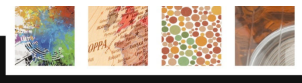
EURACHEM Workshop on Quality Assurance of Measurements from Field to Laboratory
MIKES, Espoo Finland, 20-21 May 2013



Spatial and temporal characterization of exhaust emissions with a mobile laboratory

Liisa Pirjola
Docent, Principal lecturer
Department of Technology,
Metropolia University of Applied Sciences
Helsinki, Finland

http://nuuskija.metropolia.fi

Helsinki Metropolia University of Applied Sciences

MOBILE MEASUREMENTS

MOTIVATION

- detailed monitoring of aerosol particle properties in urban and suburban areas is a challenging task, since their concentration, size, composition and sources vary strongly in time and space
- as a part of MMEA Programme (Measurement, Monitoring and Environmental Assessment, 2010-2014), we have conducted field campaigns in the poor air quality hot spot areas of the Helsinki region (FMI, TUT, HSY)
- city centre street canyons (Dec 2010), major roads (Oct-Nov 2012) and densely populated small house areas with local wood burning (Feb 2012)
- stationary and mobile online measurements, focus on particle composition, size distribution and volatility
- the combined application of several methods enables us to obtain a comprehensive view on aerosol properties and sources as well as to test new measurement methods

MOBILE LABORATORY SNIFFER

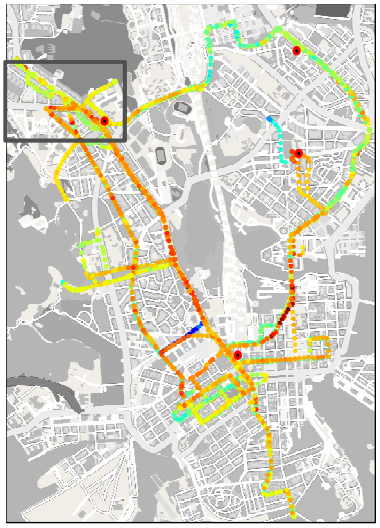
- designed and built by Metropolia in the Tekes funded projects during 2002-2005 (Pirjola et al., 2004, 2006, 2009, 2010, 2012)
- sampling above the front bumper at 0.7 m or above the wind shield at 2.4 m altitude
- enables also measurements of number and mass concentrations of non-exhaust particles behind the left rear tyre

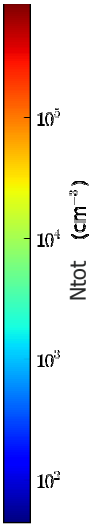
Instrumentation

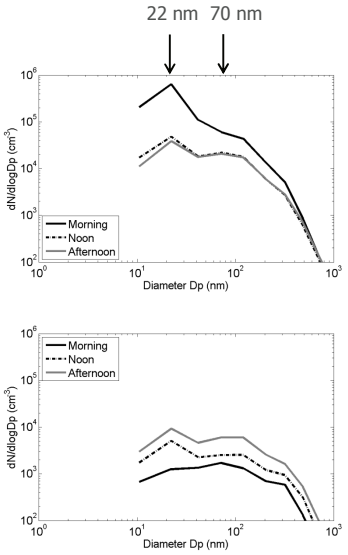
- ELPI and EELPI (Electrical Low Pressure Impactor), aerodynamic diameter 7 nm - 10 μm, 12 stages,1s time resolution
- CPC (TSI), > 2.5 nm, 1 s
- TEOM (Tapered Element Oscillating Microbalance, Series 1400A), 10 s, PM_{10}, $PM_{2,5}$
- 2 DustTraks (TSI), PM_{10}, $PM_{2.5}$ and PM_{1}, 1 s
- Gas analysers: CO, CO_2, NO, NO_2, NOx, 1 s
- Weather station (T, RH, ws, wd) at 2.9 m, GPS
- during measurement campaigns additional instruments from the partners
- electricity: 5 kW for 5 h stationary measurements, recharging while driving

