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Spatial and temporal characterization of traffic emissions in urban microenvironments with a mobile laboratory

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1.Introduction

- In urban environments, vehicle tail pipe emissions are the major source of many air pollutants such as ultrafine particles(i.e., <100 nm in diameter) and gaseous pollutants, (NO_x, CO and volatile organic compounds).These traffic particles affect the urban visibility、global climate and people's health.

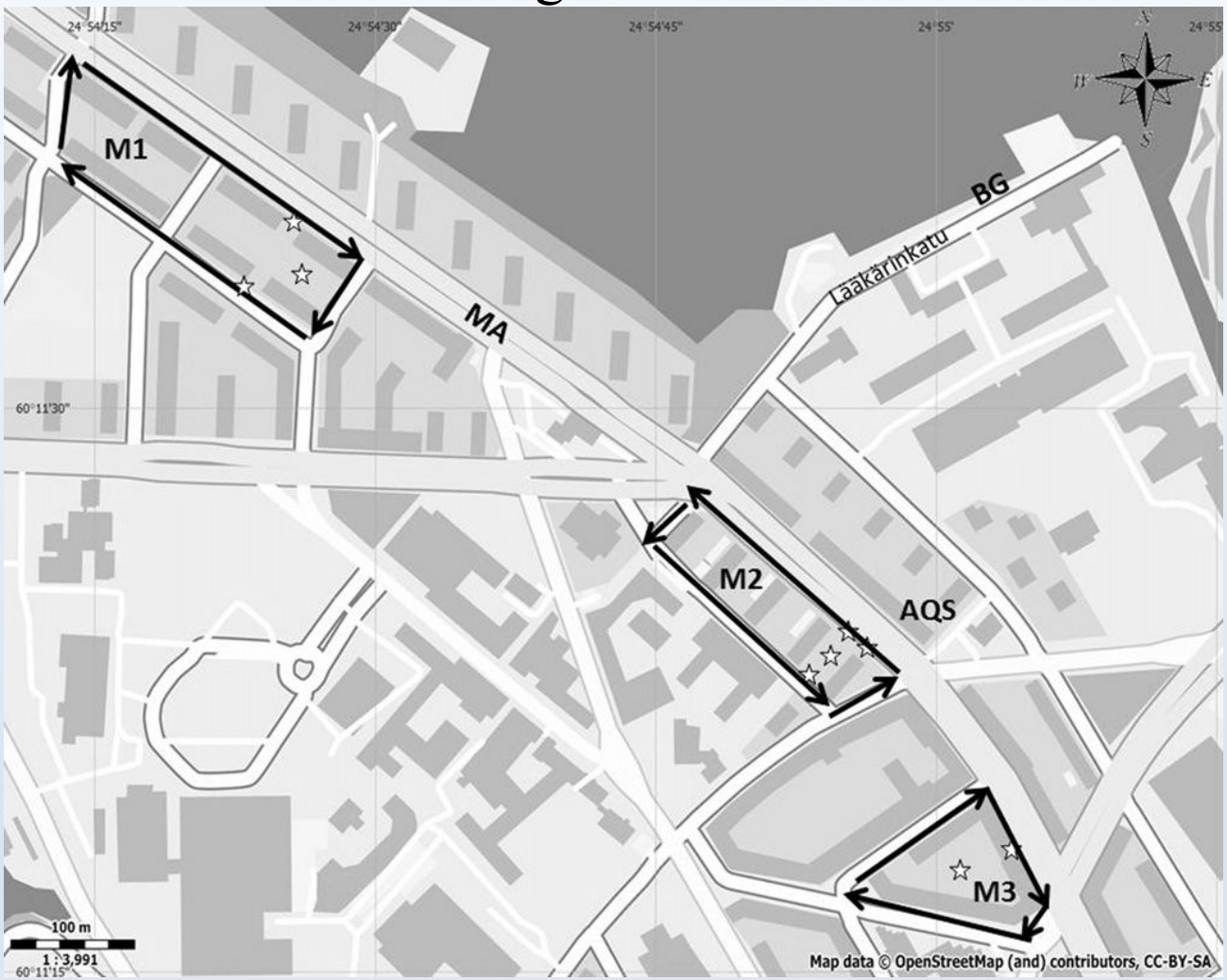
- The pollutant concentrations in urban areas consist of street canyons can be several times higher than in open areas.

- The gaseous pollutant concentrations and particle deposition on the upwind side of the canyon is much higher than downwind.

- Objective : In this article ,the author using the measurement data from "Sniffer" and AQS to describe the overview of particle number concentrations in Mannerheimintie and the effects of street canyon on the local dispersion of traffic emissions.

2.Experimental methods

2.1Measurement design



On weekdays 29/11-12/12 , a mobile laboratory van “Sniffer” was driving back and forth on MA during the rush hours at 8am-11am and 3pm-6pm, occasionally at 11am-2pm.

On Monday13/12 at 1-7 pm, and on 14/12 at 8 am-2 pm, the mobile sampling were taken in threemicroenvironments M1,M2,and M3.

Fig. 1. Map of the measurement sites (©OpenStreetMap contributors, CC BY-SA, see http://www.openstreetmap. org/). Three different microenvironments (M1, M2 and M3) were studied. MA= Mannerheimintie, AQS =stationary air quality station, BG = background measurements at Lääkärinkatu. The black arrows show the driving direction and the stars refer to the standing sites by Sniffer.

