An analysis of vehicular particle number emissions based on long-term roadside and urban background measurements

S. Klose[1], W. Birmili[1], B. Wehner[1], A. Wiedensohler[1], T. Tuch[1,2], J. Voigtländer[1], U. Franck[2] and M. Ketzel[3]

[1]IfT – Leibniz Institute for Tropospheric Research, Permoserstraße 15, 04318 Leipzig, Germany
[2]UFZ – Helmholtz-Centre for Environmental Research, Permoserstraße 15, 04318 Leipzig, Germany
[3]Department of Atmospheric Environment, National Environmental Research Institute, Frederiksborgvej 399, 4000 Roskilde, Denmark
Email: klose@tropos.de

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Motivation

- traffic-induced ultrafine (< 0.1 µm) and fine particles (< 1 µm) are known to be a hazard to human health: because of their size they can be deeply deposited
- high aerosol particle concentrations in densely built and much frequented areas because of a lack of ambient ventilation and fresh air supply
- to study the vehicle-induced contribution to urban air pollution: calculation of particles size-resolved emission factors indicating the number of particles emitted by a vehicle per driven distance
- analysis as a function of diurnal and meteorological parameters, seasonal effects as well as changes in fleet composition
- emission factors are furthermore required as input for urban air quality modelling

Objectives and methods

The analysed biennial dataset (2005/2006) includes

- aerosol particle number size distributions in a highly-trafficked street canyon (Leipzig-Eisenbahnstraße) and in the urban background (Leipzig-IfT)
- traffic census using an automated video detection system
- measurement of local wind speed and direction at the roadside measurement site
  - consideration of turbulence-depending particle transport
  - meteorology within a street canyon is especially characterised by the creation of extensive vorticies
  - dispersion from the tailpipe to the sampling point is quantified with the dispersion model OSPM (Operational Street Pollution Model)

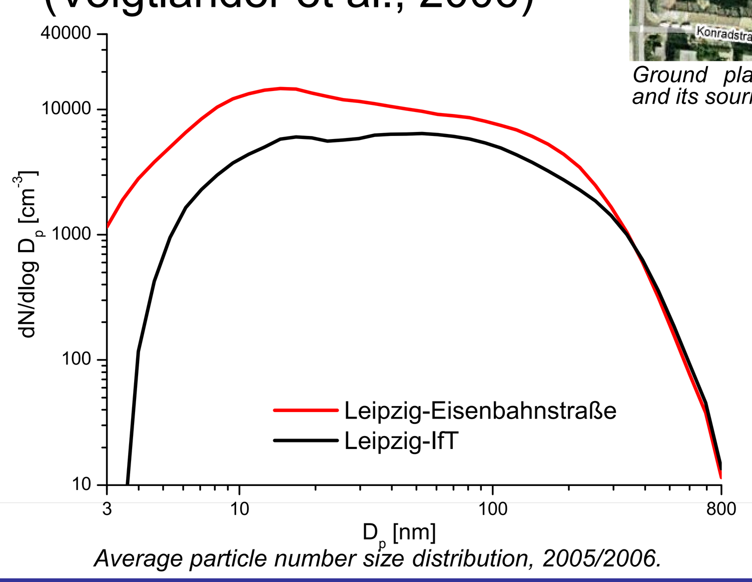
Measurements

roadside site Leipzig-Eisenbahnstraße

- regular street canyon with two lanes
- 10,500 vehicles/working day
- twin differential mobility particle sizer (3-800 nm) at a height of 6 m above ground
- ultrasonic anemometer on the roof (24 m)
- automated video detection system: counting and classifying of vehicles (Voigtländer et al., 2006)

Row of houses with particle inlet and anemometer.