TRAFFIC PARTICLES IN STREET CANYONS

Mannerheimintie



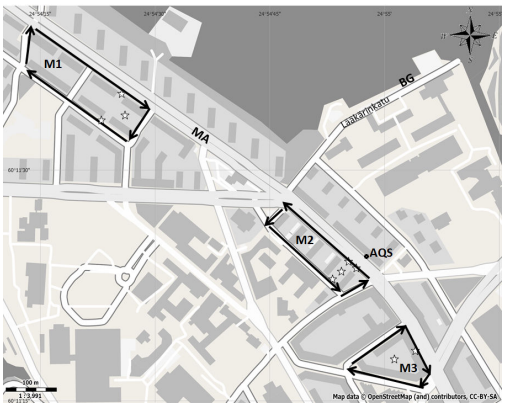




Particle number concentration averaged over all times
Max 8x10^5 cm^{-3} (1 s). Average traffic density ~40 000veh/day

Microenvironments

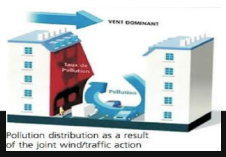
On 13-14 Dec, 2010, a special attention was given for the urban microenvironments close to the high traffic density street



- Building heights ~21 m => symmetric canyons
- Street width ~ 45 m (M1), 38 m (M2), and 27 m (M3)

⇒ aspect ratio (H/W) ~ 0.47, 0.55, and 0.78, respectively

⇒ wave interference flow is formed (Vardoulakis et al., 2003)



Challenges related to the measurements

- dynamic traffic situations spatially and temporally
  => fast time resolution of instruments => huge amount of data
- different environments and weather conditions (snow heaps)
  => needs many repetitions
- Air quality station vs. Sniffer
  different sampling heights (4 m vs 2.4 m)
  saving times of instruments (1 min vs 1 s)
  different instruments: PM2.5 TEOM vs DustTrak (calibration)
  2 EELPI's
  BC (MAAP vs Aethalometer)

=> comparison of instruments by simultaneous measurements

- Sniffer: comparison of ELPI and EELPI (one before and the other after the Thermodenuder), losses in TD, time delay in the sampling tubes
- at start zeroing, time synchronising
- vibration of instruments => rubber legs