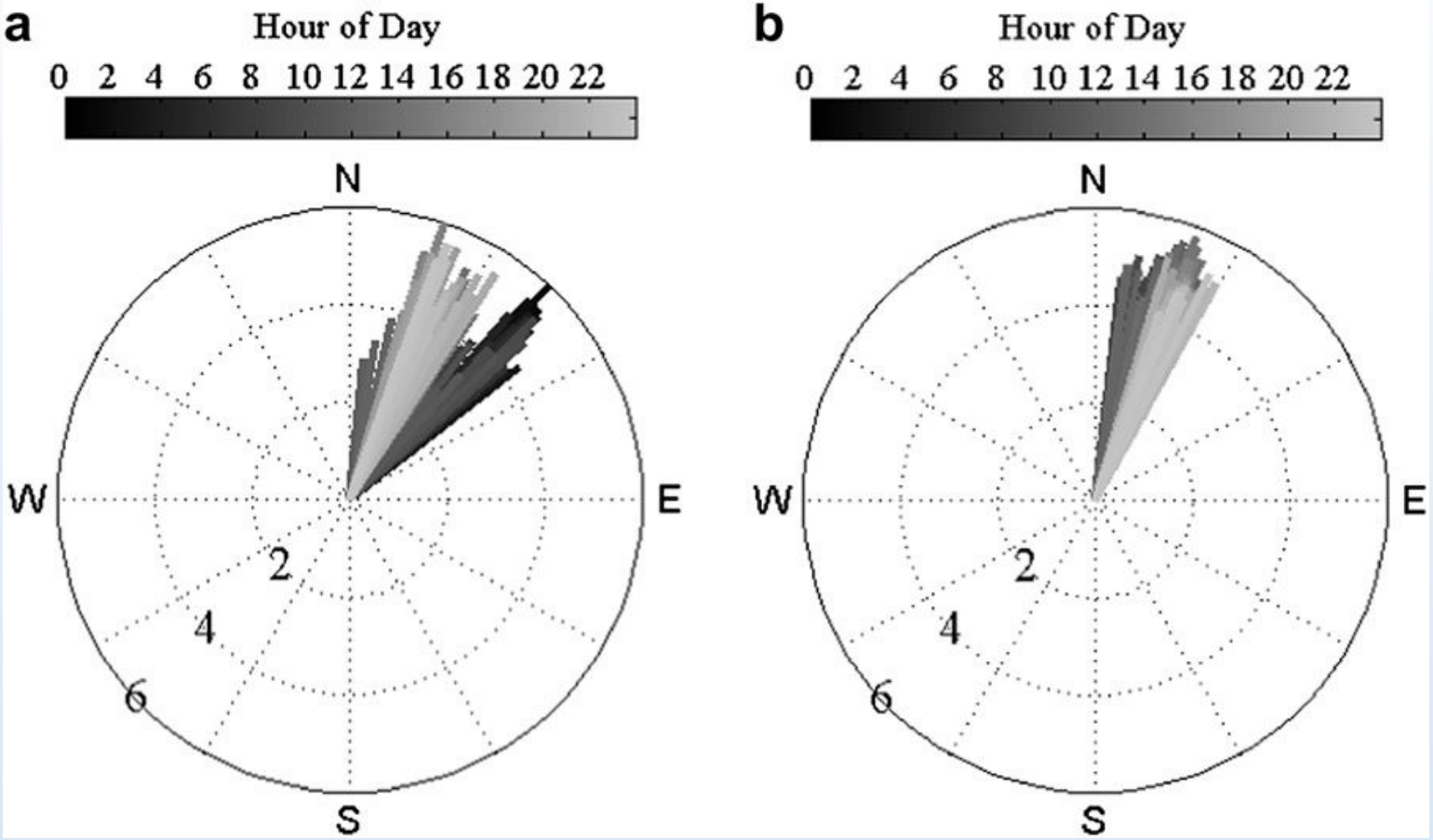


Fig. 2. Roof level wind speed and direction during 13 December 2010 (a), and 14 December 2010 (b), measured at Kaisaniemi, Helsinki. Wind speed increases from the center of the windrose; the values at three dotted circles are 2, 4 and 6 $m \cdot s^{-1}$.

The roof level wind speed is 4-5 $m \cdot s^{-1}$ and the wind direction is northeast .