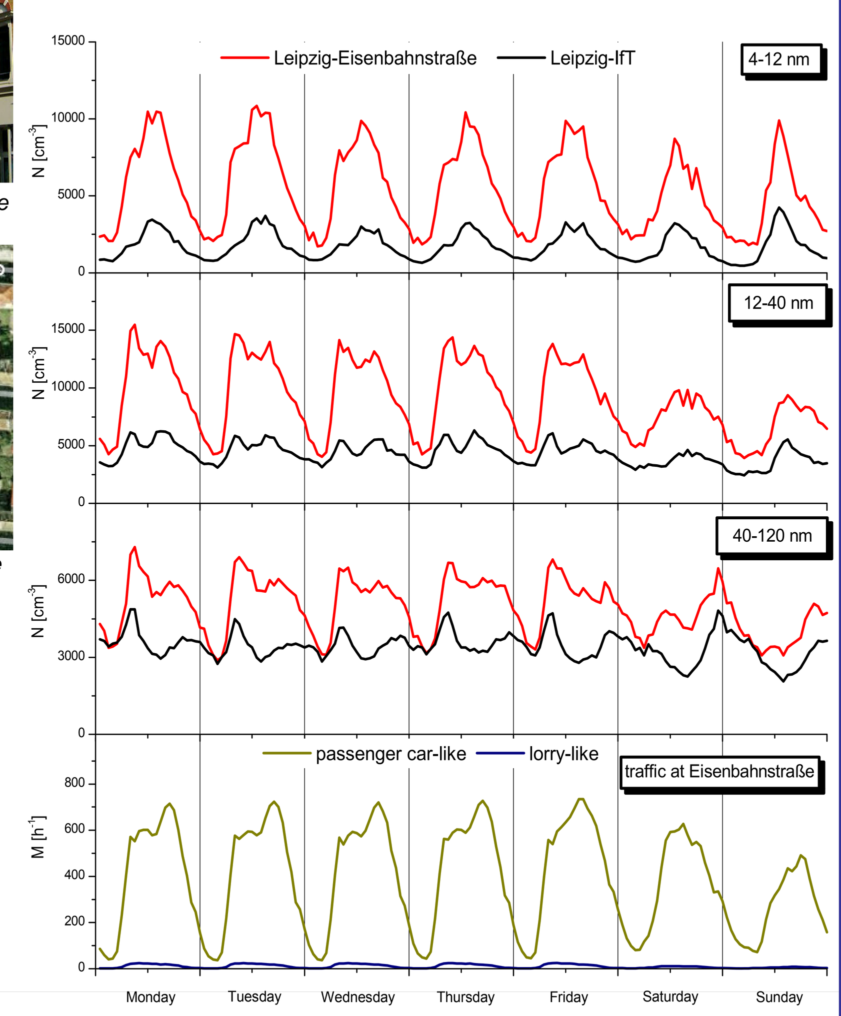
Ground plan of the site and its sourrounding area.



Average particle number size distribution, 2005/2006.

