# FINE AND ULTRAFINE PARTICLES IN THE ZÜRICH (SWITZERLAND) AREA. AN ASSESSMENT OF THE SPATIAL AND TEMPORAL DISTRIBUTION

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## INTRODUCTION

On occasion of the research project YOGAM (Year of Gas Phase and Aerosol Measurements, 2001/2002), a mobile laboratory was constructed at the Paul Scherrer Institute (Villigen, Switzerland), allowing for on-road measurements of a variety of aerosol parameters and gas phase parameters, along with geographical information and meteorological data. We already showed earlier (Bukowiecki et al., 2002) that mobile measurements are useful for short-term air pollution investigations involving a single mobile laboratory. Continuingly, it was the goal of the study presented here (Bukowiecki et al., 2003) to obtain an integral picture on the annual variation of fine (<2.5 μm) and ultrafine (<100 nm) aerosol levels in the Zürich area with help of mobile measurements. Data included in this poster were measured by a scanning mobility particle sizer (SMPS, DMA TSI 3071 and CPC TSI 3010), a condensation particle counter (CPC, TSI UCPC 3025), an optical particle counter (OPC, Grimm 1.108), a diffusion charging sensor (DC, Matter Engineering LQ1-DC) and a carbon monoxide (CO) monitor (Aerolaser AL-5002). Since measurements could be performed while driving, highly time-resolved (1 s–3min time resolution for most parameters) and spatially resolved information (continuously) on the ground pollutant level in the testing area was obtained.

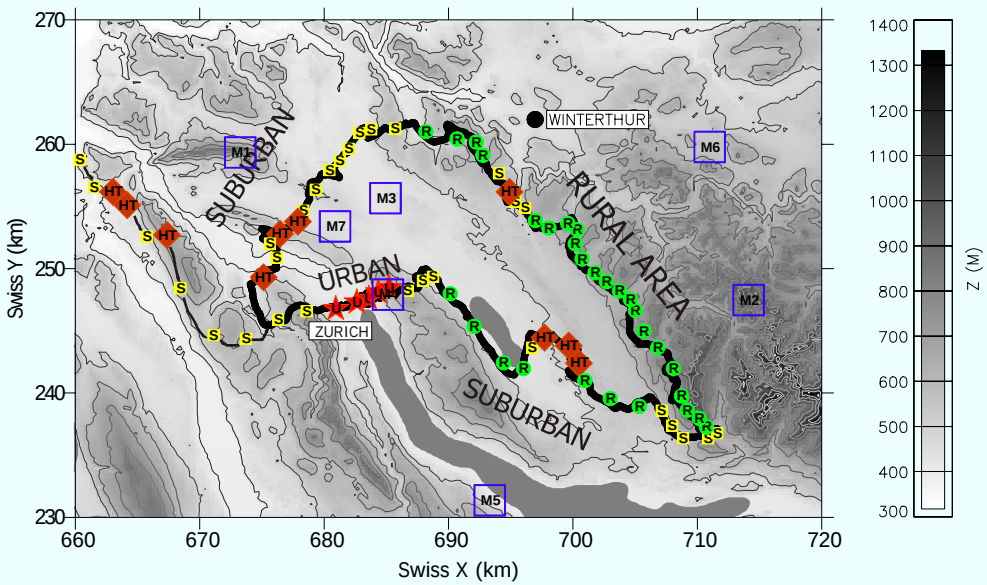



Fig. 1 During YOGAM, a selected route in the Zürich area (left graph) was driven with the PSI mobile pollutant measuring laboratory (right) on a regular base throughout the course of a year, including downtown Zürich (400m a.s.l.), suburban areas (400–500m a.s.l.) as well as rural sites (500– 900m a.s.l.). For the time frame chosen, additional data from official monitoring stations were available for comparison.

Rural and urban regions, but also locations influenced by heavy traffic, show different particle background number concentration ($N_{bkg}$) levels throughout the year (horizontal stripes). However, there are days/periods in which the overall particle background concentration appears much higher than the regional variation (vertical stripes).

