Influence of Mixing-Layer Height upon Near-Surface Particle Concentrations

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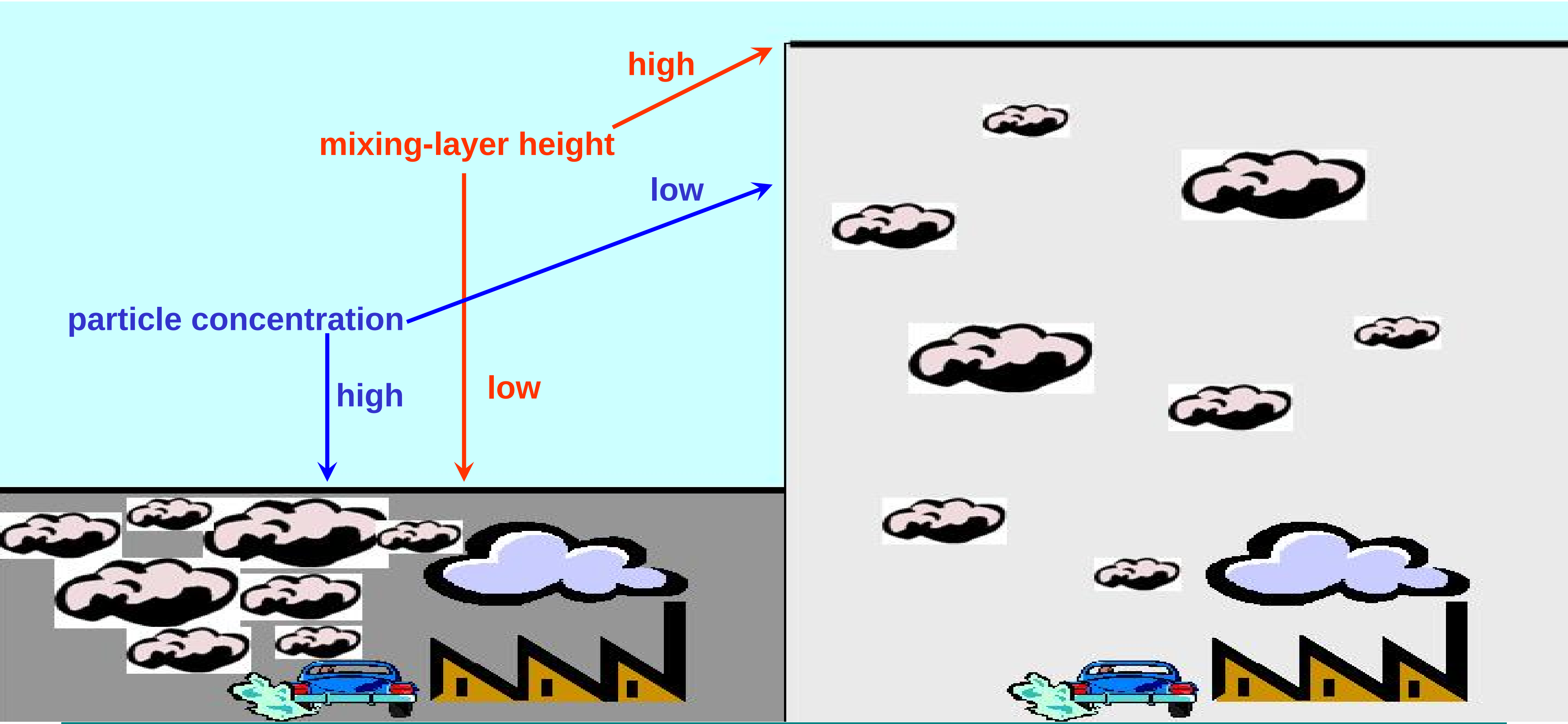
Results from: **VALIUM (AFO2000 project of BMBF (Germany))**
ICAROS NET (EU project within FP5)
ALPNAP (Alpine Space project, INTEREG IIIb, EU)

Interaction between mixing-layer height and near-surface particle concentrations



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this requires the

simultaneous measurement of

mixing-layer height and

aerosol concentrations

mixing-layer height by remote sensing

aerosol concentrations by in-situ measurements

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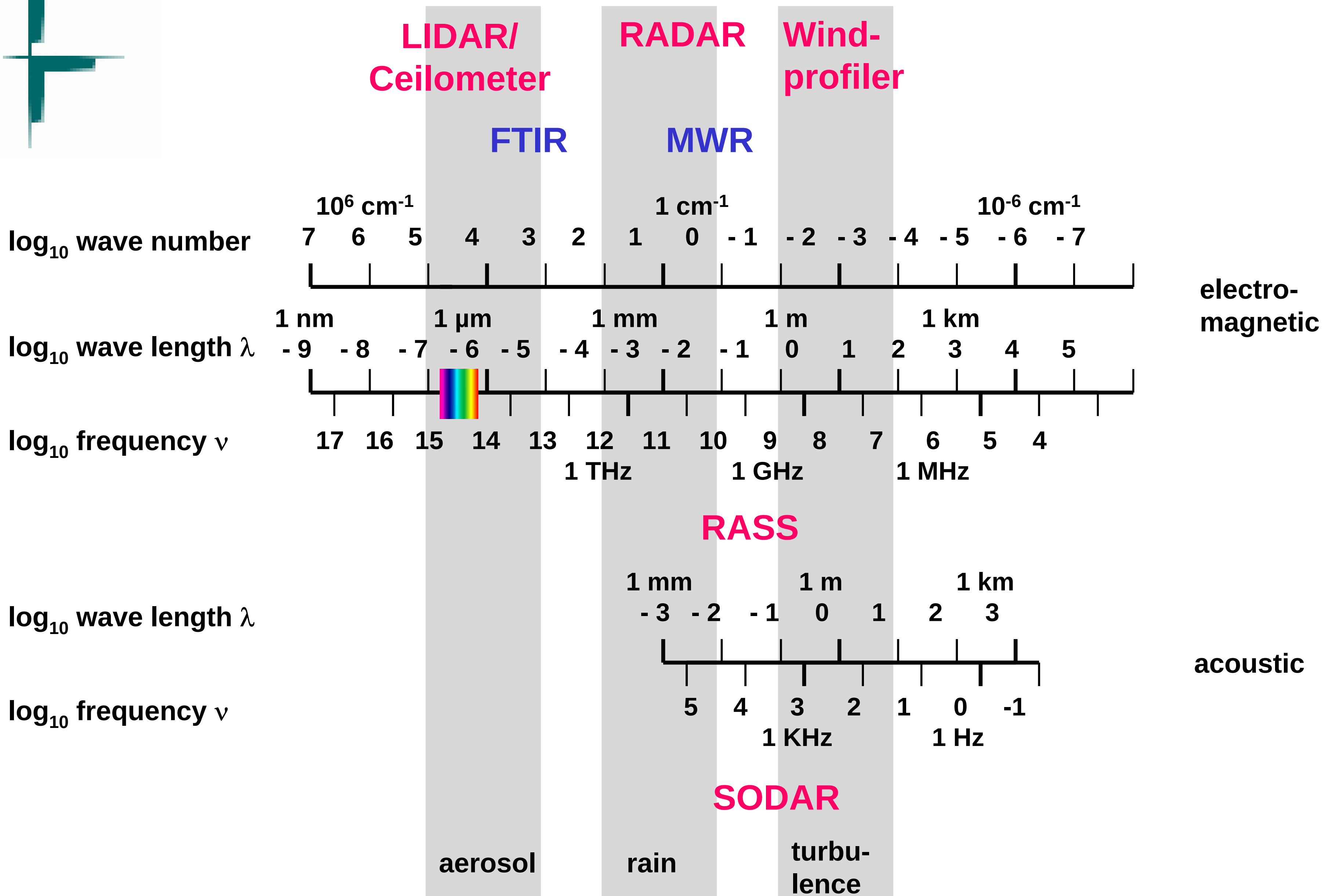
determination of the mixing-layer height

Typical frequency bands for remote sensing of the atmosphere



Modified from Fig. 8.1 in „Meteorologie in Stichworten“, Borntraeger, Berlin Stuttgart 2000

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Acoustic Remote sensing:

backscatter at thermal fluctuations and gradients (and large snow flakes) in the atmosphere

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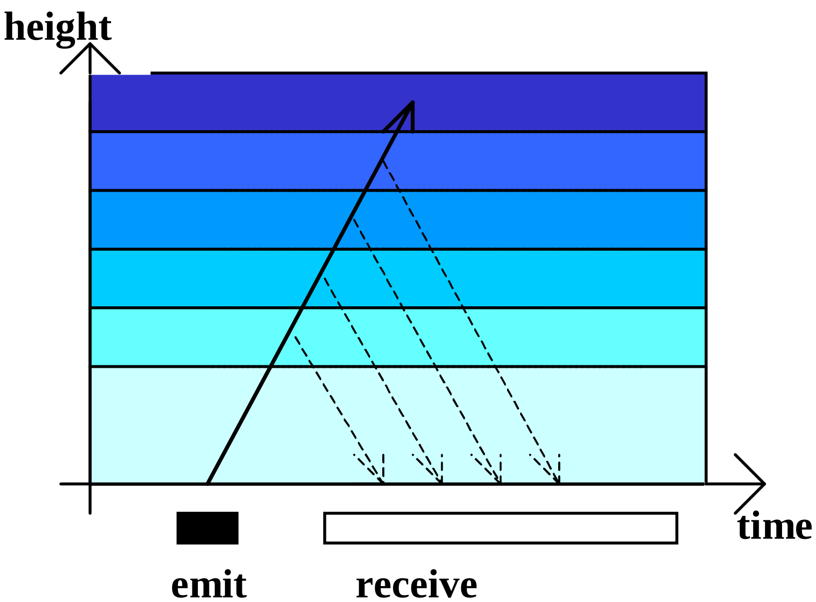
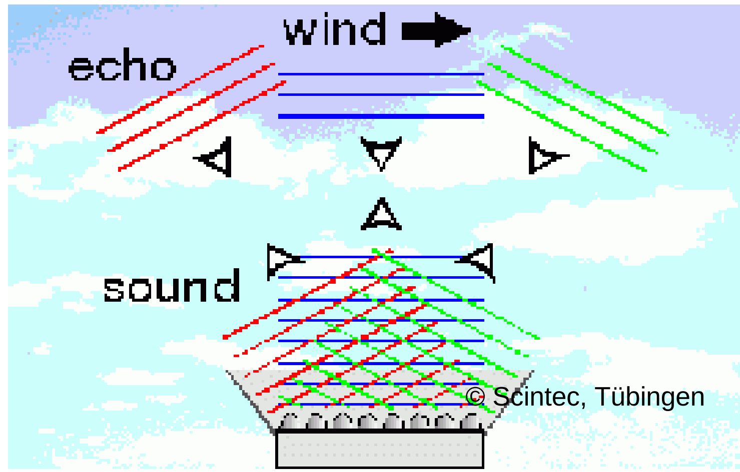
monostatic SODAR: measuring principles





deduction:

sound travel time	=	height
backscatter intensity	=	turbulence
Doppler-shift	=	wind speed

Emission of sound waves into three directions:

in order to measure all three components of the wind (horizontal and vertical)