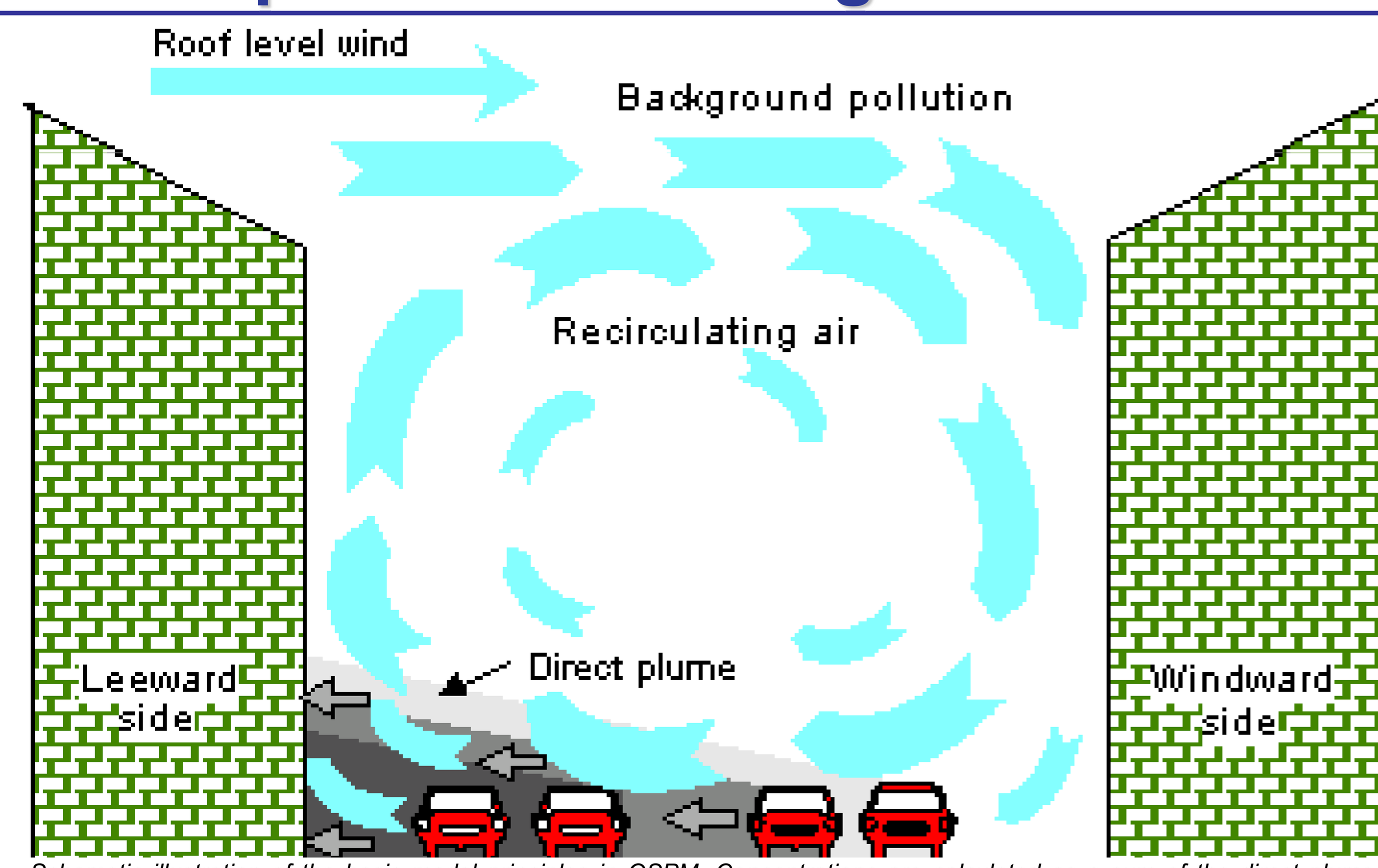
urban background site Leipzig-IfT

- twin differential mobility particle sizer (3-800 nm) at a height of 16 m
- 1.5 km distant from Leipzig-Eisenbahnstraße



Weekly cycle of particle number concentration and traffic density.

Dispersion modelling with OSPM



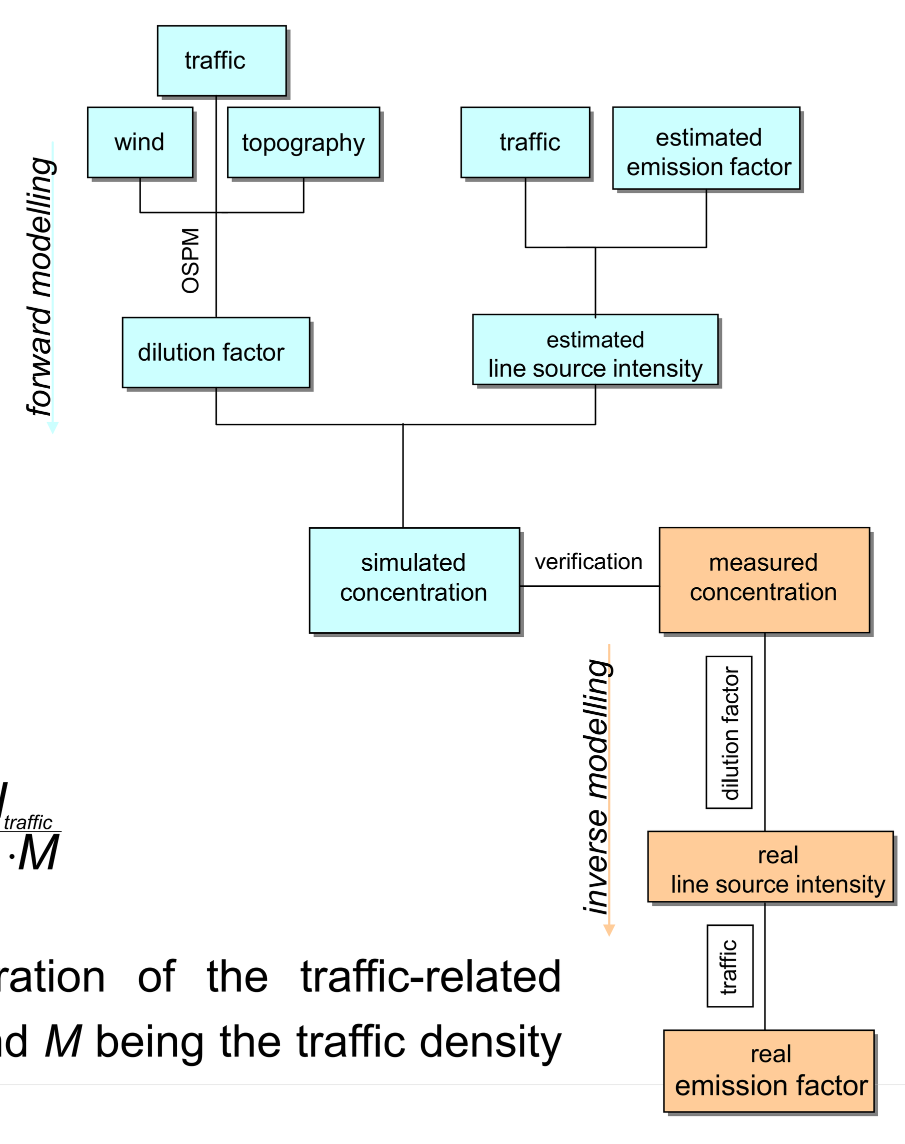
Schematic illustration of the basic model principles in OSPM. Concentrations are calculated as a sum of the direct plume contribution and the recirculating pollution (Berkowicz et al., 1997).

