5.32 THE INFLUENCE OF AEROSOL PROCESSES IN VEHICULAREXHAUST PLUMES: MODEL EVALUATION AGAINST THE DATA FROM A ROADSIDE MEASUREMENT CAMPAIGN

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INTRODUCTION

We present an evaluation of a modelling system that consists of an aerosol process model MONO32, a roadside dispersion model CAR-FMI and a meteorological pre-processing model MPP-FMI against measurement data obtained from a mobile laboratory. The main objective is to analyse the importance of the different aerosol processes in a local scale in an urban environment. The predicted particle number concentrations are compared with those measured at the mobile laboratory, and conclusions are drawn regarding the importance of various aerosol processes on the evolution of vehicular emissions. The aerosol processes considered include nucleation, condensation and evaporation, coagulation, deposition and chemical reactions, and the impacts of these are compared quantitatively with the corresponding influence of atmospheric diffusion.

MATERIALS AND METHODS

The measuring locations and equipment

The aerosol measurements have been conducted at various locations near Itäväylä, a major road in an urban area of Helsinki, during February 17 – 20, 2003. The measurement locations are presented in Figure 1a. The mobile laboratory used was constructed into a Volkswagen LT35 diesel vehicle, and contains measuring equipment for collecting of various data regarding particles, selected gaseous pollutants, and meteorological and geographical parameters, all of these with fine spatial and time resolutions *(Pirjola et al.,* 2004*).* In this study, we focus solely on particles. A schematic view of the mobile laboratory is presented in Figure 1b.

Particle size distribution is measured by the Electrical Low Pressure Impactor (ELPI, Dekati Ltd, *Keskinen et al.,* 1992). The ELPI with the electrical filter stage enables a measurement of real time particle size distribution in the size range of 0.07 nm – 10 μm (aerodynamic diameter) with 12 channels. The nucleation mode particle size distribution with the high size resolution is measured by the Hauke type Scanning Mobility Particle Sizer (SMPS), where particles are first neutralised, then classified by a DMA based on their electrical mobility, and counted by a CPC 3025 (TSI, Inc.). Measurement size range is 3 – 50 nm (mobility diameter), the number of channels is 20 and the scan-up time mostly 30 s. Additionally, the total number concentration of particles larger than 3 nm is detected by an ultra fine condensation particle counter CPC 3025 (TSI, Inc.). Due to the substantially high concentrations of traffic-originated particles, a passive clean air dilution system was installed, with a dilution ratio of 1:3. The SMPS and CPC instruments are operated by the University of Helsinki. The particle measurement inlet is located at the height of 2.4 m.

The weather station is located at the roof of the van, at the height of 3.4 m from the ground; it provides the relevant meteorological parameters, such as relative (in case of a moving vehicle) wind speed and direction by an ultrasonic wind sensor (Model WAS425AH, Vaisala) as well as temperature and relative humidity, by humidity and temperature probes (Model HMP45A, Vaisala). Additionally, a global position system (GPS V, Garmin) saves the van speed and the driving route and a video camera in the cab records visually the traffic situations.