Weather on 13-14 December 2010

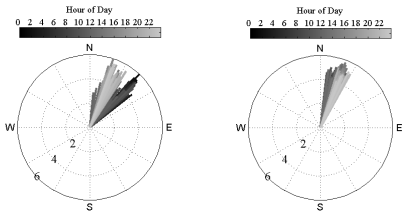
13.12. at 13.30 - 19:00

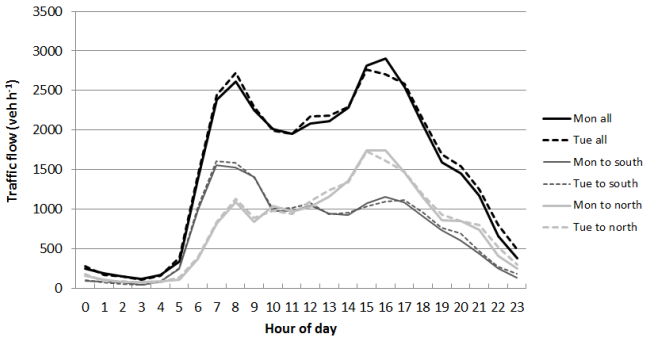
14.12. at 8:00 – 14:00

Temperature ~ -8°C

RH ~ 70-90%

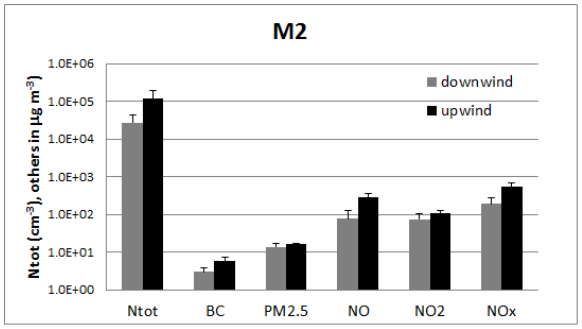
northeastern wind ws ~ 4-5 m/s





Traffic flow was 36 300 vehicles/day

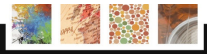
Canyon effect in M2



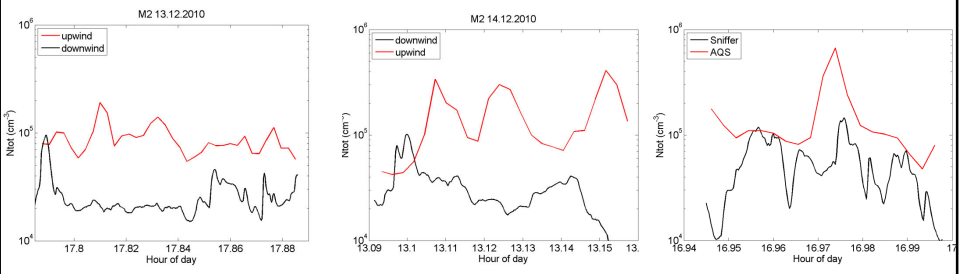
Model simulations by OSPM predicted similar results

downwind/upwind	meas	OSPM
Ntot	0.24	
BC	0.39	
$PM_{2.5}$	0.59	
NO	0.28	0.25
NO_2	0.70	0.76
NO_x	0.36	0.55

Operational Street Pollution Model, Bercowitz, 2000



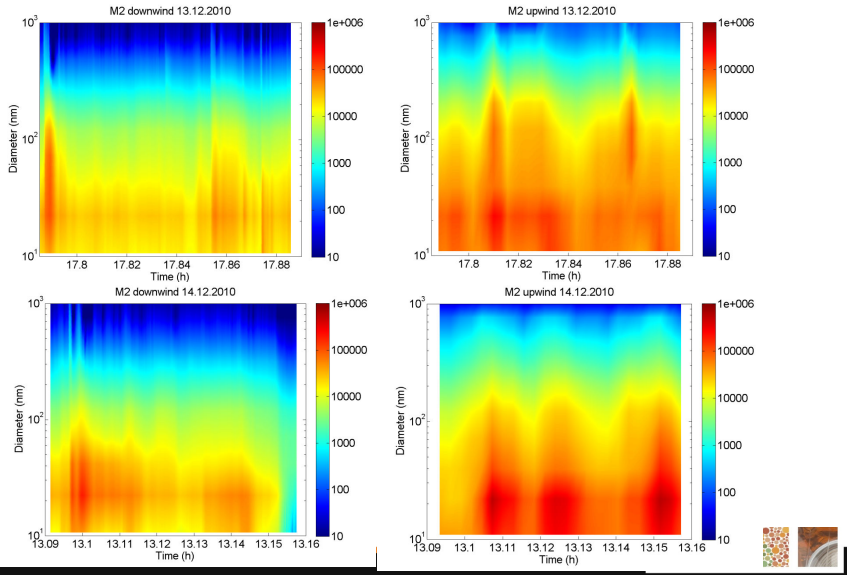
Canyon effect in M2



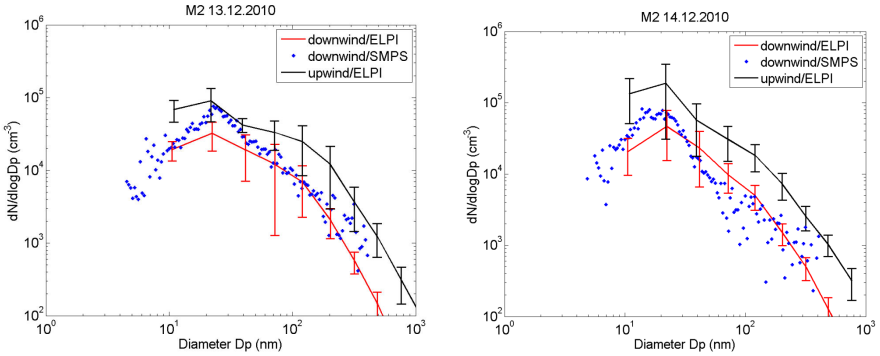
	13 Dec	14 Dec
upwind	8.9×10^4 cm^{-3}	1.6×10^5 cm^{-3}
downwind	2.6×10^4 cm^{-3}	3.0×10^4 cm^{-3}