Large SODAR of IMK-IFU (METEK DSDR3x7)

frequency: 1500 Hz
range: 1300 m
resolution: 20 m
lowest range gate: ca. 60 m

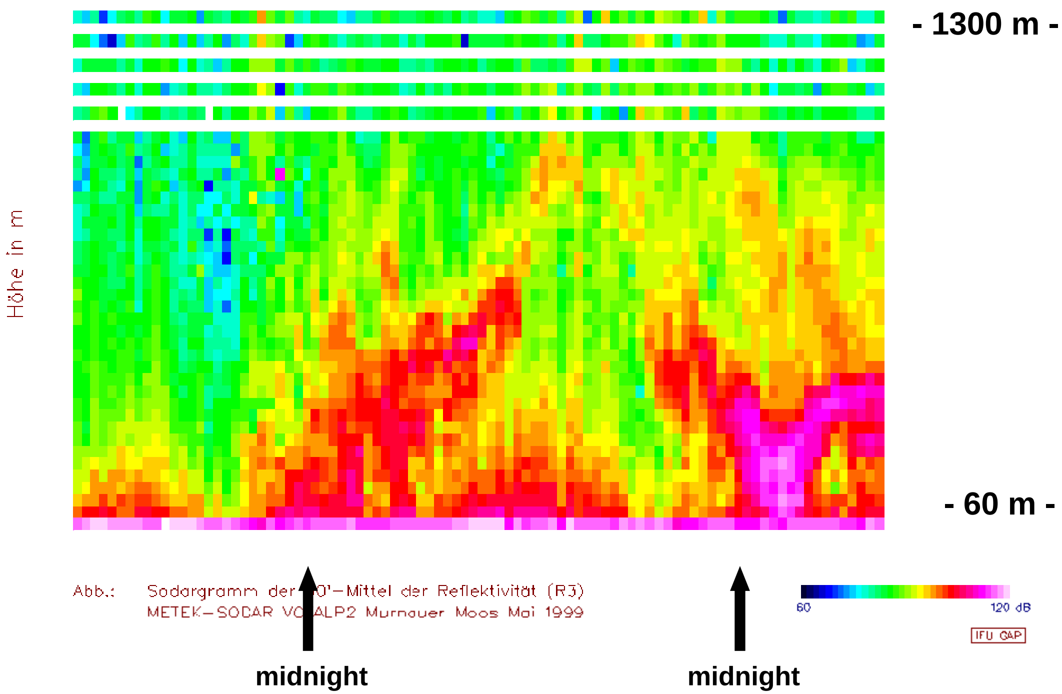
size of instrument:

height: 4 m
width: 1,50 m
length: 10 m
weight: 8 t

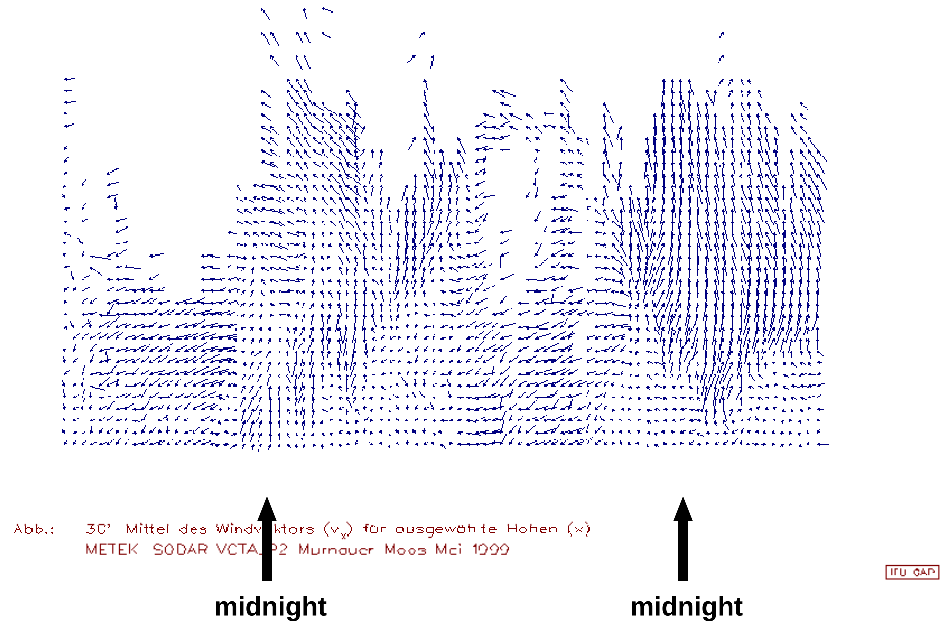
Reitebuch, O. und S. Emeis, 1998: SODAR-measurements for atmospheric research and environmental monitoring. Meteorologische Zeitschrift, N. F., 7, 11-14.

Daily variation of structure and height of the mixing layer example from a summer day

acoustic backscatter intensity



horizontal wind



Optical Remote sensing:

backscatter at aerosol particles, insects, water droplets, ice, and snow (fog and clouds are opaque) in the atmosphere

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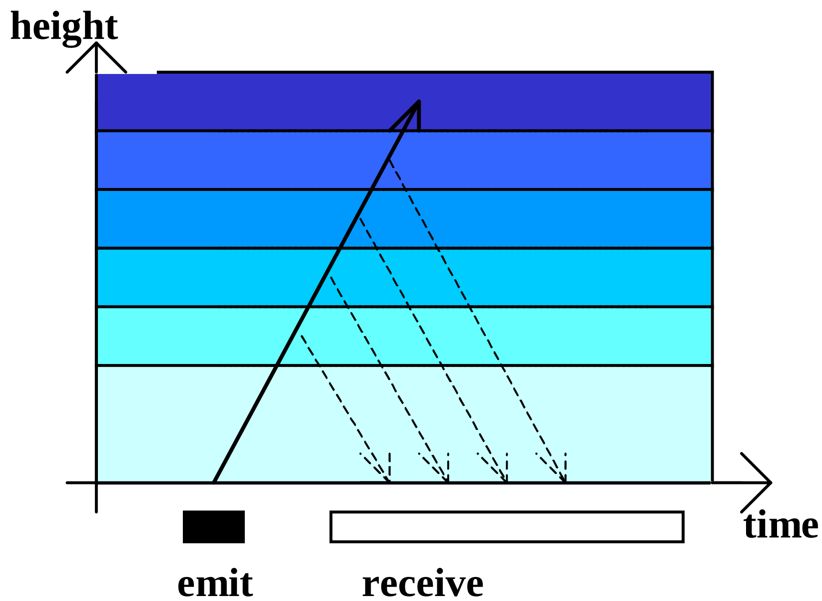
Ceilometer/LIDAR measuring principle



detection:

travel time of signal = height
backscatter intensity = particle size and number distribution
Doppler-shift = cannot be analyzed from ceilometer data
from LIDAR: velocity component in line of sight

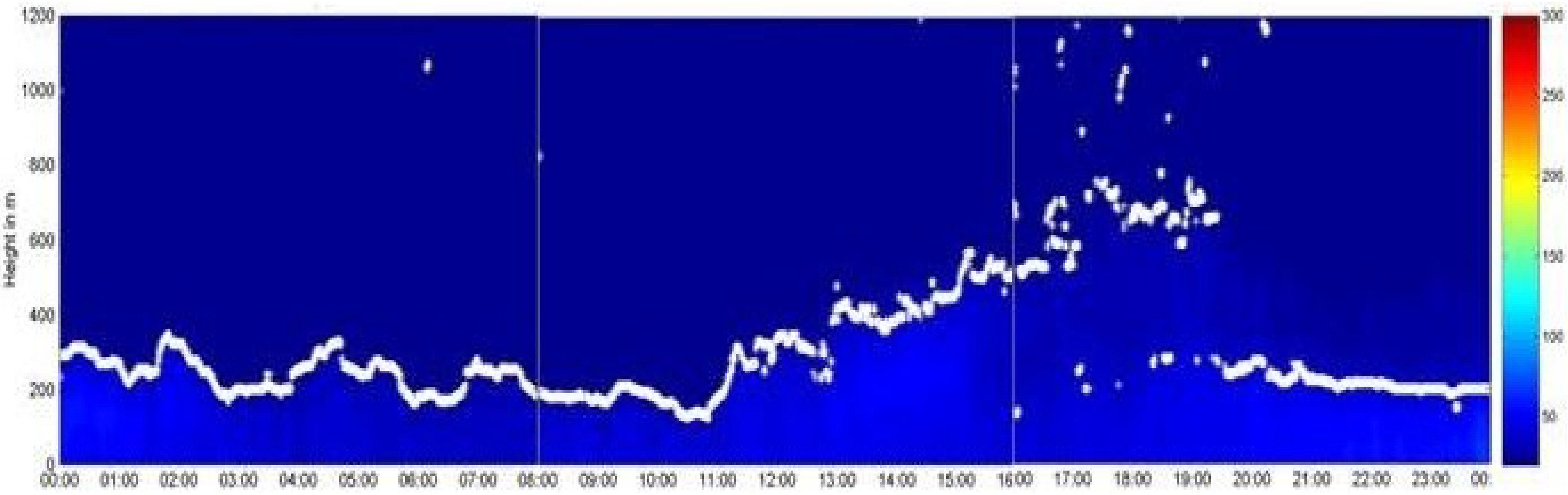
ceilometer

about 1 m in size

normally mounted vertically

emits radiation at 0.7 µm (eyesafe)

Ceilometer in Frankendorf: optical backscatter in 10^{-8} m^{-1} sr^{-1} for December 10, 2003



Difference between acoustic and optical remote sensing

acoustic remote sensing:

SODAR sees

➔ thermal structure of atmospheric boundary layer
➔ wind and turbulence profiles

optical remote sensing:

ceilometer sees

➔aerosol content of atmospheric boundary layer

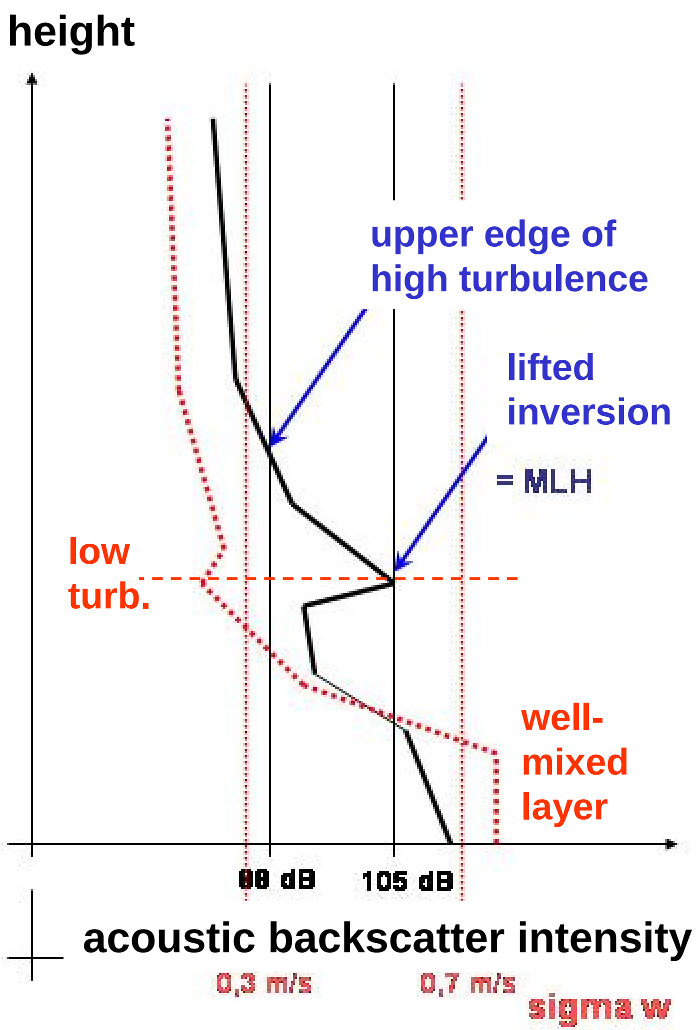
(often this follows the thermal structure of the boundary layer but not always, advection and secondary formation of aerosols has influence, too)