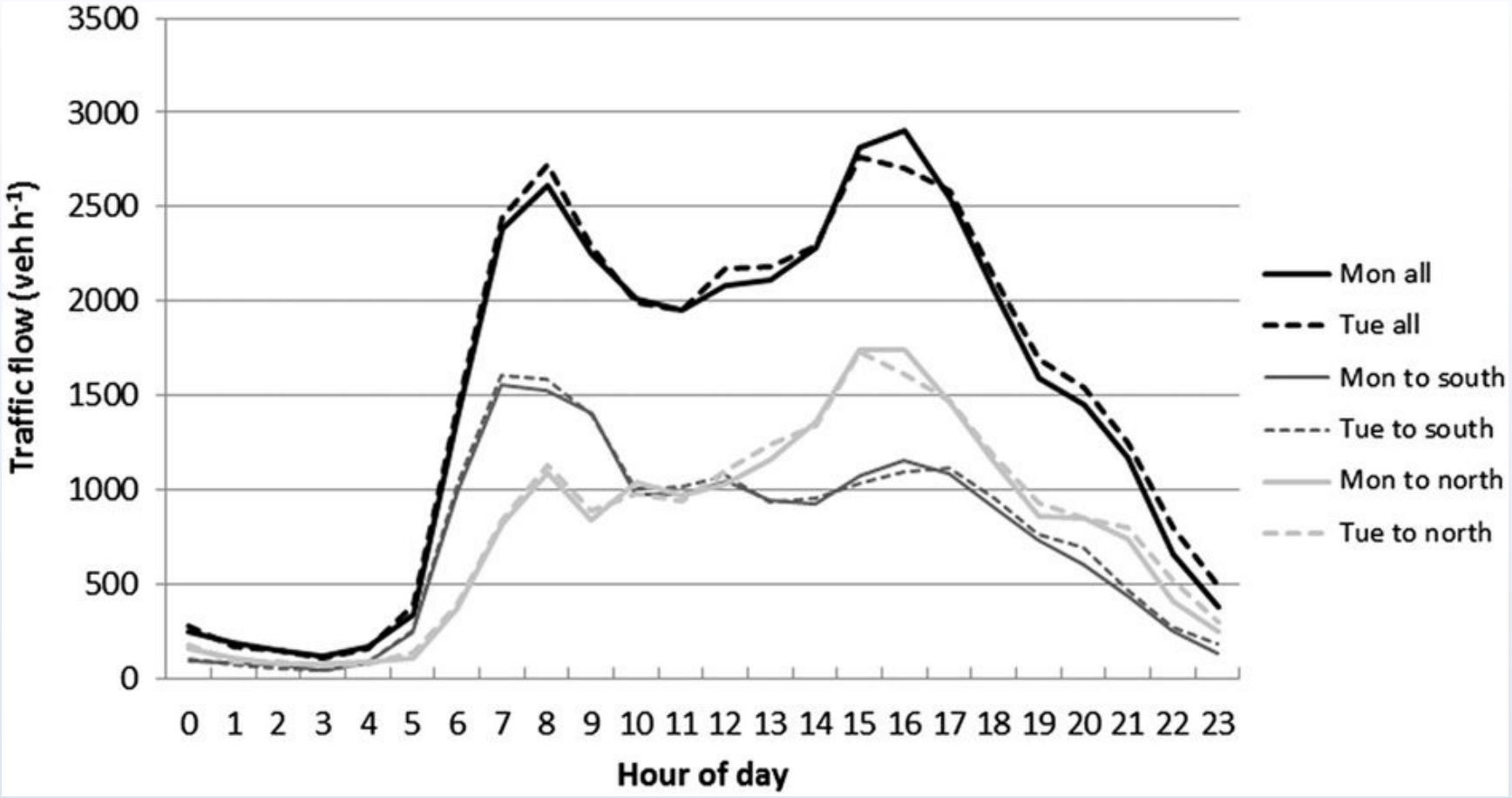


Fig. 3. Typical diurnal variation of winter-time traffic density during Monday and Tuesday in Mannerheimintie. Also shown are both directions separately.

rush hours:6-10am;2-6pm

2.2 Instrumentation for mobile and stationary monitoring

Table 1

Monitoring instruments used for the mobile laboratory Sniffer and the stationary air quality station

Instrument	Measured parameter	Resolution time	Location
ELPI, (Dekati)	Size distribution (7 nm-10 mm)	1 s	Sniffer
ELPI, (Dekati).	Size distribution (7 nm-10 mm)	10 s	AQS
Nano-SMPS (DMA 3085 and CPC 3025, TSI)	Size distribution (3-60 nm)	150 s	Sniffer
SMPS (DMA 3081 and CPC 3025, TSI)	Size distribution (10-420 nm)	150 s	Sniffer
Aethalometer (AE 22, Magee Scientific)	BC	5 s	Sniffer
APNA 260 (Horiba)	NO, NO2, NOx	1 s	Sniffer
DustTrak (Model 8530,TSI)	PM2.5	1 s	Sniffer
TEOM (Thermo Scientific, Model 1400AB)	PM2.5	1 min	AQS
MAAP (by Thermo Electron Corporation)	BC	1 min	AQS
APNA 370 (Horiba)	NO, NO2, NOx	1 min	AQS

