

**FIELD MEASUREMENTS WITHIN A QUARTER OF A CITY
INCLUDING A STREET CANYON TO PRODUCE A VALIDATION DATA SET**

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Concept of measurements

Quality assurance / quality control activities

Interpretation of measurement results

Harmonisation 09, 02 June 2004

For the execution of the [European Air Quality Framework Directive 96/62/EC](#) and its daughter directives 12-monthly air pollution maps with a spatial resolution of 200 m² are required

[Tools](#) for this task with the necessary quality are not available up to now and were developed on the basis of numerical models ([meso-/micro-scale model system M-SYS](#)) in frame of the project VALIUM (AFO 2000 program)

[Validation](#) of this model system is necessary

[Continuous measurements of air pollutants](#) inside a [street canyon](#) and in the [surrounding area of 1 km x 1 km](#) (Göttinger Straße in Hannover) were performed in addition to the routine NLO monitoring from beginning 2001 until end of 2003

Investigations were combined with [wind tunnel](#) experiments at UHH

Concept of measurements

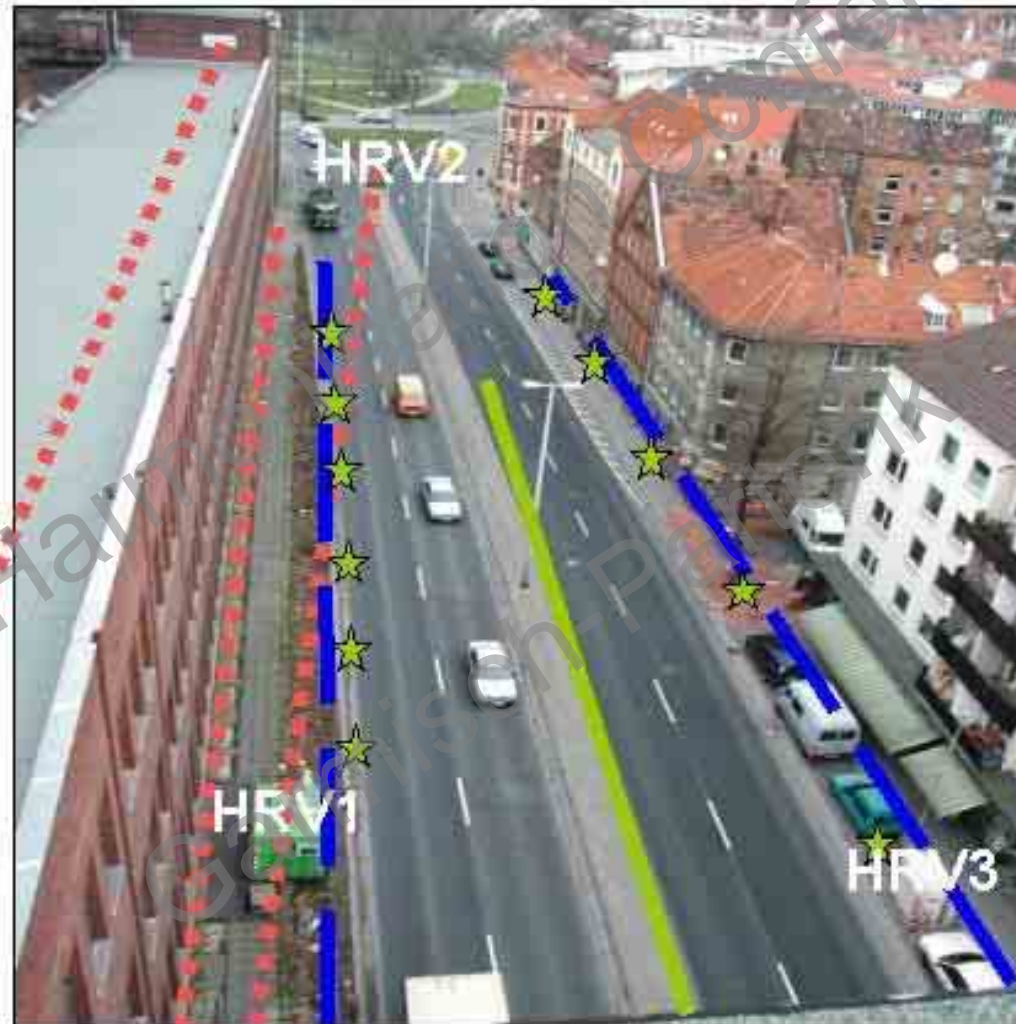
Both air pollutants and meteorological parameters were measured by in situ instruments at **four sites inside the street canyon** (HRVS, HRV1, 2, 3) and at **three sites in the surroundings** (HRSW, HRV4, HRV5)

Path-averaging optical measurement techniques (two, some times three DOAS systems) were used continuously on the ground and on the roof of a building at the street

Acoustic remote sensing of wind and turbulence profiles and mixing layer heights was performed by a **SODAR** south-west of Göttinger Straße in about 500 m distance, completed by a ceilometer and a Wind-Temperature-Radar

Three **intensive operational phases** in different seasons with **tracer** SF₆ experiments and investigation of vertical gradients (path-averaging FTIR measurements for CO, DOAS measurements for NO₂) were executed

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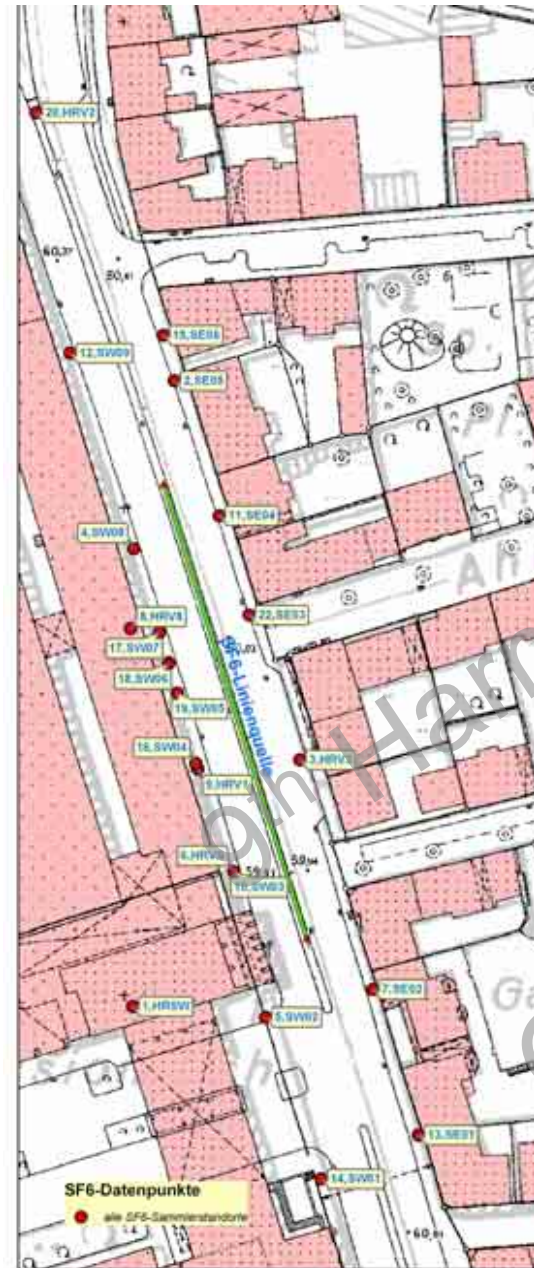


SF6 line
source and
sampling
sites

FTIR

Annual mean of **PM10 and NO₂** (year 2002) at all stations and number of days which exceed the boundary value 50 µg/m³ for PM10 and number of hours which exceed the boundary value 200 µg/m³ for NO₂ corresponding EC Daughter Directive 1999/30/EG

Station	PM10 Annual mean (µg/m ³)	PM10 Number of days >50 µg/m ³	NO ₂ Annual mean (µg/m ³)	NO ₂ Number of hours >200 µg/m ³
HRSW	29	42	25	0
HRV1	43	102	58	0
HRV2	41	104	61	4
HRV3	40	90	53	3
HRV4	28	34	27	0



Intensive operational phases

Tracer 07 August 2002, 09:00 – 16:00 CET

northerly winds (street parallel) up to 3 m/s

23 October 2002, 13:00 – 17:00 CET,

westerly winds around 6 m/s

24 October 2002, 09:00 – 17:00 CET,

westerly winds around 7 m/s

25 October 2002, 13:00 – 17:00 CET,

southerly winds (street parallel) around 6 m/s

26 October 2002, 11:00 – 17:00 CET,

westerly winds around 10 m/s

11 April 2003, 09:00 – 17:00 CET,

westerly winds around 3 m/s

23 April 2003, 09:00 – 17:00 CET,

easterly winds around 3 m/s,

probe sampling without tracer release also

canister sampling analyses for about 50 VOC

2 USA in 3 m altitude in the street canyon

Quality assurance / quality control activities

Long-term comparison of different measurement methods (ISO 13752
Air quality)