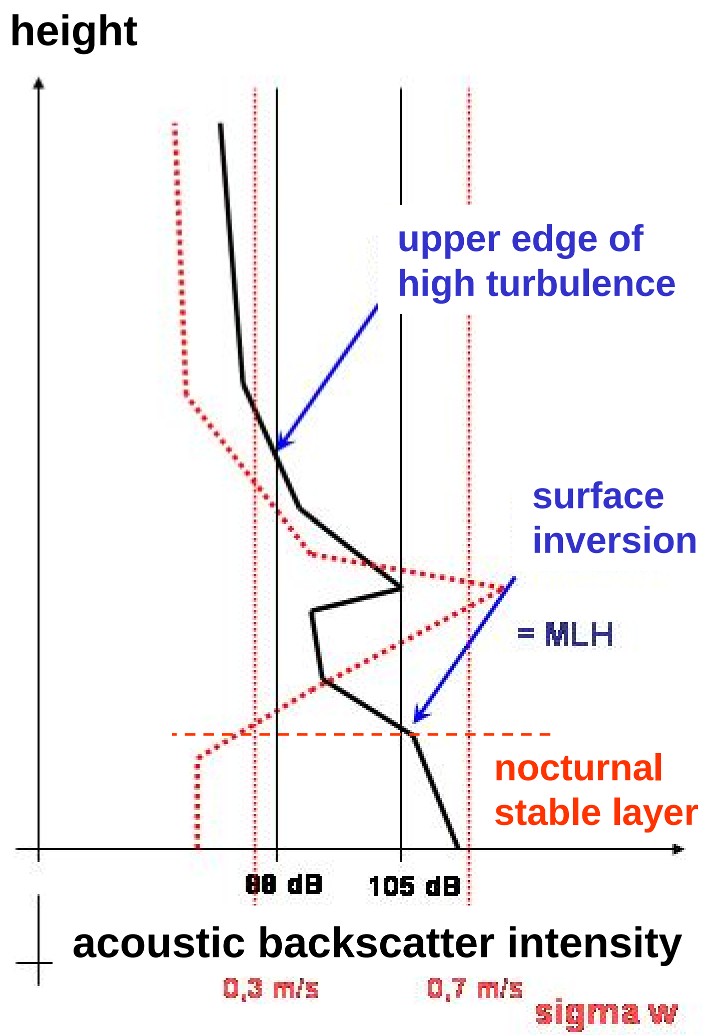
Algorithms to detect MLH from SODAR data

criterion 1:
upper edge of high turbulence

criterion 2:
surface and lifted inversions

MLH = Min (C1, C2)

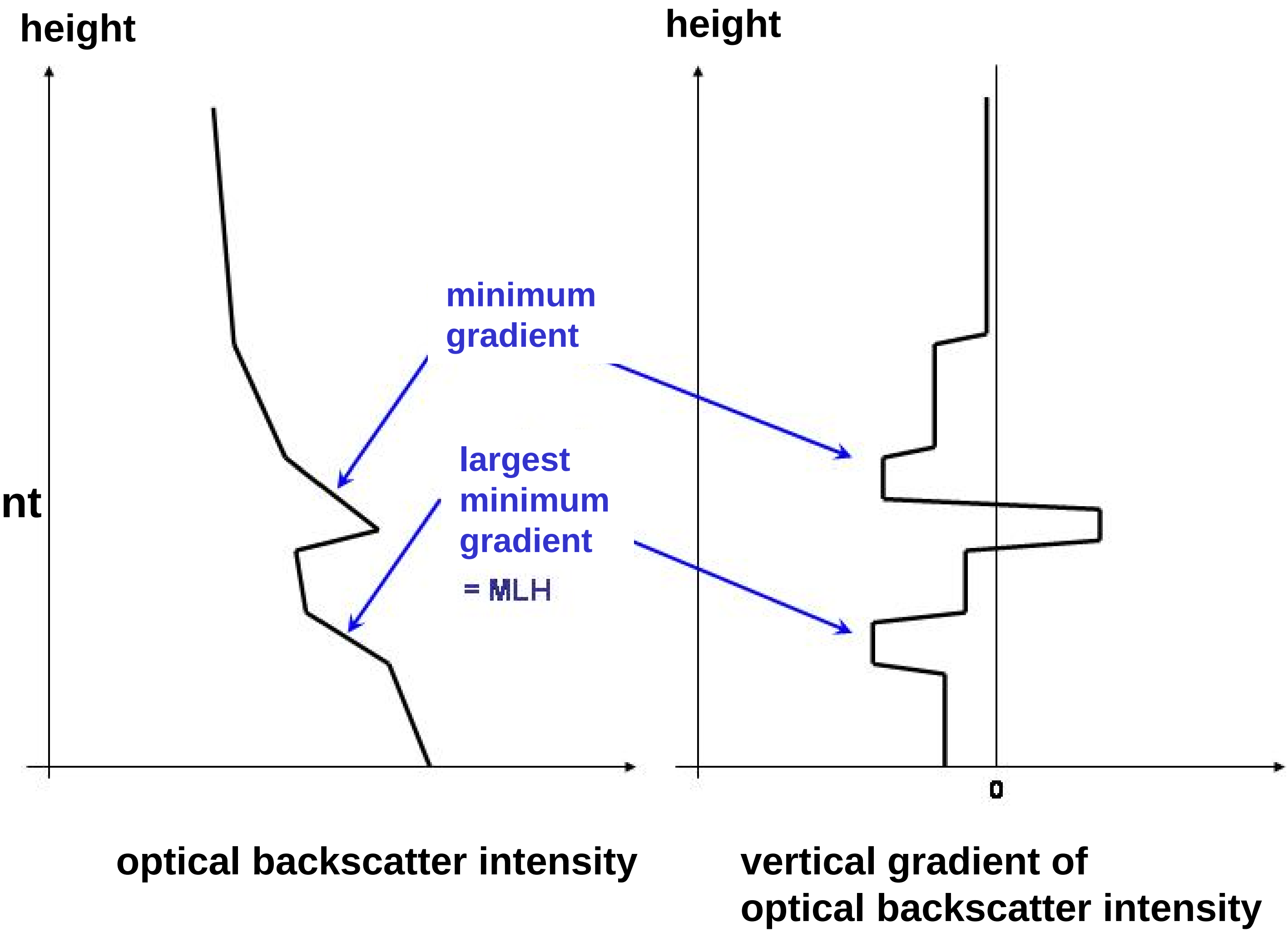




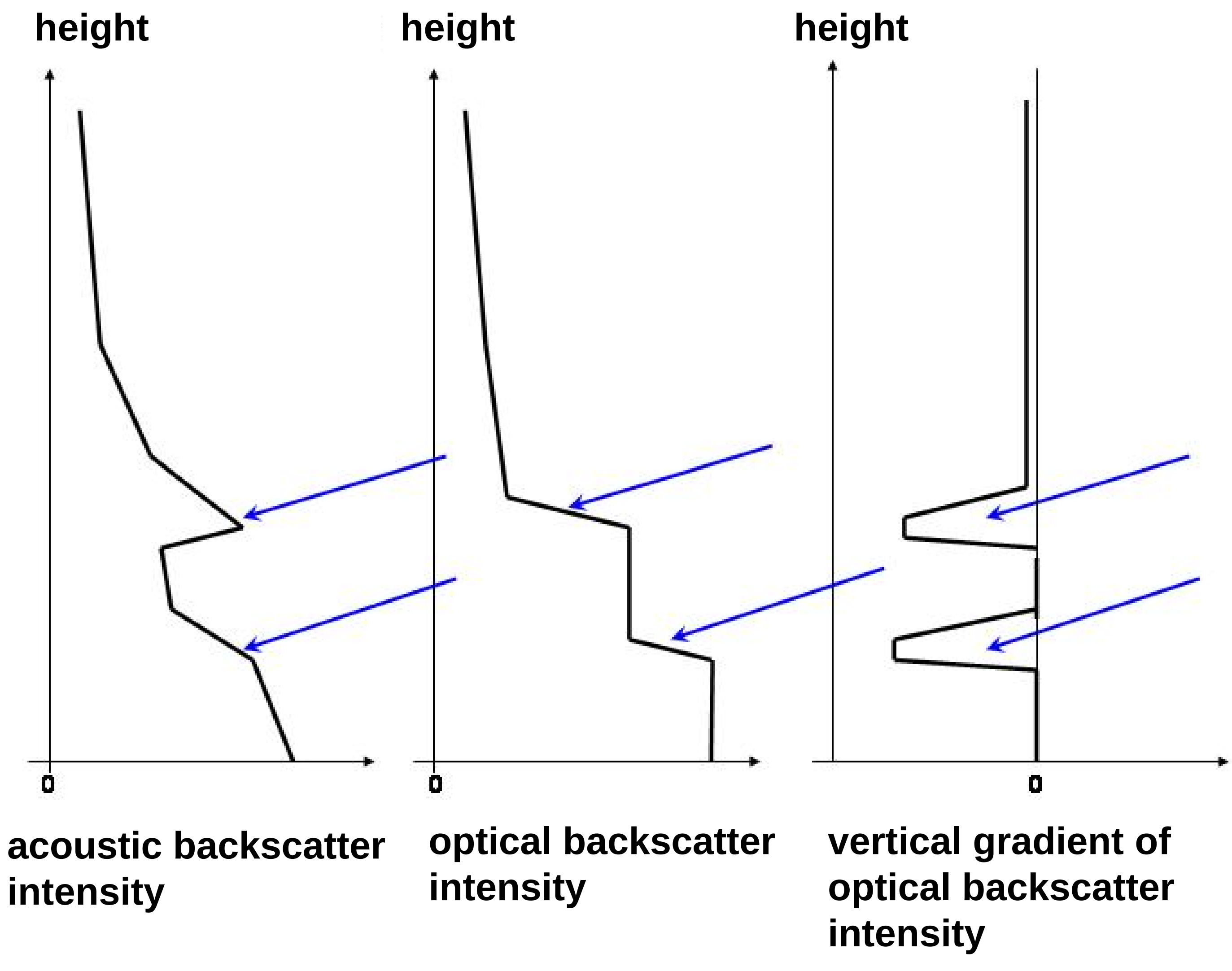
Algorithms to detect MLH from Ceilometer-Daten

