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

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INTRODUCTION

Tools are needed for the execution of the European Air Quality Framework Directive 96/62/EC and its daughter directives which are developed on the basis of numerical models in frame of the project VALIUM. To produce a validation data set for meso/micro-scale model systems 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 NLÖ monitoring (Müller et al., 2001) from beginning 2001 until end of 2003. The concept of measurements is coupled with corresponding investigations in the wind channel (Schäfer et al., 2003).

MEASUREMENTS

Both air pollutants and meteorological parameters were measured by in situ instruments at four sites inside the street canyon and at three sites in the surroundings. 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 (Schäfer et al., 2002; Bächlin et al., 2003). Vertical gradients of air pollutants in the street canyon were measured by these DOAS systems too. Acoustic remote sensing of wind and turbulence profiles with vertical resolution down to 12.5 m as well as mixing layer heights was performed by a SODAR south-west of Göttinger Straße in about 500 m distance.

During three intensive operation phases including tracer experiments with a SF_6 line source and sampling techniques at up to 15 sites were performed (Figure 1). Path-averaged CO and SF_6 concentrations at both sidewalks of the street were measured by FTIR spectrometry too.

Additionally, a ceilometer (aerosol backscatter profile) was operated at the roof of a building by Vaisala. During some time a wind-temperature-RADAR (temperature profile) of the IMK was measuring nearby. After evaluating the SODAR mixing layer heights (MLH) by these data, long-term statistics for MLH were produced. Concentration measurements at roof level anti-correlated well with MLH, those inside the street canyon did not.

These data together with NLÖ network monitoring data are available in the representative data bank ValiDATA as a validation data set for meso/micro-scale model systems. The database provides a pre-analyses tool also.

QUALITY ASSURANCE / QUALITY CONTROL

The QA/QC work included long-term comparison of all measurement techniques. Before or after each IOP the different measurement techniques were operated simultaneously in the same air mass. The comparisons give deviations in the order of the measurement accuracy.

The measurement values of each monitoring system were classified according to the amount and the absolute and relative standard deviation as discussed in Van der Meulen et al. (2003).

The comparison of wind data from the SODAR and the roof-top station shows the influence of near-by buildings on the wind data from the roof-top station.

RESULTS

Results for representativity of measurement sites and methods

The spatial and temporal representativity of concentration measurements was investigated by comparing in situ and path-integrated techniques. As an example the tracer gas measurements (SF_6) inside the street canyon are discussed. The measurement techniques are ambient air sampling in Teflon bags which were analysed in the laboratory by gas chromatography and FTIR absorption spectrometry at open paths of 136 m length which were operated with a temporal resolution of 30 minutes. The comparison of the results of the single in situ with the path-integrated measurements is characterised by higher temporal variations of the in situ measurements. This is 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. An example of spatial and temporal SF_6 distributions at ground level during a cross-wind episode with westerly winds is shown in Figure 1.

