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Temporal and spatial variation of nanoparticle number concentration in the urban area

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Introduction

Urban areas are important sources of anthropogenic aerosols due to the high number of combustion processes including vehicle emissions. Particulate matter is emitted directly as well as precursor gases for the secondary formation of new particles or particle growth through condensation.
The negative consequences for human health are thougt to be caused particularly by particles with diameters below 100 nm. These effects depend mainly on number concentration of particles. The so-called nanoparticles contribute significantly to the total number of particles, but their contribution to the mass concentration can be neglected. Therefore, the investigation of health effects in the urban area needs long-term studies of number concentration with temporal and spatial resolution.
This paper contains the main results of experiments at two differently polluted sites in the urban area of Leipzig, Germany.

The measurement system

The best way to measure size-resolved particle concentration down to a few nanometer is the mobility analysis. During the presented experiments a Twin Differential Mobility Particle Sizer (TDMPS) system was used. It was developed at the Institute for Tropospheric Research, IfT (Birmili, 1997) and measures number size distributions in the size range from 3 to 800 nm. This measurement system consists of two parallel working systems: one ultrafine DMPS (3-20 nm, UDMA + CPC TSI 3025) and one DMPS (20-800 nm, DMA + CPC TSI 3010).

Results

This paper will present results of two immission studies. With an immission study the particle concentration at a certain point in the urban area is measured. That represents usually a combination of directly emitted particles and those formed or transformed by several processes in connection with emitted precursor gases.
One of these experiments was performed on the roof of the institute building of the IfT. The measurements are running continuously since February, 1997, and contain number size distributions, several trace gases, as well as meteorological parameters. The inlets for aerosol and trace gas are about 16 m above ground. The research complex, were the Institute is located, is surrounded by several busy raods with a distance of about 300 m in minimum. This experiment represents a long-term study with a very large database, suitable for various investigations.
One aim of the experiment was to investigate the results with regard to diurnal, weekly, and seasonal variations. Therefore, the dataset was divided into the different seasons and days of the week.

Fig. 1 shows the diurnal variation of number size distributions for workdays in summer and winter, including the data from 1997 – 1999.

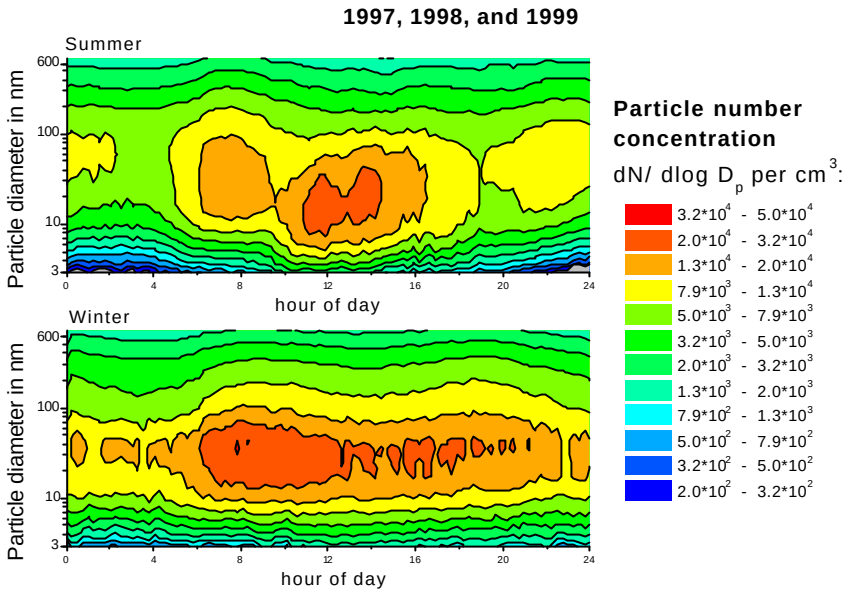

Figure 1: Workdays in summer (June – August) and winter months (December – February).

The next figure illustrates the different behaviour of the different days of the week. It contains again the average over workdays in summer as well at the mean evaluation on weekends.