3.Results and discussion

3.1 General view on particle number concentrations in Mannerheimintie

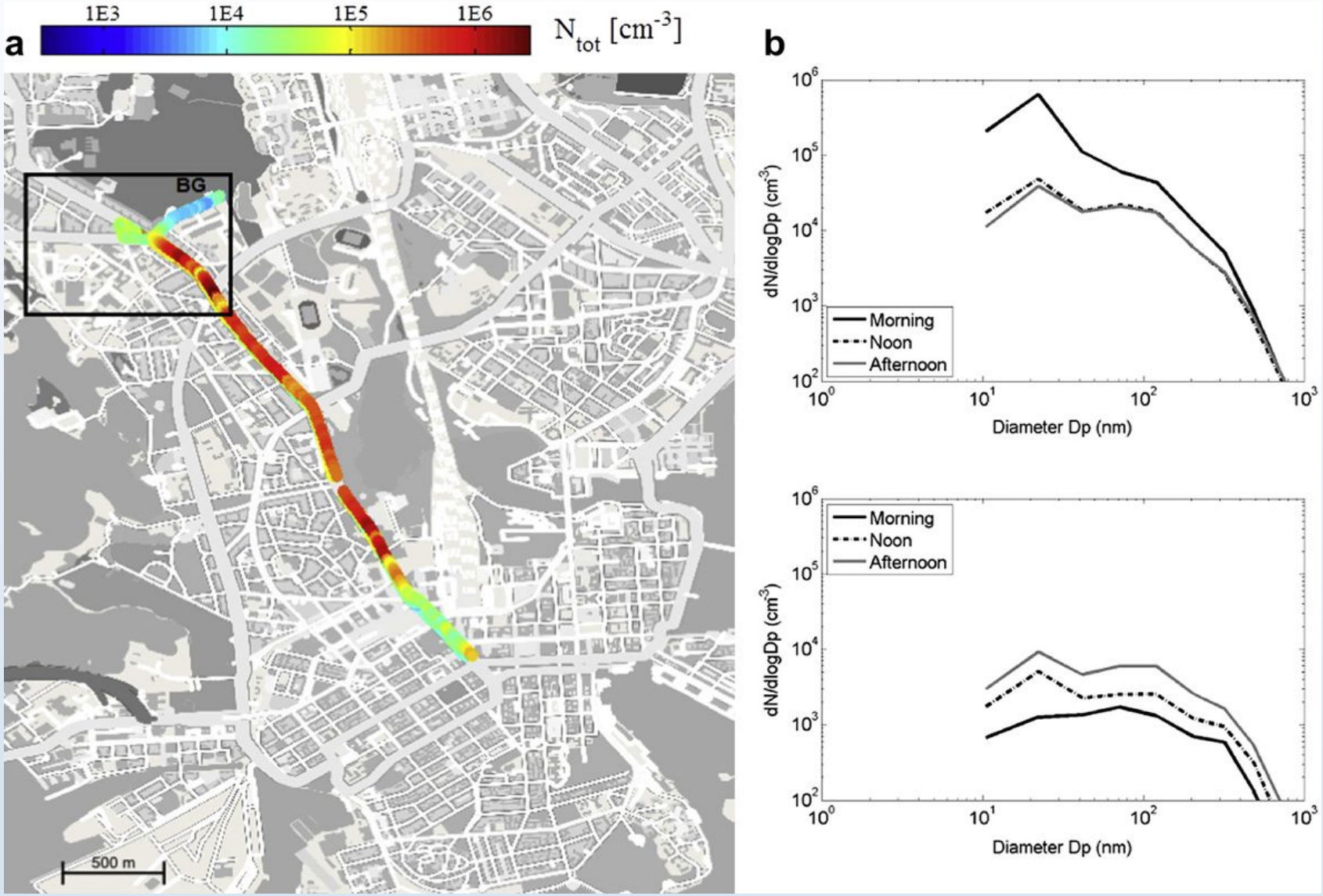


Fig. 4. a) Average total number concentration along Mannerheimintie. Color bar refers to particle concentration, BG to background measurements, and rectangle to the area in **Fig. 1.b)** Typical daytime variation of average particles size distribution at Mannerheimintie (upper panel), and in urban background area at Lääkärinkatu (lower panel).

