Tampere University

Liikenteen pienhiukkaspäästöt kaupunkiympäristössä

Topi Rönkkö

Aerosol Physics Laboratory, Physics Unit, Faculty of Engineering and Natural Sciences

Tampere University

Content

- Research methods
- Primary exhaust aerosol - Fresh exhaust aerosol - Aged exhaust aerosol
- Ambient aerosol in traffic environments
- Summary

Methods in traffic emission studies

Engine and vehicle laboratories

Highly controlled environment and test conditions, repeatability

PEMS

Realistic driving conditions

Chasing vehicles on road

Realistic driving conditions and exhaust dilution and cooling

Roadside / on-road in traffic

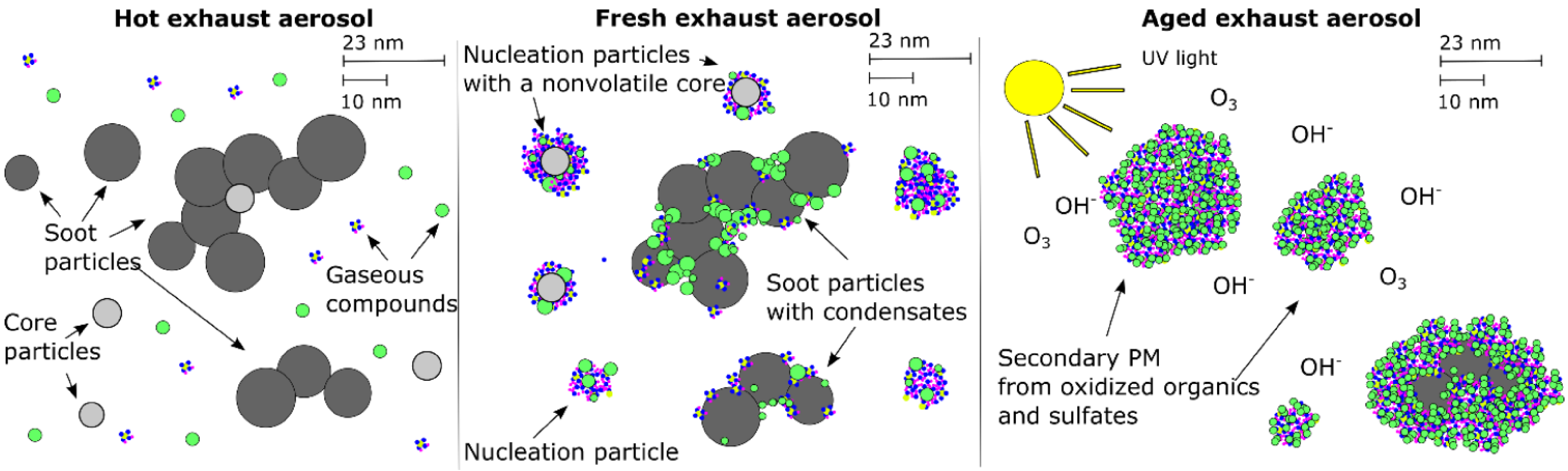
Emissions of whole vehicle fleet

Chamber studies

Atmospheric ageing taken into account

Effects of fuels, filtration, catalysts, engine oils, engine loading…

Exhaust aerosol



In hot exhaust

Directly after emission to the atmosphere

After oxidation processes in the atmosphere

Figure: Panu Karjalainen

Time scale

Deposition of particles in respiratory tracts

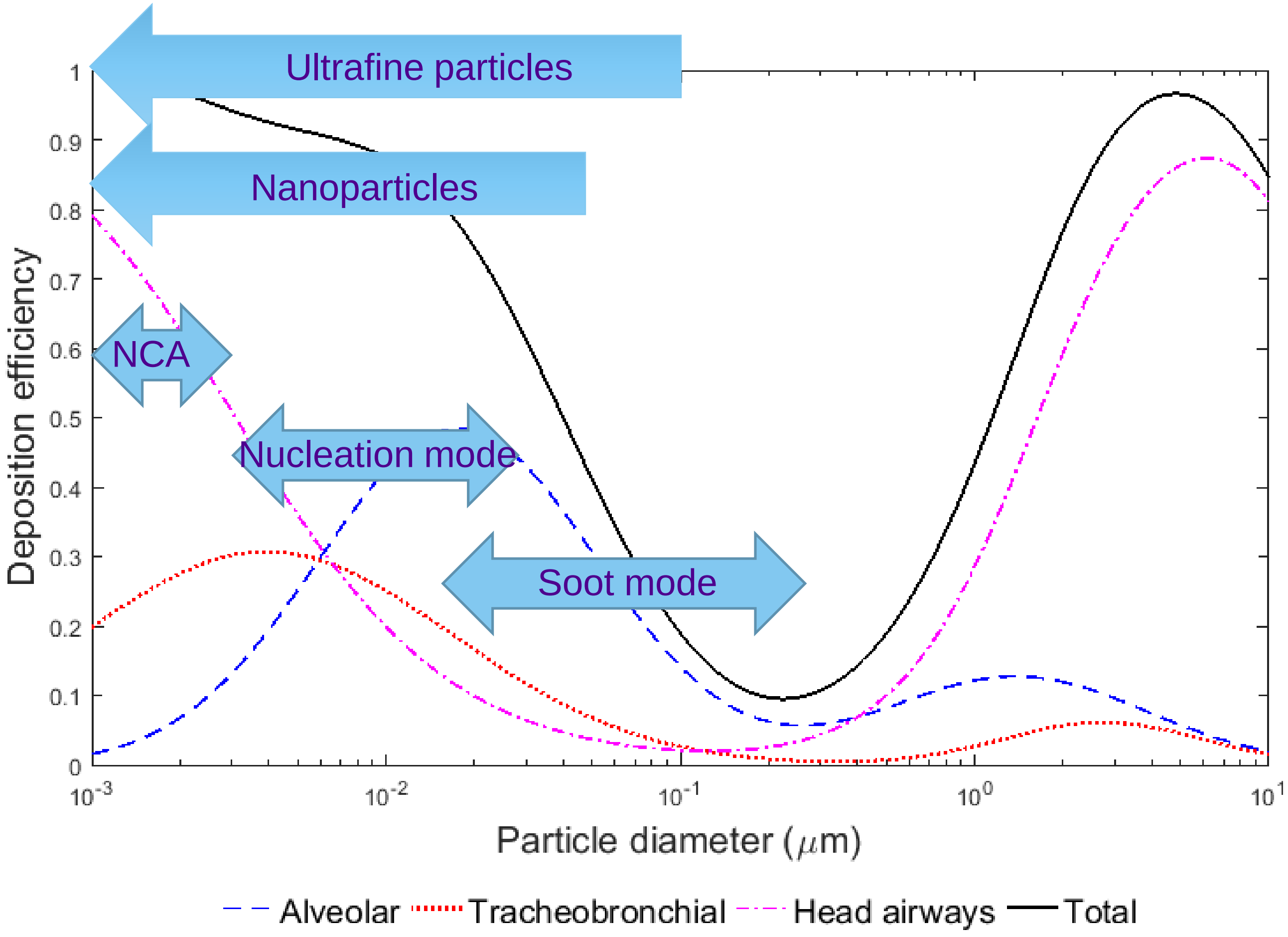
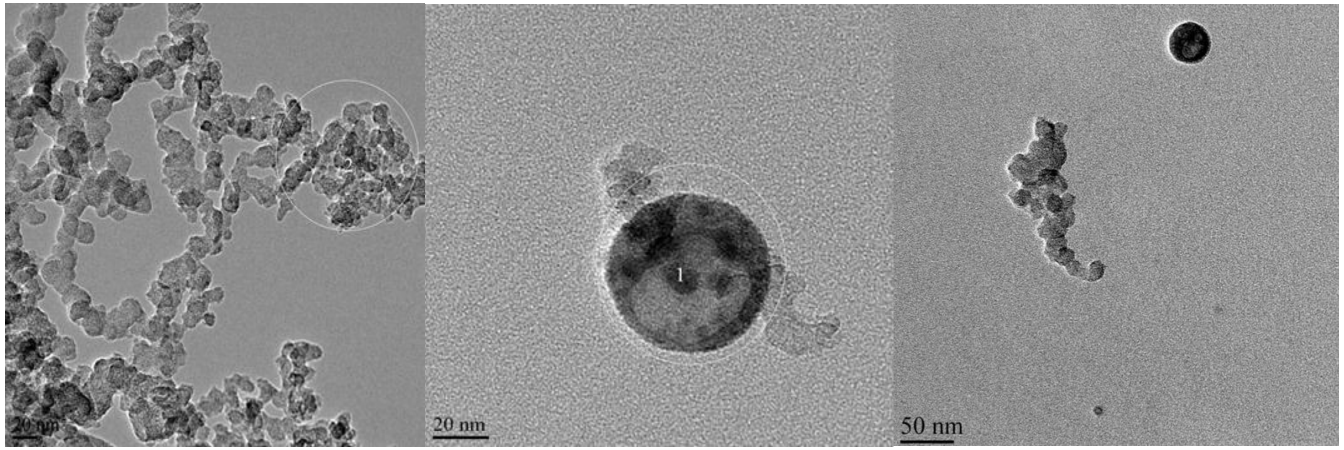