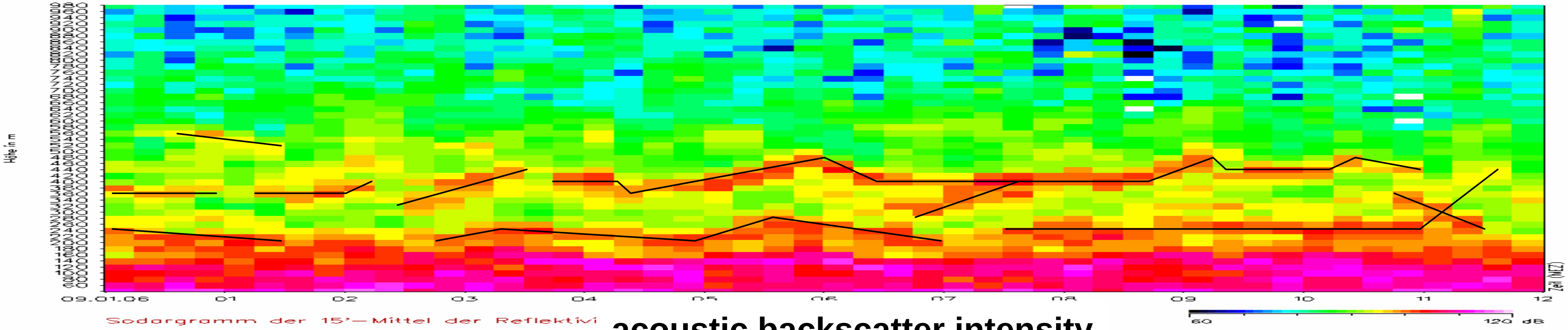
criterion

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

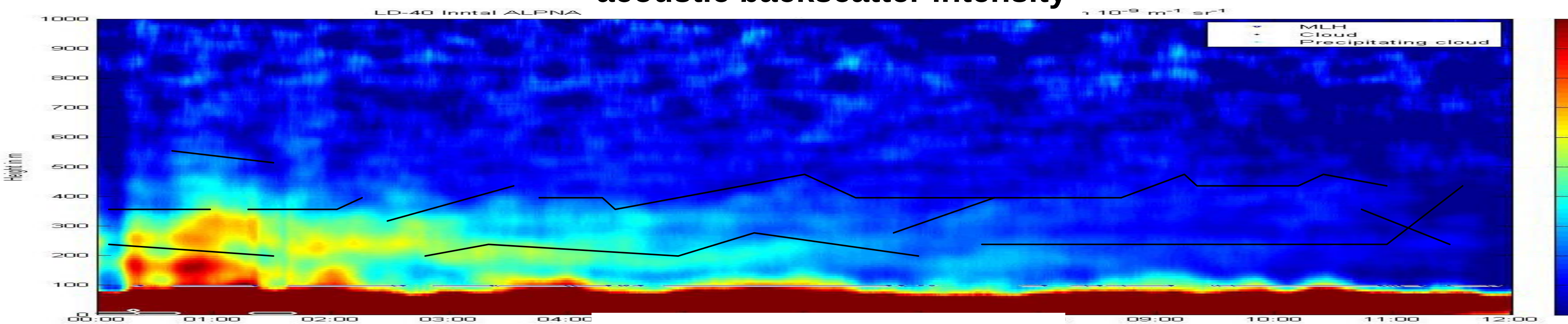


comparison of both algorithms

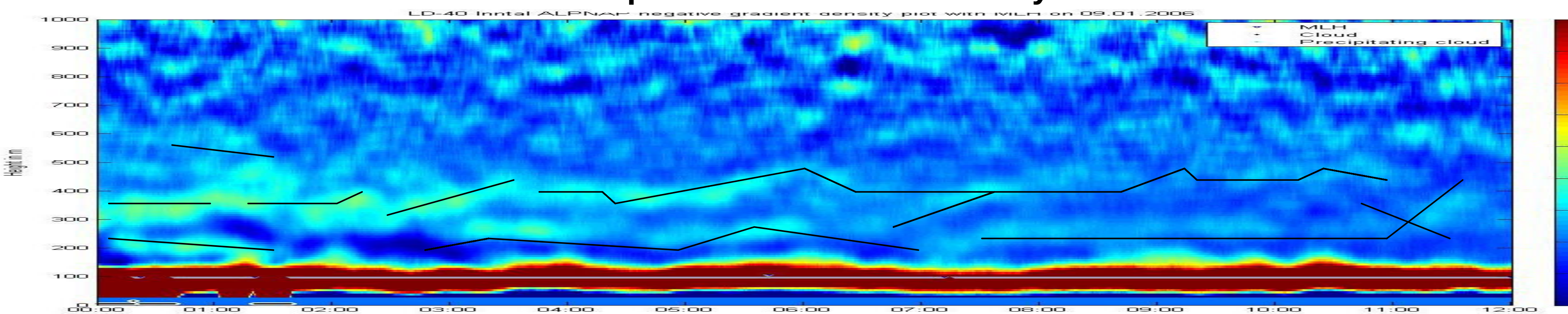




acoustic backscatter intensity



optical backscatter intensity



vertical gradient of optical backscatter intensity

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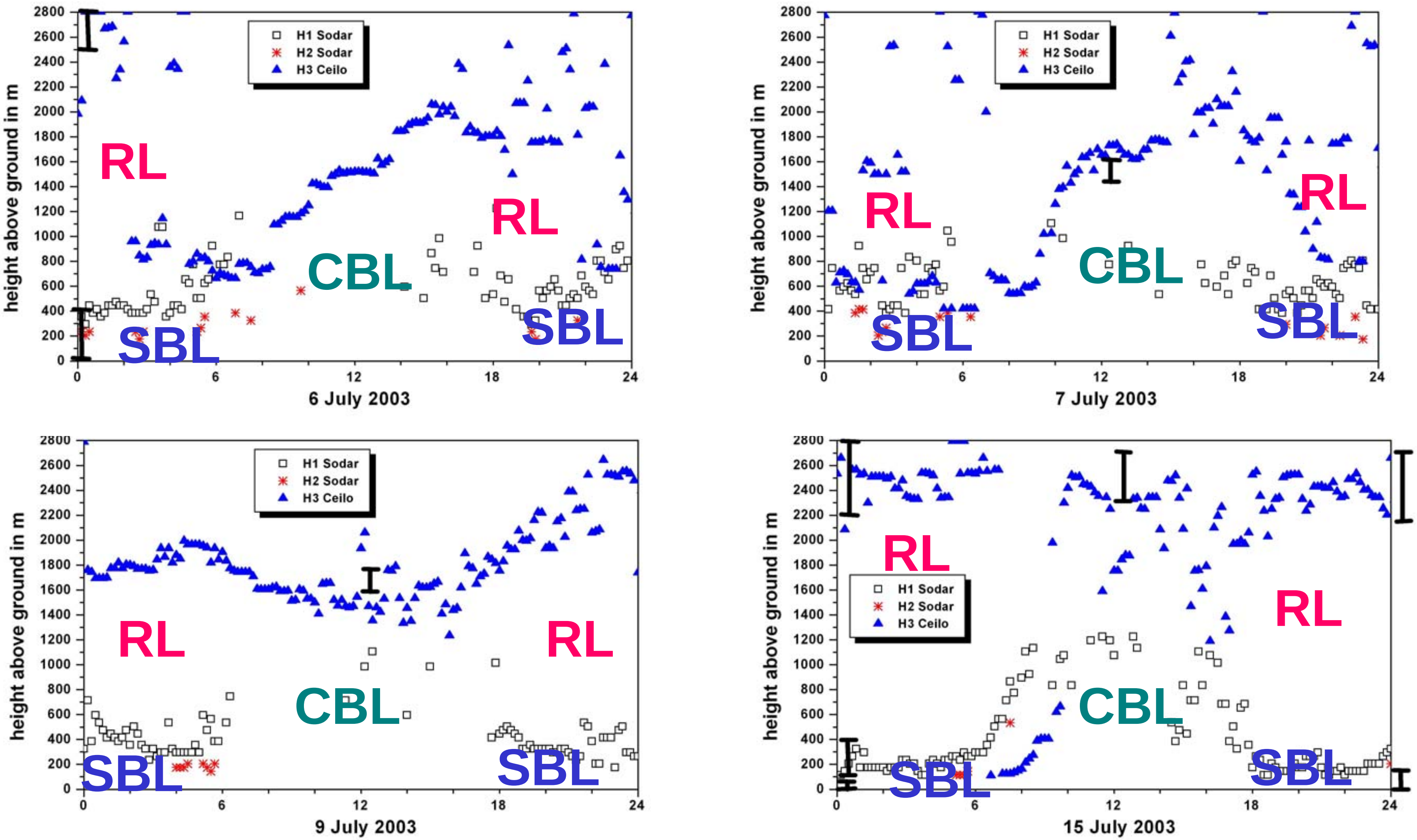
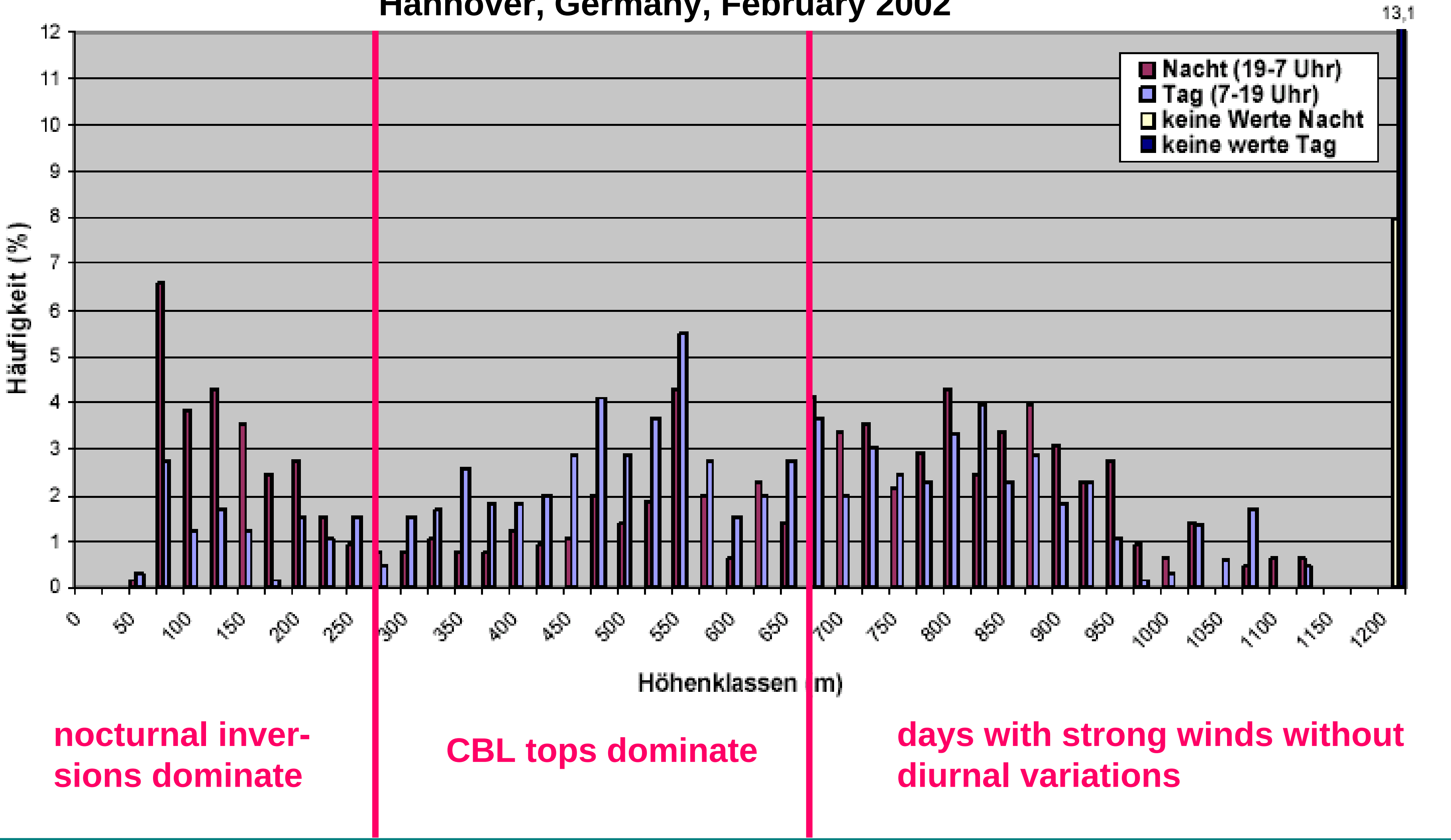
Simultaneous operation SODAR-Ceilometer: examples for summer days