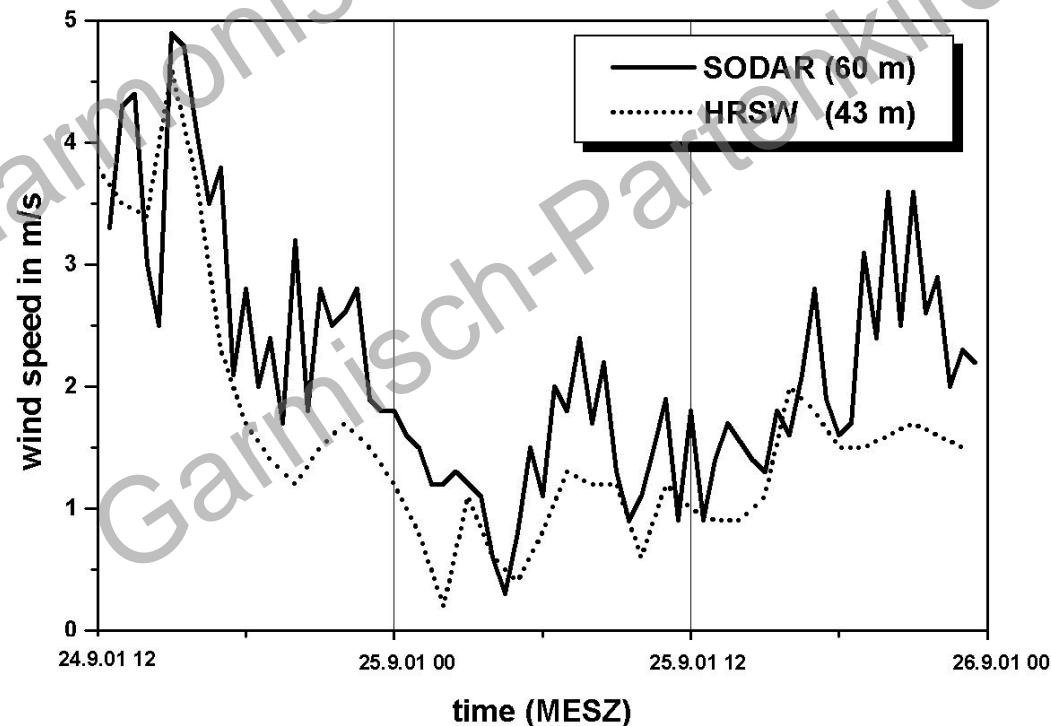
Comparisons of different measurement systems during 36 hours
before / after IOPs

Measurement systems of NLÖ are references

Long-term meteorological investigations

- Doppler-SODAR measurements with vertical resolution down to 12.5 m
- Comparison between wind data from SODAR and from roof-top station shows influence of surrounding buildings upon roof-top measurements
- Due to stable layering larger differences at night exist

Comparison IMK-IFU-SODAR (60 m) NLO roof-top station HRSW (43 m)

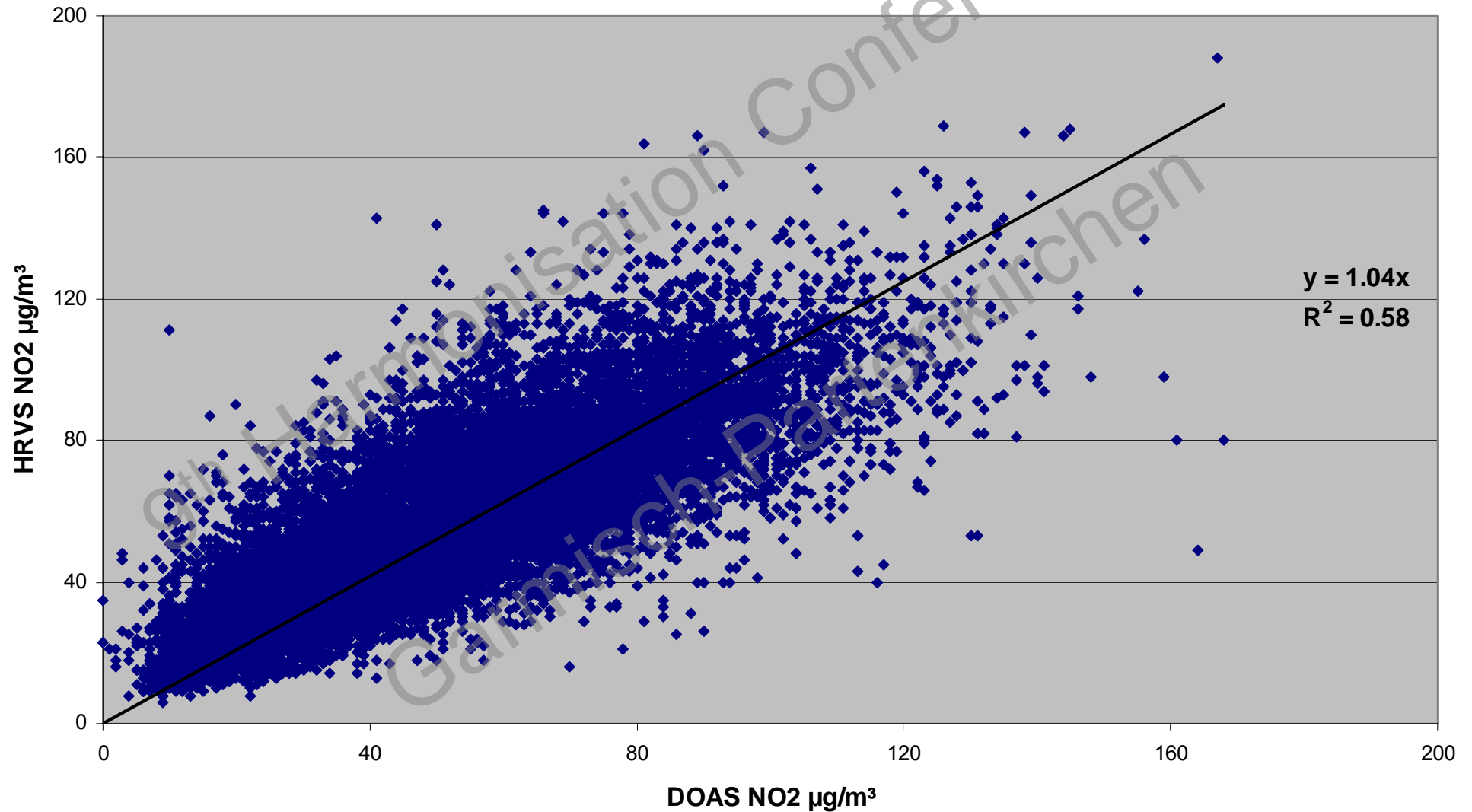


Long-term NO₂ study of the path-integrated DOAS and in situ measurements at different stations from February 2001 until May 2002:

- Means of all simultaneous half-hourly means of the stations HRVS, HRV1, HRV2, HRV3: range from 30 up to 70 µg/m³
- Correlation of the DOAS measurement with single and averaged in situ measurement results including about 16,000 up to 18,000 values