upwind	1.5×10^5 cm^{-3}
driving	5.3×10^4 cm^{-3}

Canyon effect – size distributions in M2



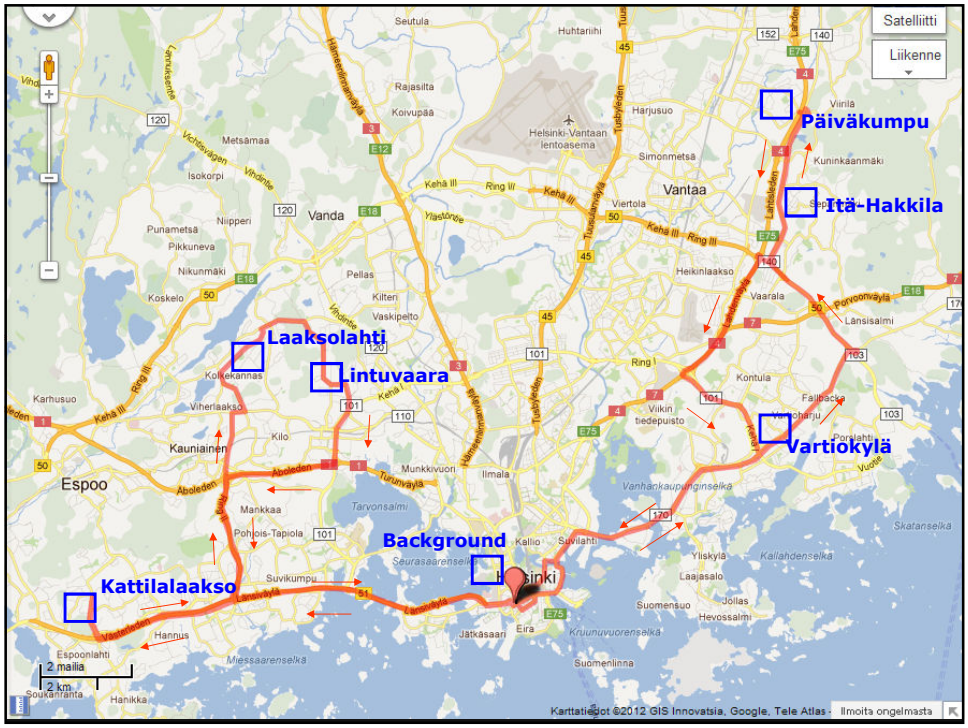
Canyon effect – averaged size distributions in M2



D(nuc) ~20 nm
D(acc) ~80 nm

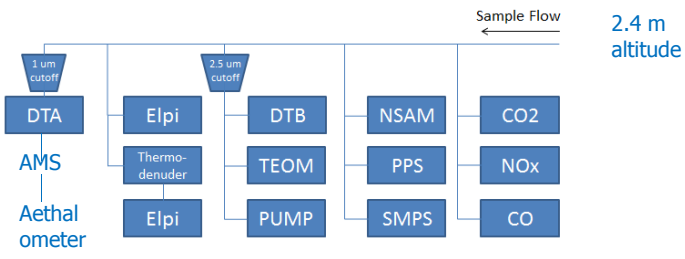
More in Pirjola et al., Atmos. Environ, 2012