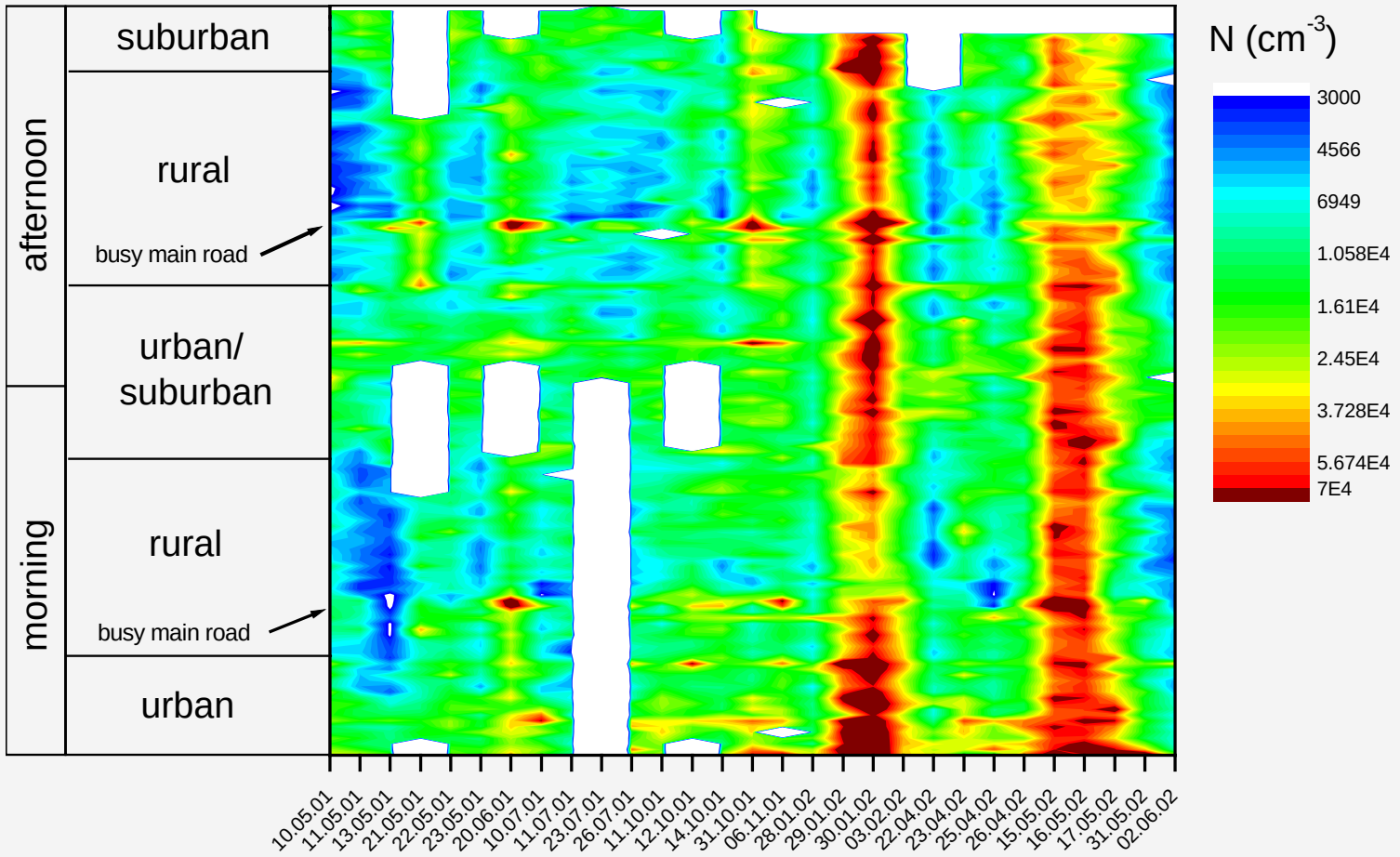



Fig. 2: Date vs. location contour plot for the 5% percentile (background, $N_{bkg}$) values of the total particle number concentration.

