EXPERIMENTAL AND MODELLING STUDIES OF ULTRAFINE PARTICLE CONCENTRATIONS IN URBAN STREET AND BACKGROUND ENVIRONMENT

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Summary

The presentation has two main parts focussing on a) results from ambient particle measurements and b) application of different air pollution models to estimate the particle concentration at kerbside and in the urban background.

Measurements

We reported previously on long term measurements of particle size distribution (size range 10-700nm) and PM10 at street and urban background location in Copenhagen (Ketzel et al., 2003a). These measurements enable us to estimate vehicle emission factors. In addition we present here seasonal variations and correlation with meteorological parameters (e.g. temperature, wind speed, rain events) (Palmgren et al., 2003).

We show that we are able to fit the size distributions averaged separately for each hour of the week with 3 lognormal modes. The variation of these 3 modes together with CO and NOx measurements gives the basis for a factor analysis. As one possible solution we obtain 3 factors resembling the following profiles:

Factor 1:	Mode 1+2;	NOx
Factor 2:	Mode 1+3;	NOx
Factor 3:	-	NOx; CO

An interesting aspect is that the Factor 3 explains all the variation in CO (tracer for gasoline vehicles) but does not contain any ultrafine particles. That means that we can interpret our field measurements without gasoline particle emissions and only two different types of 'diesel factors'.

We also report first results of a short term measuring campaign (6 weeks) conducted simultaneously at an urban background station in Copenhagen and two rural background locations ca. 30 km west and 60 km northeast of Copenhagen (Ketzel et al., 2003b). These measurements allow for estimating the contribution from the city to the elevation of particle number concentration and PM10.

Modelling

In this study we are applying these emission factors together with a street pollution model OSPM (Berkowicz, 2000b) to predict time series of particle number and NOx at street level. We show that an assumed temperature dependence of the particle emissions can improve the model results.

The time scales for particle dynamic processes (e.g. coagulation, deposition, dilution) are estimated for urban street and background environment and discussed in their relevance for influencing the particle size distribution. In agreement with the literature (Pohjola et al., 2003; Vignati et al., 1999) we conclude that coagulation is too slow to alter the size distribution in the exhaust plume and dilution is the dominating process. A similar conclusion can be drawn for the street scale. In a more confined environment as e.g. a road tunnel the removal processes coagulation and deposition might play a important role (Gidhagen et al., 2003).

First model results for the urban scale using a simple plume approach for the pollutant dispersion(Berkowicz, 2000a) in connection with the aerosol model AERO3 (Vignati, 1999) show that 1) the coagulation and deposition account for ca. 20% loss of particles in the urban background compared to street level and 2) the size dependent removal lead to a slight increase in 'max' - diameter of the particle size distriution.

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Experimental and Modelling Studies of Ultrafine Particle Concentrations in Urban Street and Background Environment