3.2 Street canyon effect

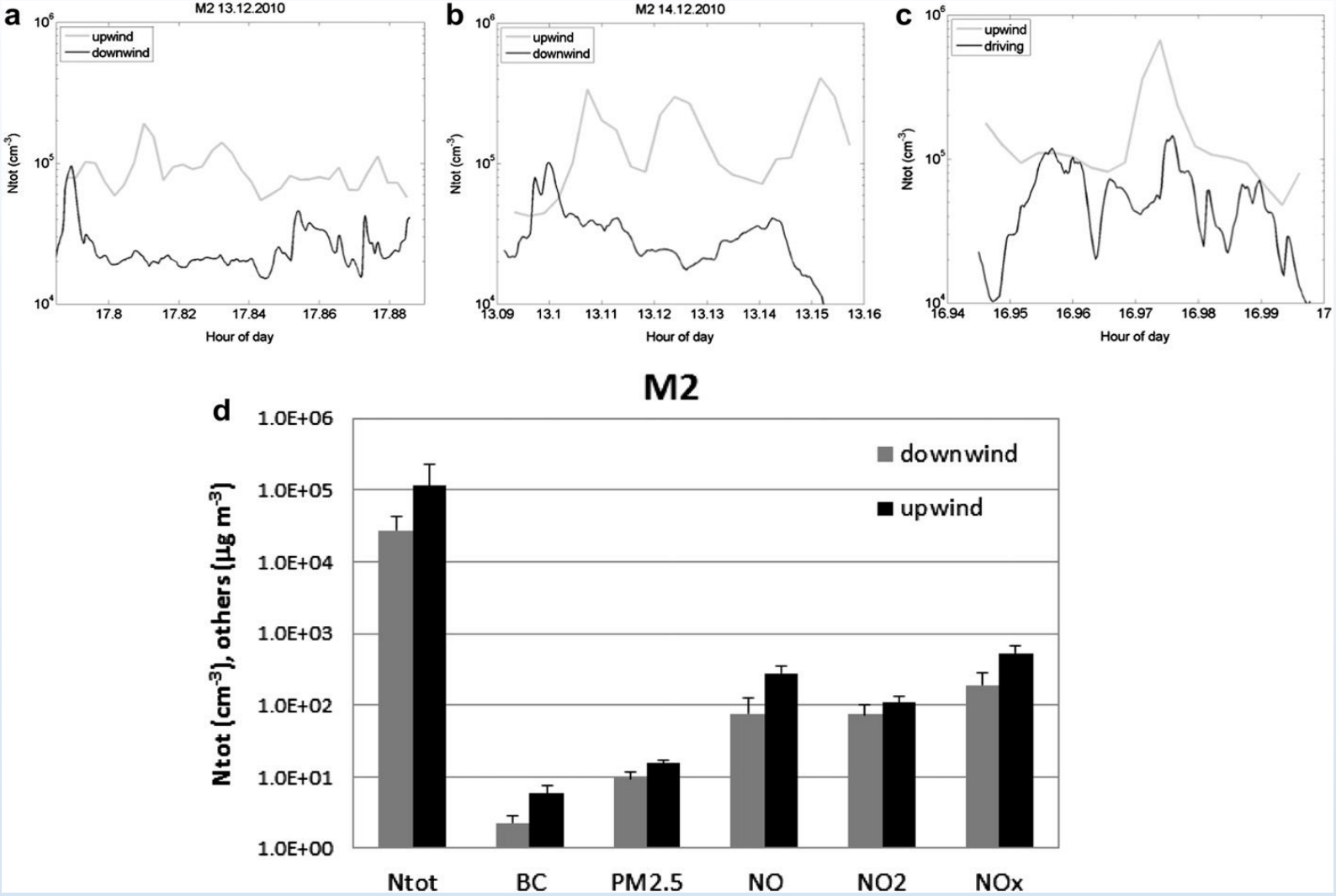


Fig. 5. Time series of total particle number concentrations on 13 Dec. (a), 14 Dec. (b), when Sniffer was standing at the pavement of MA in the downwind side, and the upwind side measurements were provided by the air quality station. The upwind data are 10 s averages whereas the downwind data are 1 s data. (c) Time series of simultaneously measured data by AQS and by Sniffer while it was driving MA to north on 13 Dec. (d) Average concentrations with standard deviations of the main pollutants over the time periods presented in (a) and (b).

	M2		M3	
	Meas	OSPM	Meas	OSPM
Ntot	0.24		0.22	
BC	0.39		0.27	
$PM_{2.5}$	0.59		0.79	
NO	0.28	0.25	0.18	0.18
NO_2	0.70	0.76	0.65	0.70
NO_x	0.36	0.55	0.30	0.48

Table 2
Ratios of the average concentrations of particles and nitrogen oxides between the downwind and upwind sites based on the measurements and the OSPM model studies in microenvironments M2 and M3. Upwind concentrations are measured at AQS.

OSPM:Operational Street Pollution Model

Table 2 shows that for the nitrogen oxides the model predicted rather similar results than what was measured.