Figure: Teemu Lepistö

Primary exhaust aerosol

Primary particles from gasoline and diesel engine exhausts

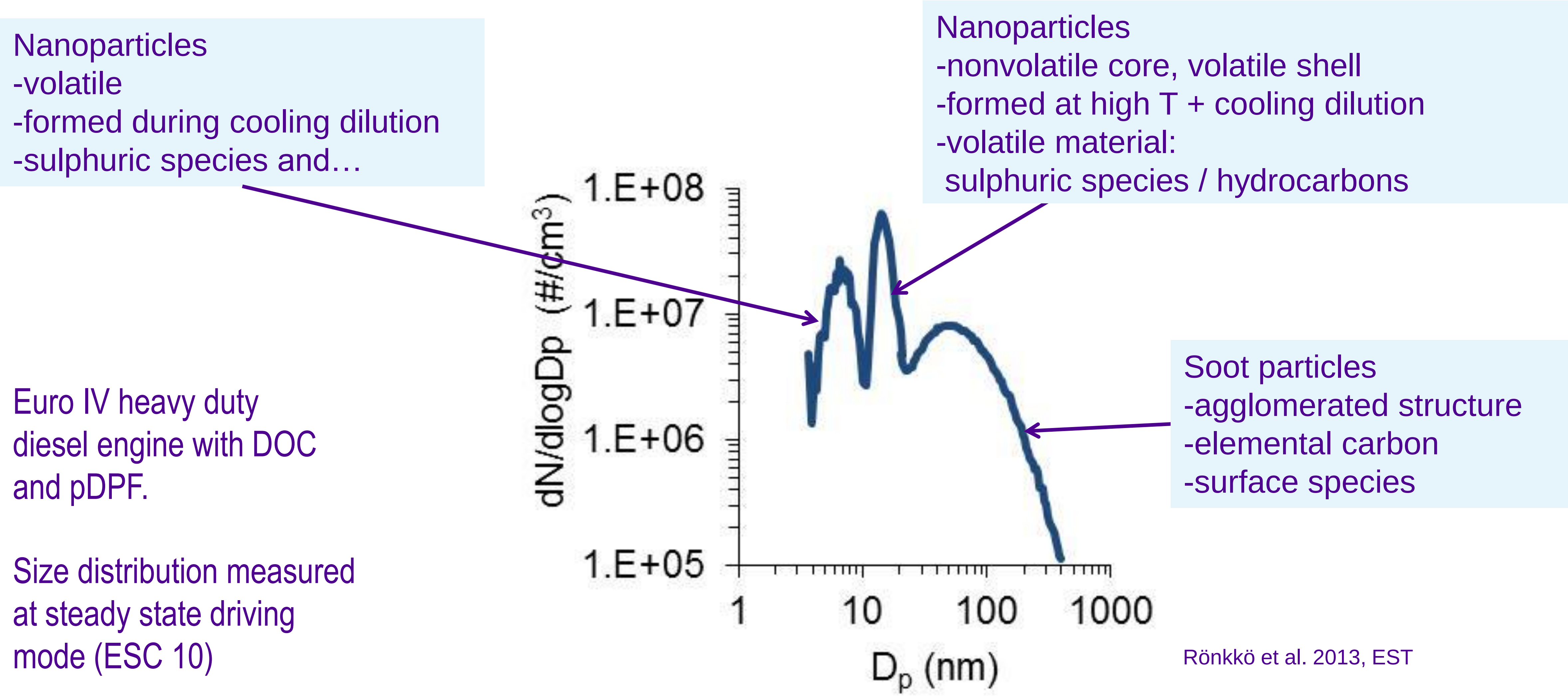


Rönkkö et al., 2014 Kuuluvainen et al., in prep.

Fresh exhaust aerosol
= exhaust aerosol after the cooling dilution of exhaust

Tamper University

Fresh exhaust from diesel engine can contain different types of particles



Euro IV heavy duty diesel engine with DOC and pDPF.

Size distribution measured at steady state driving mode (ESC 10)