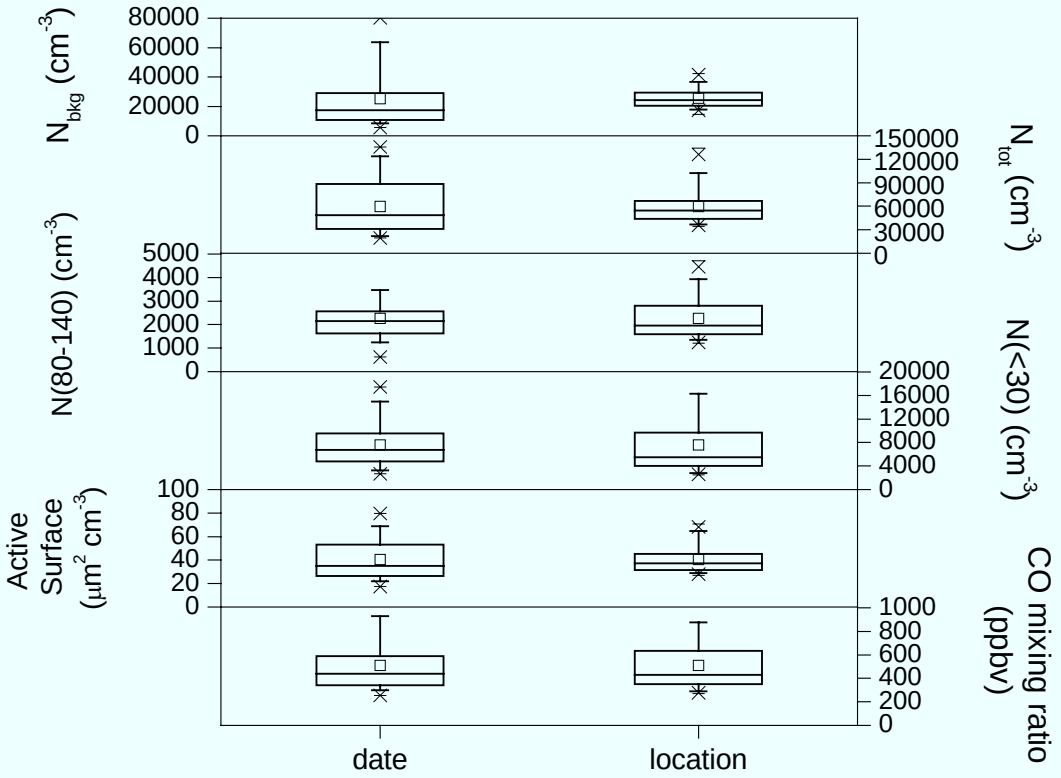



Fig. 3: Box plots for the measured levels of Nbkg, Ntot, N(80–140), N(< 30), active surface and CO, separated both by date (daily averages over all locations) and location (location bin averages over all dates).

Analysis of variance (ANOVA) was performed, to examine the influence of both daily weather conditions and local pollution characteristics on the measured parameters.

• The ANOVA showed that for all the selected parameters the variance both in date and location was significant.

• For $N_{bkg}$, $N_{tot}$ , N(80–140 nm) and the active surface, the variation in date exceeds the variation in location. For these parameters, the ANOVA model also quantitatively confirms the qualitative finding drawn from Figure 2.

• For N(< 30 nm) and CO, the spatial variation is more similar to the day-to-day variation. It is suspected that this is due to the regularly observed formation of relatively short-lived primary ultrafine particles in heavy-trafficked areas along with high CO concentrations.