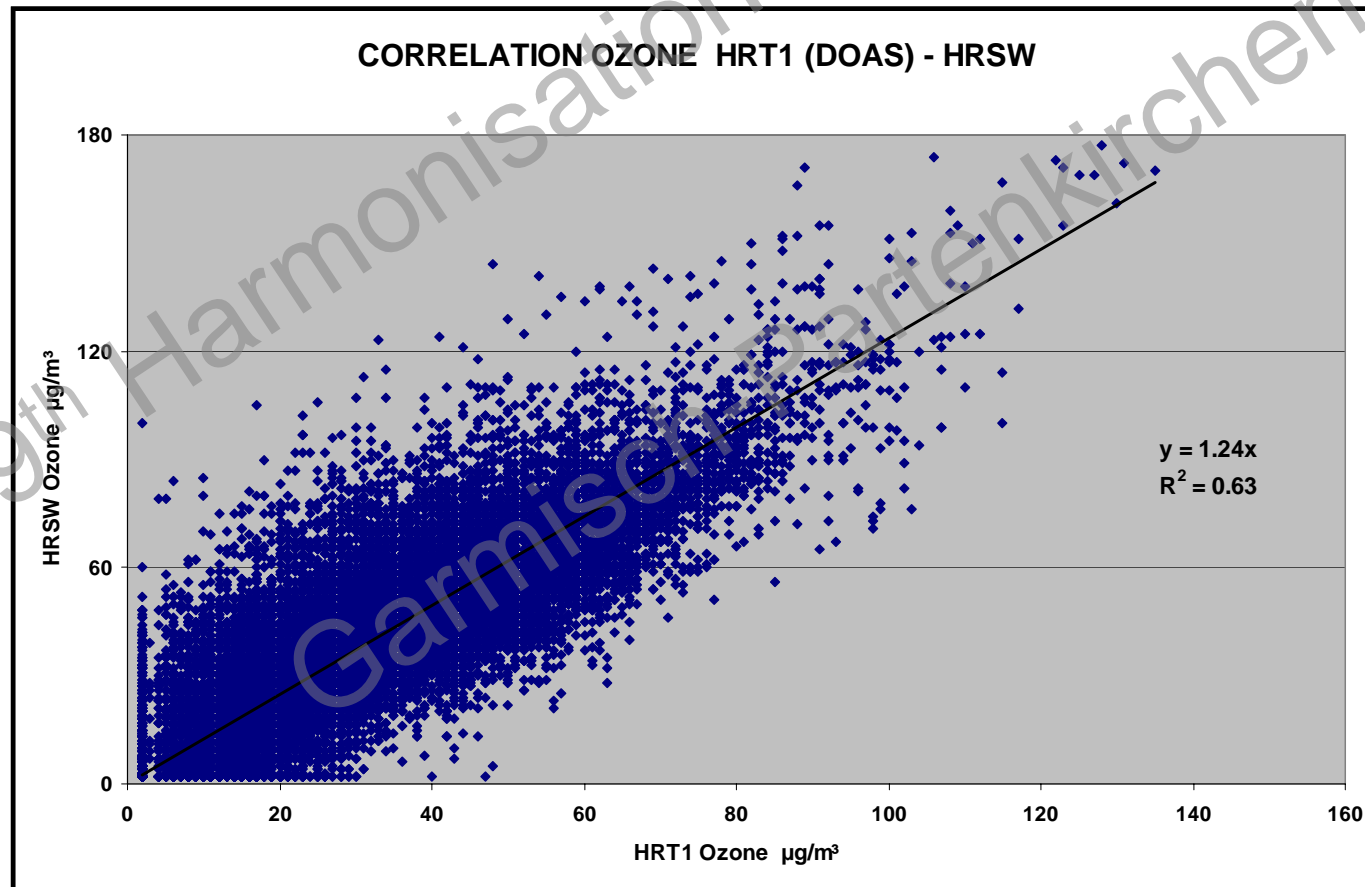
Station	Correlated Station	Correlation		Standard Deviation S _r , [%]
		Gradient	R ²	
HRT1	HRVS	1.04	0.58	-
HRT1	HRV1	1.01	0.44	23.6
HRT1	HRV2	0.97	0.32	-
HRT1	HRV1/V2	1.00	0.46	24.1
HRT1	HRVS/V1/V2/V3	0.98	0.55	20.2
HRVS	HRV1	0.94	0.67	18.1

CORRELATION HRT1 (DOAS) - HRVS



Ozone comparison

- HRV4 and HRV5 with R^2 equal to 0.96, HRV4 and HRSW 0.95
- HRT1 and HRSW with R^2 equal to 0.63, long-term mean 44 $\mu\text{g}/\text{m}^3$ at HRSW and 34 $\mu\text{g}/\text{m}^3$ at HRT1



Comparison of different measurement systems

- CO and CH₄ by both FTIR spectrometers with HRV5 (in situ device TE48) at that site (homogeneous mixing)
- Weather stations HRV5 and HRV8 with HRSW

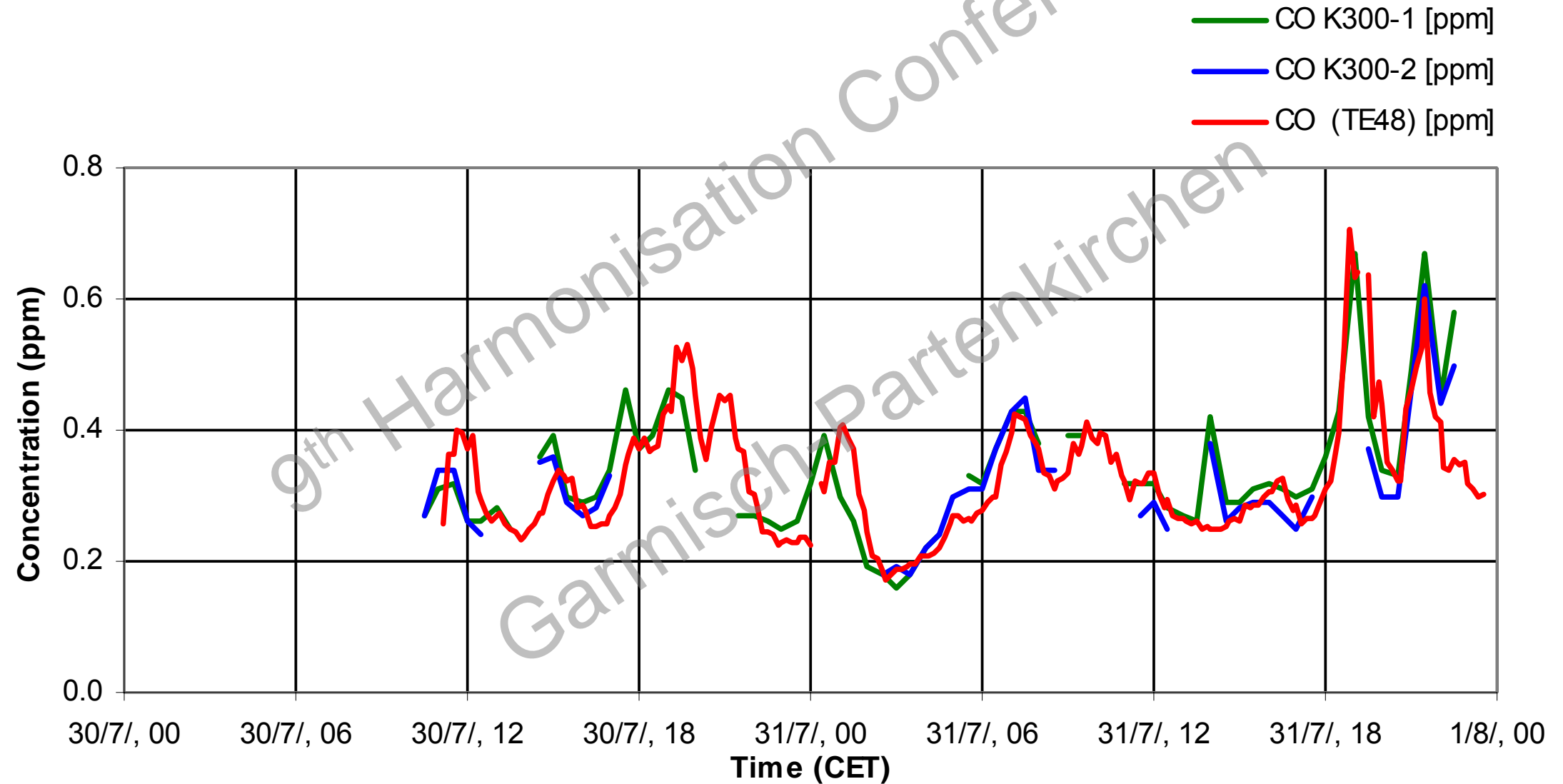
Differences in the order of measurement accuracy