Emeis, S., K. Schäfer, 2006: Remote sensing methods to investigate boundary-layer structures relevant to air pollution in cities. Bound.-Lay Meteorol., 121, **377-385**

frequency distribution of MLH
Hannover, Germany, February 2002



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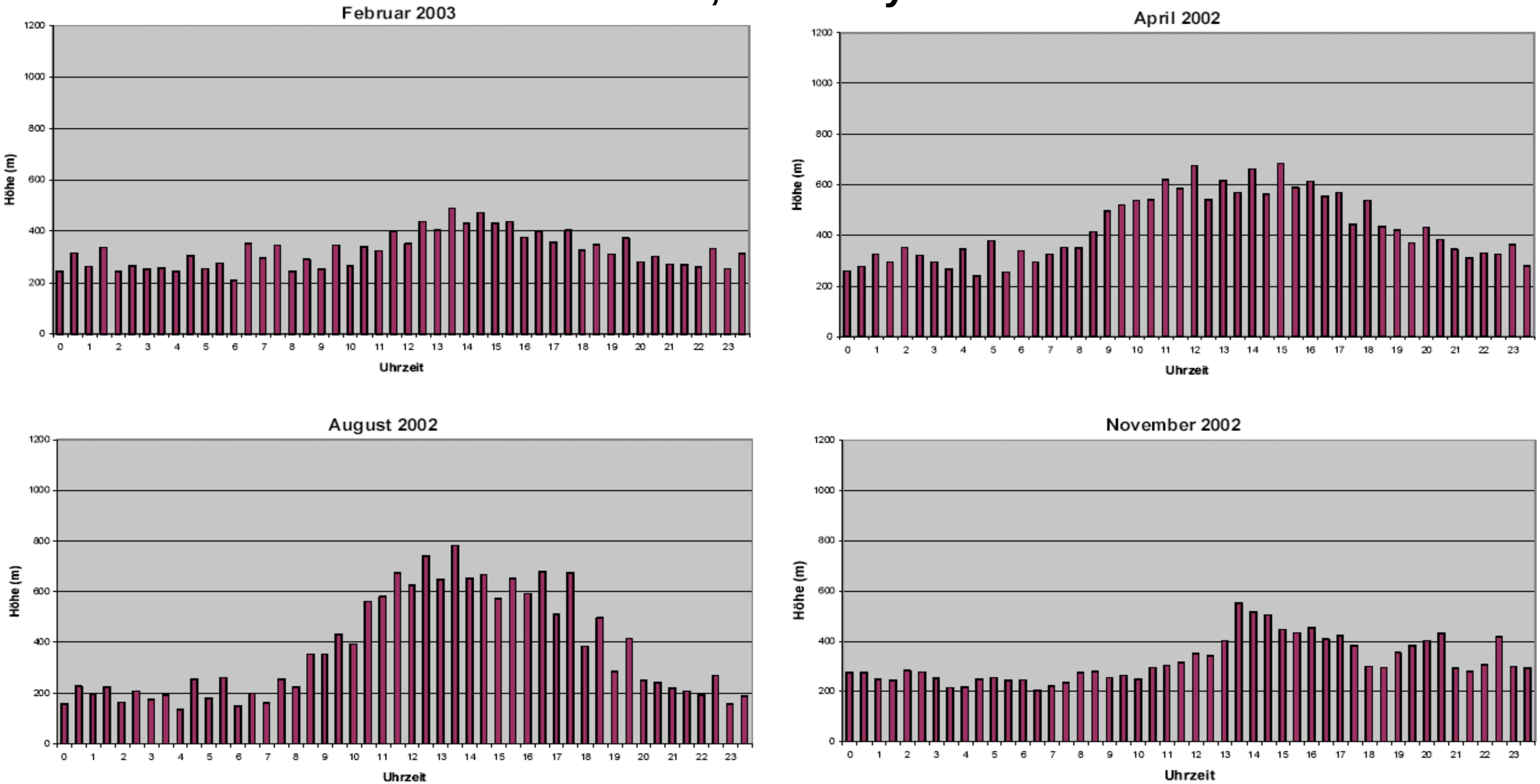
Monthly mean diurnal courses of mixing-layer height

Hannover, Germany 2002/03

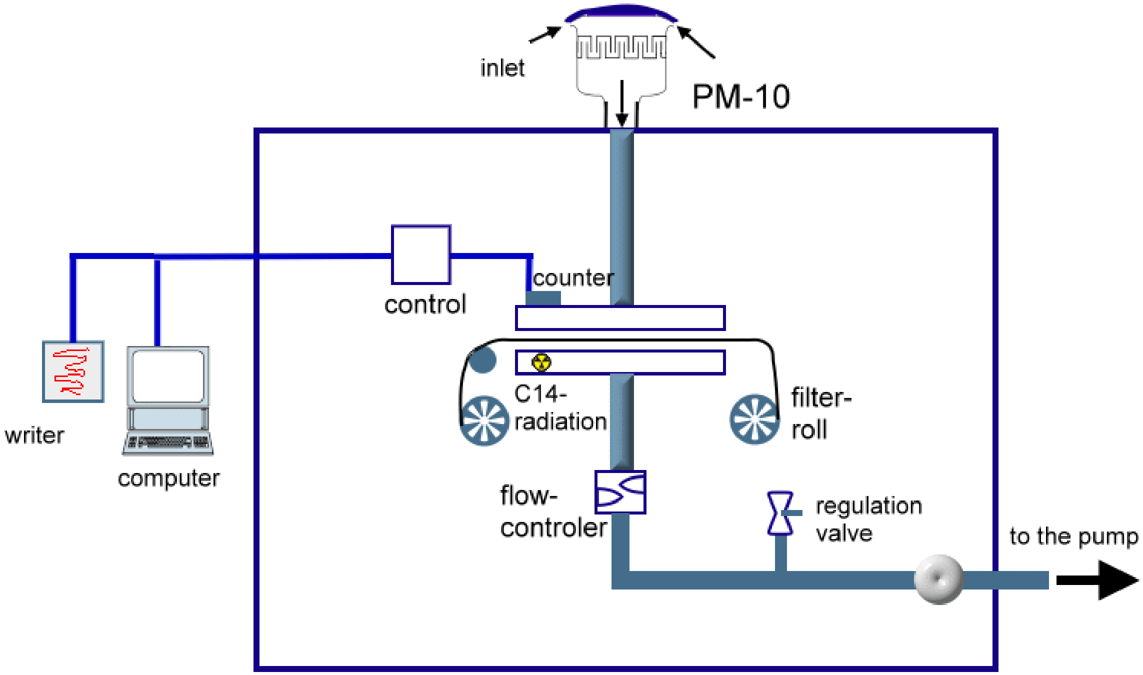


Emeis, S., M. Türk, 2004: Frequency distributions of the mixing height over an urban area from SODAR data. Meteorol. Z., 13, 361-367.

determination of PM10

measurement of aerosol concentrations by in-situ measurements

using beta absorption



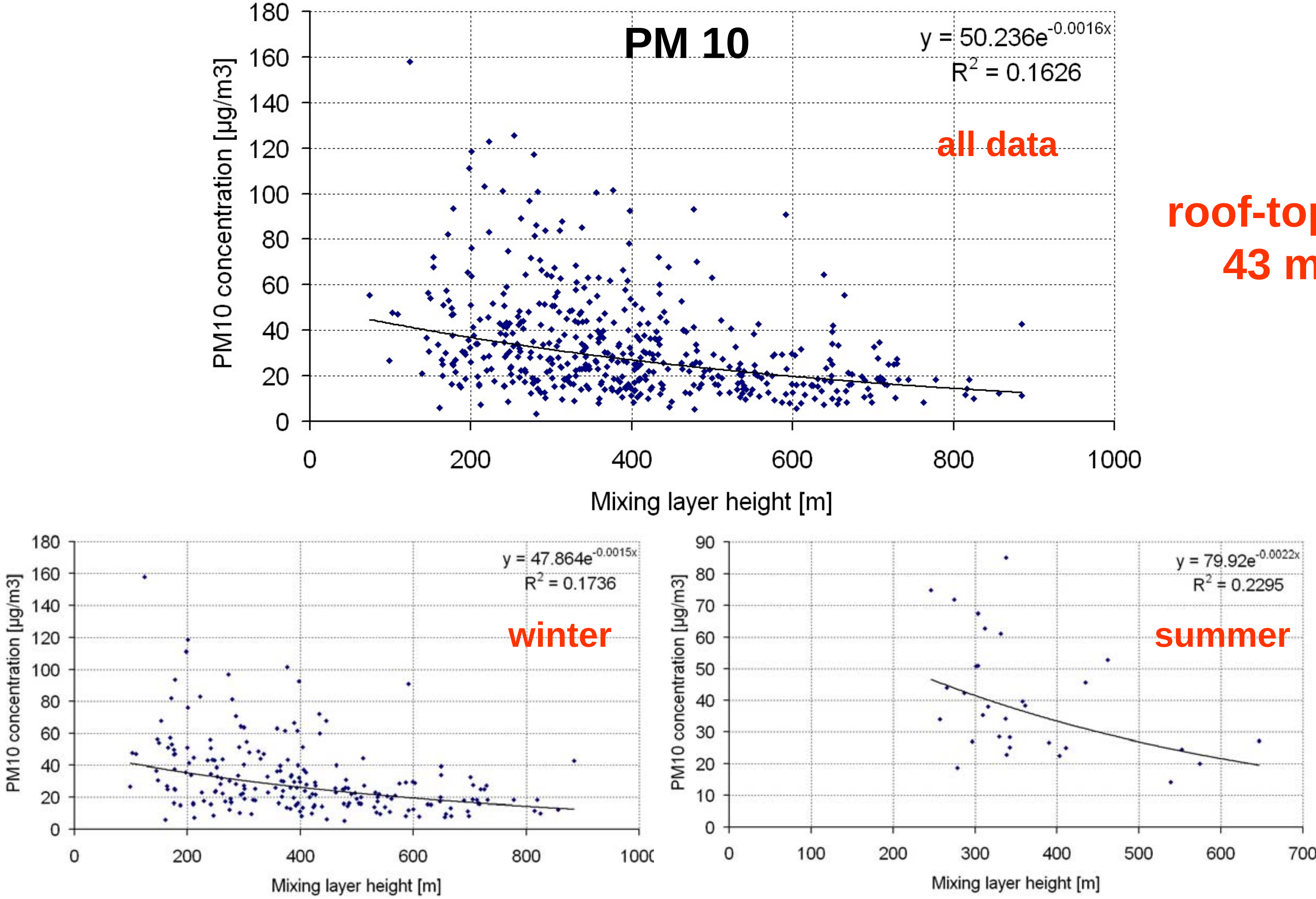
Source: www.atmosphere.mpg.de
ACCENT Global Change Magazine for Schools

case study: Hanover (Germany), Göttinger St., 2001 – 2003

correlation of daily mean values

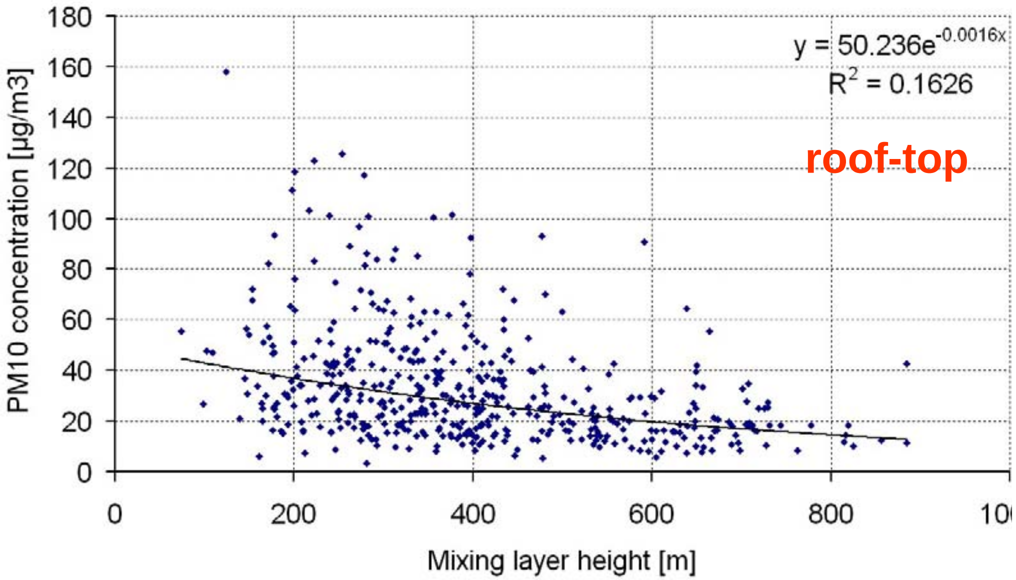
avoids interferences from the correltion of the daily courses of MLH and emission source strength

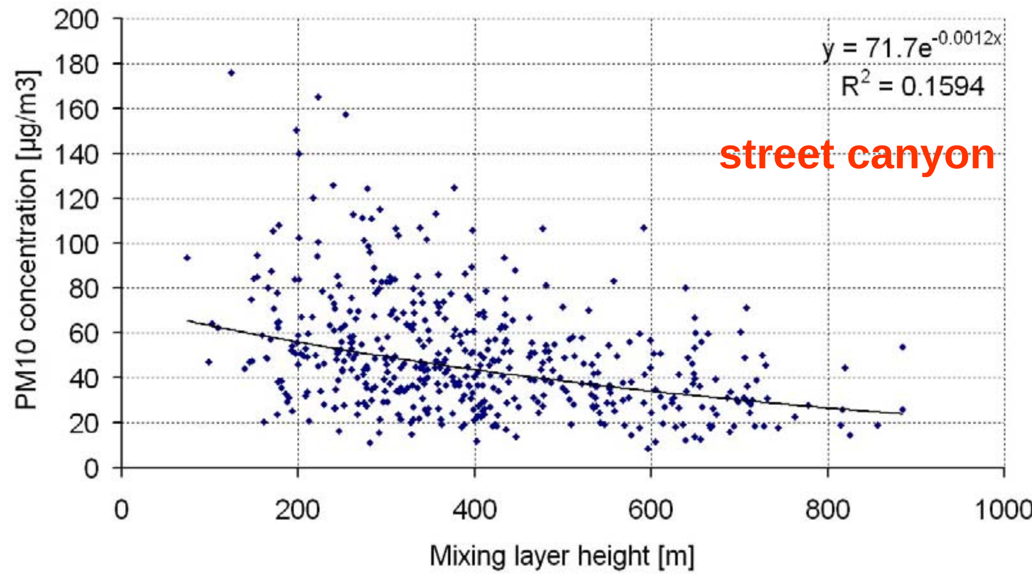
street canyon
Hanover, Göttinger St.