7th ETH Conference 2003

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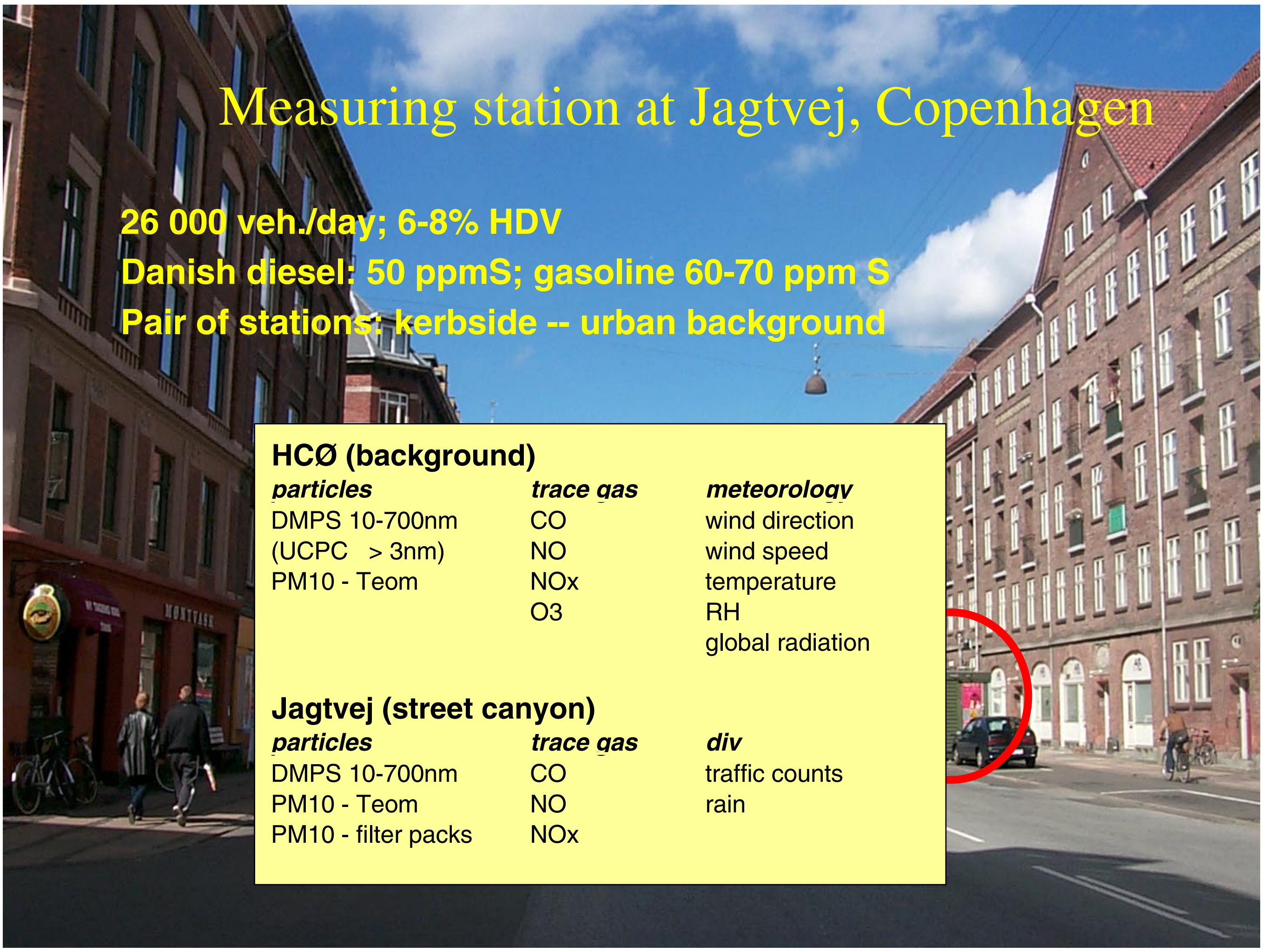
Funding: Danish EPA

Outline of the presentation

- Objective
- Particle measurements in Copenhagen
  (follow up of last years presentation)
- Dispersion modelling
  - time scale analysis
  - kerbside modelling
  - urban scale modelling

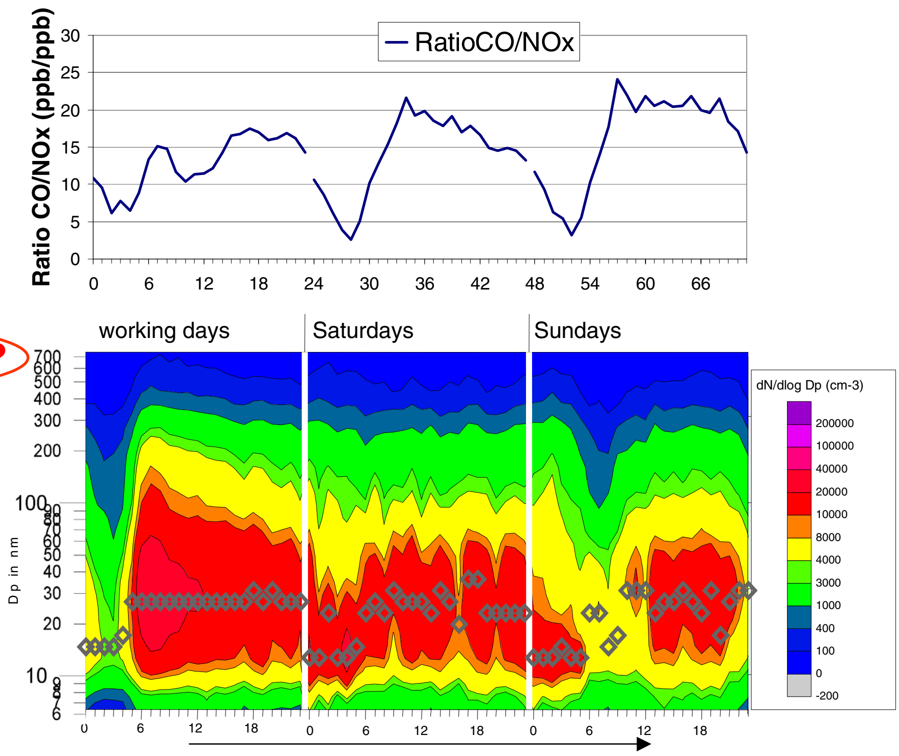
Objective

- ambient measurements of nanoparticles
  - 'real world' particle emission factors + size distribution
  - separated for vehicle classes (gasoline/diesel; LD/HD)
  - analyse dependence on meteorological parameters
- include particles in our dispersion models
  - forecast of pollution levels
  - scenario calculations
  - ...