Comparison of tracer SF₆ measurements

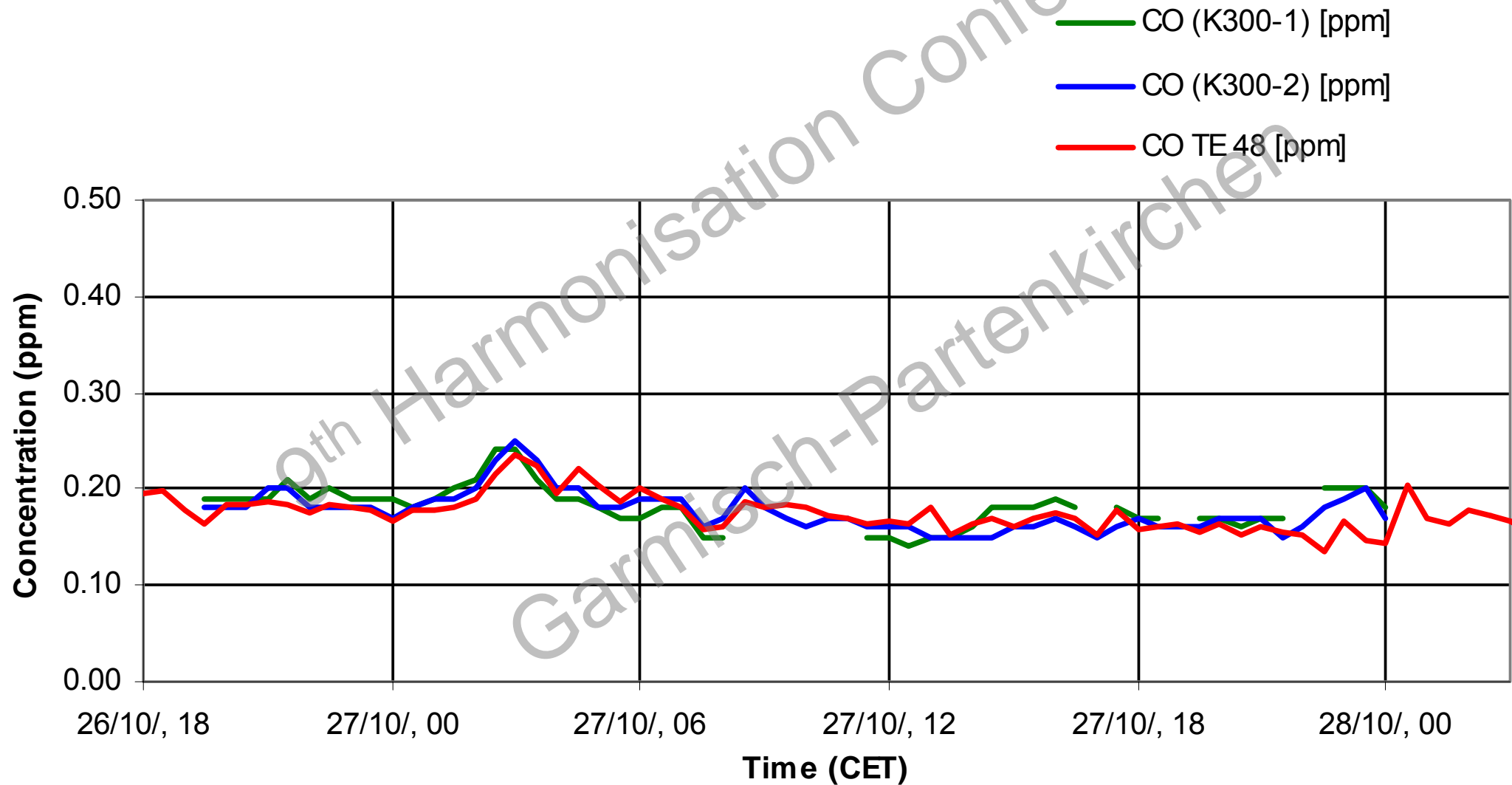
- SF₆ by FTIR spectrometry with probe sampling / laboratory analysis in the UHH wind tunnel (15 January 2002)
- Path-averaging of sample analyses results and FTIR

No systematic differences between path-averaging and probe sampling measurement techniques

30 July 2002, about 10:00 until 31 July 2002, about 23:00



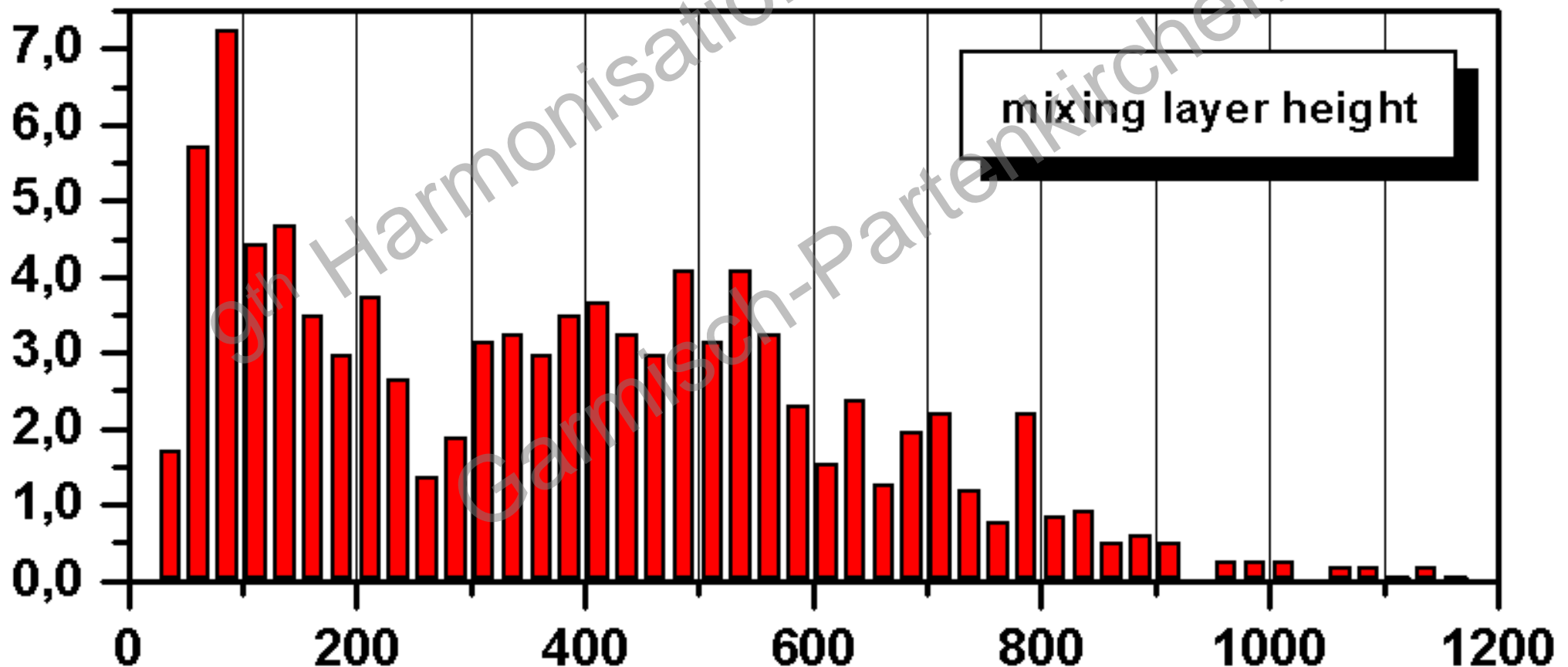
26 October 2002, about 19:00 until 27 October 2002, about 24:00



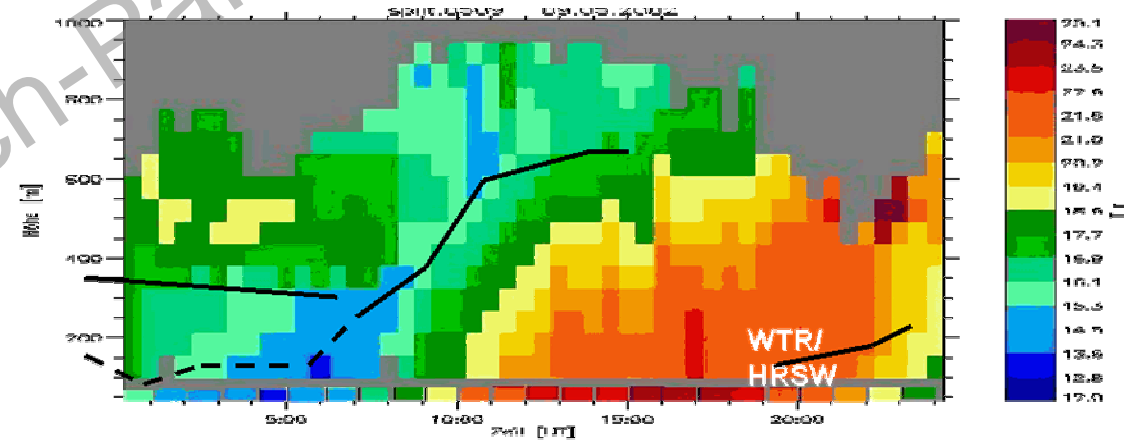
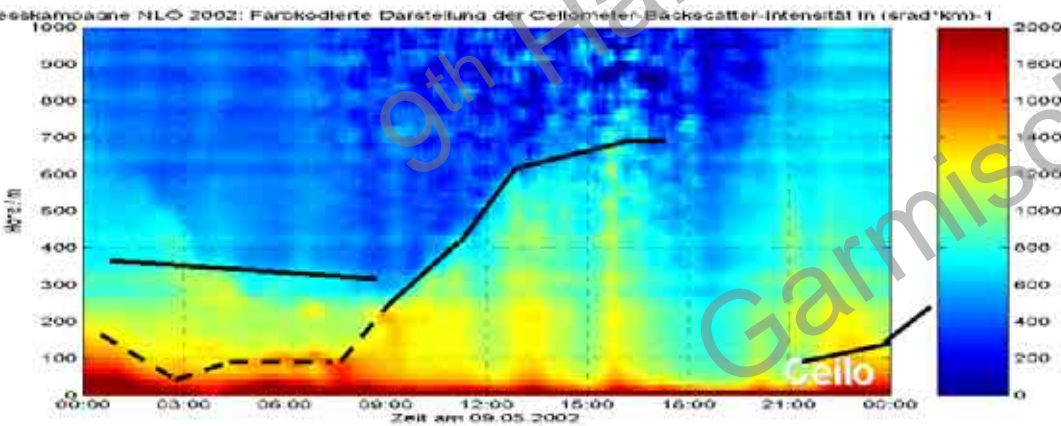
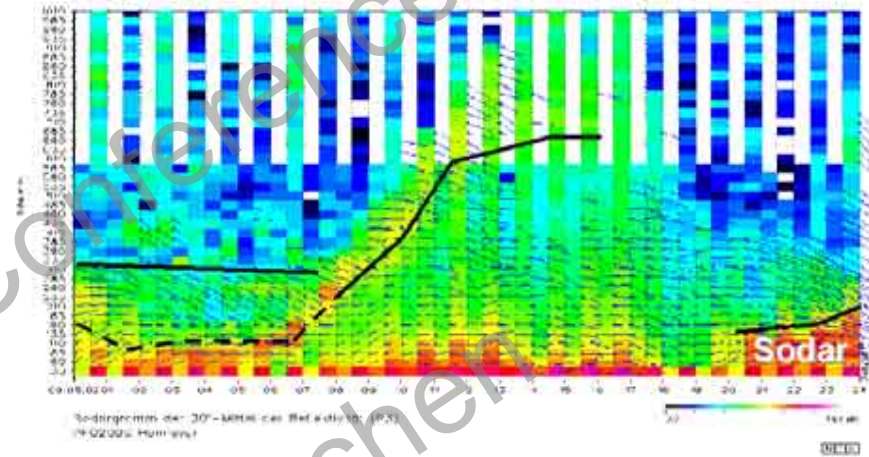
Mixing layer height (MLH) from SODAR data