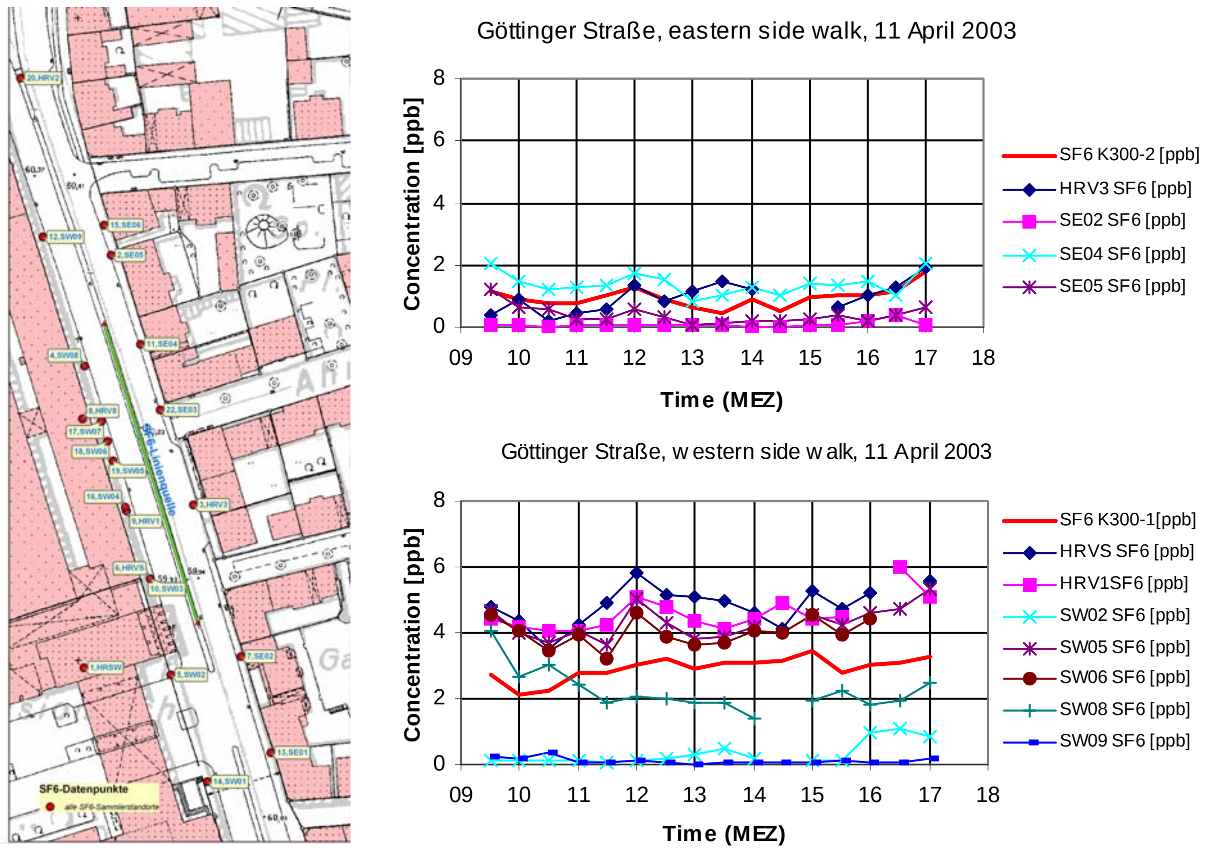
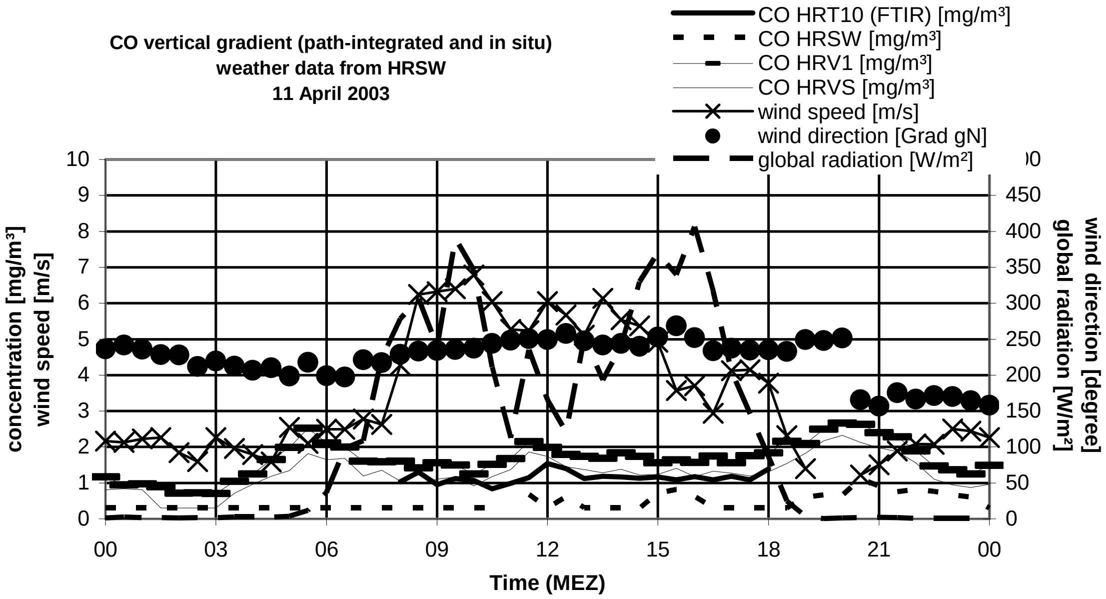