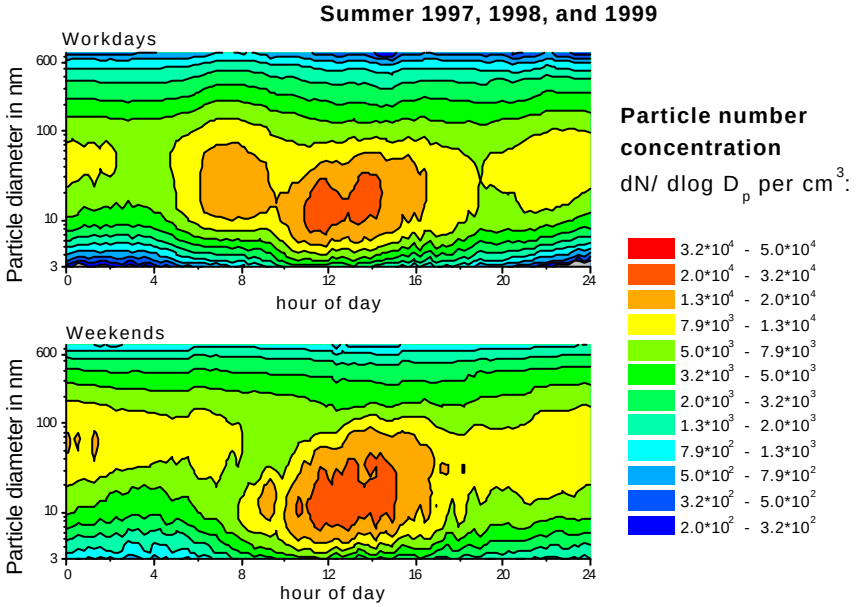

Figure 2: Workdays and weekends in summer (June – August).

The second experiment was carried out in a street canyon of a very busy road in Leipzig. The street is surrounded by 4 – 5 floor appartment houses, which suppress a fast dilution of the traffic emissions with upper air masses. Thus, the measured concentrations can be considered as being strongly dominated by traffic emissions. The measurements took place from October

to December, 1997 and comprise number size distributions as well as several trace gas concentrations. The dataset was investigated with regard to varying concentrations on the different days of the week. Fig. 3 shows the evolution of the number size distribution on workdays as well as on sundays, averaged over the whole measurement period.

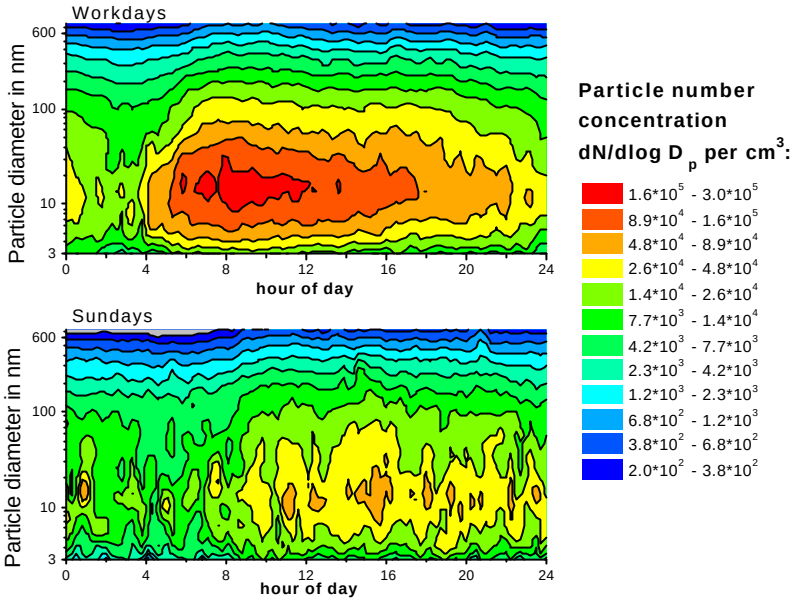

Figure 3: Workdays and sundays in the street canyon.

The total number concentration of particles in the observed size range was calculated by integrating over the complete number size distribution. The next figure (Fig. 4) contains the total number concentration on workdays and on sundays and additionally the concentration of NO, which is an indicator for the occurence of car traffic.

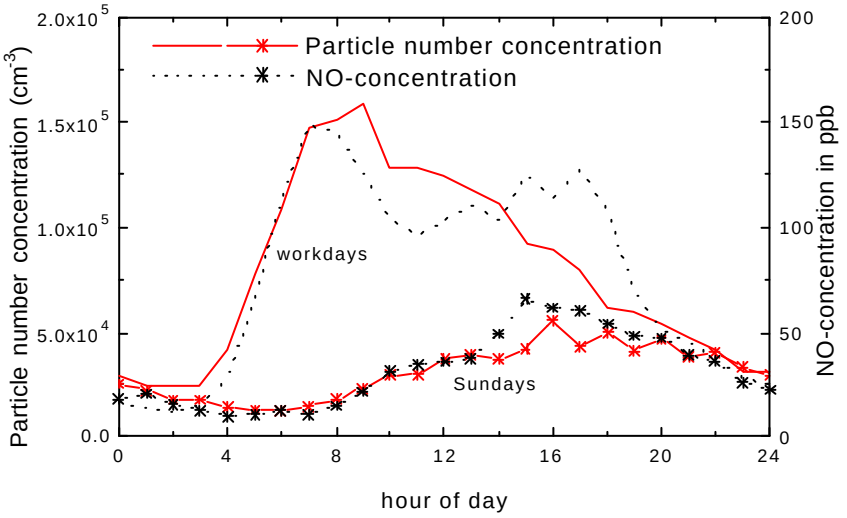

Fig. 4: Total number concentration and NO on workdays and sundays (Street canyon).