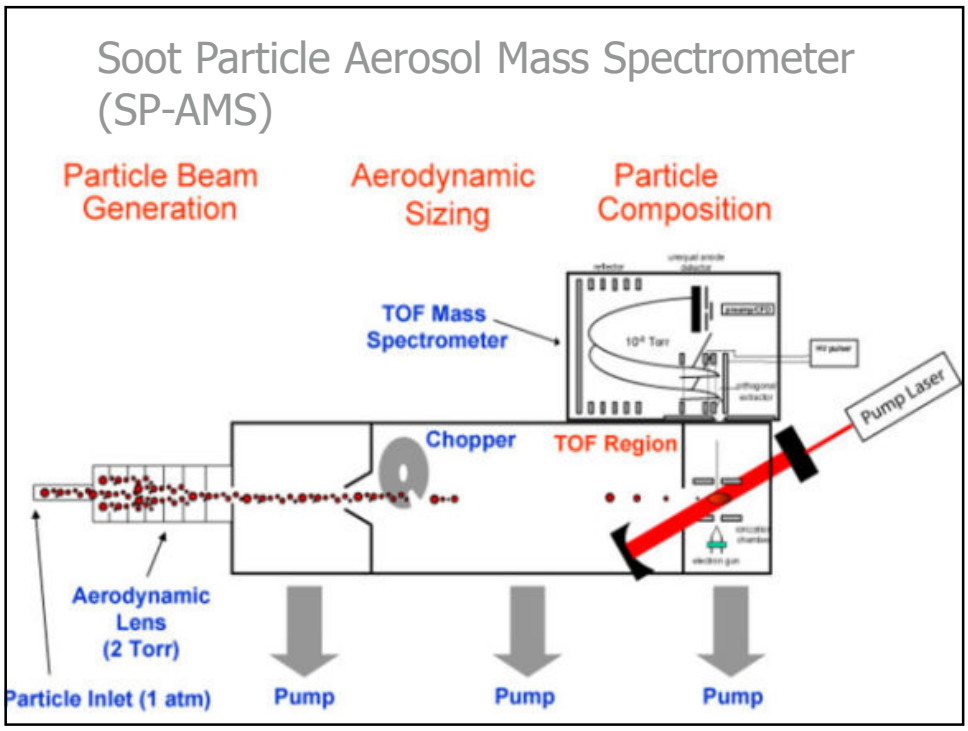
WOOD COMBUSTION

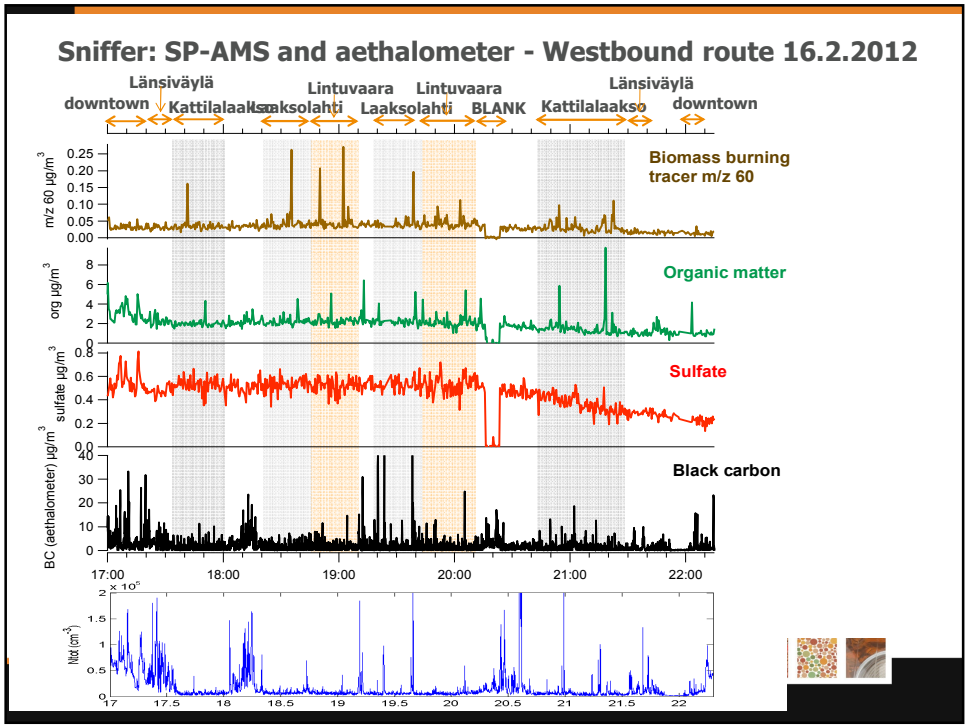


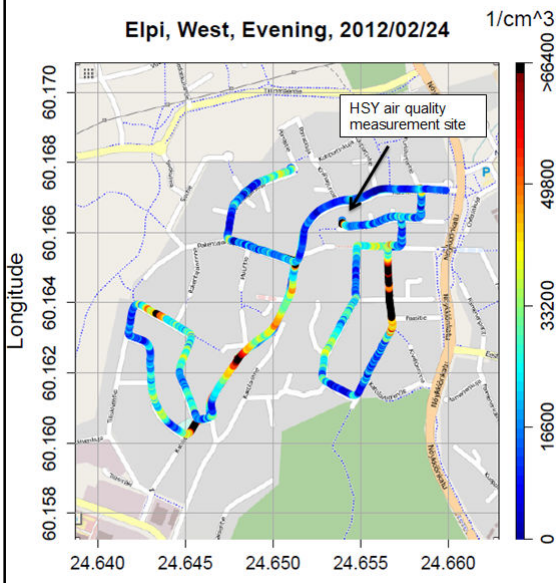
Sniffer measurements 15-27 Feb 2012

- SP-HR-AMS, 5 s (FMI)
- Aethalometer, cut-off size 1 μm, 5s (FMI)
- NanoSMPS 3-60 nm, 1.5 min (TUT)
- ELPI ja EELPI, 1s (Metropolia)
- Thermodenuder 265 ºC (TUT)
- PPS-sensor (Pegasor)
- NSAM (TUT)
- Rotating NanoMOUDI, 15 min (FMI)
- $PM_{2.5}$ TEOM, 10s (Metropolia)