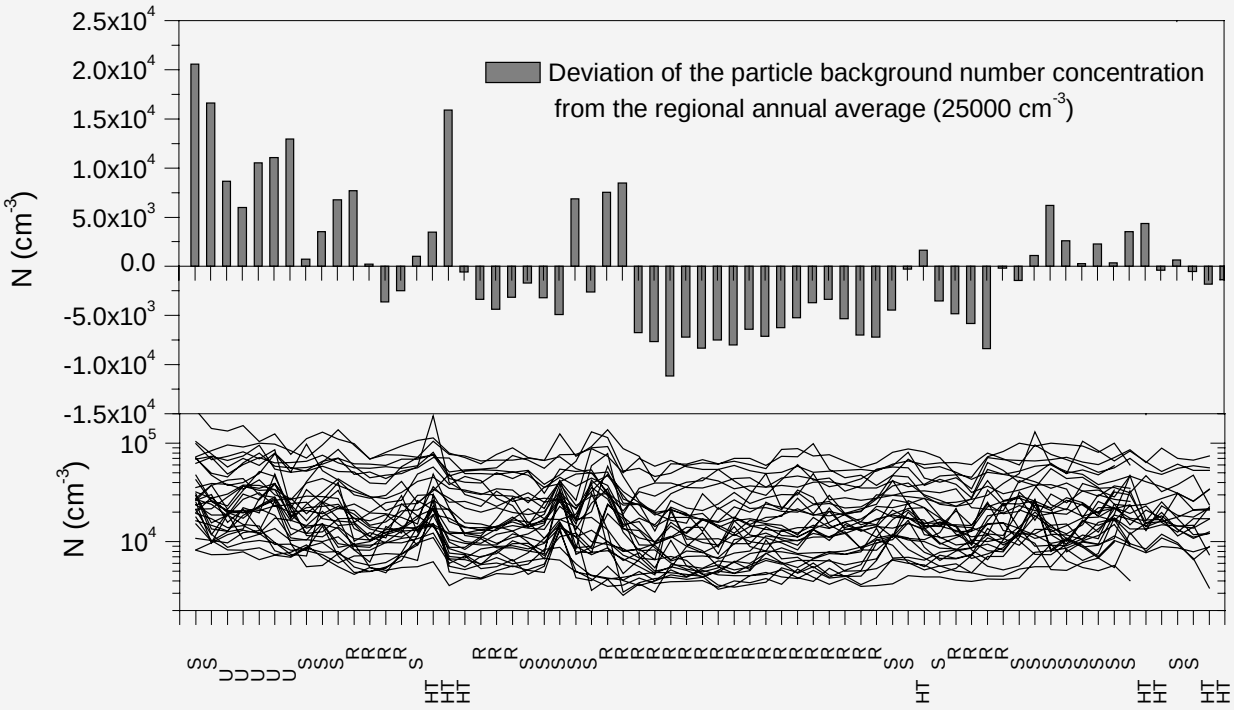



Fig. 4: The upper plot shows the deviation of the particle background number concentration from the annual average in the YOGAM area. As shown in the bottom plot, the signal scattering (i.e. the day-to-day variance) is basically constant for all location bins (note the logarithmic scale).

Conclusively, Figure 4 illustratively describes the variation of the particle background number concentration in the YOGAM area. Depending on the daily weather condition, the curve is shifted up or down, always maintaining a similar shape. On average, a clear differentiation for urban (U), suburban (S), rural (R) and heavy-trafficked (HT) areas is recognized on a per-route base.

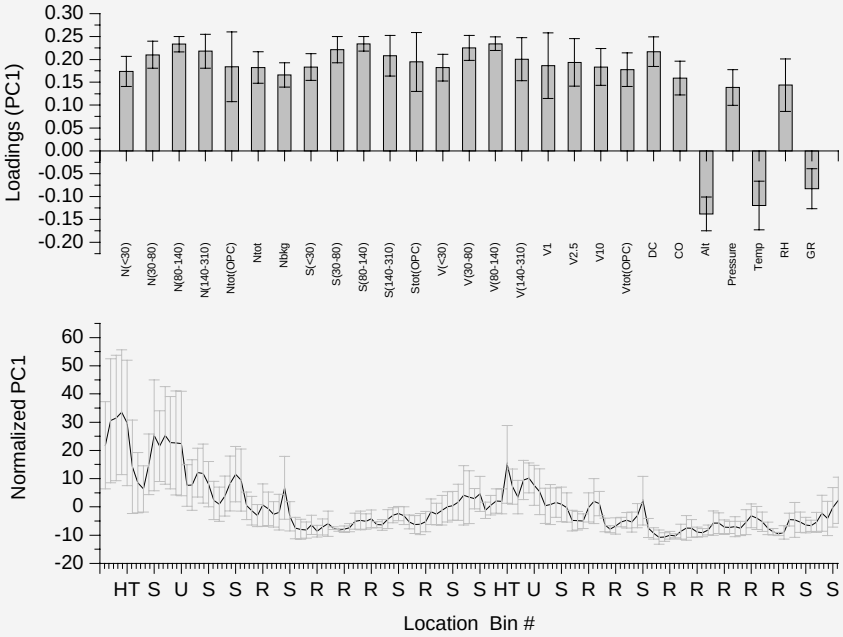



Fig. 5: Annual average of the first principal component (bottom), along with its loading pattern (top).