Average weekly profile of size distribution, Difference Street - background
periode 15-05 to 23-11-2001 ca. 12 weeks of data (1h averages)

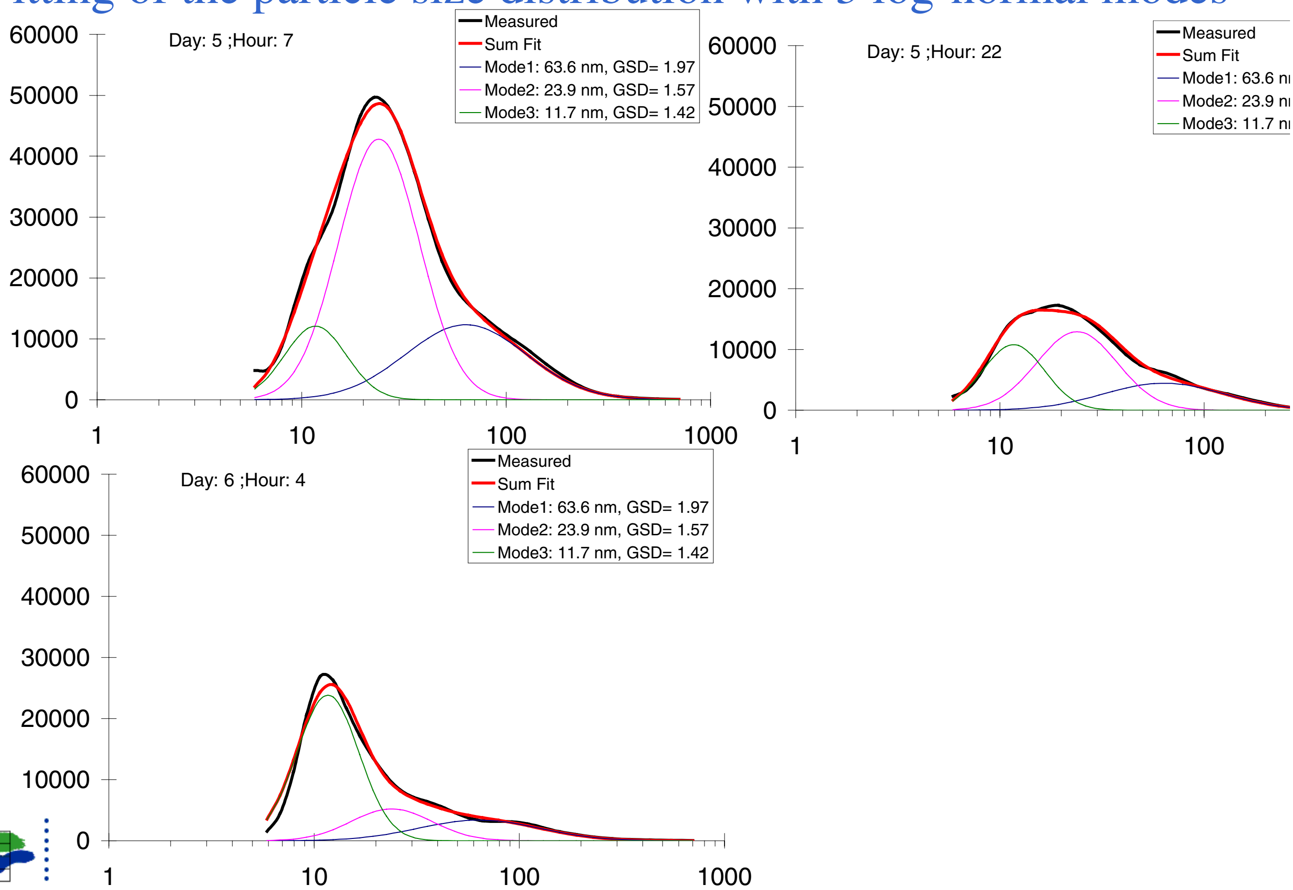
- constant mode diameter during day
  - diesel ≈ gasoline ??
- night time shift to smaller sizes
  - diesel taxi + oxicat.
  - nucleation ?!



time ('hour of the week')