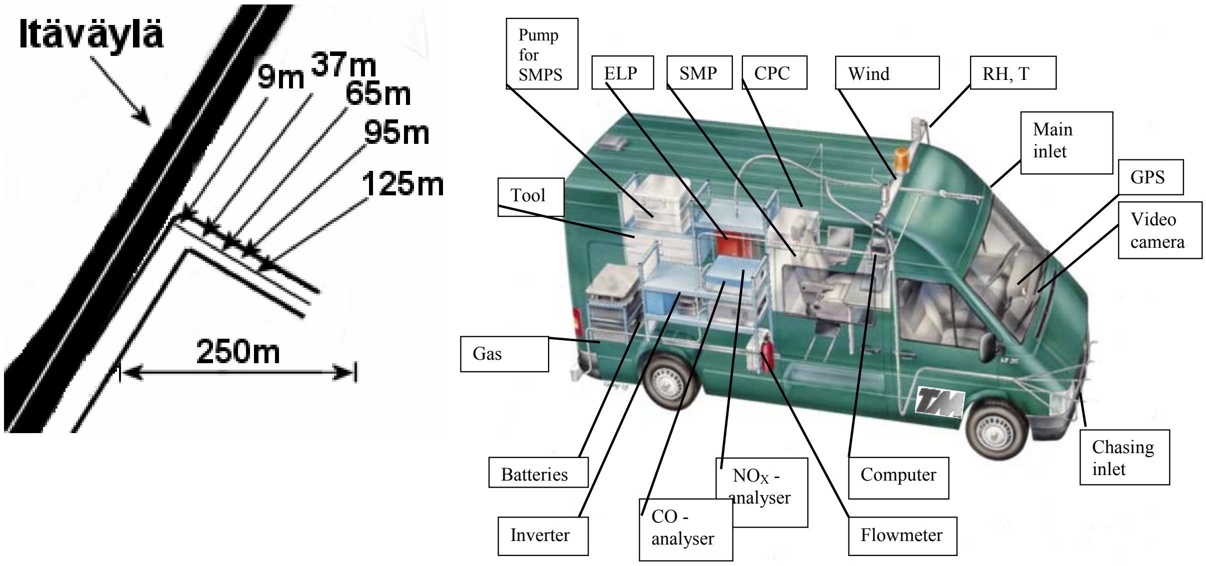

Figure 1. a) The measurement locations in the vicinity of the road Itäväylä that is situated in Eastern Helsinki. The distances shown are measured from the edge of the road. b) A photograph of the mobile laboratory that also shows the locations of the main instrumentation.

MODELLING METHODS

According to *Kauhaniemi* (2003), in the Helsinki Metropolitan Area, light duty vehicles constitute about 90% of all traffic, 80% of which are petrol vehicles and 20% diesel light duty vehicles. It was assumed that all heavy duty vehicles are diesel operated.

There are only a few studies, in which both the particle number distributions and their composition would be simultaneously reported. *Harris et al.* (2001) have reported particle number size distributions for light-duty diesel and gasoline vehicles. *Norbeck et al.* (1998) have reported compositions for light duty diesel and gasoline vehicles. *Shi et al.* (2000) have studied the particle size distributions, number concentrations, density and chemical composition as functions of engine load concerning heavy-duty diesel vehicles. We have used a combination of these datasets to compile the description of the characteristic vehicle exhaust emission.

The CAR-FMI model includes an emission model, a dispersion model and statistical analysis of the computed time series of concentrations. The CAR-FMI model utilises the meteorological input data evaluated with the meteorological pre-processing model MPP-FMI. The dispersion equation is based on an analytic solution of the Gaussian diffusion equation for a finite line source (*Luhar and Patil,* 1989). For a more detailed description of these models, the reader is referred to *Härkönen et al.* (2002) and *Karppinen et al.* (2000 a, b).

The aerosol dynamics model MONO32 is a box model, which includes gas-phase chemistry and aerosol dynamics, and can be applied under clear sky conditions. The model uses monodisperse representation for particle size distribution with four size modes: nucleation (diameters d<20nm), Aitken (20nm<d<0.1μm), accumulation (0.1μm<d<2.5μm), and coarse

(2.5μm<d<10μm). All particles in a mode are characterised by the same size and the same composition. Particles can consist of soluble material such as sulphuric acid, ammonium sulphate, ammonium nitrate and sodium chloride, organic carbon which can be soluble, partly soluble or insoluble, and insoluble material like elemental carbon and mineral dust.

Size and composition of particles in any class can change due to multicomponent condensation of sulphuric acid and organic vapours as well as due to coagulation between particles. MONO32 has altogether 32 differential equations to predict the aerosol size and composition distributions. For a more detailed description of the MONO32 model and its evaluation against measurement data, the reader is referred to *Pirjola et al.* (2000, 2001, 2003) and *Pohjola et al.* (2003).

RESULTS

Model computations

The meteorological data used was from the period February 17 - 20, 2003.

The characteristic particle description for the model MONO32 was compiled from the works of *Harris et al (2001), Norbeck et al.* (1998) and *Shi et al.* (2000) combined with the vehicle data by *Kauhaniemi* (2003). The properties of the exhaust particle modes are presented in Table 1.

For instance, we present the modelling for February 19, at 14 p.m., when the relative humidity was 62%, wind speed at 10 m height was 4.9 m/s, and the traffic volume at Itäväylä was 2940 vehicles per hour.