Figure 1. Path-averaged FTIR measurements (K300-1 and K300-2) and in situ measurements of the tracer SF_6 along the open FTIR path at the eastern side walk (right, above) and western side walk (right, below) of the Göttinger Straße on 11 April 2003 during westerly winds with 3 up to 6.5 ms^{-1}. On the left location of trace line source and sampling points (SE and SW).

Circulation patterns inside the street canyon - the rotor

Air pollutant concentrations at both sides at the ground of the Göttinger Straße and at roof-top level during cross-wind air flow conditions indicate clearly a rotor-like circulation inside the street canyon which is in correspondence with results described in the literature (Xie et al., 2003). Path-averaged and in situ CO and tracer gas concentrations inside the street canyon were used for investigation of re-circulation flow patterns inside the street canyon together with corresponding wind tunnel experiments. An example during westerly winds is shown in Figure 2 for CO, wind, and radiation. After the change of wind direction from west to south in the evening the horizontal and vertical gradients became lower. The spatial and temporal variations of NO_x, NO and NO_2 concentrations are very similar.



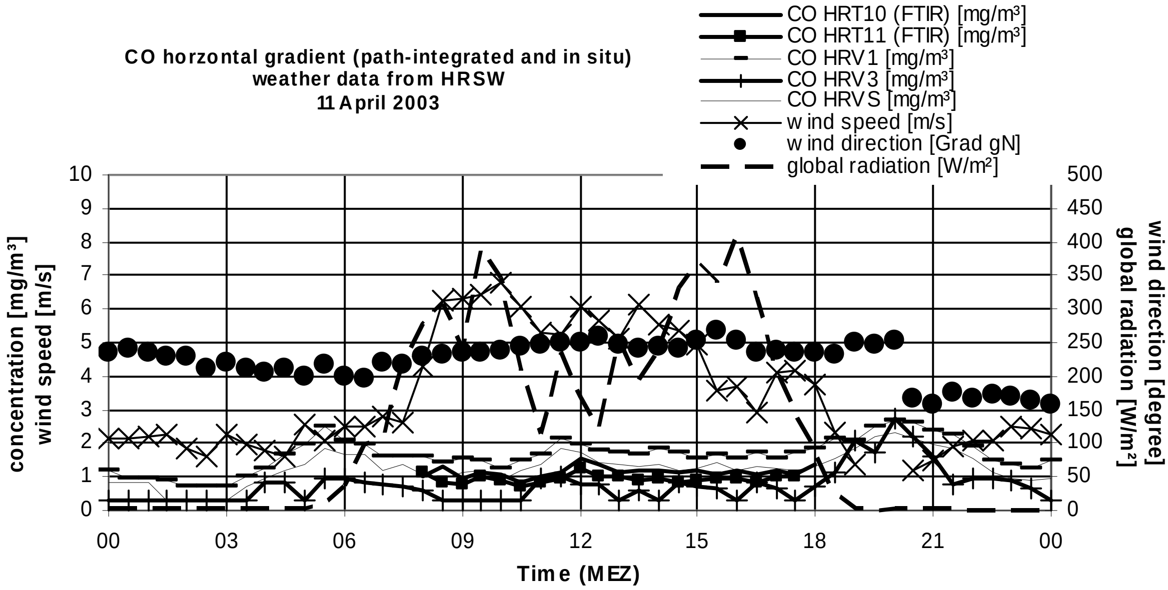


Figure 2. Path-integrated FTIR measurements (HRT10 at western side walk and HRT11 at eastern side walk) and in situ measurements at 3 single sites (HRVS and HRV1 along the western open FTIR path and HRV3 along the eastern open path) at ground level as well as at roof level (HRSW) of CO in the Göttinger Straße at 11 April 2003 during westerly winds with 3 up to 6.5 ms-1 showing a negative vertical (above) and a horizontal (below) gradient from east to west at the ground