- DustTrak $PM_{2.5}$ ja PM_1, 1 s (Metropolia)
- NO, NO_2, CO, CO_2 (Metropolia)
- Weather+GPS (Metropolia)

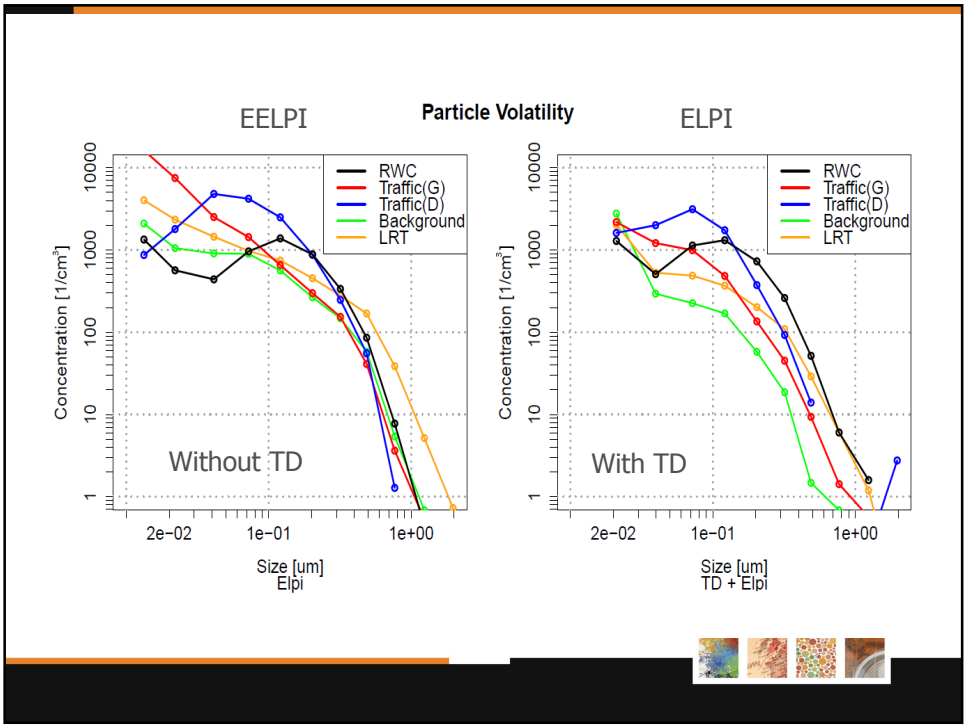


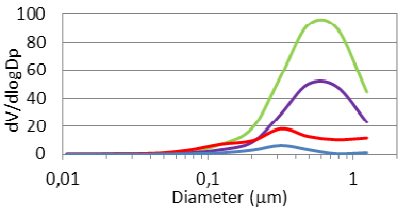

Soot Particle Aerosol Mass Spectrometer (SP-AMS)
Particle Beam Generation
Aerodynamic Sizing
Particle Composition
TOF Mass Spectrometer
Chopper
TOF Region
Pump Laser
Aerodynamic Lens (2 Torr)
Particle Inlet (1 atm)
Pump
Pump
Pump