- OSPM is used to determine the dilution factor *F* (Berkowicz et al., 1997)
- the model is particularly suitable for regular street canyons
- the dilution factor *F* depends on the wind-induced turbulence and the turbulence vehicles induce themselves, the following information is required:
  - roof level wind direction and wind speed
  - traffic speed and density
  - topography of the street canyon: orientation, height, width, distance to next crossing streets, height of particle inlet

Calculation of emission factors

To verify the results of the simulation, the run of the time series of the simulated particle concentration can be compared with the measured traffic-related increment concentration.

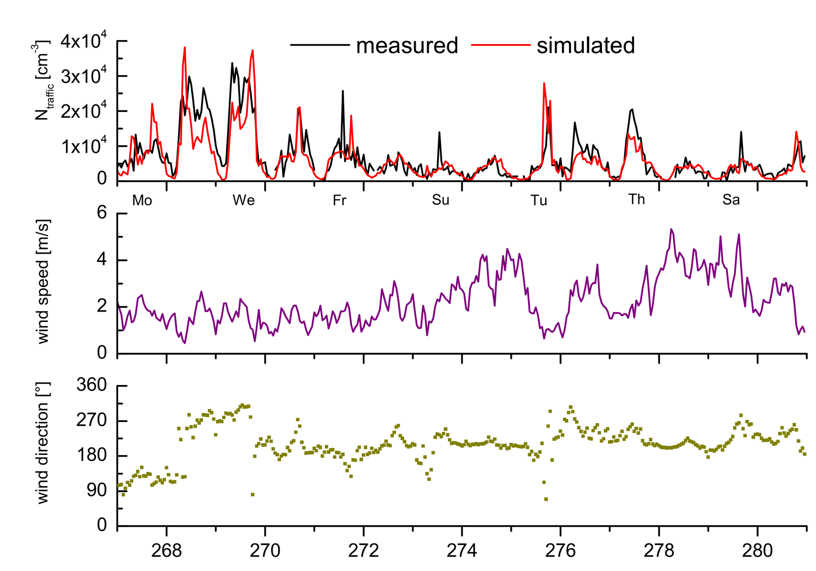
If the dilution is described adequately with respect to changing wind directions and wind speeds, the dilution factor *F* (s m^{-2}) can be used to determine the emission factor *E* (veh^{-1} km^{-1}):



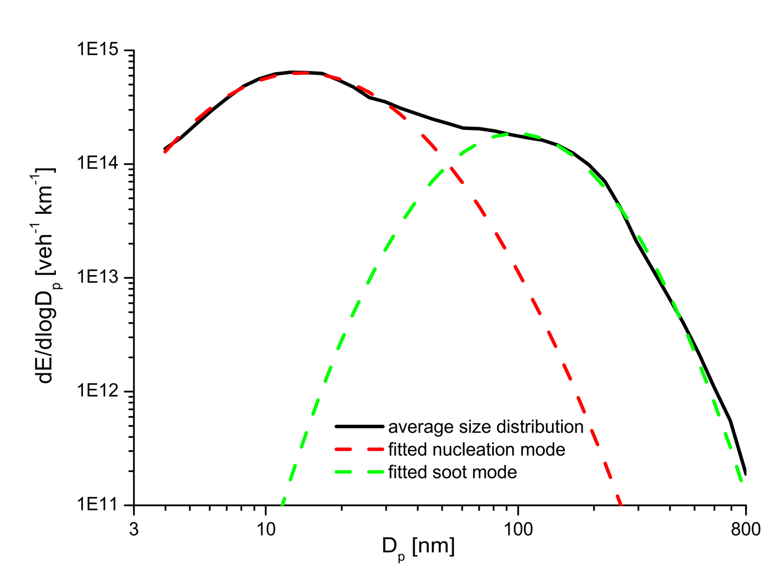
$$E = \frac{N_{traffic}}{F \cdot M}$$

with $N_{traffic}$ being the particle concentration of the traffic-related increment ($N_{roadside} - N_{background}$ (cm^{-3})) and *M* being the traffic density (veh s^{-1}).