Principal component analysis is first of all a data reduction technique. Figuratively, it extracts the directions in which a cloud of data points is maximally stretched, i.e. has a maximal variance. The most relevant information of the data set is contained in these directions (i.e. principal components, PCs). The PCs represent orthogonal and therefore independent linear combinations of the original variables. Taking only these PCs, the original data set can be stored and compressed with a lower amount of variables, and the original data can be restored with only a minor loss of information.

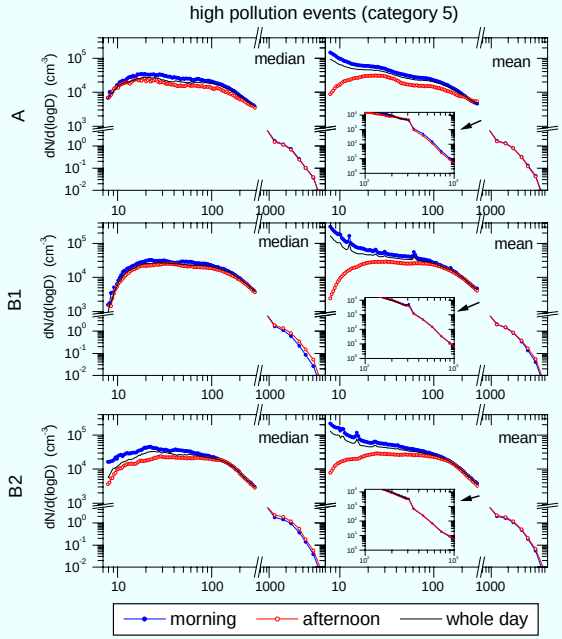
PCA (Principal Component Analysis) was individually performed for every measuring day. The goal was to obtain “footprints” for every day, telling more about the influence of e.g. meteorological conditions on the spatial and daily variation of the pollutants. The first principal component (PC) explained 60±5% of the total variance, whereas the second PC accounted for 15±5%.

The loading pattern for the first component shows relatively little variation throughout the year. The parameters that are contributing most to the first PC are N, S, V(80–140 nm) or N, S, V(140– 310 nm), as well as CO and the active surface area. They showed a minimal contribution to PC2. This suggests that this component represents a general degree of pollution.

The standardized PC1 (bottom) shows high values in urban regions and regions with heavy traffic and low values in rural areas. The largest variation in our daily data sets is hence caused by the degree of anthropogenic influence on the respective measuring location.

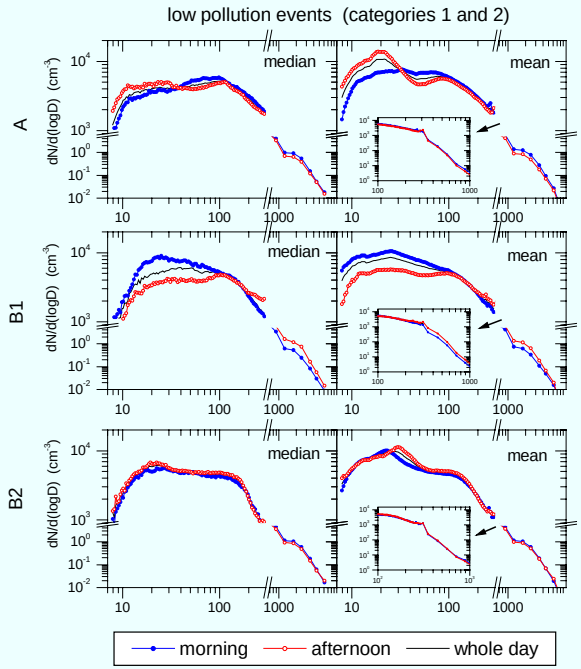
PC2 showed no uniform loading pattern throughout the year. To reveal similarities in the loading patterns of PC2, a cluster analysis was performed. Namely differences in temperature, global radiation and wind speed at high altitudes split the YOGAM days into different categories (A, B and C), each possibly reflecting a particular meteorological situation. Particle number size distributions show differences for these individual categories (Fig. 6,7):

