Validation Data for Small-scale Numerical and Physical Models of a City Quarter

Contribution to subproject SATURN

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Summary

The investigations to yield evaluation data for numerical and wind tunnel models within a quarter of a city (Göttinger Straße in Hannover) is part of the umbrella project "Development and validation of tools for the implementation of European air quality policy in Germany" (Val I Um within AFO2000 of BMBF) co-ordinated by M. Schatzmann, University Hamburg. Existing data sets for the validation of micro-scale model systems have insufficient quality. Since current validation data sets for real conditions do not consider the background conditions sufficiently field measurements are performed in a street canyon and the surrounding area of 1 km x 1 km for one year starting mid 2001.

Air pollutants (NO, NO_2, SO_2, O_3, CO, HC, benzene, toluene, p-xylene, dust, PM10, PM2.5) and meteorological parameters are measured continuously by in situ stations at 5 sites inside the street canyon completed by path-integrating optical measurement techniques (two DOAS systems at four open paths). In the surrounding of the Göttinger Straße two in situ measurement stations are operated. The measurements are performed on the ground and on the roof of the buildings nearby the street. Additionally, road traffic is counted. First results are showing considerable spatial differences of air pollutant concentrations in the street canyon which can vary between single compounds such as NO and NO_2 or PM10 and PM2.5.

Three intensive measurements campaigns during different seasons are planned with additional experiments (SF_6 line tracer source, identification of cars in road traffic and measurements of more compounds). In August 2001 a first test of instrumentation and measurement concept was organised. Path-integrated concentrations of CO, CH_4, N_2O, CO_2 and of the tracer SF_6 were measured at different paths along the road by FTIR spectrometry giving e.g. for CO general coincidences with in situ measurement results along the open paths but differences during certain conditions also.

Long-term sodar measurements are operated on a nearby industrial ground upwind of the street canyon. The purpose of the measurements is to get statistical data on the onflow conditions to the street canyon. This comprises typical vertical wind profiles and mixing layer heights. Deriving mixing layer heights a combination of three criteria has been chosen. First, the height of the ground-based echo layer is determined from backscatter intensity. Here the absolute value of this intensity is considered as well as the vertical gradient of this quantity. Second, elevated maxima of the backscatter intensity above a certain threshold are interpreted as elevated inversions even if they are well within the ground-based echo layer. Finally the minimum of ground-based echo layer height and elevated echo maximum height is taken as mixing layer height. A statistical evalution of these mixing layer height data is presented. E.g., for October 2001 it shows a bimodal distribution of the mixing layer height with a primary maximum around 100 m and a secondary but much broader maximum around 500 m. These results will be used in the corresponding wind tunnel investigations of the Göttinger Straße.

Introduction

The German research project Val I Um "Development and validation of tools for the implementation of European air quality policy in Germany" is executed within the framework of the research cluster AFO2000 of the German Federal Ministry of Education and Research (BMBF) Part of this project which is described here has been designed to yield evaluation data for numerical and wind tunnel models of a street canyon (Göttinger Straße in Hannover, Germany) embedded in the larger context of a city quarter. The project started in 2001.

Newly developed model systems must be validated with data of field measurement campaigns. Existing validation data sets for the micro scale have insufficient quality. Data of field measurement campaigns and wind tunnel investigations are used separately for model validations up to now.

Objectives

Field measurements within this quarter of the city will be performed to produce a validation data set for the meso / micro scale model system M-SYS which will be developed within the project by the University Hamburg. The concept of measurements will be combined with wind tunnel measurements which are performed in the University Hamburg. Since current validation data sets for real conditions do not consider the background conditions sufficiently field measurements are also performed in the street canyon and in the surrounding area of 1 km x 1 km during one year.