Ketzel et al. 2003 Atmos. Env. 37, 2735

Fitting of the particle size distribution with 3 log-normal modes



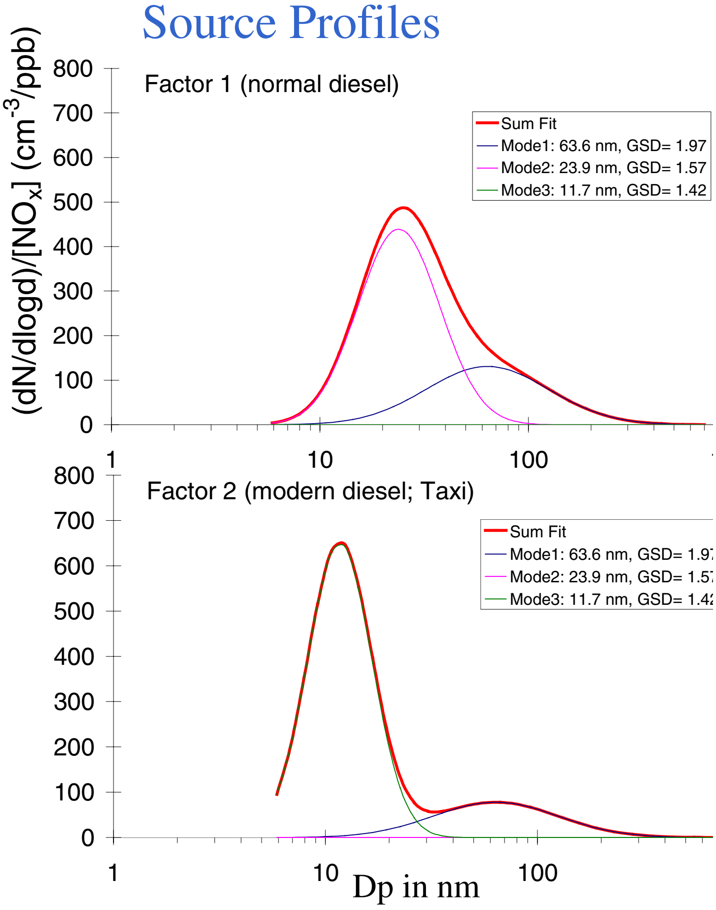
Factor Analysis

- Average weekly variation of
  - NOx
  - CO
  - Strength of Mode 1-3

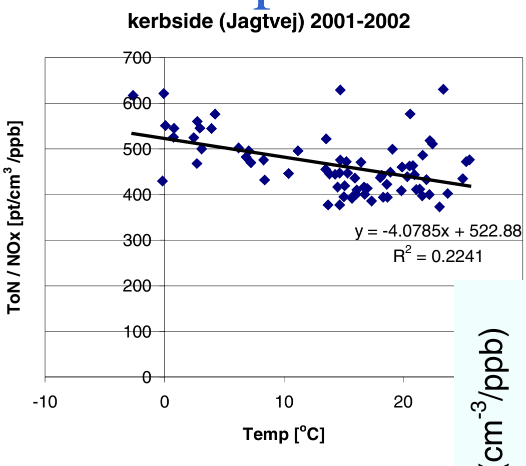
  (all corrected for background !)

- Possible Solution:
  - Factor 1: Mode 1+2; NOx
  - Factor 2: Mode 1+3; NOx
  - Factor 3: - NOx; CO

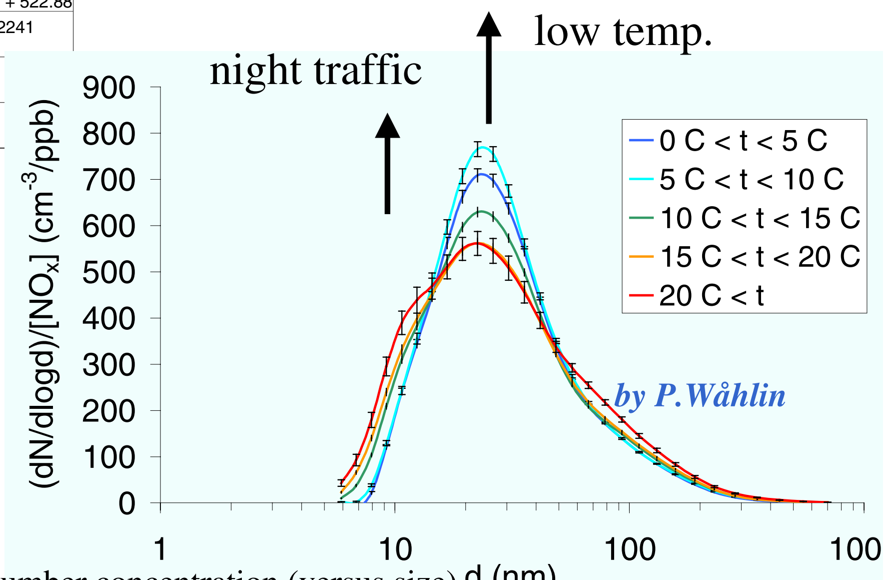
Source Profiles



Temperature variations - particle number



lower particle / NOx ratio at lower temperatures



Ratios between particle number concentration (versus size) and the NOx concentration at HCAB (street station).