For the smallest distances from the road, we have extrapolated the power function of dilution against distance from the road, as predicted by the CAR-FMI model. This function is predicted only for distances larger than approximately 10 m in the CAR-FMI model, mainly due to the influence of traffic-induced turbulence. The first time instance modelled was selected to be at a distance of 5 cm from the exit of the tailpipe.

The modelling of nucleation, due to the temperature decrease immediately after the exhaust pipe, has not been included.

Table 1. The properties of the vehicle-originated exhaust particles.

Particle size mode	Dry radius (nm)	Number concen-tration (cm^{-3})	Total mass (ng cm^{-3})	Mass composition (%)				
				Organic carbon	Elemental carbon	Mineral dust	Ammonium nitrate	Ammonium sulphate
nucleation	0.5	1.94e6	1.7e-06	30.1	64.4	3.3	1.3	0.9
Aitken	10	2.64e7	0.19	26.8	63.5	7.2	0.3	2.2
accumulation	50	1.65e7	14.9	25.5	62.6	8.8	0.3	2.8

Comparison of modelled and measured concentrations

The comparison of modelled and measured total number concentration of particles smaller than 2.5 μm at 2 p.m. on February 19, 2003 is presented in Figure 2.

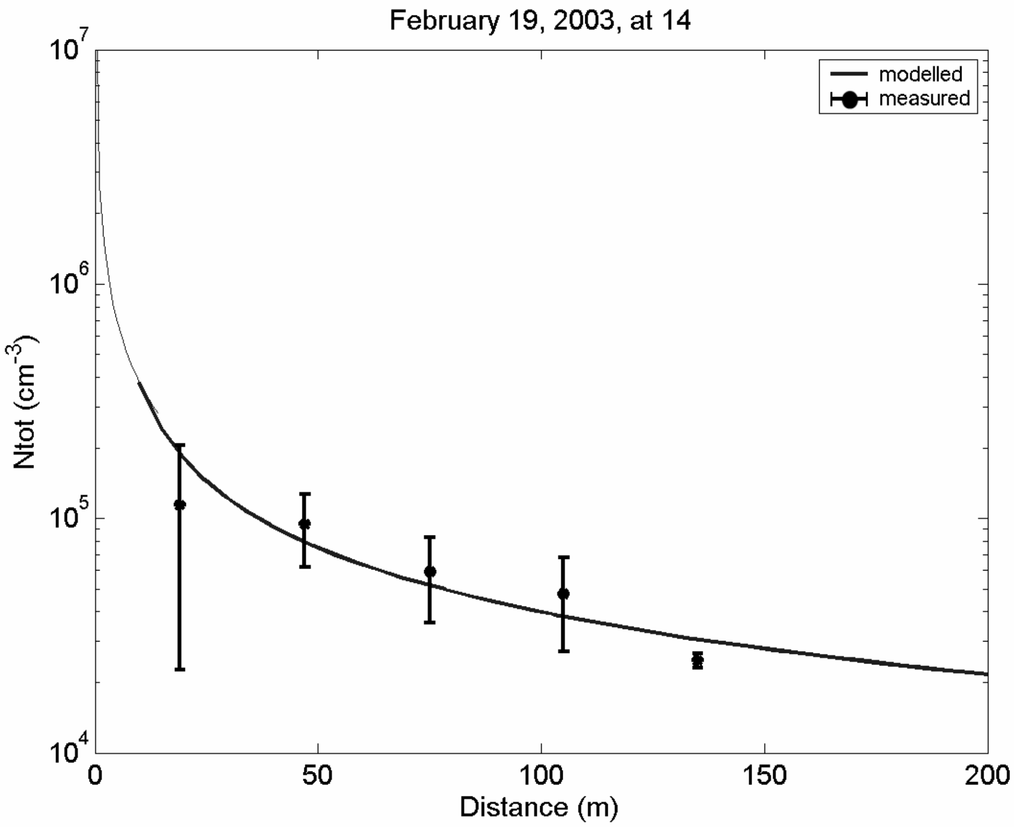

Figure 2. The modelled and measured total number concentrations of particles as a function of distance from the edge of the road Itäväylä at 2 p.m. on February 19, 2003.

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