Activities

Air pollutants (NO, NO_2, SO_2, O_3, CO, HC, benzene, toluene, p-xylene, dust, PM10, PM2.5) and meteorological parameters (wind, pressure, temperature, humidity, solar radiation) are measured continuously from the Lower Saxony State Agency for Ecology by in situ stations at 5 sites inside the street canyon. These measurements are completed by path-integrating optical measurement techniques (two DOAS systems and four open paths: NO, NO_2, SO_2, O_3, benzene, toluene, p-xylene) which are better adapted for model validation than point measurements. In the surrounding of the Göttinger Straße two in situ measurement stations are measuring air pollutants and meteorology. The measurements are performed on the ground and in the height of the roof of the buildings nearby the street. Additionally, road traffic is counted.

Three intensive measurements campaigns during different seasons are planned with additional tracer gas experiments (line tracer source of SF_6 inside the street from company Lohmeyer, identification of cars in road traffic from University Stuttgart and measurements of more compounds). In August 2001 a first test of instrumentation and measurement concept was organised. Path-integrated concentrations of CO, CH_4, N_2O, CO_2 and of the tracer SF_6 were measured at different paths along the road by FTIR spectrometry.

Apart from flow and air quality measurements in the street canyon itself and on top of the surrounding buildings, long-term sodar measurements have started in May 2001 which will last at least one year. The sodar is operated on a nearby industrial ground upwind of the street canyon. The purpose of the measurements is to get statistical data on the onflow conditions to the street canyon. This comprises typical vertical wind profiles and mixing layer heights. The mixing layer height is an important parameter for the vertical dispersion of the pollutants emitted by the traffic and secondarily formed afterwards.

The sodar (METEK DSDR3x7, see also Reitebuch and Emeis, 1998) operates since October 2001 in a special mode which was chosen to have both a high vertical resolution near the ground and a large range. 30 min means are recorded. Every half hour the instrument is changing between a vertical resolution of 12.5 m (47 range gates from 22.5 to 597.5 m) and a

resolution of 25 m (48 range gates centered between 35 and 1210 m). Although sodars have been used several times in environmental studies to detect flow conditions and inversion heights (e.g. Dosio et al., 2001) deriving mixing layer heights from sodar measurements is still a tedious task (Beyrich, 1997). Here, after scanning through several months of data a combination of three criteria has been chosen. First, the height of the ground-based echo layer is determined from backscatter intensity. Here the absolute value of this intensity is considered as well as the vertical gradient of this quantity. Second, elevated maxima of the backscatter intensity above a certain threshold are interpreted as elevated inversions even if they are well within the ground-based echo layer, because they will surely limit the vertical dispersion. Finally the minimum of ground-based echo layer height and elevated echo maximum height is taken as mixing layer height.

Results

First results of continuous air pollutants measurements are showing considerable spatial differences of air pollutant concentrations in the street canyon which can vary between single compounds such as NO and NO_2 or PM10 and PM2.5. Path-integrated measurements by FTIR spectrometry giving e.g. for CO general coincidences with in situ measurement results along the open paths but differences during certain conditions also.

A statistical evalution of the mixing layer height data for October 2001 is presented in Figure 1. The lower two frames display the separate analyses of the ground-based echo layer height and of the elevated echo maximum height. The mean height of the ground-based echo layer is about 500 m with a large scatter between 100 and about 1000 m. The elevated echo maximum occurs in this month about 30% of the time (e.g. in November 2001 it occured only in about 17% of the time) with a most frequent height of about 100 m. Combining these two data sets as explained above leads to a bimodal distribution of the mixing layer height with a primary maximum around 100 m and a secondary but much broader maximum around 500 m. In months with less frequent elevated echo maxima, the broader maximum to the right is the dominant one.

Conclusions

First results of the long-term air pollution measurements inside and in the surrounding of the street canyon confirm the measurement concept and show interesting spatial variations of some compounds. Remote sensing measurements complete substantially in situ measurements to produce a validation data set by path-integrated and altitude resolved measurements as well as additional information such as mixing layer height.

Acknowledgements

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References

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Aims of next year

Intensive measurement campaigns during different seasons will be performed and quality assurance activities will be continued.