Mixing layer height (MLH) from SODAR data

Mixing layer height is determined as the minimum of ground-based echo layer height and height of elevated echo maximum were used as criteria for the determination of mixing layer height (Emeis and Türk, 2004). Additionally, a ceilometer (aerosol backscatter profile, run by Vaisala) and in May and October 2002 a wind-temperature-RADAR (temperature profile) of IMK-ASF were operated nearby. These data were used to validate the SODAR wind and MLH data (Emeis et al., 2004). The comparison between SODAR, WTR, and ceilometer was used in order to validate the inversion information from the SODAR and to demonstrate the applicability of the ceilometer in this context.

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

Correlation analyses show that about 36 % of NO_x concentration variations at roof-top level are caused by the mixing layer height (see Figure 3). At ground-level stations inside the street canyon this dependence cannot be found. The correlation for PM10 and PM2.5 is not significant (see Figure 3) and not much different for ground and roof-top level data (see Figure 4). PM10 and PM2.5 concentrations at ground level inside the street canyon are higher by a factor of 1.5 as well as 1.25 of roof-top level values. Roof-top level and background monitoring stations are representative for the urban boundary layer.

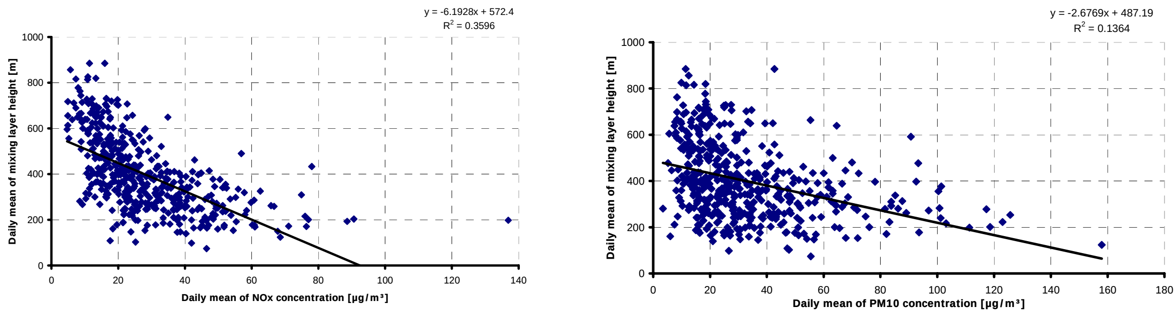


Figure 3. Correlation of NO_x with MLH (left) and PM10 (right) for the roof-top station HRSW.

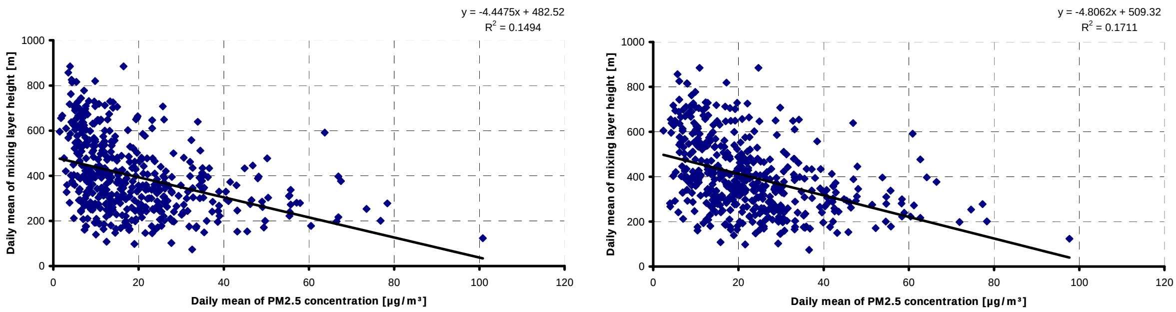


Figure 4. Correlation of PM2.5 with MLH for the roof-top station HRSW (left) and for the street-level station HRVS (right).