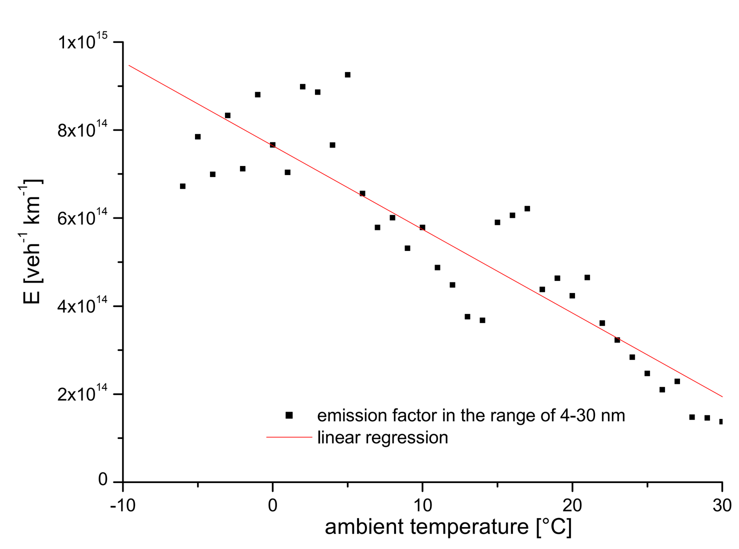
Results & Discussion



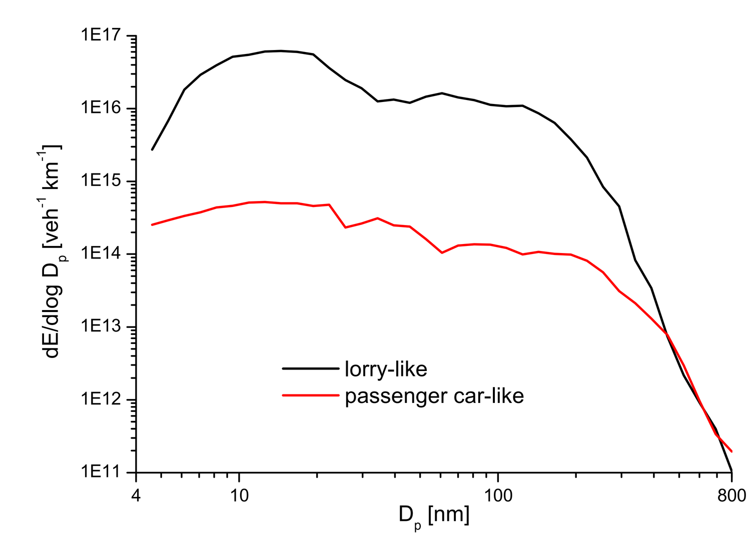
Measured vs. simulated particle concentration for changing inflow conditions.



Average size distribution of the emission factor of an average vehicle.



Emission factor of ultrafine particles vs. ambient temperature.



Size distributions of emission factors for different vehicle classes.

- two aerosol population modes in the size-resolved emission spectrum: the nucleation mode (diameter 14 nm) and the soot mode (diameter 98 nm)
- dependency of the nucleation mode (particles between 4 and 30 nm) on the ambient temperature resulting in a annual cycle, e.g. $E(summer) = 5.9 \cdot 10^{14}$ veh^{-1}km^{-1}, $E(winter) = 8.9 \cdot 10^{14}$ veh^{-1}km^{-1}
- an average lorry-like vehicle emits approximately 80-times as many particles as an passenger car-like vehicle does: $E(lorry\text{-}like) = 4 \cdot 10^{16}$ veh^{-1}km^{-1}, $E(passenger\ car\text{-}like) = 4.8 \cdot 10^{14}$ veh^{-1}km^{-1}
- fairly agreement with other comparable studies
  - $2.8 \cdot 10^{14}$ veh^{-1}km^{-1} (Ketzel et al., 2003)
  - $1.5 \cdot 10^{14}$ veh^{-1}km^{-1} (Imhof et al., 2006)

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Acknowledgements

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