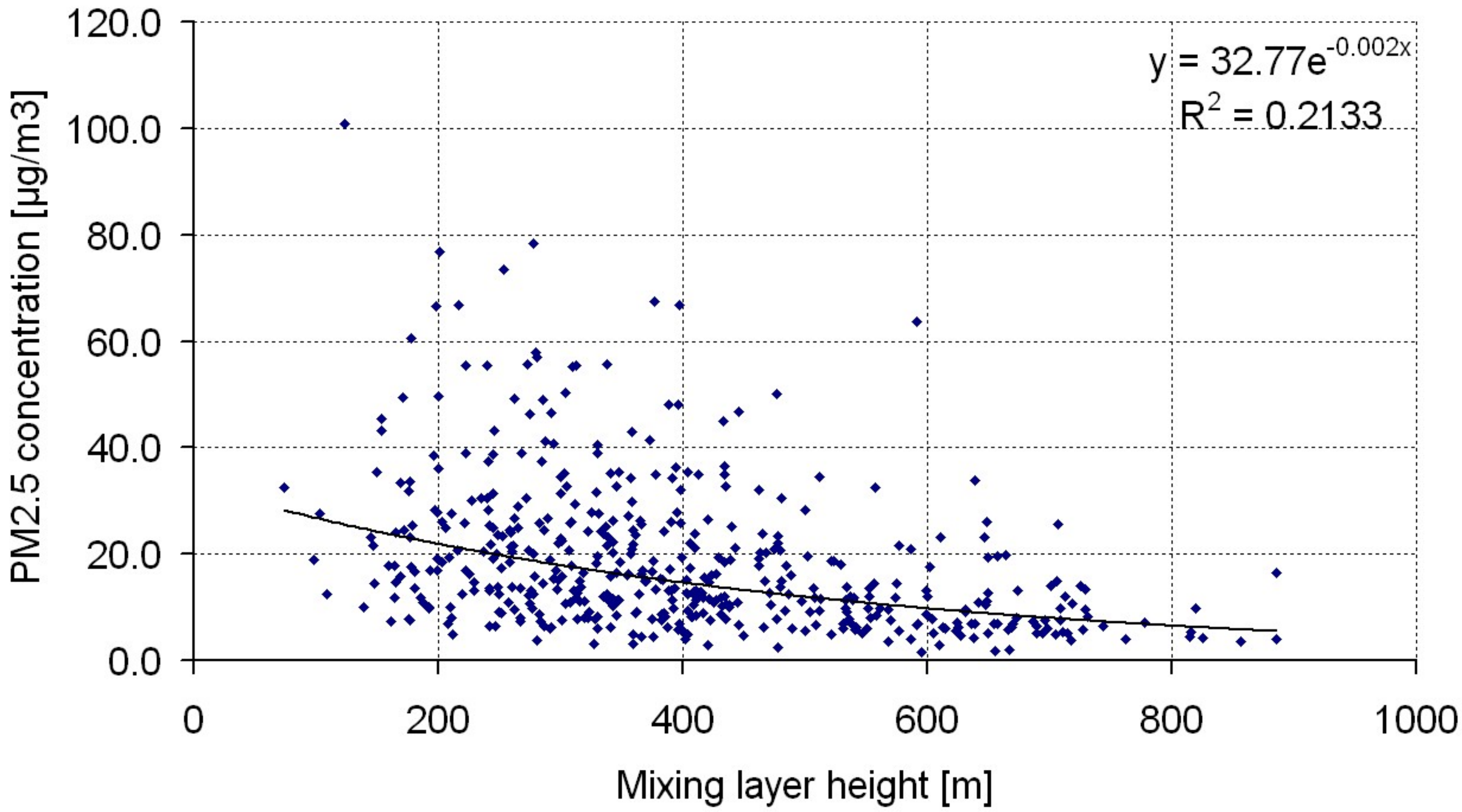
roof-top station
43 m a.g.l.

PM 10


y = 50.236e^-0.0016x
R^2 = 0.1626
roof-top
PM10 concentration [µg/m3]
Mixing layer height [m]
0
20
40
60
80
100
120
140
160
180
200
400
600
800


y = 71.7e^-0.0012x
R^2 = 0.1594
street canyon
PM10 concentration [µg/m3]
Mixing layer height [m]
0
20
40
60
80
100
120
140
160
180
200
400
600
800
1000

PM 2.5



roof-top station 43 m a.g.l.

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case study: Munich (Germany), May/December 2003

correlation of daily mean values

avoids interferences from the correltion of the daily courses of MLH and emission source strength

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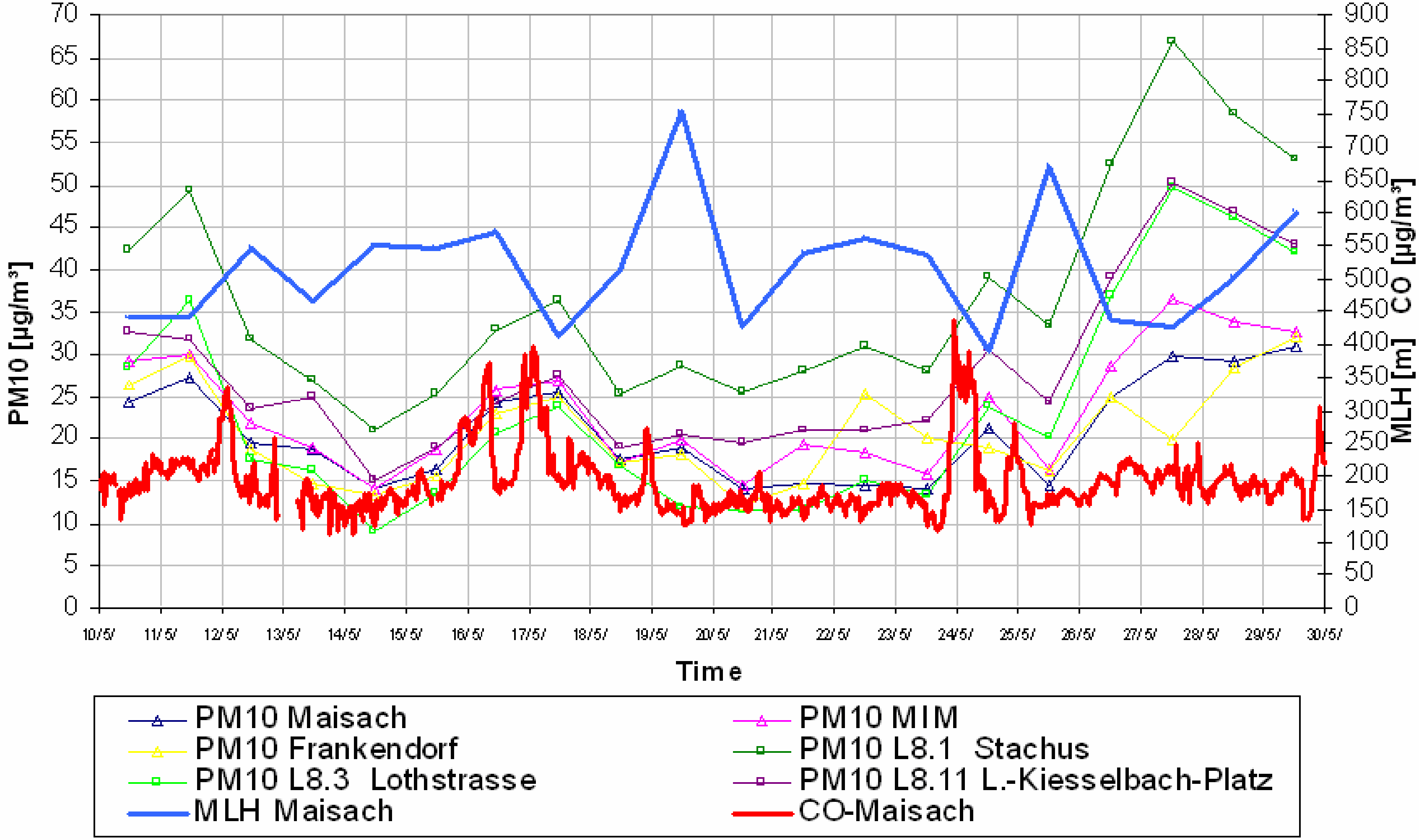
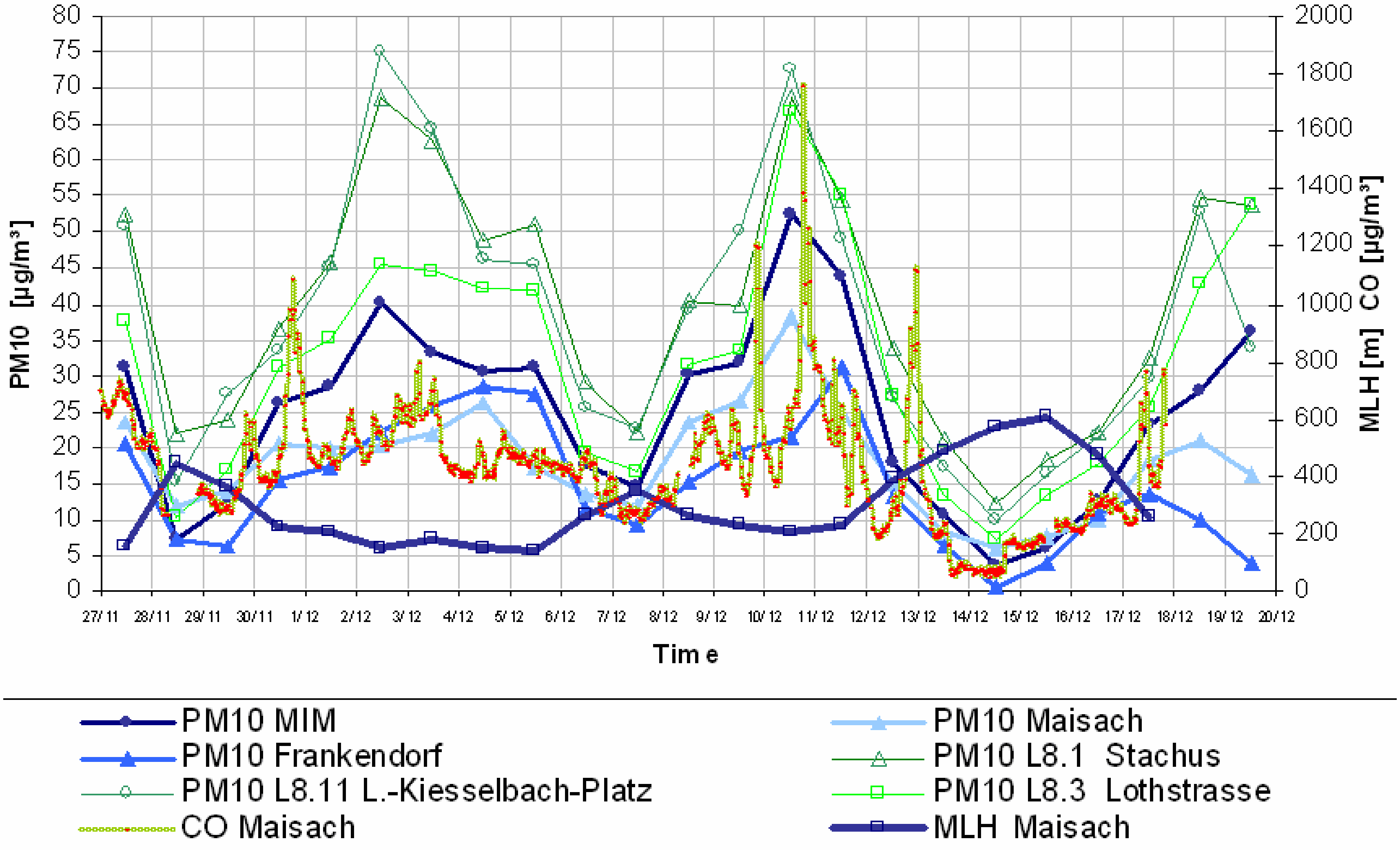
summer