Minimum of two criteria: height of sharp decrease of echo intensity and height of elevated echo maximum

Frequency of occurrence (in % per 25 m height interval) in October 2001:



Comparison of SODAR
measurements with data from a
Wind-Temperature-RADAR (WTR)
of IMK-ASF and a ceilometer of
Vaisala (backscatter at $0.9 \mu\text{m}$) for
09 May 2002



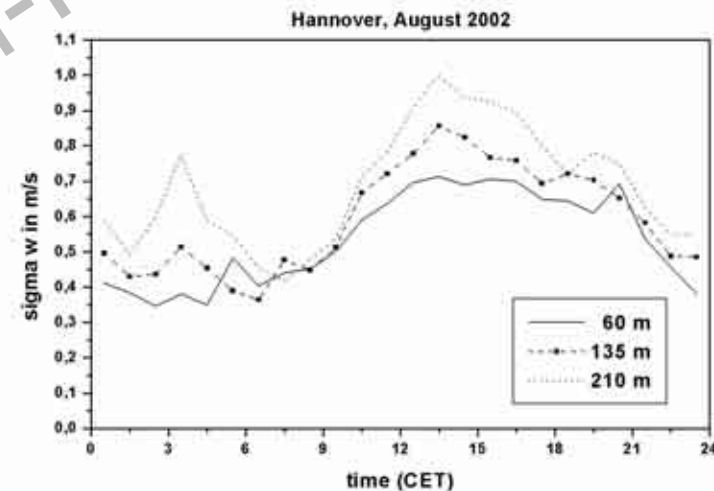
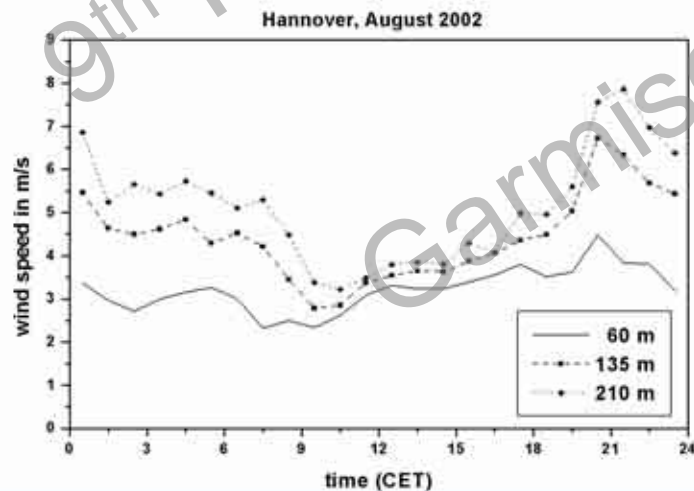
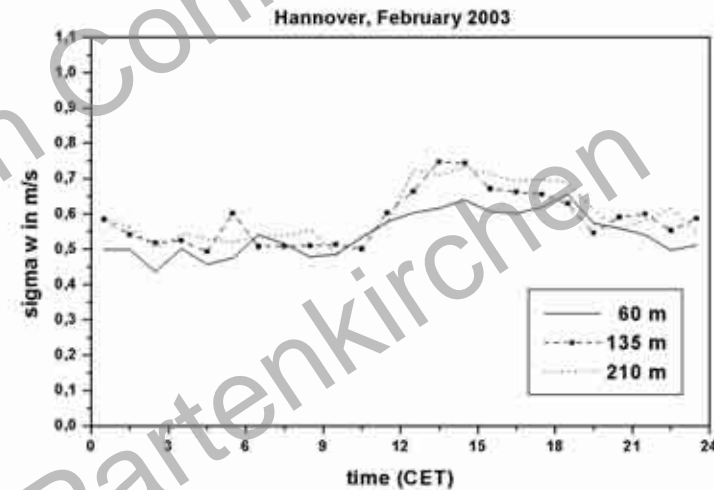
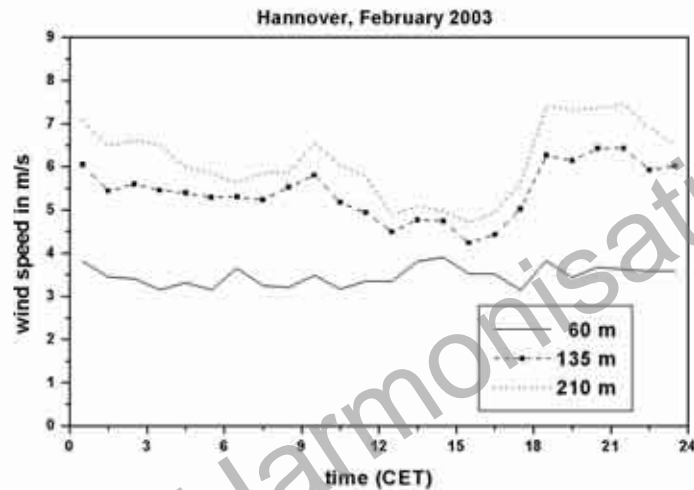
Interpretation of measurement results

SODAR measurement results of urban boundary layer

- Missing daily course of wind speed 40 m above roof level like over rough forests
- Daytime increase of variance of vertical wind speed with height up to 200 to 350 m agl, in summer and autumn even at night
- Daytime increase in turbulence intensity in summer stronger than over level terrain

Vertical profiles and the diurnal course of the variance are coined by the thermal properties of the urban surface and cannot be found over other rough surfaces

Daily variation of wind speed and turbulence parameter σ_w in different altitudes from SODAR measurements in February 2003 and August 2003