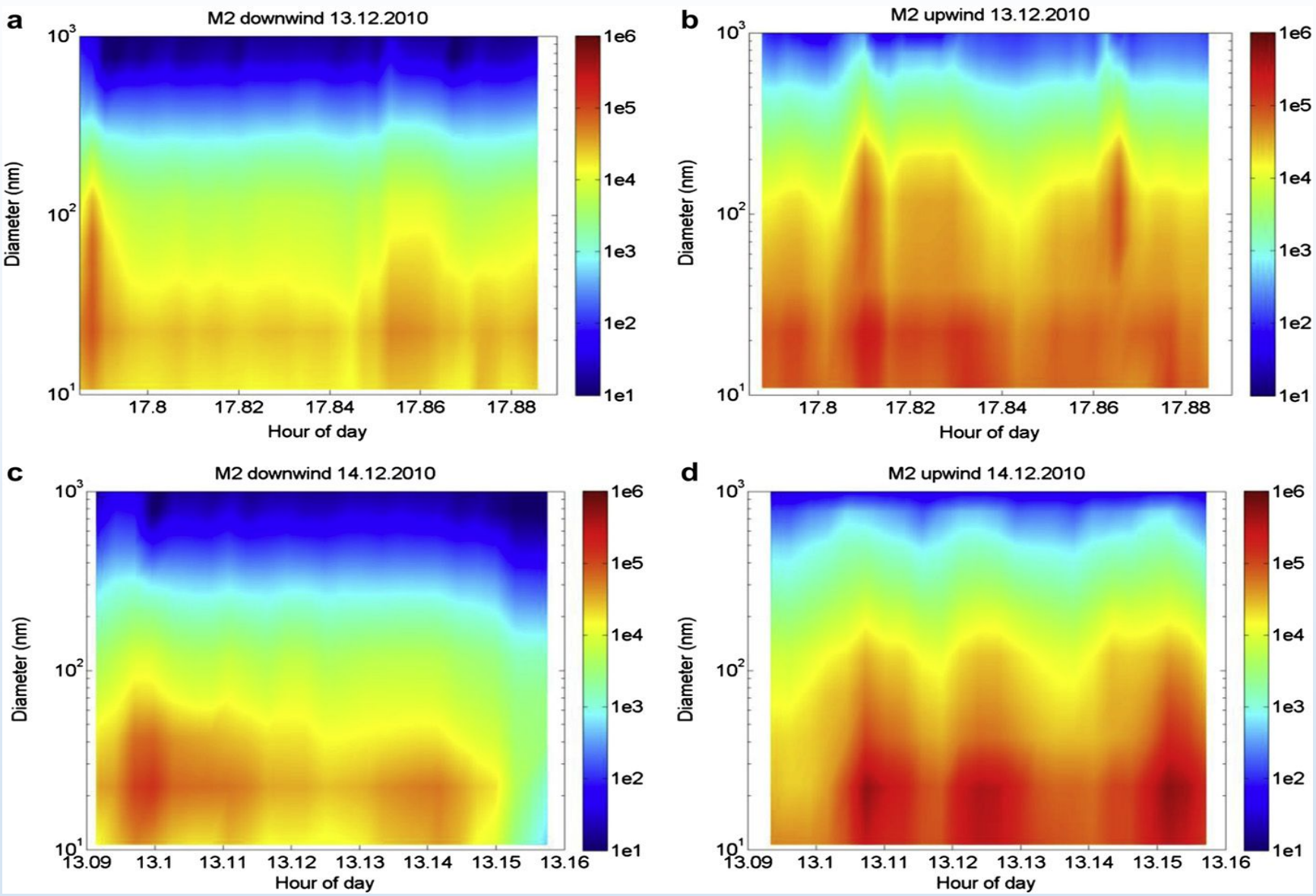


Fig. 6. Contour plots of temporal variations of particle number size distribution under downwind (a) and (c), and upwind (b) and (d), conditions in the street canyon M2. x-Axis refers to hour of day, y-axis to particle diameter in nm, and color to particle number concentration dN/dlogDp in cm_x0003_3. The downwind data are from Sniffer and the upwind data from AQS. Sniffer data are here averages over 10s as are the AQS data.

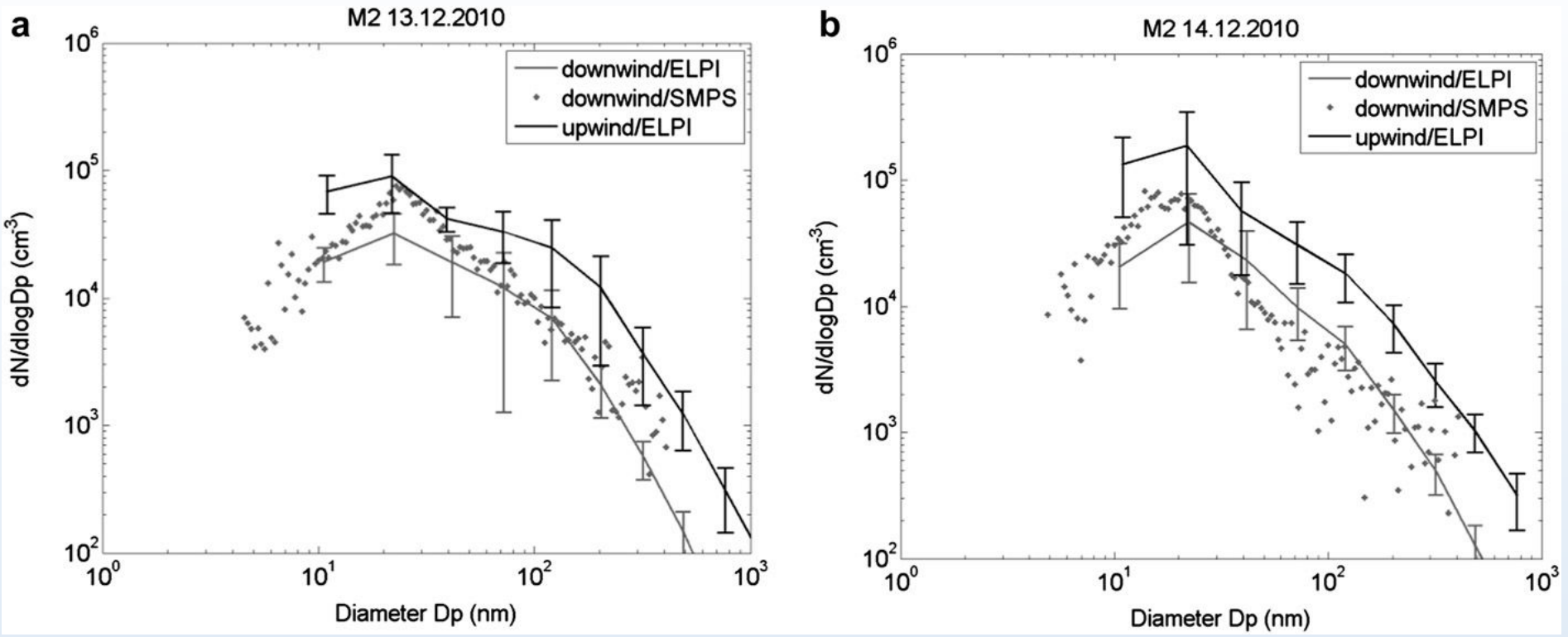


Fig. 7. Downwind and upwind particle number size distributions with standard deviations averaged over the times Sniffer was standing at the pavement of MA in M2 on 13 Dec. (a) and 14 Dec. (b). The downwind data are from Sniffer and the upwind data from AQS.

The size distributions averaged over the standing times with standard deviations are plotted.

In both cases, a clear nucleation mode was peaking at 20 nm and a soot mode at around 80 nm.