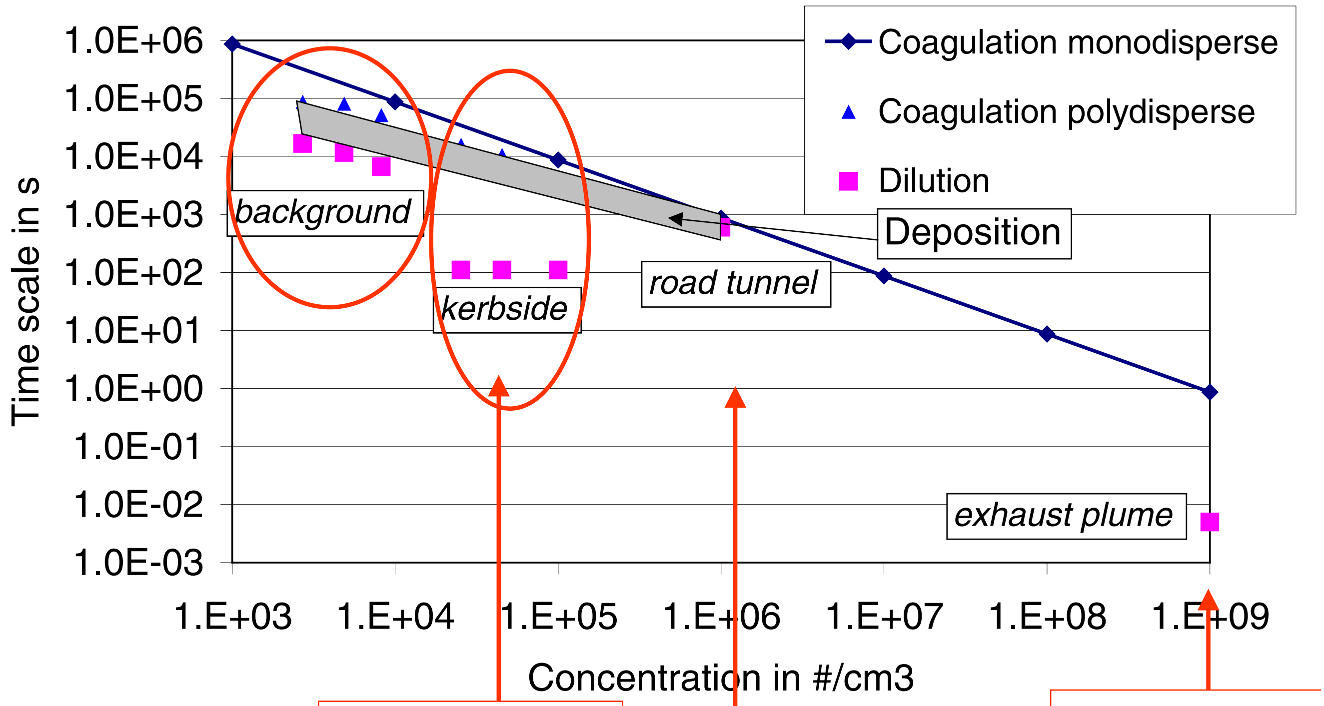
Conclusions - ambient measurements:

- fleet emission factors could be estimated (last years talk)
- 3 - modal structure of the size distribution
- possible factor solution:
  - 2 factors (NOx + particles)
  - 1 factor (NOx + CO, no particles)
- temperature dependence

Modelling of ambient ultrafine particles

- Which particle transformation processes are relevant at the different scales?

