 (PhD Hong Ling at LAPC)

DOAS at LAPC building

three retroreflectors

automatic operation

Air quality studies in Beijing

Measurement sites: LAPC tower, ceilometer, DOAS

Optical remote sensing:
Ceilometer
Vaisala LD40 / CL31
wave length: 855 / 910 nm
range: 4000 m
resolution: 15 / 5 m

Optical remote sensing: DOAS

Third

First

Second

The Badaling motorway

Particle concentrations ($PM_{2.5}$) on 8 m and 80 m altitude at 325 m LAPC tower

Air quality studies in Beijing

- Inorganic composition of PM with weekly passive samples (adhesive acceptor plates) and active daily samples (Mini-volume sampler $PM_{2.5}$) since 2005 (KIT/IMG, DWD)

- Two campaigns in 2009 in various heights at LAPC

  $PM_{2.5}$ by weekly passive sampling (DWD, KIT/IMG)

  $PM_{2.5}$ by active daily samplers (KIT/IMG)

  TEOM instruments (LAPC)

Air quality studies in Beijing

If planetary boundary layer > 1000 m: often multiple layering,
if < 1000 m during daytime: often one layer

Influence of MLH upon $PM_{2.5}$ and NO_2 concentrations is relevant

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

Correlations of NO and SO_2 with MLH are not significant

Concentrations of benzene, toluene, xylene, and formaldehyde
are near the detection limit of DOAS

Air quality studies in Beijing

Further influences upon air pollution (PhD Ruiguang Xu)

winds

emissions (in the case of NO and SO_2)

air chemistry (photochemistry in the case of NO_2)

concluded from the daily courses of NO_2 concentrations

Tasks for air quality studies in Beijing

Model evaluation on the basis of traffic emission and air pollution measurements as well as MLH investigations (PhD Hong Ling at KIT/IMK-IFU)

DOAS together with in situ concentrations

meteorological data

ceilometer data – MLH

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Process studies

Source apportionment

Air quality studies in Beijing

Daily $PM_{2.5}$ filter sampling with 2 High-volume samplers

from 21 June 2010 on for one year (PhD Rong-rong Shen)
with Jianying Wang, Jing Wang (CUMTB), HMGU, CUGB

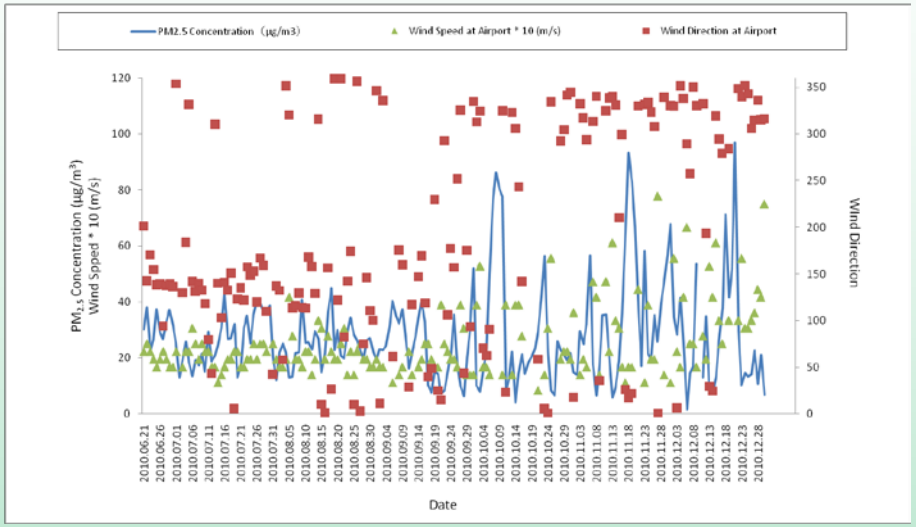
Ultra-sonic anemometer at the sampling site