3.3 Local dispersion in the microenvironments

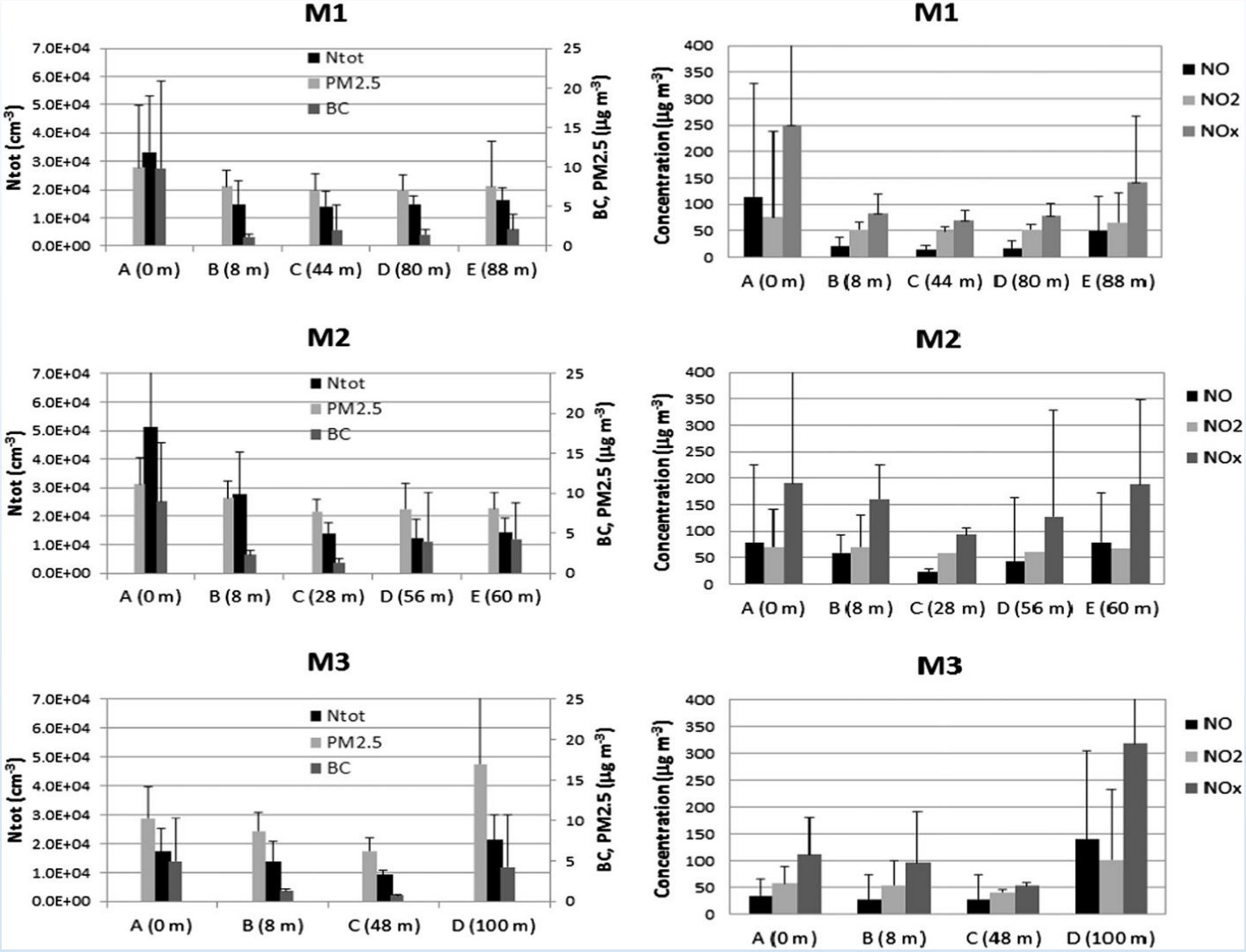


Fig. 8. Local dispersion of particles (left panel) and gases (right panel) in M1, M2 and M3. Shown are the average concentrations with standard deviations. A refers to driving in MA; B, C, D standing at the distances from MA (mentioned in brackets); E driving on a street parallel to MA at the distance in brackets. In M3, standing occurred only at two distances (B, C), and thus D refers to driving. See text for more details.

Table 3

Averaged concentrations with standard deviations in M2 while driving or standing around 10 min at different distances from MA. Also given is the background concentrations measured at Lääkärinkatu.

M2	Ntot (cm^{-3})	BC ($mg \cdot m^{-3}$)	$PM_{2.5}$ ($mg \cdot m^{-3}$)	NO ($mg \cdot m^{-3}$)	NO_2 ($mg \cdot m^{-3}$)	NO_x ($mg \cdot m^{-3}$)
A (0 m)	(5.12±3.05) × 10^4	9.0± 7.4	11.2 ±3.2	78.1±146.3	70.2±70.2	189.9±255.6
B (8 m)	(2.58 ± 1.22) × 10^4	2.3 ±0.4	9.5 ±2.2	58.9±34.6	70.5±24.0	160.9±63.4
C (28 m)	(1.66± 0.20) × 10^4	1.4 ±0.4	7.7 ±1.5	22.4±7.0	59.2±5.8	93.6±13.0
D (56 m)	(1.32 ± 0.84) × 10^4	4.0±6.1	8.1 ±3.3	43.9±119.3	59.7±70.9	127.0±201.5
E (60 m)	(1.42 ± 0.52) × 10^4	4.3 ±4.5	8.1 ±2.1	79.3±92.7	66.5±59.3	188.0±161.5
BG (-360 m)	(1.37 ± 0.63) × 10^4	1.0 ±0.3	7.0 ±2.7	8.6±7.9	29.6±23.1	38.2 ±31.0