Comparison of both measurement sites

Two differently polluted sites were chosen to measure the concentration of submicrometer particles in the urban area. Differences in the number size distribution will show the influence of different particle sources as well as transformation processes.
As a case study one workday in November, 1997 was selected to compare the particle concentration. Fig. 5 shows the results for both sites.

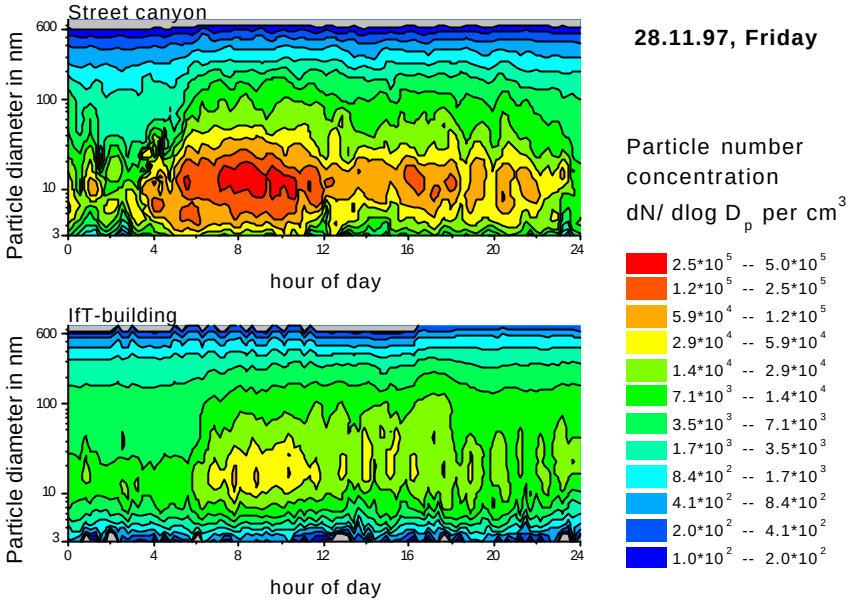

Fig. 5: Case study: results at both sites on November, 28.

To compare both sites quantitatively more data need to be considered. The morning rush hour (6:00 - 9:00) was selected to be the most interesting time period. Thus, a mean rush-hour-size distribution was calculated for every workday by averaging over the measured scans in this time period. The mean curves for the whole measurement period (October – December, 1997) are shown in Fig. 6. Additionally, three lognormal modes are fitted to both curves.

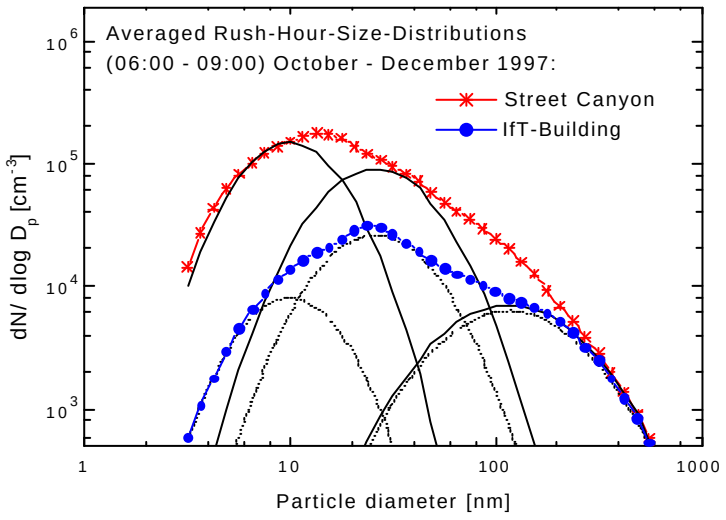

Fig. 6: Mean rush hour size distributions for two differently polluted sites in Leipzig.

Conclusions

The large dataset of these experiments, particularly that of the long term study, provides a large and unique database concerning the concentration of submicrometer particles in the urban atmosphere. The results are suitable to be included into aerosol and radiation models. Furthermore, they can be used to investigate health effects in the urban atmosphere with epidemiological studies.

The number concentration of the submicrometer particles depends obviously on the distance to a street as a particle source. With an increase of this distance, the total concentration decreases while the mean diameter of the curve is shifted to large diameters. Thus, the traffic emissions will be diluted in the atmosphere and the small particles grow up, probably by coagulation and condensation processes. However, these transformation processes between tailpipe and a measurement point close to the street are not well understood so far. Further experiments are necessary to get more information about that problem.

It was also shown that a very high concentration of ultrafine particles occurs on workdays as well as on weekends around noon. Probably, they are a result of photochemical production of new particles. However, these processes are also not completely explained yet and need further investigation. This phenomenon was observed on workdays as well as on weekends in the urban area of Leipzig. The concentration of precursor gases is obviously always high enough in the urban area.

Reference

Birmili, W., F. Stratmann, A. Wiedensohler (1997) Design of a DMA-based size spectrometer for a large particle size range and stable operation, J. Aerosol Sci., **30**, 549-554.