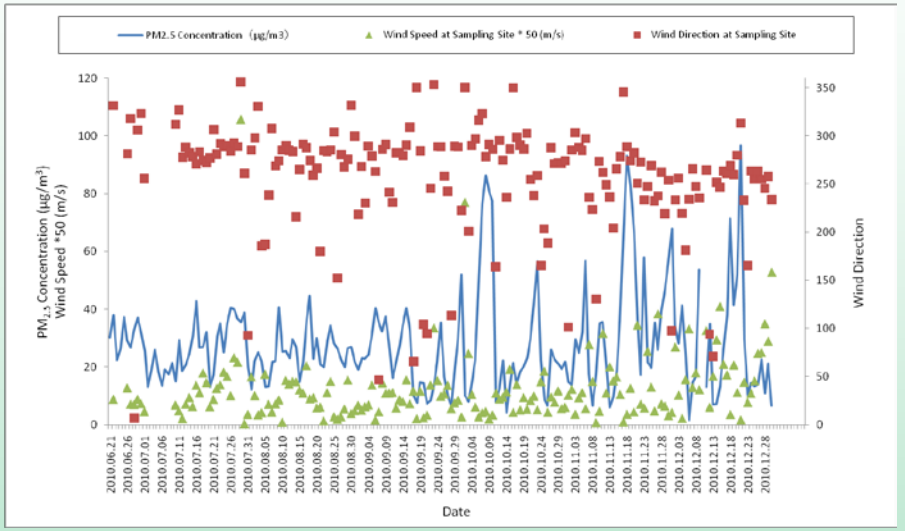
10 m distance to instrumentation of DWD and KIT/IMG

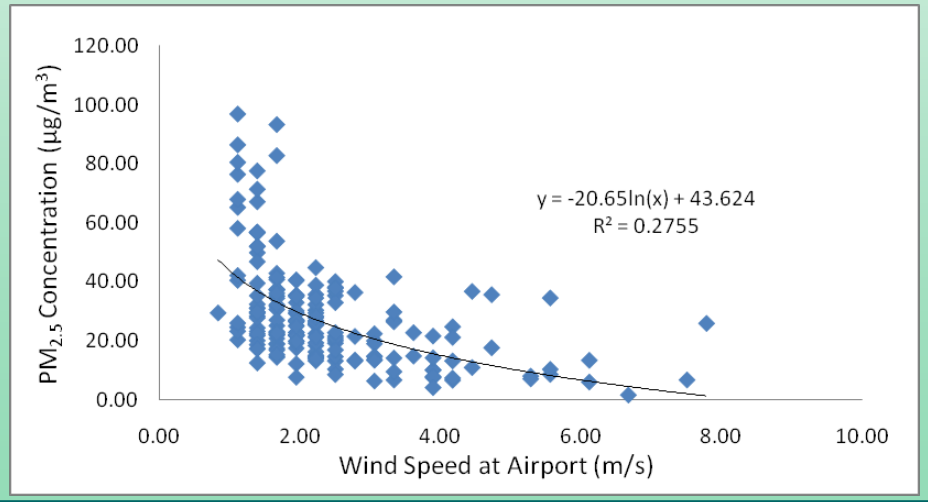
Air quality studies in Beijing

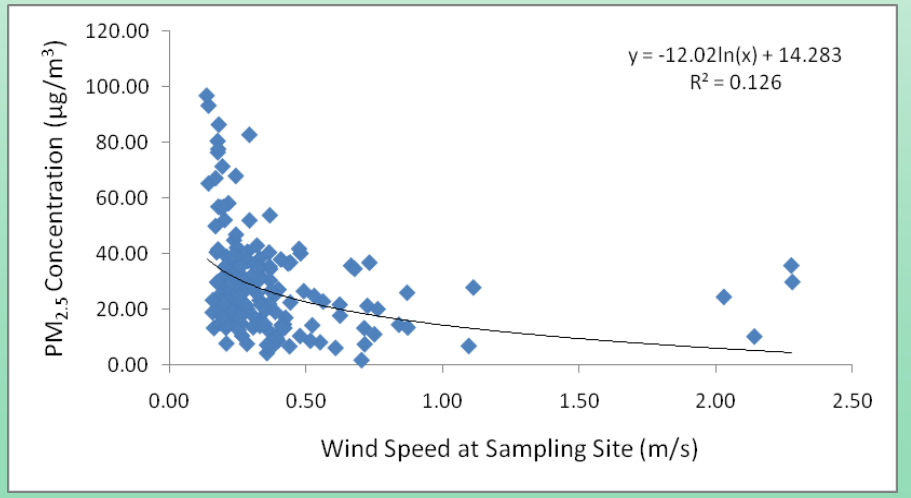
Wind influence upon sampled $PM_{2.5}$ mass at CUGB