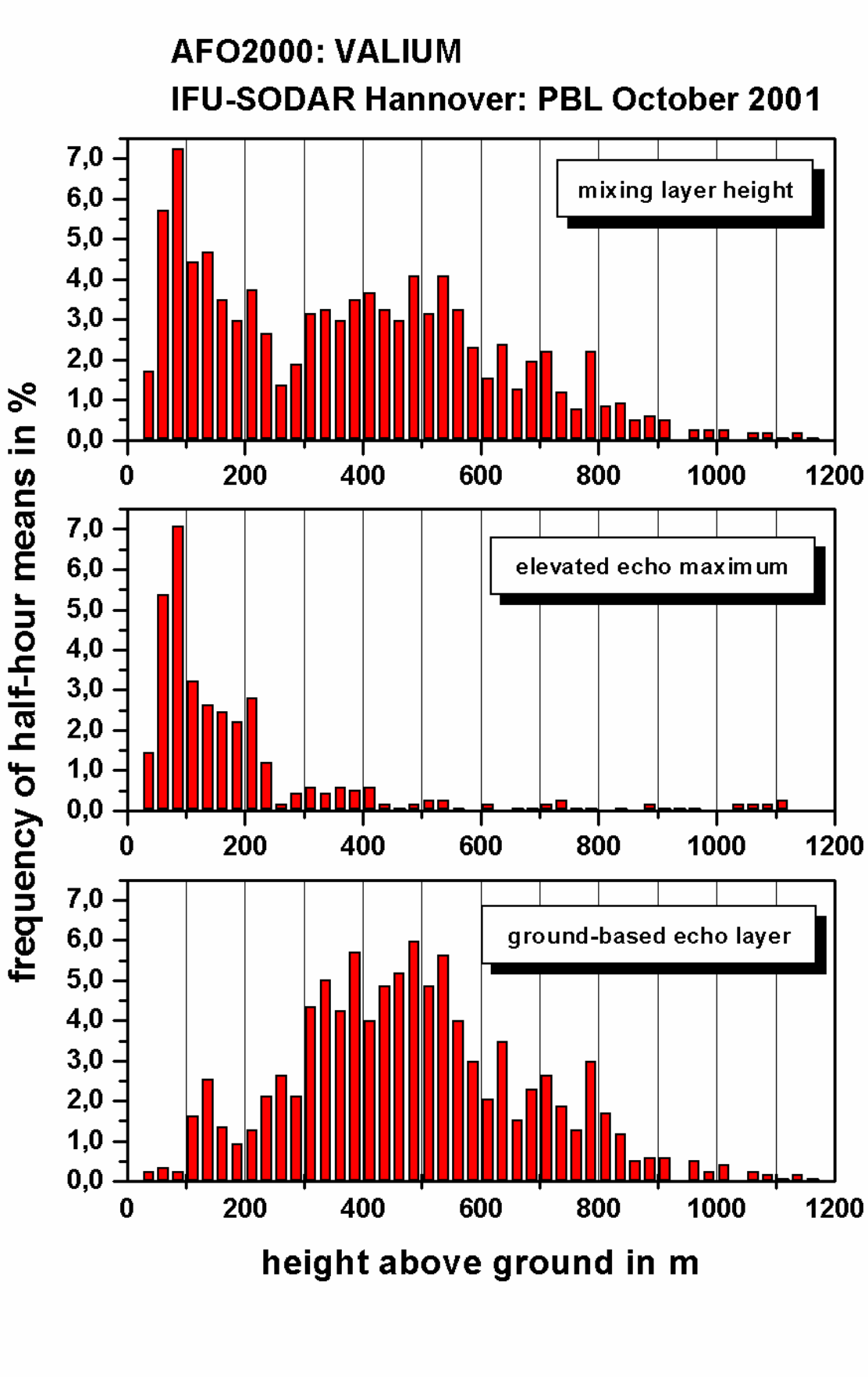

Figure 1: Inversion statistics for Hannover, Germany for October 2001 from half-hourly SODAR data.