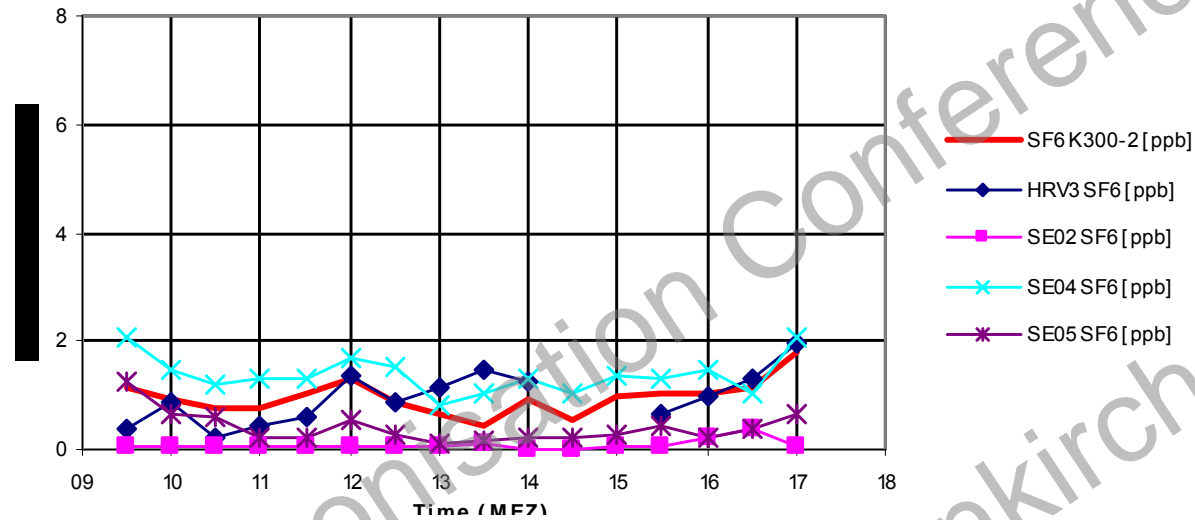


Results for representativity of measurement sites and methods

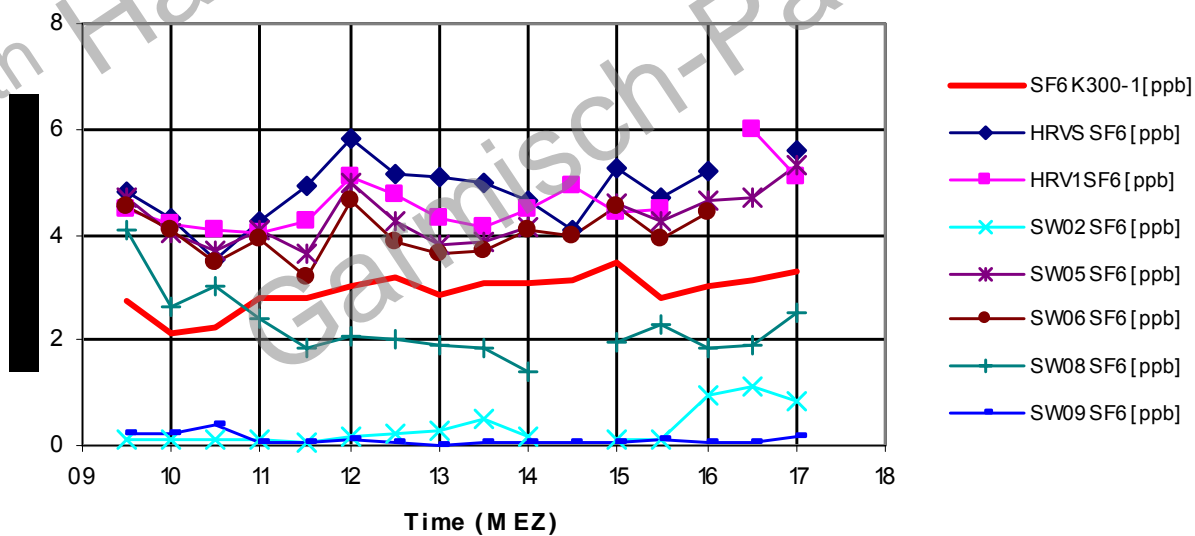
- Investigation of **in situ and path-averaged** measurements of SF₆
- In situ measurements are characterised by higher temporal variations - in correspondence with the high spatial variation of the in situ measurements along the measurement paths
- The highest differences between the results of both measurement techniques were found during street-parallel wind directions
- Spatial and temporal SF₆ distribution at ground level during a cross-wind episodes shows a rotor-like circulation pattern

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Göttinger Straße, eastern side walk, 11 April 2003



Göttinger Straße, western side walk, 11 April 2003

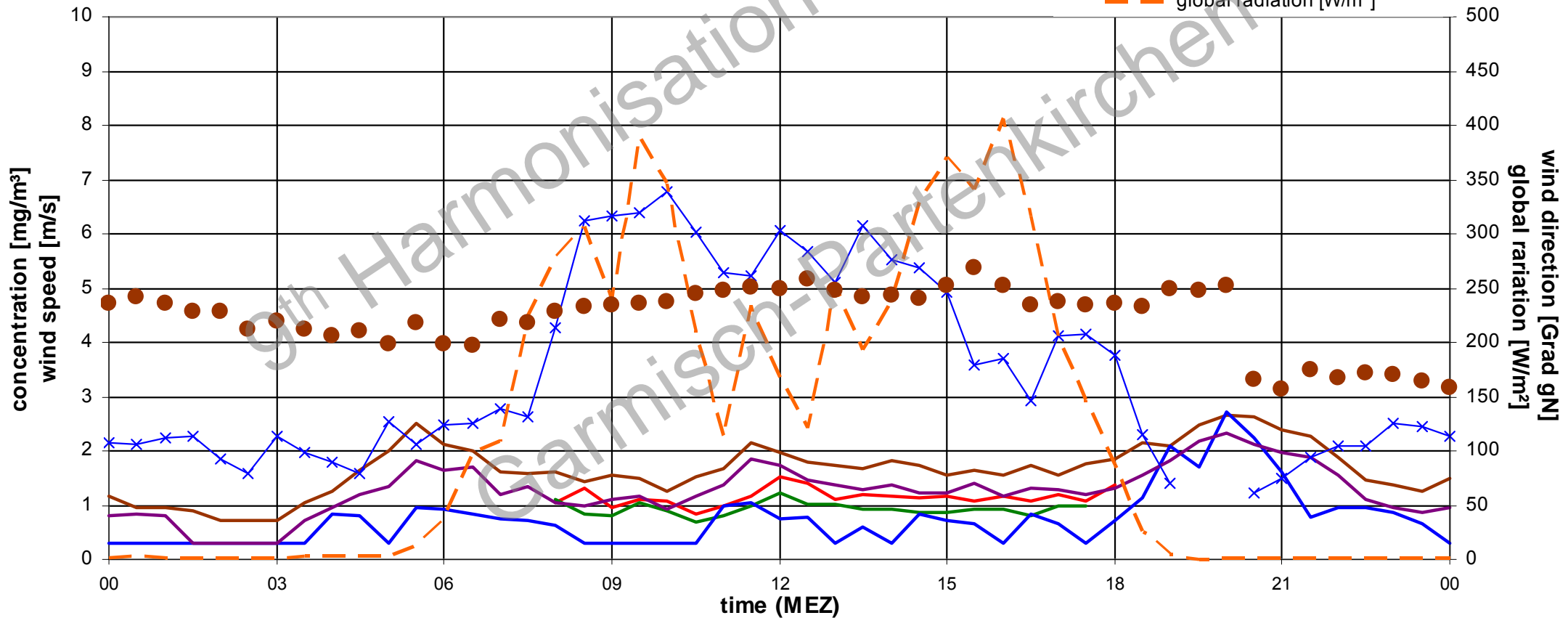


Circulation patterns inside the street canyon – the rotor

- Air pollutant concentrations (CO, NO₂) measured in situ and path-averaged by FTIR and DOAS
- at both sides near the ground of the Göttinger Straße
- at roof-top level and near the ground at the western side of Göttinger Straße
- cross-wind air flow conditions