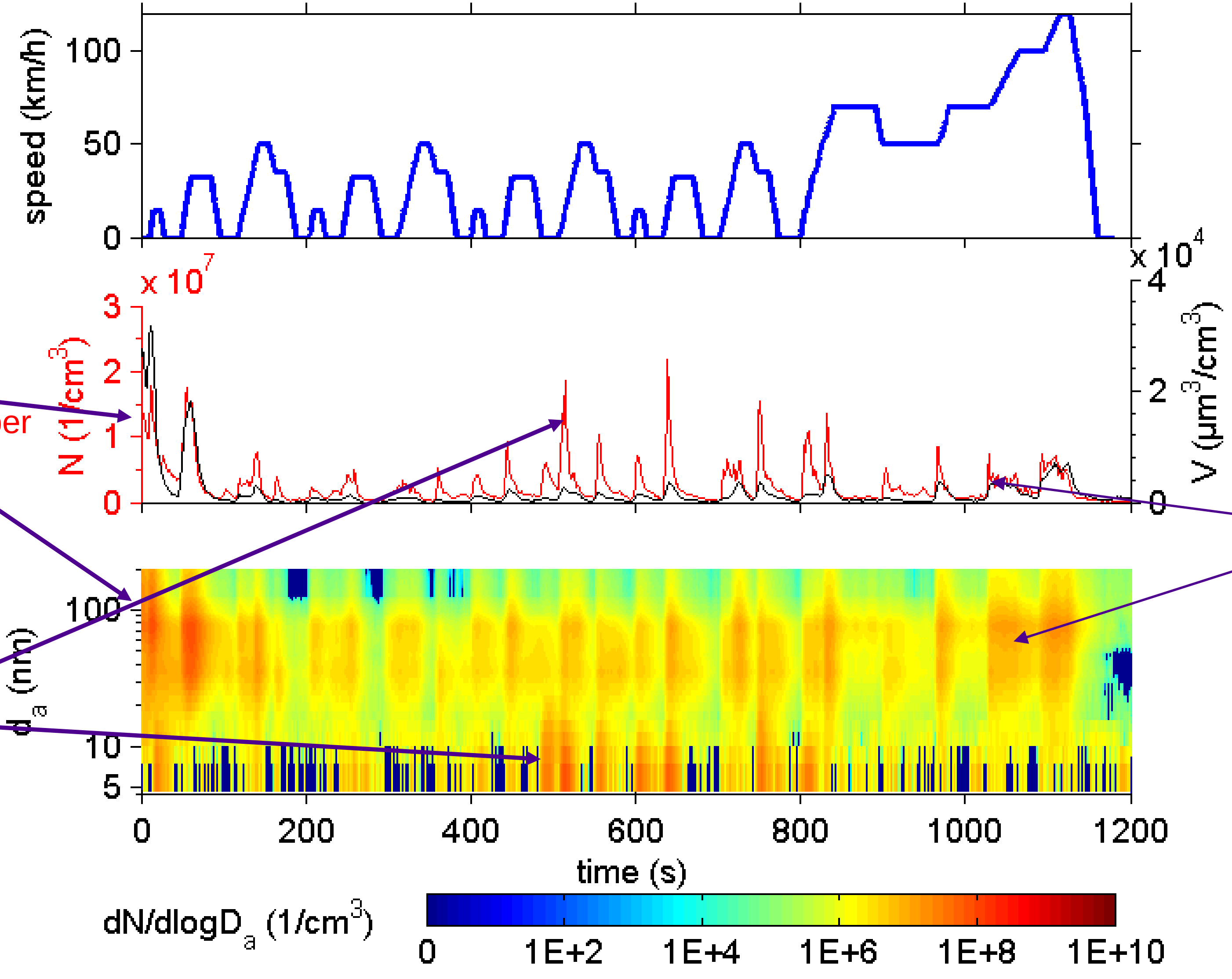
Rönkkö et al. 2013, EST

Fresh exhaust aerosol, gasoline car

GDI car
E10 gasoline,
NEDC

Cold start increases particle emissions

High number concentration associated with sub 10 nm nanoparticles



High volume concentration associated with soot mode