Time scales for several processes



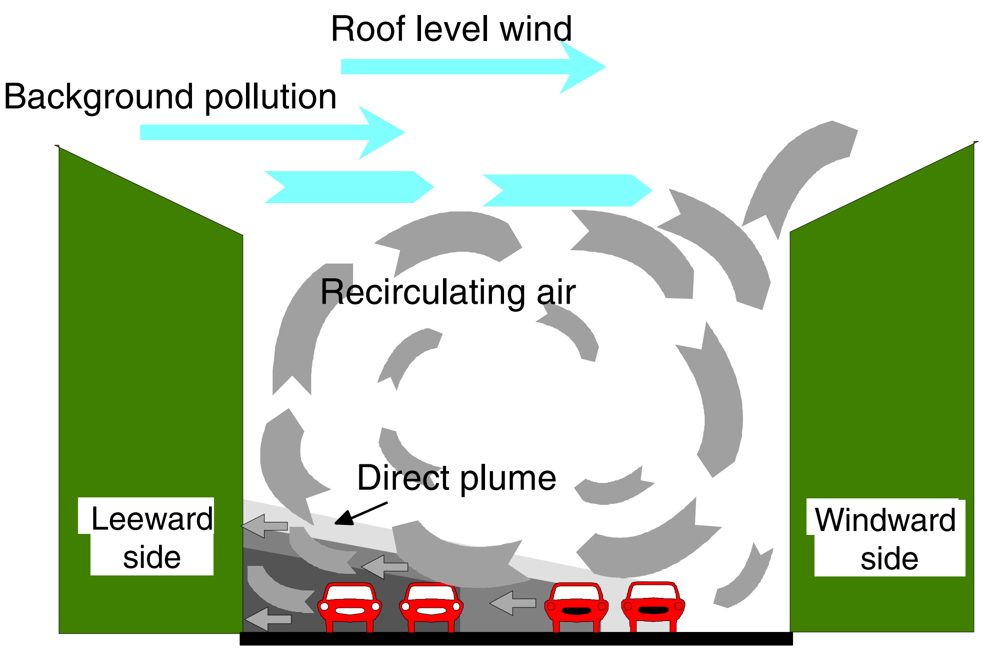
Gidhagen et al. poster here

Gidhagen et al. 2003
- 77% loss for Dp < 10nm
- 41% loss for Dp 10-29nm

Vignati et al. 1999
Pohjola et al. 2003 :
-no effect of coag.

Modelling the dilution at kebside

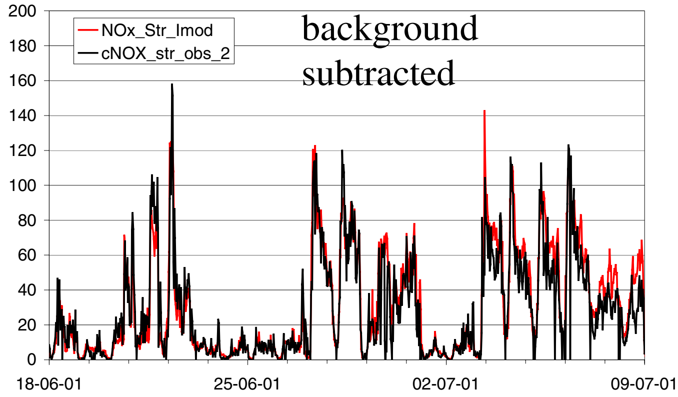
- Operational Street Pollution Model (OSPM); Berkowicz et al. 1989...2003

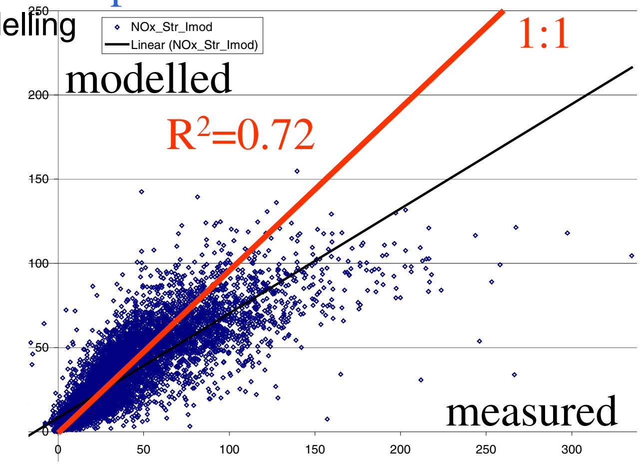


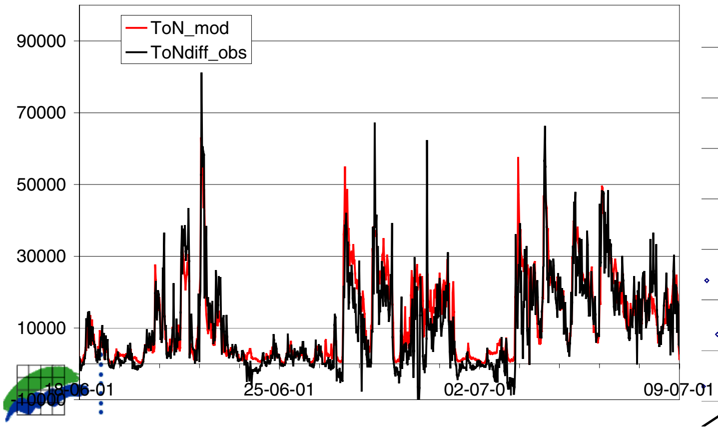
C = F(wind direction, wind speed, vehicle speed ...) * Q [pt/km/s]

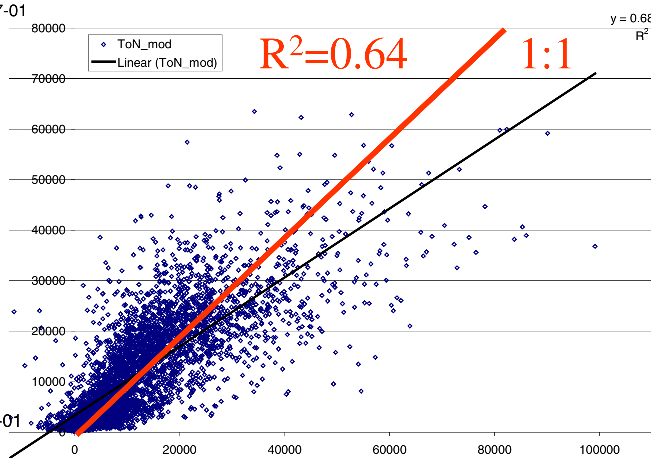
Modelling at kebside for NOx and total particle number