PM10 [µg/m³]
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
MLH [m] CO [µg/m³]
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
10/5/
11/5/
12/5/
13/5/
14/5/
15/5/
16/5/
17/5/
18/5/
19/5/
20/5/
21/5/
22/5/
23/5/
24/5/
25/5/
26/5/
27/5/
28/5/
29/5/
30/5/
Time
PM10 Maisach
PM10 Frankendorf
PM10 L8.3 Lothstrasse
MLH Maisach
PM10 MIM
PM10 L8.1 Stachus
PM10 L8.11 L.-Kiesselbach-Platz
CO-Maisach

winter



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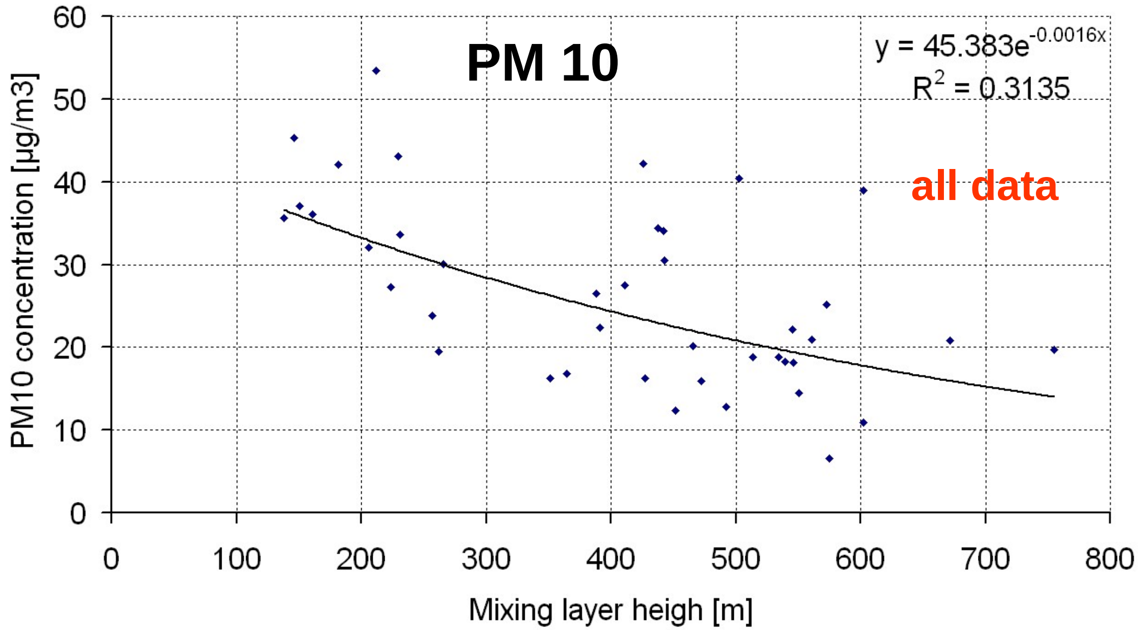
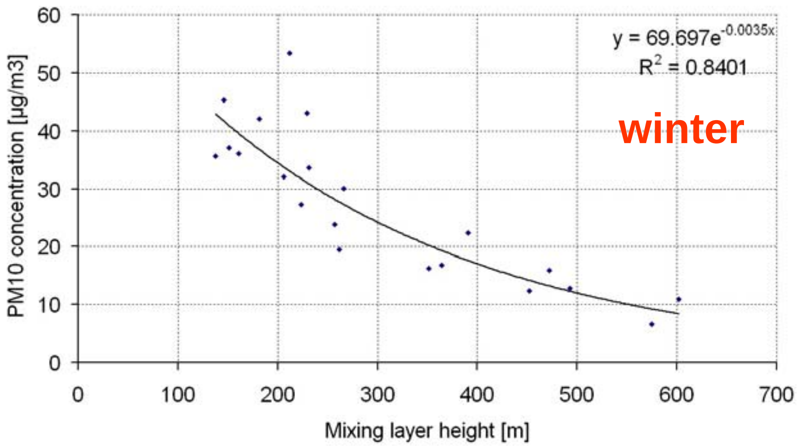
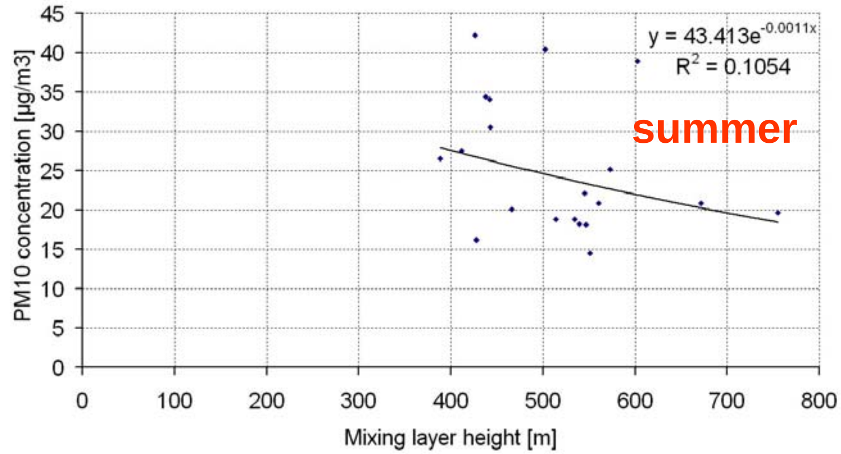
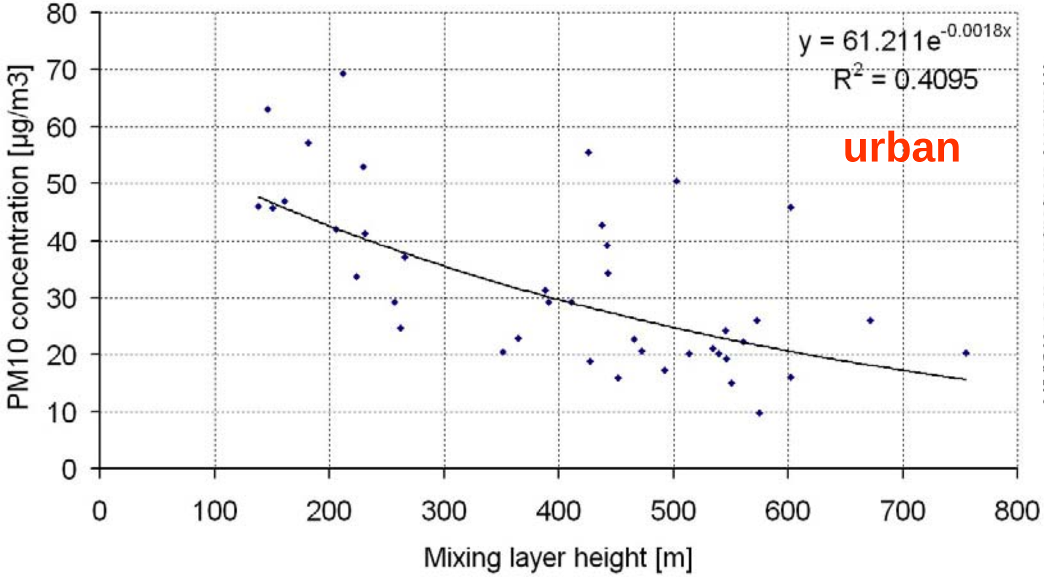