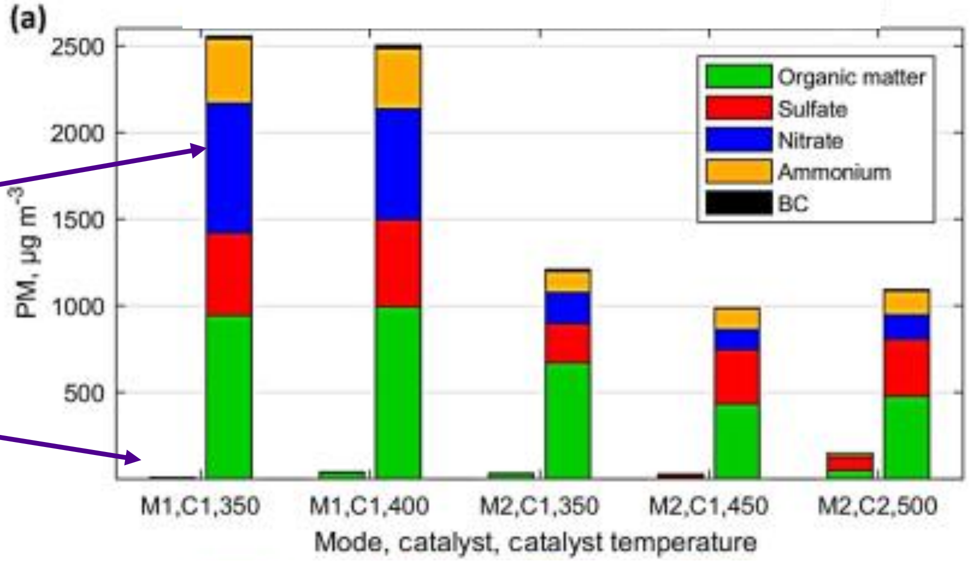
Karjalainen et al. 2016

Aged exhaust aerosol

Comparison of fresh and aged exhaust aerosols, natural gas engine

Aged exhaust

Fresh exhaust



Low emissions levels

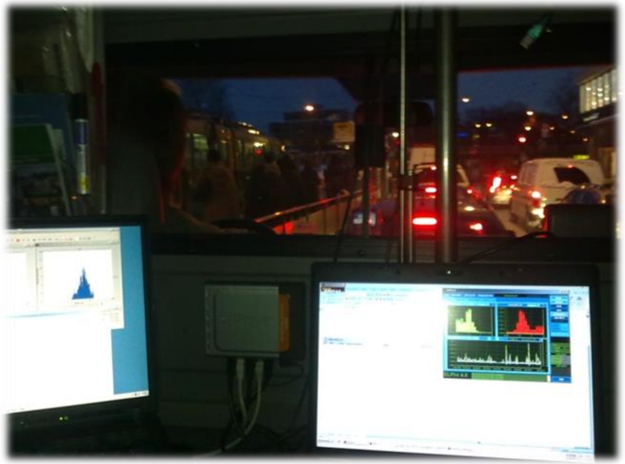
Huge difference between fresh and aged exhaust aerosol concentrations