- OSPM and emission factors from inverse modelling
- inert particles (no particle dynamics)

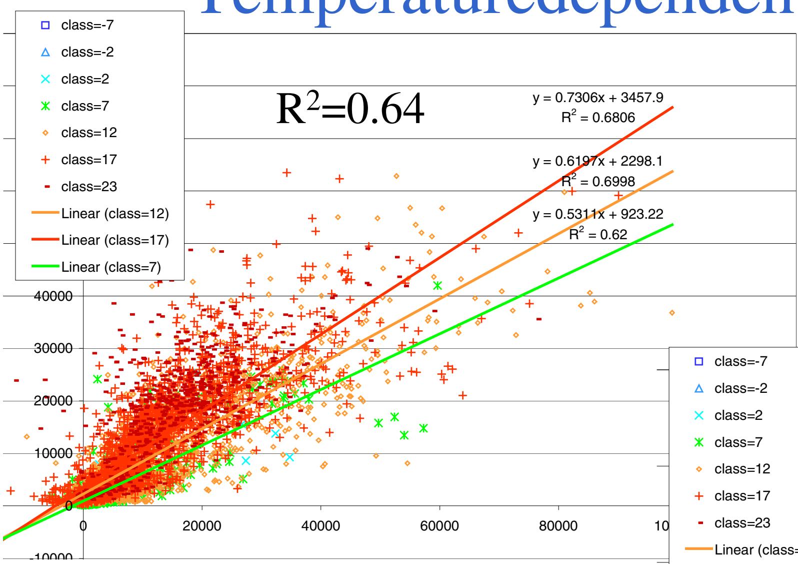


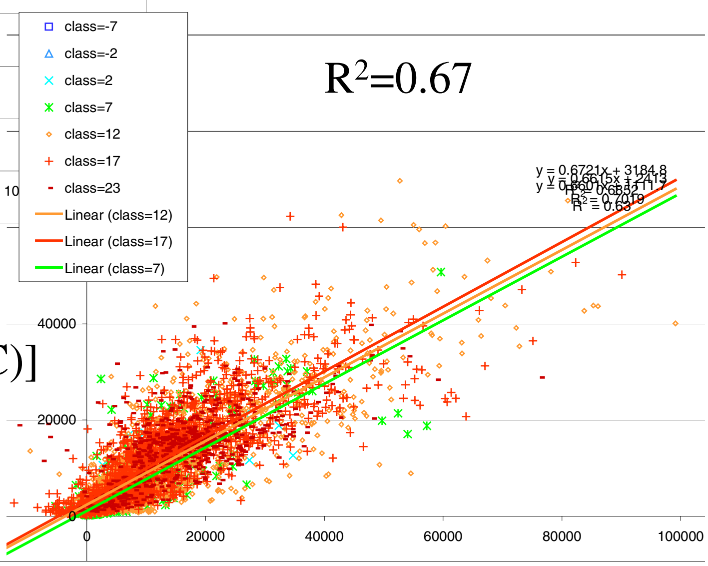






Temperaturedependent Emissions

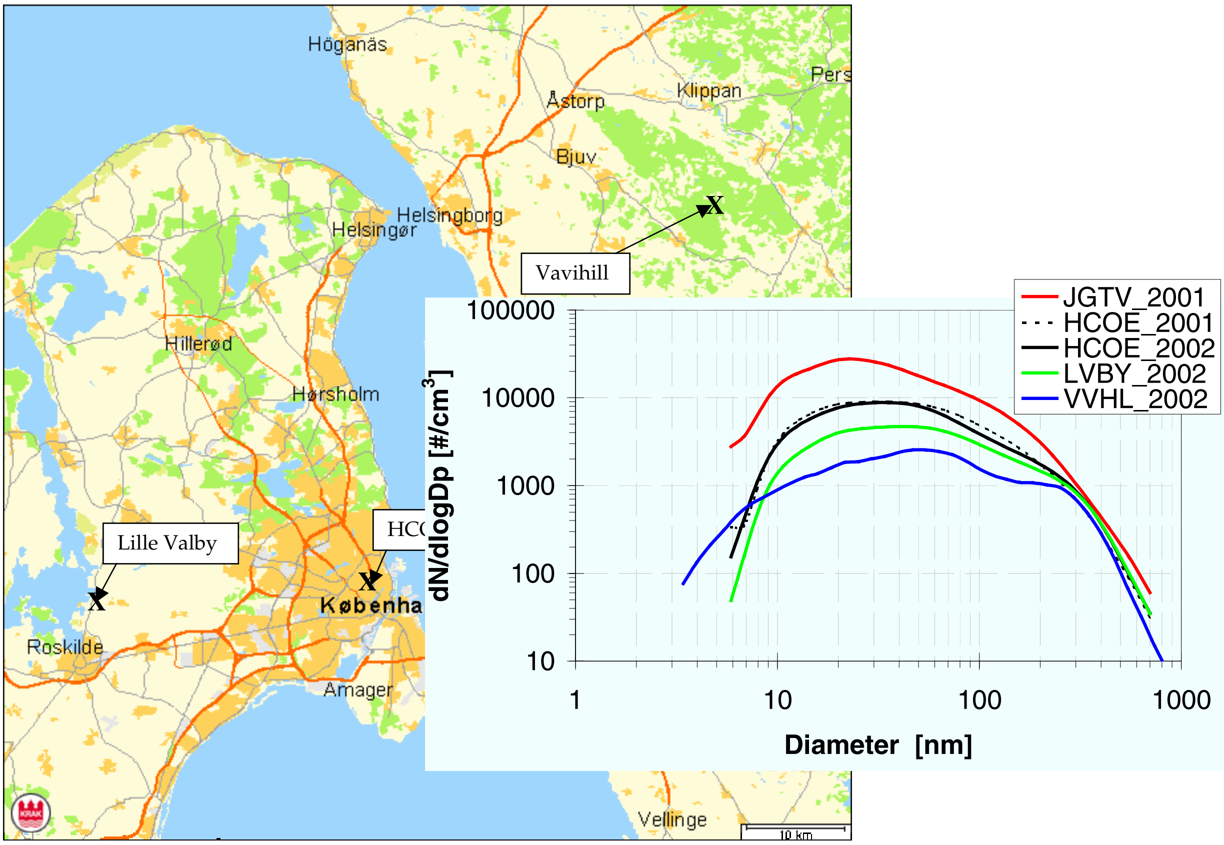




$$E(T) = E(15C)*[1 - 0.034\ (T-15C)]$$

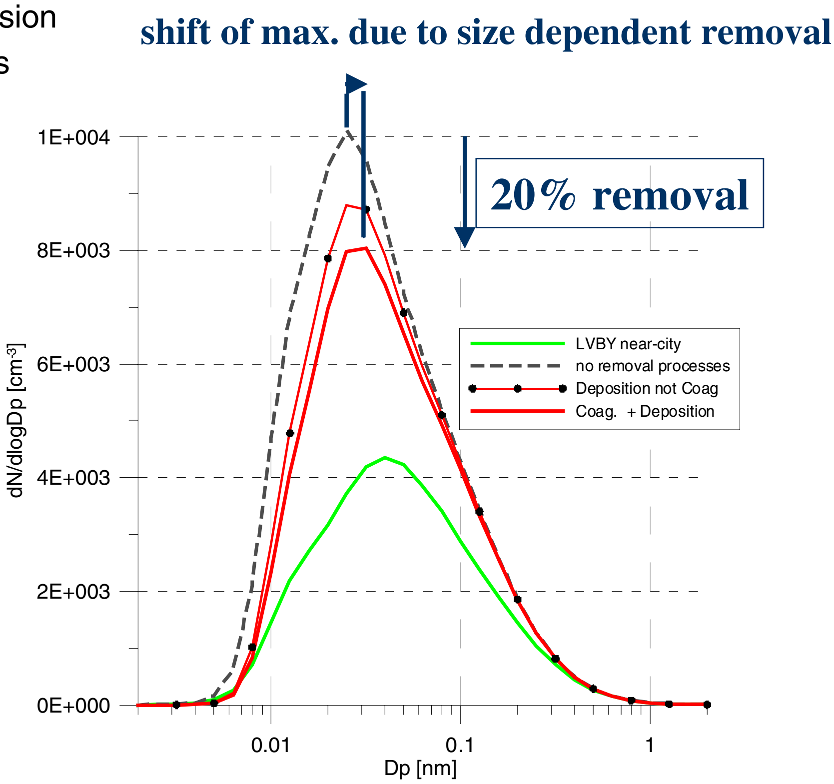
$$E(0)/E(15) \sim 150\%$$

Measurements at urban, near-city and rural level



Modelling of the urban background

- 'plume' model for vertical dispersion
- background from measurements
- emission factor + size distrib. from kerbside measurements
- sectional model for particle dynamics including
- processes modelled:
  - background
  - emission
  - vertical dilution
  - deposition
  - coagulation



Conclusions - modelling:

- street level
  - coagulation is too slow to alter the size distribution
  - dilution is the dominant process at street level
  - OSPM (without particle dynamics) can be used also for particles
  - temperature dependent e-factors increase correlation observed vs. modelled results
- urban scale
  - coagulation and deposition account for ca. 20% loss of particles
  - size dependent removal leads to a slight increase in 'max' - diameter