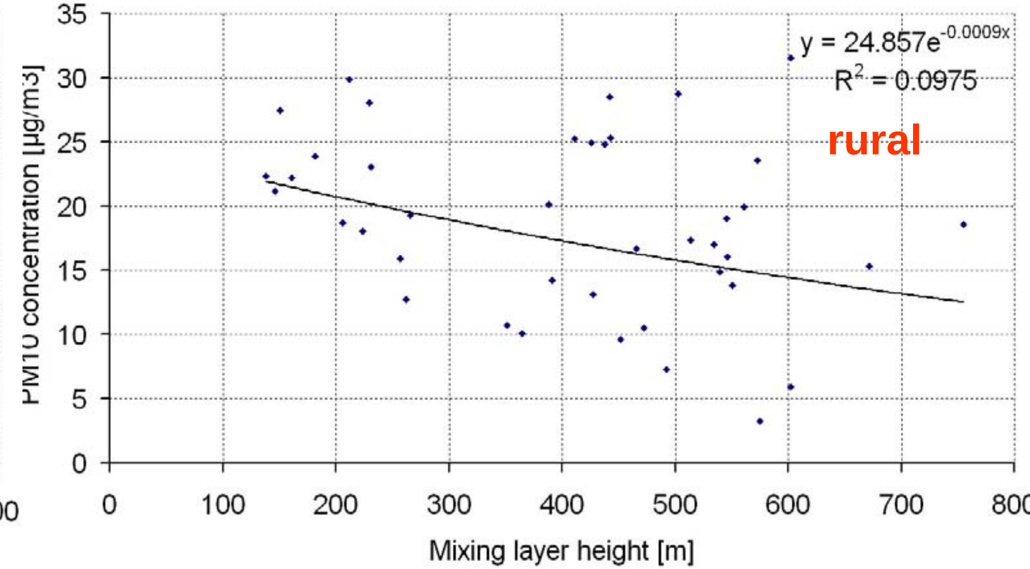
Munich all stations





PM 10

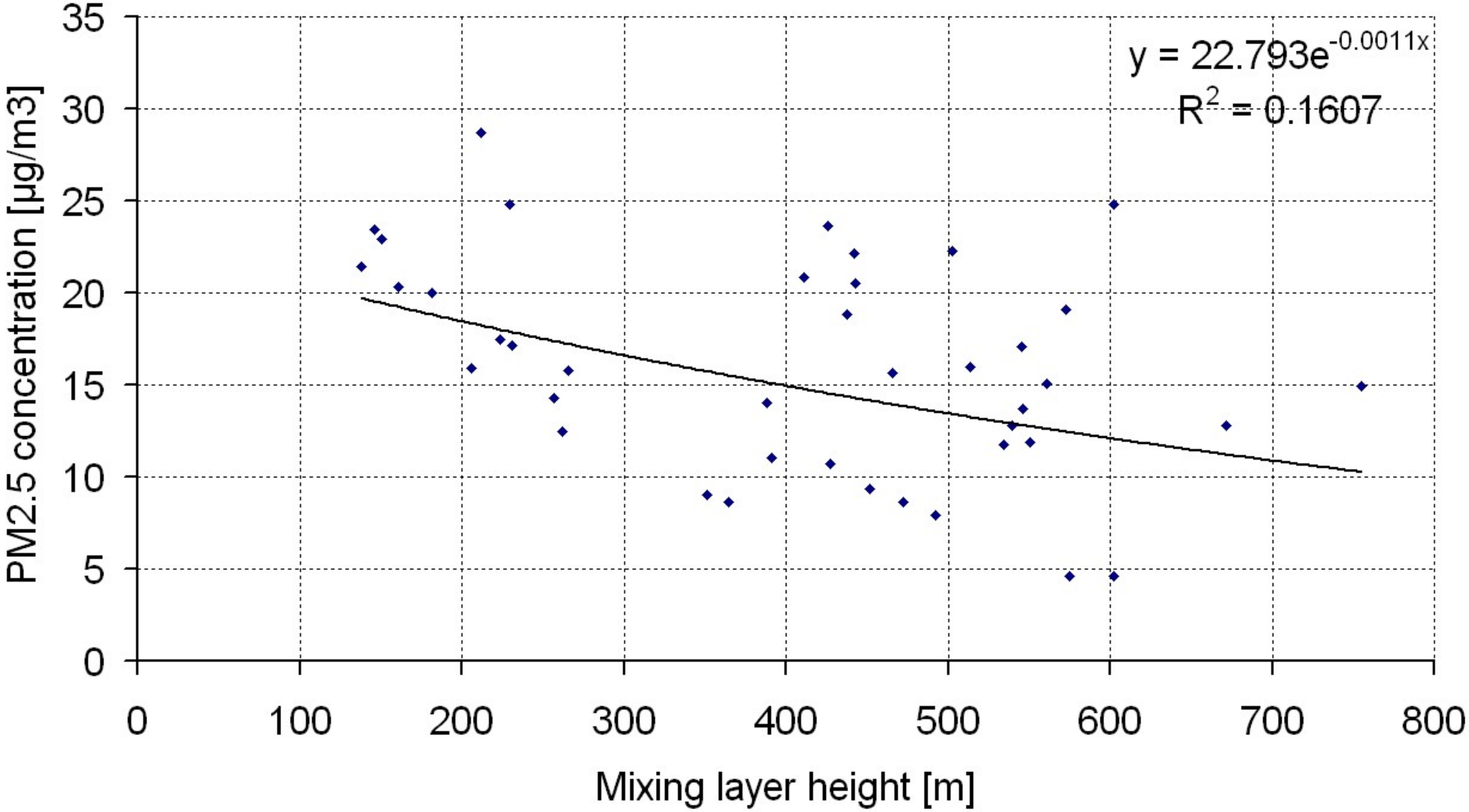




Munich and surroundings

PM 2.5

rural and urban background stations



case study: Inn valley January 2006

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09:45

15:05

15:55

17:35

January 29, 2006

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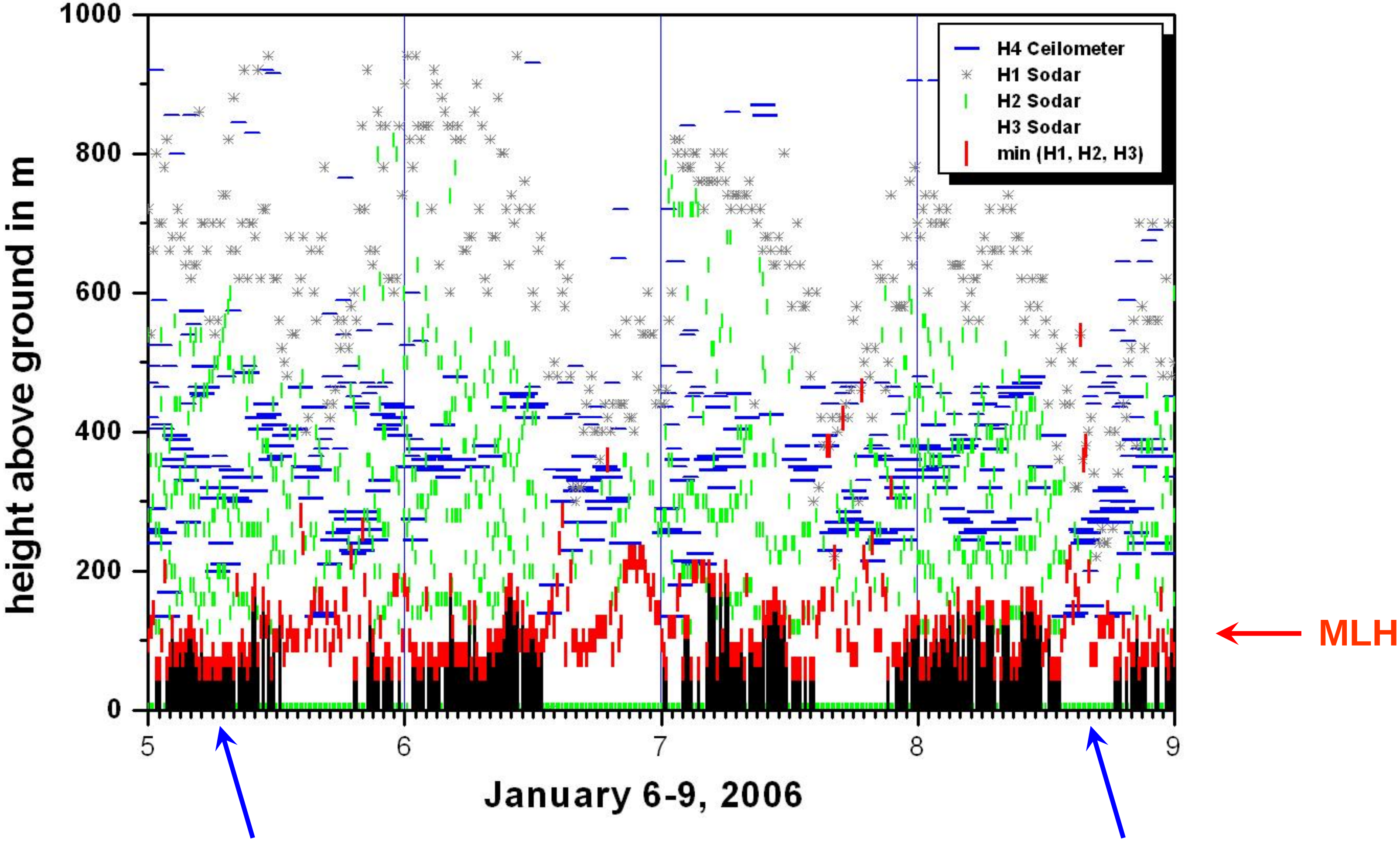
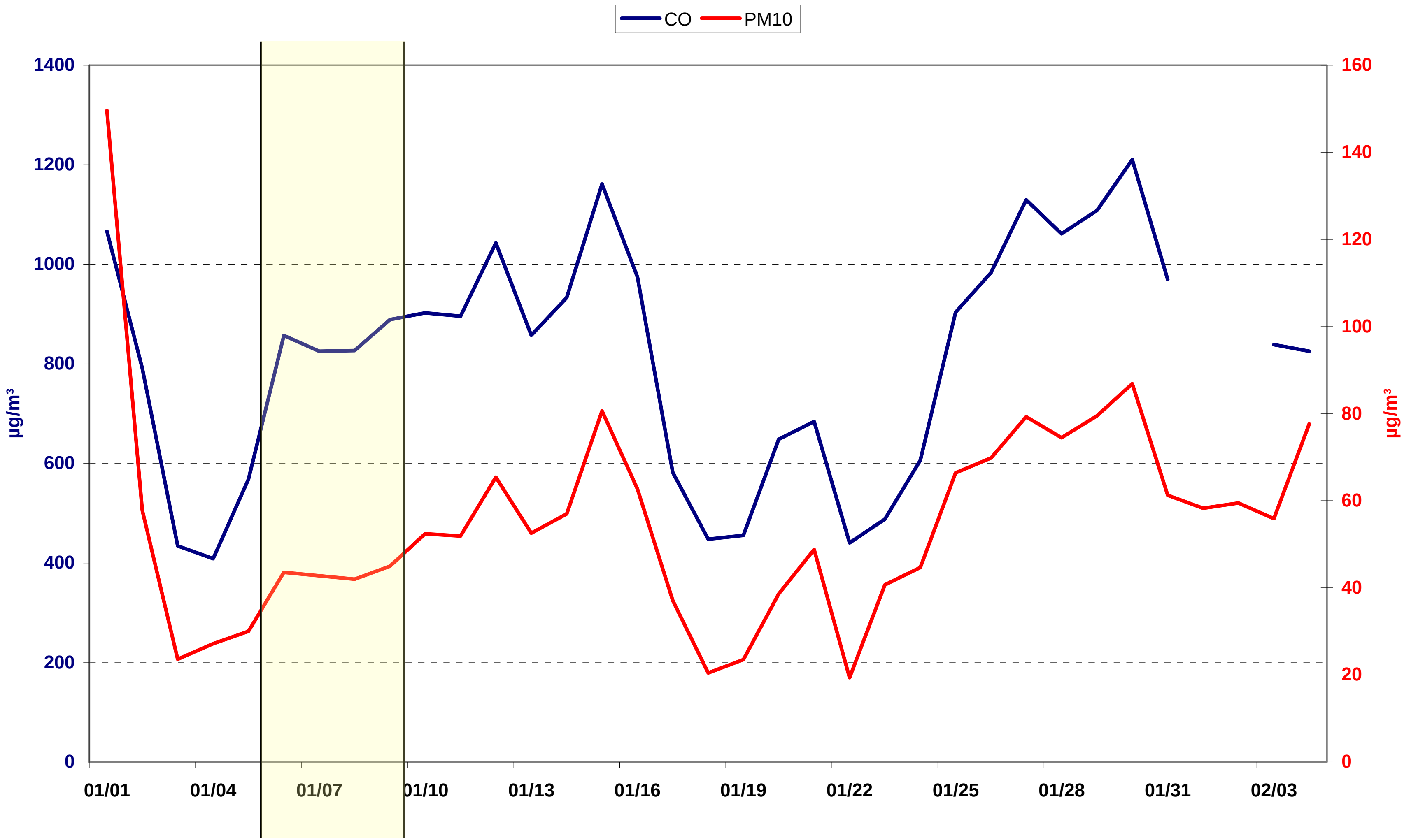
3
2
1
4
5
6
NOx



completely stable nocturnal surface layer (NSBL)

near-neutral day-time surface layer

Inn valley


CO
PM10
1400
1200
1000
800
600
400
200
0
µg/m³
160
140
120
100
80
60
40
20
0
µg/m³
01/01
01/04
01/07
01/10
01/13
01/16
01/19
01/22
01/25
01/28
01/31
02/03

Conclusions

correlation between MLH and PM is stronger in winter than in summer (lower MLH, less secondary formation of PM) (Munich)

PM concentrations in street canyon higher than at roof-top level, but no significant differences in correlation (Hanover)

correlation between MLH and PM is stronger for urban sites than for rural sites (Munich)

correlations for PM 10 and PM 2.5 with MLH are not significantly different (Hanover and Munich)

correlations for PM with MLH are usually less than those for NO_x with MLH (50% to 70% for r^2) (Hanover and Munich)

PM increases for longer periods with nearly constant MLH (Inn valley)

Outlook

current acticities:

Augsburg (combined ceilometer and sodar measurements (MLH) and air quality measurements), impact of residential heating (biomass) on air quality

method is applicable for larger cities (effects of urban heat island on air quality and public health)

MLH-air quality correlations are important data for evaluation and enhancement of mesoscale numerical air quality simulation models

planned activities:

TERENO (Terrestrial Environmental Observatories), HGF, one measurement site will be in the pre-Alpine area

Santiago de Chile (HGF-initiative: „Risk Habitat Megycities“)

Thank you for your attention