During days with high pollution level (e.g. on 13 December 2002 daily mean concentration of PM10 89 µg/m^3, PM2,5 77 µg/m^3 and NO_x 78 µg/m^3 at HRSW) the mean mixing layer height is relatively low (380 m). Otherwise during days with low pollution level (e.g. on 27 October 2002 daily mean concentration of NO_x at HRSW 7 µg/m^3) the mean mixing layer height is relatively high (735 m). It can be concluded that the pollution at roof-top level is caused by meteorological and transport conditions mainly and not by the emission situation.

OUTLOOK

The mixing layer height defines the volume for the dilution of emitted air pollutants and by this way the near-surface pollutant concentrations as could be shown for gaseous compounds earlier by Schäfer et al. (2002) also. But the origin of spatial distribution of particulate matter needs further evaluation. At appropriate weather conditions the ceilometer is a useful tool to investigate layering of lower atmosphere and its particulate matter content.

The field measurements for validation data of small-scale models will be continued.

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REFERENCES

Bächlin W., H. Frantz, A. Lohmeyer, A. Dreiseidler, G. Baumbach, W. Theurer, B. Heits, W.J. Müller and K.-P. Giesen, 2003: Feinstaub und Schadgasbelastungen in der Göttinger Strasse, Hannover. Niedersächsisches Landesamt für Ökologie, Nachhaltiges Niedersachsen **23**, 28 pp.

Emeis, S., C. Münkel, S. Vogt, W. Müller, K. Schäfer, 2004: Determination of mixing-layer height. Atmospheric Environment, **38**, 2, 273-286.

Emeis, S. and M. Türk, 2004: Frequency distributions of the mixing height over an urban area from sodar data. Meteorologische Zeitschrift, accepted.

Müller, W. J., B. Heits and M. Schatzmann, 2001: A Prototype Station for the Collection of Urban Meteorological Data. harmo8, http://www.harmo.org/Conferences/Proceedings/_Sofia/publishedSections/Pages326.pdf

Schäfer, K., G. Fömmel, H. Hoffmann, S. Briz, W. Junkermann, S. Emeis, C. Jahn, S. Leipold, A. Sedlmaier, S. Dinev, C. Reishofer, L. Windholz, N. Soulakellis, N. Sifakis and D. Sarigiannis, 2002: Three-Dimensional Ground-Based Measurements of Urban Air Quality to Evaluate Satellite Derived Interpretations for Urban Air Pollution. International Journal on Water, Air, and Soil Pollution: Focus **2**, 5-6, 91-102.

Schäfer, K., H. Hoffmann and S. Emeis, 2002: Erfahrungen und Ergebnisse beim Einsatz von DOAS zur Bestimmung von Immissionen und diffusen Emissionen. In: Neuere Entwicklungen bei der Messung und Beurteilung der Luftqualität, VDI-Berichte *1656*, Kommission Reinhaltung der Luft im VDI und DIN - Normenausschuss KRdL (ed.), VDI-Verlag, Düsseldorf, Germany, 277 – 286.

Schäfer, K., S. Emeis, H. Hoffmann, C. Jahn, W.J. Müller, B. Heits, D. Haase, W.-D. Drunkenmölle, B. Leitl, F. Pascheke, M. Schatzmann and W. Bächlin, 2003: Comparison of path-integrated and in situ measurements within a street canyon to produce a validation data set. In: Transport and Air Pollution, part 2, Robert Joumard (ed.), Actes INRETS, Institut National de Recherche Sur les Transports et leur Securite, Bron cedex, France, Vol. **92**, 119-124 (ISSN 0769-0266, ISBN 2-85782-588-9).

Van der Meulen A., D. van Straalen, B.G. van Elzakker, B. Heits, E. Helmholz and H. Rienecker, 2003: Field Comparison of Air Monitoring Networks. Niedersächsisches Landesamt für Ökologie, Nachhaltiges Niedersachsen **22**, 57 pp.

Xie, S., Y. Zhang, L. Qi and X. Tang, 2003: Spatial distribution of traffic-related pollutant concentrations in street canyons. Atmospheric Environment **37**, 3213-3224.