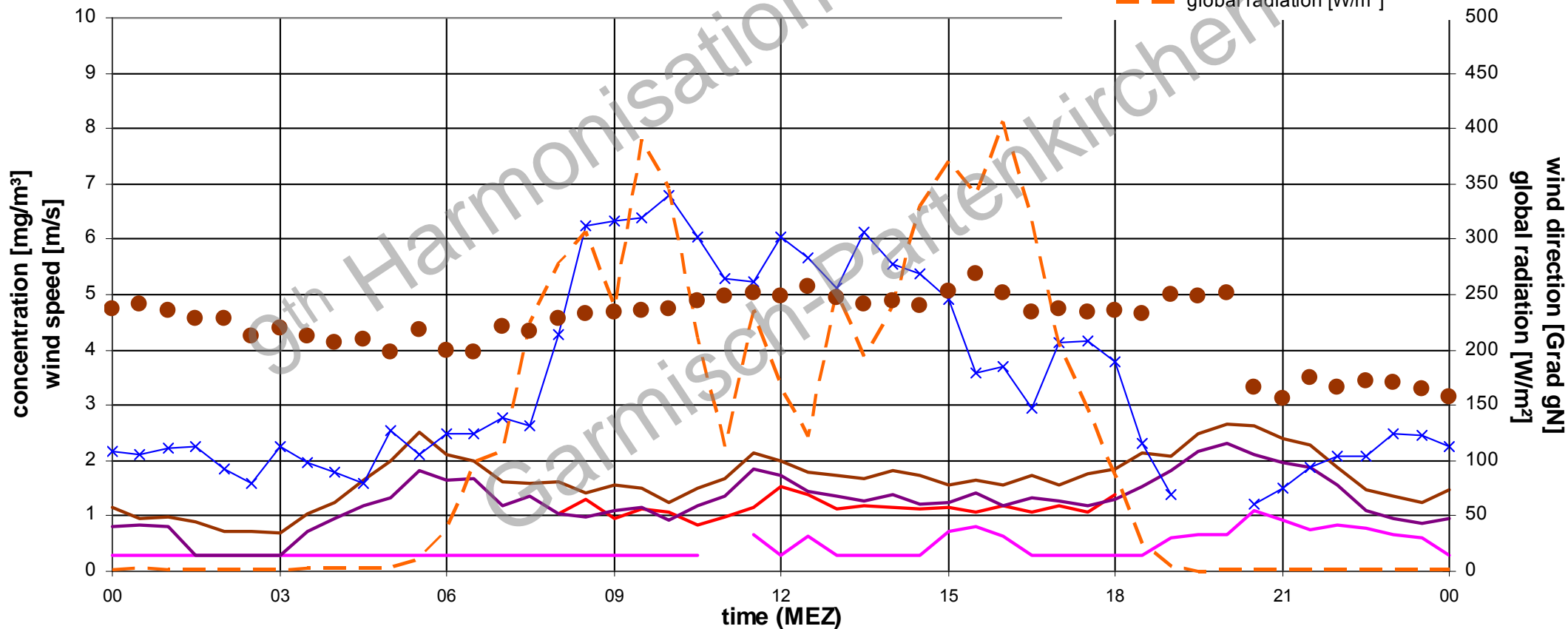
CO measurements (path-integrated and in situ)
weather data from HRSW
11 April 2003

- CO HRT10 (FTIR) [mg/m³]
- CO HRT11 (FTIR) [mg/m³]
- CO HRV1 [mg/m³]
- CO HRV3 [mg/m³]
- CO HRVS [mg/m³]
- × wind speed [m/s]
- wind direction [Grad gN]
- - - global radiation [W/m²]



CO measurements (path-integrated and in situ)
weather data from HRSW
11 April 2003

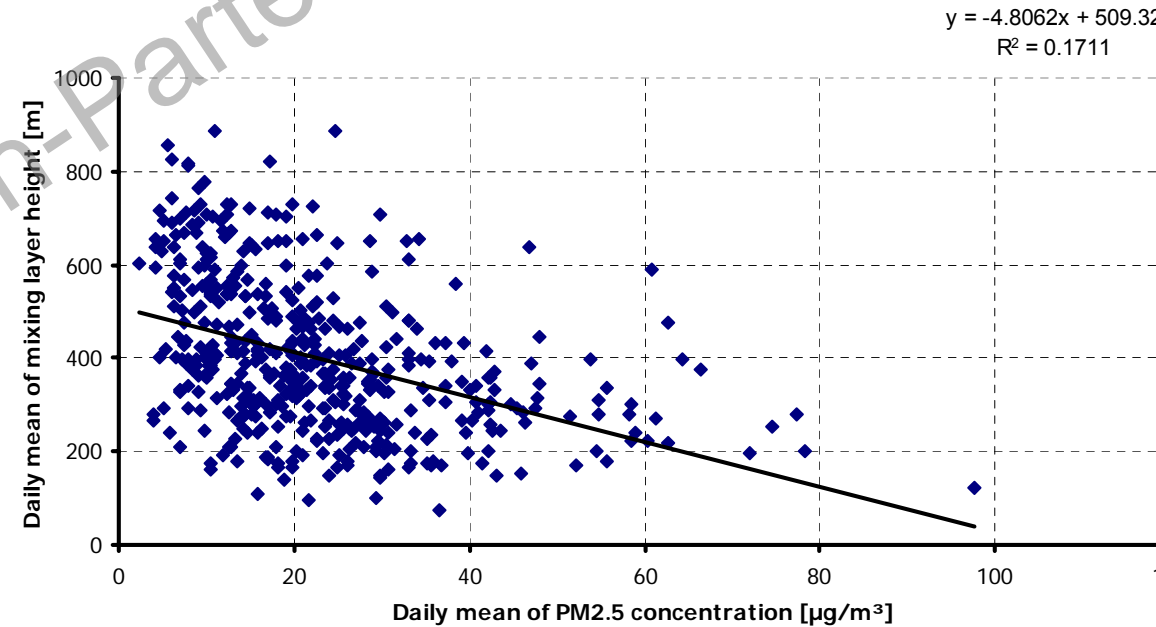
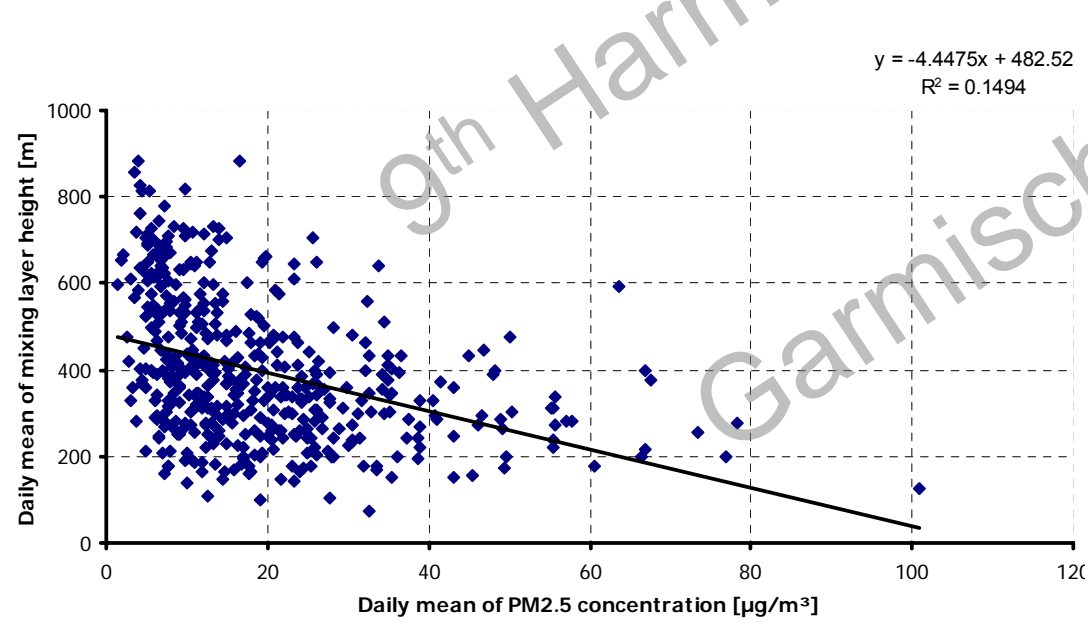
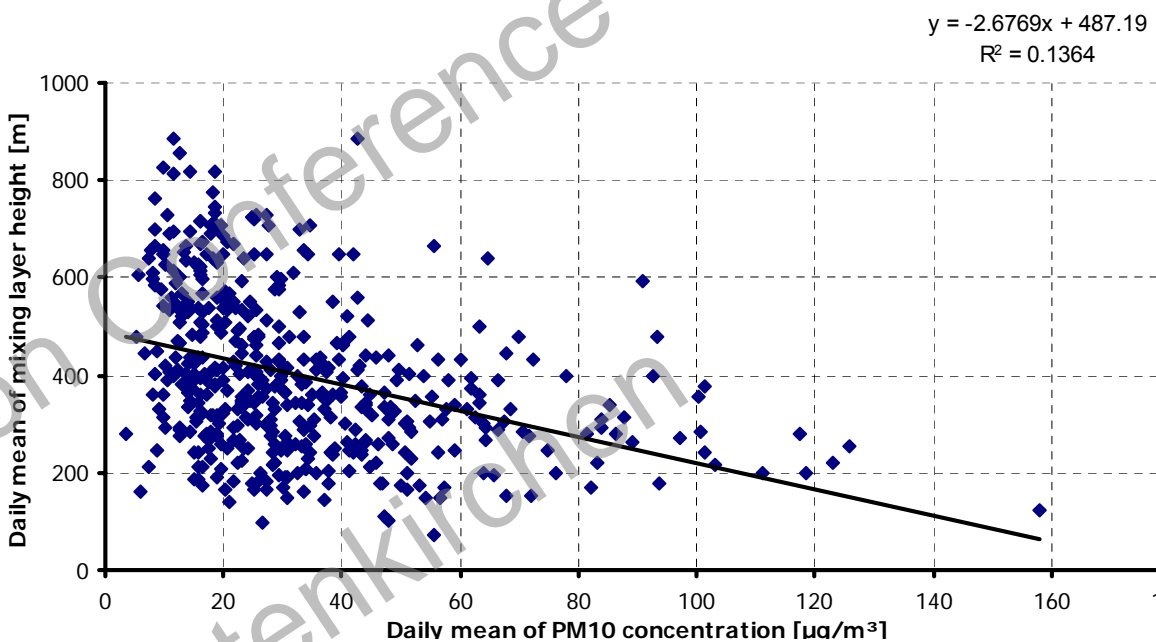
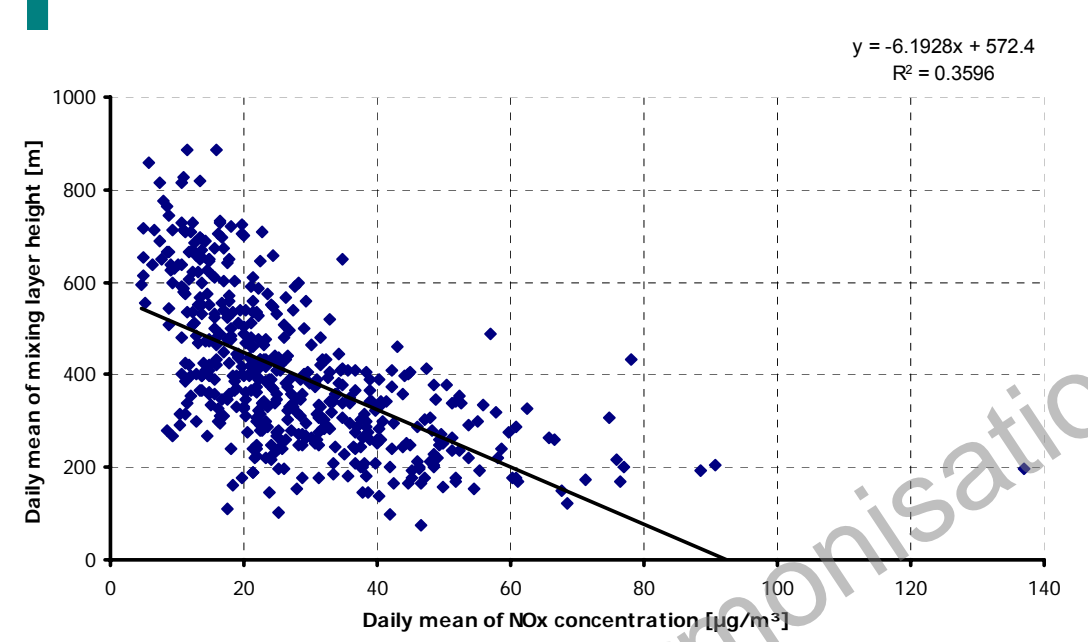
- CO HRT10 (FTIR) [mg/m³]
- CO HRSW [mg/m³]
- CO HRV1 [mg/m³]
- CO HRVS [mg/m³]
- wind speed [m/s]
- wind direction [Grad gN]
- global radiation [W/m²]