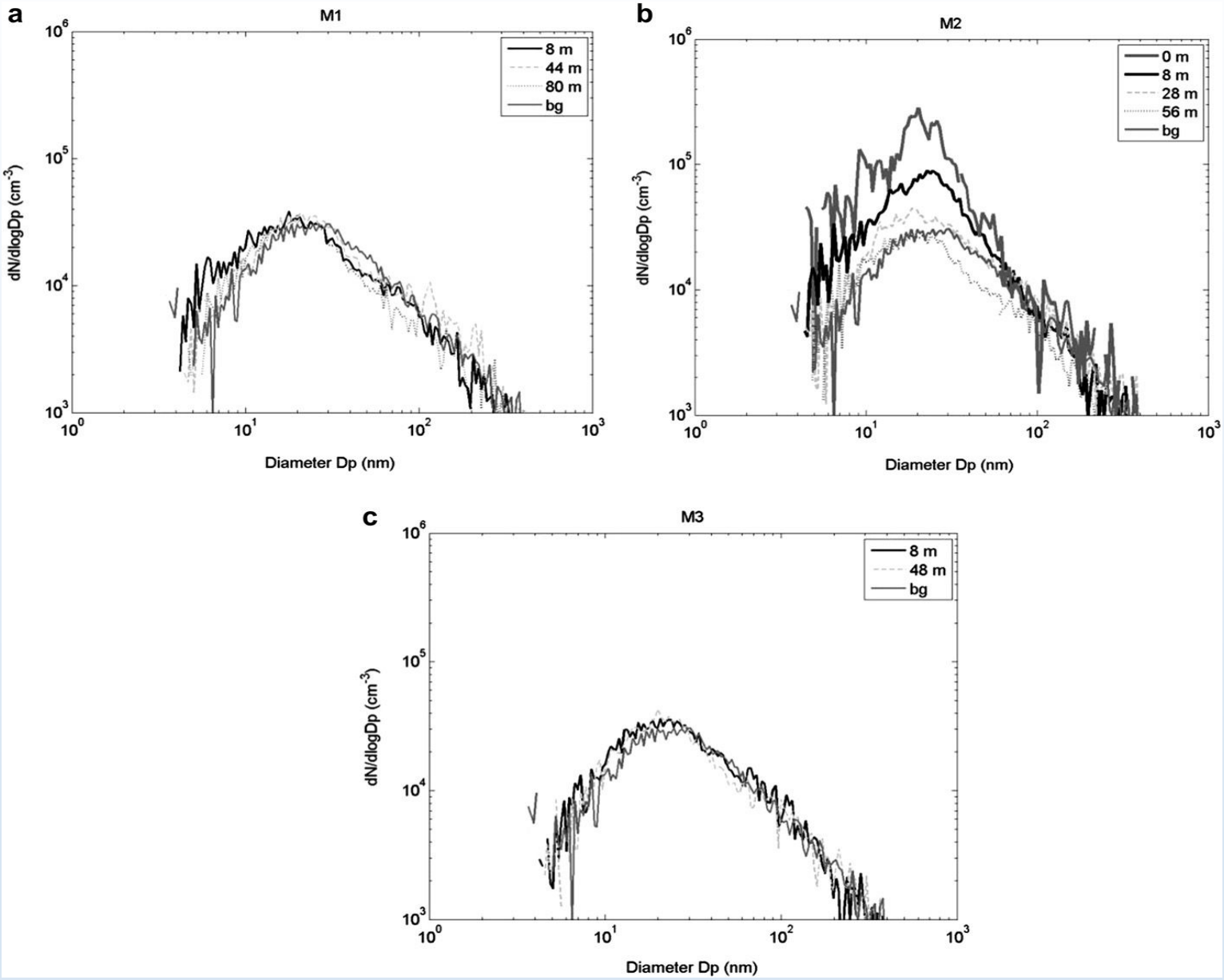


Fig. 9. Particle number size distributions, averaged over the standing times during dispersion, in M1 (a), M2 (b), and M3 (c). Also shown are the background size distributions. In addition, the particle size distribution while driving on MA is presented in (b). The standing distances from MA are mentioned by the legends. All data were measured by Nano-SMPS and SMPS in Sniffer.

4.Conclusions

- On Mannerheimintie ,the highest particle concentration was $8\times10^{5}cm^{-3}$ and around 94% of the particles was $\leq$ 40 nm. There are about 65% of the particles are volatile after heating the sample to 265 ℃.

- Due to the street canyon effect by the surrounding building:

① The downwind side particle number concentrations were smaller than the upwind concentrations ;

② The upwind concentrations on the sidewalk were even higher than the simultaneously measured concentrations within the traffic flow.

③ On the pavements of the side streets parallel to Mannerheimintie , the concentrations were higher,increasing the exposure risk for pedestrians and cyclists.

4.Conclusions

- In the microenvironments , the concentrations dropped significantly at the pavement and still lightly decreased in the courtyards when the downwind buildings were parallel to Mannerheimintie. When the downwind buildings were perpendicular to Mannerheimintie,a dilution similar to open environments was observed.

Thanks for your attention!

Happy National Day!