Effects of the mixing layer height on ultrafine particles in Augsburg, Germany

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Problems and objectives
Methodology: remote sensing, particulate sampling
Influences of mixing layer height
Discussions, conclusions and outlook
Problems

A lot of measures for
• emission reduction (health protection) and
• efficient energy consumption (climate protection)
in the traffic and industrial sector realised

High amount of ultrafine particles is background

$\text{NO}_2/\text{NO}_x$ ratio in ambient air continuously increasing

How to fulfil EC regulations for particles and $\text{NO}_2$ from 2010 on?

Are these threshold values high enough for health protection?
Solutions

Knowledge 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 question

- Which regional meteorological situations (transport and exchange conditions) and
- which emission processes cause high particulate matter (PM) exposures?

In particular:
- Local wind systems
- Secondary circulation systems
- Heat island effect
- Mixing layer height (MLH)
Prevailing wind direction WSW, low wind speeds during easterly winds
Significant wind influences
Tasks

Analyses of MLH influences on particles

• MLH: PM backscatter intensities by ceilometers, also SODAR, RASS (IMK-IFU, Vaisala), radiosondes
• Particle size distributions (HMGU) and concentrations (HMGU, IMK-IFU)
• PM composition (HMGU, BlfA, University of Augsburg)
• Weather conditions for high PM pollution (IMK-IFU)

Determination of the variation of MLH across the urban region

Determination of spatial distribution of PM load (IMK-IFU)

Acoustic remote sensing: Wind profiles, turbulence profiles
Large SODAR
(METEK DSDR3x7)
frequency: 1500 Hz

Radio-acoustic remote sensing:
Temperature profiles
SODAR-RASS (METEK)
acoustic frequ.: 1500 – 2200 Hz
radio fr.: 474 MHz

Optical remote sensing:
Particle backscattering
Ceilometer
(Vaisala LD40/CL31)
wave length: 855/905 nm
range: 4000 m
resolution: 15 m

SNOW

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Mixing layer height

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

Quantitative knowledge essential for the determination of speed and range of vertical dispersion

Future climate change influences MLH and thus the quality of living in large cities

Mixing layer height determined from radiosonde temperature profiles (at 13:00 LT at Munich/Oberschleißheim)

Number concentration of ultrafine particles of 3 up to 100 nm from Twin Differential Mobility Particle Sizer, (averaged between 12:00 and 16:00)

2005 - 2006
### Spearman correlation coefficients: mixing layer height and particle size fractions

**Winter** (October-March: mean MLH ≈ 1400 m)
**Summer** (April-September: mean MLH ≈ 500 m)
Significance is at 0.01 level

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<td>nm</td>
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<td>Winter</td>
<td>-0.14*</td>
<td>-0.16*</td>
<td>-0.23*</td>
<td>-0.32*</td>
<td>-0.36*</td>
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<tr>
<td>Summer</td>
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<td>-0.13</td>
<td>-0.16*</td>
<td>-0.19*</td>
<td>-0.04</td>
<td>-0.14</td>
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Algorithms to detect MLH from ceilometer data

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

16.04.2007

Min temp = 6°C Max temp = 21°C Mean temp = 14°C
Ave hum = 44 %
Ave wind speed = 8 km/h Max wind speed = 22 km/h Wind dir = E – NE
Clear all day
19.04.2007
Min temp = -1°C Max temp = 18°C Mean temp = 8°C
Ave hum = 53 %
Ave wind speed = 2 km/h Max wind speed = 11 km/h Wind dir = all directions
Clear all day
20.04.2007
Min temp = 2.2°C Max temp = 19.2°C Mean temp = 11.0°C
Ave hum = 63 %
Ave wind speed = 7.9 km/h Max wind speed = 16.6 km/h Wind dir = all directions
Clear all day
20/04/2007
Comparison of LD40 & CL31
21.04.2007
Min temp = 1°C Max temp = 18°C Mean temp = 10°C
Ave hum = 54 %
Ave wind speed = 2 km/h Max wind speed = 13 km/h Wind dir = NE
Clear all day
Results for MLH monitoring

Strong diurnal variation and from day to day during convective conditions

Low altitude variation during stable conditions (e.g. during winter and snow covered surface)

Several layers or lifted inversions are possible

During a few hours in the early afternoon the surface-based inversion can be broken up by sunshine


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

Correlations smallest inside street canyons

Correlations larger in winter than in summer

Correlations of NO\textsubscript{X} larger than of particle concentrations

Highest correlations: winter 50 – 100 nm, summer 100 – 500 nm

Varying emission source strengths for gases and particles and gas-to-particle conversions within air masses


Relationship between atmospheric optical depth and particle concentration

Ground-based measurements
• Daily mean measurements of PM$_{10}$, PM$_{2.5}$ and PM$_{1}$ at rural and urban background sites
• AOD from ground-based sun-photometer at 560 nm
• MLH from SODAR and ceilometer

Correlation with linear regression: $\beta_{\text{ext}} = \frac{\text{AOD}}{\text{MLH}} = a \times \text{PM}$
a: mass extinction efficiency; winter $R^2 \approx 0.8$, summer $R^2 \approx 0.5$

Spatial distribution of PM load using satellite images

Regions of 100 km x 100 km (SPOT, Landsat: 30 m x 30 m):
• green spectral range (520 nm) - particle diameter 0.2 - 1.0 µm
• one image during very clear atmospheric
• one image during different pollution levels

Retrievals of aerosol optical depths
• blurring - degradation of image texture by contrast reduction
• screening - attenuation of reflectance and distortion of patterns
• opacity - veiling of images in the infrared spectral range

Particulate load near surface from PM $= \frac{1}{a} \beta_{ext} = \frac{1}{a} AOD/MLH$

Spatial distribution of $\text{PM}_{10}$ concentrations in Augsburg on 20 April 2007 with the reference image on 06 July 2006

PM$_{10}$ concentrations in Augsburg: Rotes Tor, Fachhochschule and around B300
Spatial distribution of PM$_{2.5}$ and PM$_{1}$ concentrations in Augsburg on 20 April 2007 with the reference image on 06 July 2006.
Applications of methodologies and co-operations

IAP, Chinese Academy of Sciences, **Beijing**, Yuesi Wang, Jinyuan Xin: MLH and air pollution

Universidad de Chile, **Santiago de Chile** / RHM, Rainer Schmitz: MLH and air pollution

UNAM, **Mexico City**, Michel Grutter: MLH and air pollution; Agustin Garcia: ICAROS platform

Vaisala, Christoph Münkel: Remote sensing MLH

UFZ **Leipzig**, Ulrich Franck; BUW, Peter Wiesen; LMU **Munich**, Matthias Wiegner; UIBK **Inn valley**, Friedrich Obleitner; NKUA **Athens**, Costas Helmis: health effects, MLH, ICAROS platform, air pollution/chemistry
Thank you very much for your attention