Fig. 6: STRONGLY POLLUTED EPISODES




- Generally higher ultrafine number concentrations in the morning than in the afternoon, indicating higher importance of primary (directly traffic related) ultrafine particles compared to secondary formation.
- In all categories considerably higher average than median ultrafine number concentrations, indicating the high importance of special episodes with high primary ultrafine concentrations.

Fig. 7: WEAKLY POLLUTED EPISODES




- In class A with high radiation and rather high temperature days, higher ultrafine number concentrations in the afternoon indicate formation of secondary ultrafine aerosols.
- At days with high winds (B2) there is hardly any concentration difference between morning and afternoon.
- Even in low polluted areas significant primary ultrafines are formed in winter time at cold temperatures (B1).

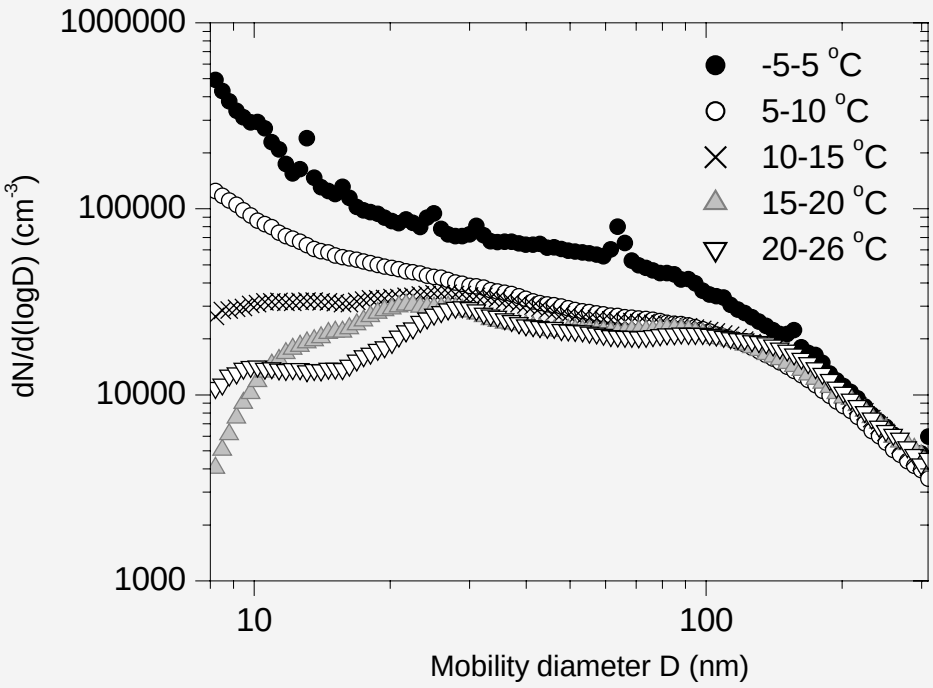



Fig. 8: Mean particle number size distributions measured under strongly polluted conditions, resolved by temperature.

The formation of primary (traffic related) ultrafine particles is clearly enhanced at cold temperatures, as it is seen in Figure 8.

## ACKNOWLEDGEMENTS

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## REFERENCES

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Bukowiecki, N., Dommen, J., Prévôt, A. S. H., Weingartner, E. and Baltensperger, U., Fine and ultrafine particles in the Zürich (Switzerland) area measured with a mobile laboratory. An assessment of the seasonal and regional variation throughout a year, *Atmos. Chem. Phys. Discuss.*, **3**, 2739-2782, 2003.