Correlation between MLH and air pollutants in the street canyon and at roof-top level

- About 36 % of NO_x concentration variations at roof-top level are caused by the MLH
- At ground-level stations no such correlation is found
- The correlation for PM_{10} and $\text{PM}_{2.5}$ with MLH is not significant at both levels
- PM_{10} and $\text{PM}_{2.5}$ concentrations at ground level inside the street canyon are higher than at roof-top level by a factor of 1.5 and 1.25 respectively whereas the factor is 6 for NO_x
- Roof-top and background monitoring stations are representative for the urban boundary layer

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ValiData - Database and pre-analysis tool

Air monitoring data: Gaseous components, particle matter PM10, PM2.5

Meteorological data: Temperature, pressure, humidity, solar radiation, wind and turbulence fields, mixing layer height

Intensive operating phases data: SF₆ tracer experiments, open-path measurement systems (DOAS, FTIR)

Location of measurement sites: Inside street canyon, above roof sites, background sites

Description: Measurement sites, measurement equipment, quality data

Time: Duration of continuous, measurements: 2001 – 2003, minimum temporal resolution: 30 minutes, Central European Time

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ValiData - Testversion © 2003 EDV-Entwicklungen Tobias Nolte

Start Measuring Point Description Measured values Filter Time Range Control Export Analyses

Network

General Station Information

Classification Of Station

Name of the network: Luthygiensches Ueberwachungsnetz Niedersachsen

Abbreviation: LUEN

Name of body responsible for the management of the network: Niedersächsisches Landesamt fuer Oekologie

Name of person responsible: B. Heits

Address of responsible body: Göttinger Str. 14; D-30449 Hannover

Telephone and fax numbers: +49 511 4446-364 Fax -365

E-mail address: bernd.heits@nlloe.niedersachsen.de

Web site address: www.nlloe.de

Time reference basis of the data series (utc, local)

Map of Goettinger Street

Measuring site Station HRS

2.4 Measurement device information

ValiData - Testversion © 2003 EDV-Entwicklungen Tobias Nolte

Start Measuring Point Description Measured values Filter Time Range Control Export Analyses

Network

General Station Information

Classification Of Station

Name and manufacturer of the measurement device: TE 42; Thermo Instruments

Analytical principle or measurement method: Chemolumineszenz

Characteristics of sampling: continuous

Height of sampling point: 1,5 m at VS; 3,5 m at HRSW HRV5

Result-integrating time: 30 min

Function Control Time Interval: every 25 hours

Detection Limit: 2 µg/m³ bei NO; 3 µg/m³ bei NO2

Expanded Uncertainty: 13%

Components of station HRSW

3. Measured values

Matrix
Component/
station

Choice of dataset

ValiData - Testversion © 2003 EDV-Entwicklungen Tobias Nolte

Start Measuring Point Description Measured values Filter Time Range Control Export Analyses

AllNone NO NO2 NOX XPM10 PM1 CO BENZ XYLO O3 STB SO2 RUSS PM10 DD FF TF PPP G RR RD MH1 MH2 CKDD CKNO3 CKCI

AllNone

HRSW DD

HRV1

HRV3

HRV8

HRV2

HRV4

HRV5

HRT1

HRT2

HRT3

HRT4

HRV8

GATE

25 components at each >30
continuous and temporary sites

Description following EU Guidelines
for Air Quality

Quality Assurance parameters for
each component

Validata - Testversion © 2003 EDV-Entwicklungen Tobias Notte

Start Measuring Point Description Measured values **Filter** Time Range Control Export Analyses

day range

- Monday
- Tuesday
- Wednesday
- Thursday
- Friday
- Saturday
- Sunday
- weekends
- statutory holidays

filter terms

station & filter for each measured value

HRSW_DD >= 0 <= 360 0.000 - 360.000 * exclusive

HRSW_NO2 >= 2 <= 133 2.000 - 133.000 µg/m³ exclusive

resolution

- 1/2 hour
- 1 hour
- 2 hours
- 6 hours
- 12 hours
- 24 hours
- 1 week
- 1/2 year
- 1 year

4. Filterfunktionen

- value limits
- day range
- time resolution

Start Measuring Point Description Measured values Filter Time Range Control Export Analyses

7.1 Analysis scatterplot

scatterplot with linear regression (Excel) max. charts per workbook 20

build Excel-chart

Öffnen

Suchen in: Export

- dataexport 10.12.2003 225331sort009
- dataexport 10.12.2003 225331sort0010
- dataexport 10.12.2003 225331sort0011
- dataexport 15.03.2004 223158
- dataexport 21.01.2004 115618
- dataexport 21.01.2004 115723
- dataexport 24.11.2003 220357
- dataexport 26.01.2004 173846
- dataexport 26.01.2004 173846-0
- dataexport 21.01.2004 110035
- dataexport 26.01.2004 173846-1
- dataexport 26.01.2004 175443

Export-Datei: dataexport 15.03.2004 223158

Microsoft Excel - dataexport 15.03.2004 223158-0

Filter

time range: 23.04.2002 02:30:00 - 07.06.2002 08:30:00

resolution: 1/2 hour

day range: all days of week

station: HRSW_DD component filter >= 0 AND <= 360 (exclusive)

HRSW_NO2 >= 2 AND <= 133 (exclusive)

time: 23.04.2002 02:30 246,108 36

23.04.2002 03:00 255,847 47

23.04.2002 03:30 261,673 40

correlation - hrsrw_dd vs hrsrw_no2

$y = -0,0166x + 23,906$
 $R^2 = 0,0158$

correlation - hrsrw_no2 vs hrsrw_dd

$y = -0,9518x + 237,77$
 $R^2 = 0,0158$

7.2 Analysis polardiagram

Microsoft Excel - dataexport 15.03.2004 223158

diagram with HRSW NO2 and HRSW DD as direction

polardiagram with second component

build Excel-chart

Microsoft Excel - dataexport 15.03.2004 223158 / BerechnungPKD_DiagrammPKD /