Evaluation of Aerosol Processes Between Roadside and Neighbourhood Scale

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Summary

This study evaluated the influence of aerosol processes on the particle number (PN) concentrations in three major European cities on the neighbourhood scale. We have used selected measured data of particle size distributions from previous campaigns in the cities of Helsinki, Oslo and Rotterdam. The aerosol transformation processes were evaluated using an aerosol dynamics model MAFOR (*Karl et al., 2011*; http://mafor.nilu.no), combined with a simplified treatment of roadside and urban atmospheric dispersion. We have compared the model predictions of particle number size distributions with the measured data. The chemical transformation of gas phase compounds and the nucleation of gas-phase vapors to form new particles were not taken into account in this study. Dry deposition and coagulation of particles were identified to be the most important aerosol dynamical processes controlling the removal of particles.

Campaigns

Measurements of particle number size distributions at a traffic station and at an urban background (UB) station, during campaigns in the cities Oslo, Rotterdam and Helsinki:

1) Rotterdam: Traffic site Bentinckplein, UB site Zwartewaal-straat, period 6–19 May 2011.
2) Oslo: Traffic site Smestad, UB site Sofienberg park, period 12 Dec. 2007 to 17 Apr. 2008.
3) Helsinki, SAPPHIRE case I: Traffic site Herttoniemi, UB site Kumpula, period 23–28 Aug. 2003 (*Hussein et al., 2007*).
4) Helsinki, SAPPHIRE case II: Traffic site Herttoniemi, UB site Kumpula, period 9– 11 Feb. 2004 (*Hussein et al., 2007*).
5) Helsinki LIPIKA: Traffic site Herttoniemi, UB site Saunalahti bay, period: 17–20 Feb. 2003 (*Pirjola et al., 2006*).
6) Helsinki, MMEA: Traffic site Mannerheimintie, UB site Lääkärinkatu, period 13–14 Dec. 2010 (*Pirjola et al., 2012*).

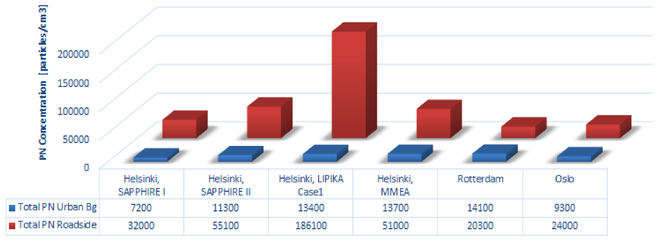

Figure 1: Campaign average of total PN concentration measured at roadside traffic station (red) and UB station (blue).

Model Approach

MAFOR is a one-dimensional model; hence coupling to some dispersion model would be required to simulate atmospheric transport processes. In order to approximate atmospheric dispersion, we used a simplified treatment of dilution of particle numbers. The dilution concept implies the assumption of a well-mixed state within the plume volume. Model runs were performed with different dispersion conditions to address the response of PN concentration changes to a range of realistic dilution regimes.

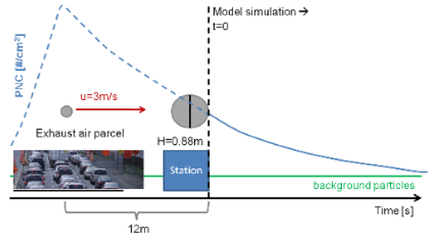

Figure 2: Illustration of the idealised scenario for model simulations with MAFOR to study aerosol processes between roadside and neighbourhood scale.

Comparison modelled and measured size distributions

Size distributions after 10 min of travel time (U=3 m s^{-1}) predicted by the aerosol model compared well with the size distributions measured at the respective urban background sites, despite the simple representation of atmospheric dispersion. The considered aerosol processes accounted for PN concentration changes of up to 20% after 10 minutes and up to 30% after 30 minutes travel time, respectively.

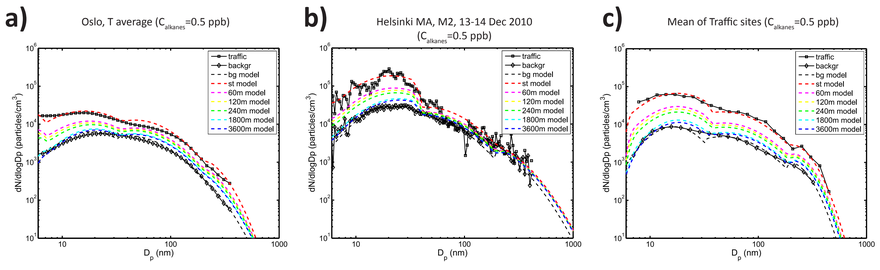

Figure 3: Number size distributions downwind of busy roads in a) Oslo campaign, b) MMEA campaign, Helsinki, and c) the constructed mean traffic distribution. Measurements: roadside (black squares), UB (black diamonds). Modelled: initial model distribution and modelled distributions at distances of 60, 120, 240, 1800, and 3600 m, respectively.

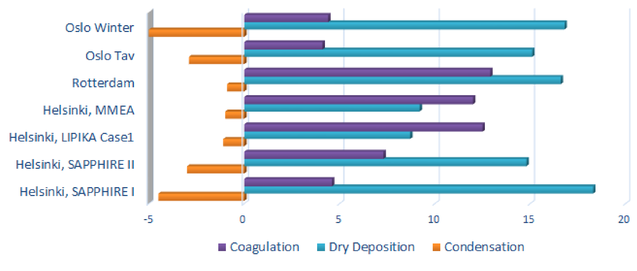

Figure 4: Contribution of aerosol processes to the percentage change of PN concentration (%) between roadside station and neighborhood environment for inefficient dispersion conditions.

A Simple PN Parameterization for Urban Models

As a first step of the implementation of a treatment of aerosol processes in urban air quality models, a separation of total PN is required: three particle number concentration (PNC) categories were defined: PNC_1 ("Nucleation"), PNC_2 ("Aitken"), and PNC_3 ("Accumulation").

Dry deposition is implemented according to:

$$\left.\frac{dPNC_k}{dt}\right|_{depo} = -PNC_k \frac{\overline{v_{d,k}}}{H_{grid}}$$

Coagulation is implemented according to:

$$\left.\frac{dPNC_k}{dt}\right|_{coag} = -PNC_k \cdot \left(\overline{K_{coag,k}} \cdot PNC_k^0\right)$$

Table 1: Parameters for aerosol processes.

Size category	Size ranges [nm]	Initial size distrib. ratio [–]	v_d [cm s^{-1}]	K_{coag} [cm^3 s^{-1}]	τ_{depo} [h]	τ_{coag} [h]
PNC_1	8.5–25	0.70	0.53	4.51×10^{-9}	1.1	1.9
PNC_2	25–100	0.29	0.12	3.10×10^{-9}	4.7	6.6
PNC_3	100–500	0.01	0.02	8.82×10^{-10}	24	589

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