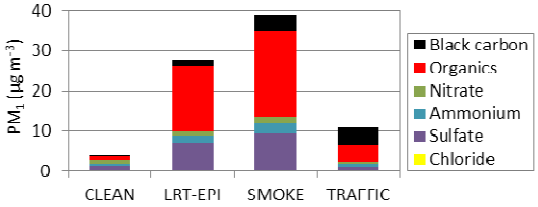

Sniffer: SP-AMS and aethalometer - Westbound route 16.2.2012
Länsiväylä downtown
Kattilalaakso
Lintuvaara Laaksolahti
Lintuvaara Laaksolahti
BLANK
Kattilalaakso
Länsiväylä downtown
Biomass burning tracer m/z 60
Organic matter
Sulfate
Black carbon
17:00
18:00
19:00
20:00
21:00
22:00



Map of Kattilalaakso with the measured total particle number concentrations plotted on the driven route on the 24th of February 2012





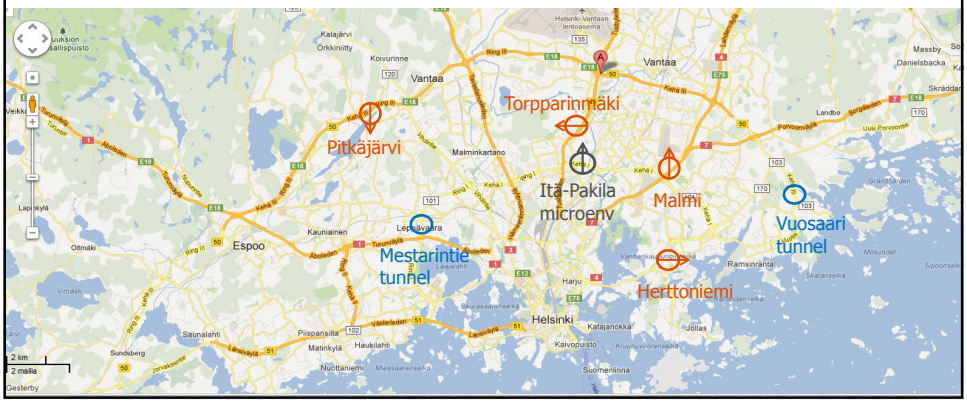


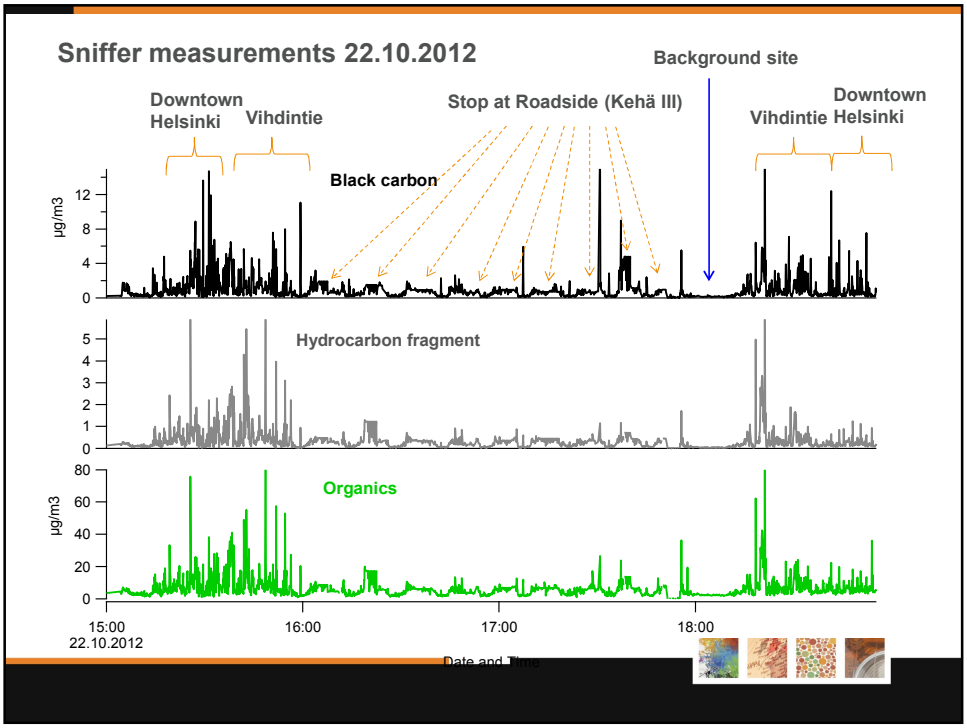
1. very clean period (CLEAN) at urban background site on seashore due to air flows from the Atlantic Ocean (Feb 21 morning),
2. strong long-range transported pollution episode (LRT-EPI) at urban background site on seashore due to air flows from eastern Europe (Feb 18 evening),
3. fresh smoke plumes from biomass burning (SMOKE) in suburban small house area mixed with LRT pollution (Feb 18 evening), and
4. fresh emissions from traffic (TRAFFIC) at kerbside of busy street in Helsinki city centre during morning rush hour (Feb 24 morning).