First results









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Tasks for air quality studies in Beijing

- PM composition from filter samples (PhD Rong-rong Shen)

  carbon fraction, organic speciation (HMGU, UR)

  inorganic composition (KIT/IMG)

  isotopic composition $^{13}C/^{12}C$ (KIT/IMK-IFU)

- Source apportionment for $PM_{2.5}$ with PMF software of US-EPA (PhD Rong-rong Shen)

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Process studies

Spatial distribution of PM

Tasks for air quality studies in Beijing

Application of satellite-based remote sensing data systems and coupling with numerical modelling (PhD Stefanie Schrader)

with University of Thessaloniki (Dimosthenis Sarigiannis and Nicolas Moussiopoulos)

comparison with dispersion model COSMO ART

Task: Input for the ICAROS platform

Satellite images (Landsat)

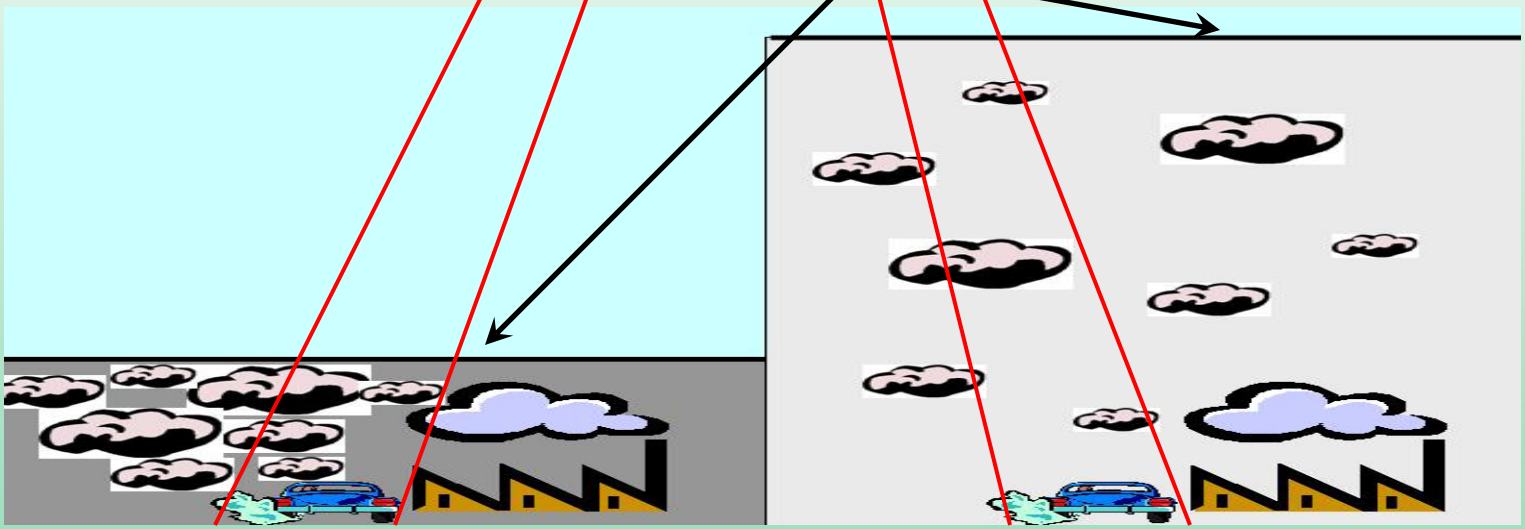
100 km x 100 km, 30 m x 30 m

520 nm: PM size 0.2 - 1.0 µm

- reference - clear atmosphere
- polluted situation

Ground-based measurements

- Aerosol mass extinction efficiency β_{ext} =AOD/MLH=aPM
- AOD – sun photometer
- MLH - ceilometer



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Future work and perspectives

Tasks for air quality studies in Beijing

- Toxicological assessment with one-year daily $PM_{2.5}$ filter samples

  (Master thesis Jianying Wang, Jing Wang at CUMTB)

- Co-operation with epidemiological studies: PM composition, NO_2, O_3, BTX, SO_2 (University of Peking, HMGU)

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