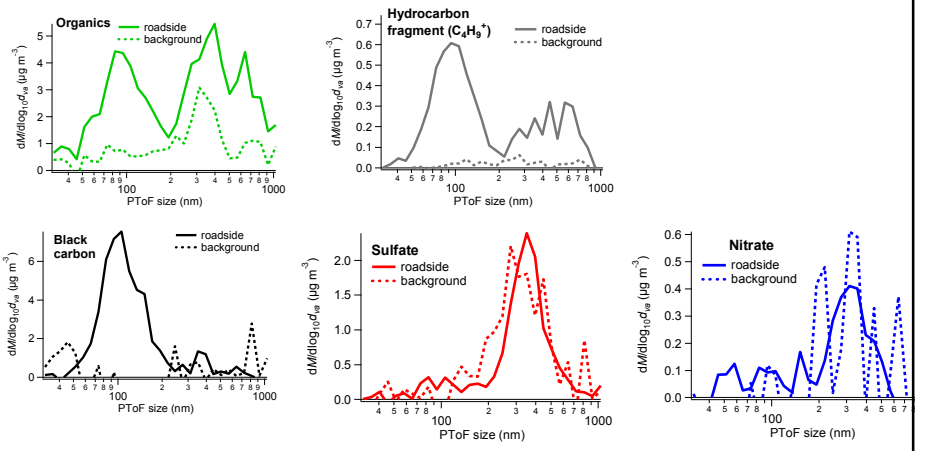
LOCAL DISPERSION (GRADIENTS) OF TRAFFIC PARTICLES FROM HIGHWAYS DOWNWIND

SNIFFER measurements Oct – Nov 2012

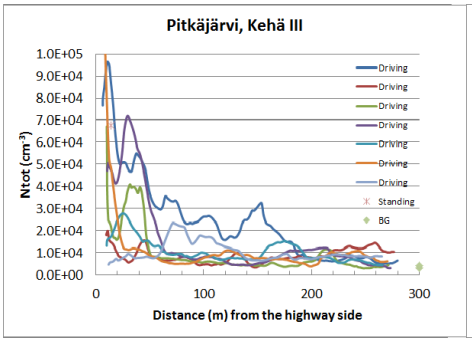
- SP-HR-AMS (FMI)
- Aethalometer, PM1, 1 s (AEROSOL.SI)
- EEPS, 5.6-560 nm size distribution, 1 s (TUT)
- Thermodenuder at 265 ºC (TUT)
- CPC, > 2.5 nm, 1 s (Metropolia)
- EELPI, ELPI (7 nm-10 μm), 1 s (Metropolia)
- PM2.5, PM1, CO, CO2, NO, NOx (Metropolia)
- T, RH, Wind, GPS (Metropolia)

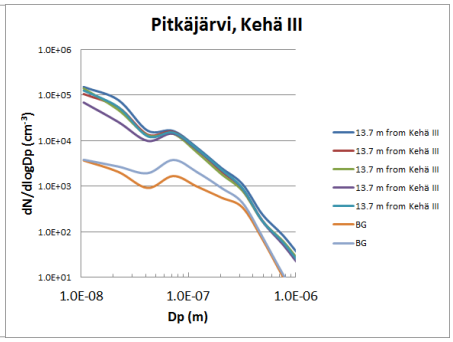






Kehä III – Pitkäjärvi





To west
136 LD + 13 HD
97 LD + 4 HD

To east
88 LD + 9 HD
71 LD + 6 HD

CONCLUSIONS

- detailed monitoring of aerosol particle properties in urban and suburban areas is a challenging task, since their concentration, size, composition and sources vary strongly in time and space
- the combined application of several methods enables us to obtain a comprehensive view on aerosol properties and sources as well as to test new measurement methods