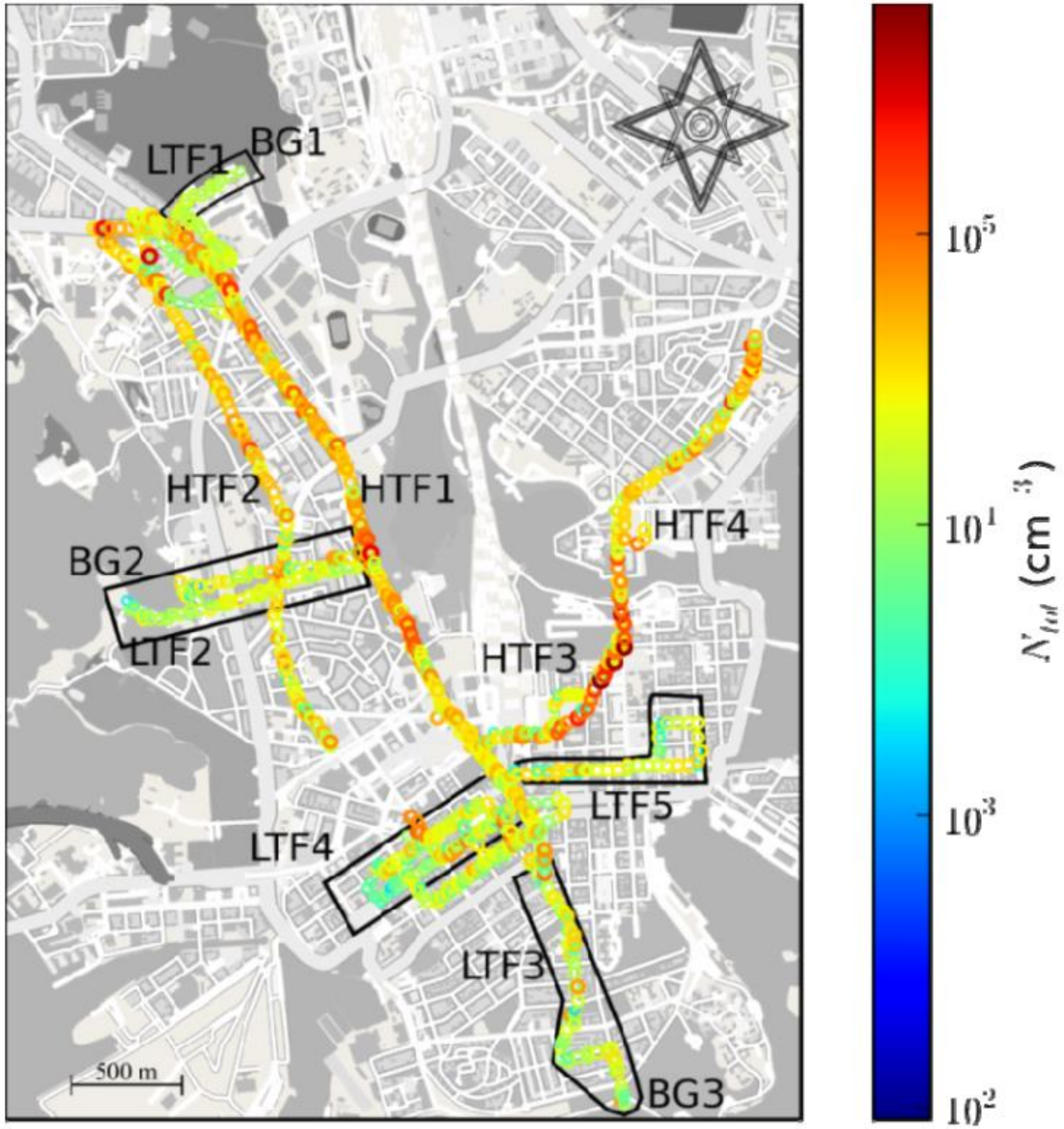
Alanen et al. 2017

Ambient aerosol in traffic environments

Tampere University

Mobile laboratory study in Helsinki





High particle numbers in environments affected by traffic

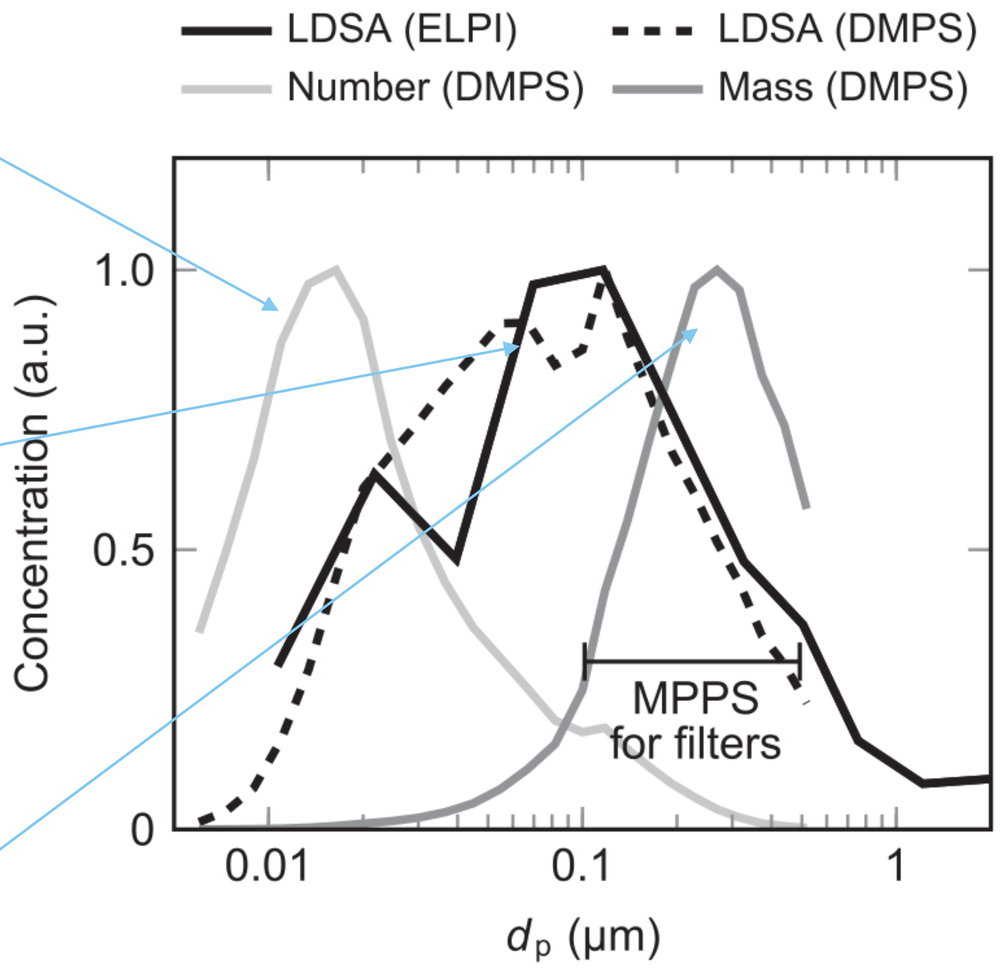
Lähde et al., 2014

Particle size distributions in traffic environments

Small, sub 30 nm particles dominate the number concentration

100 nm is important diameter in respect of lung deposited surface area (LDSA) of particles.

Particulate mass is dominated by particles larger than 100 nm.

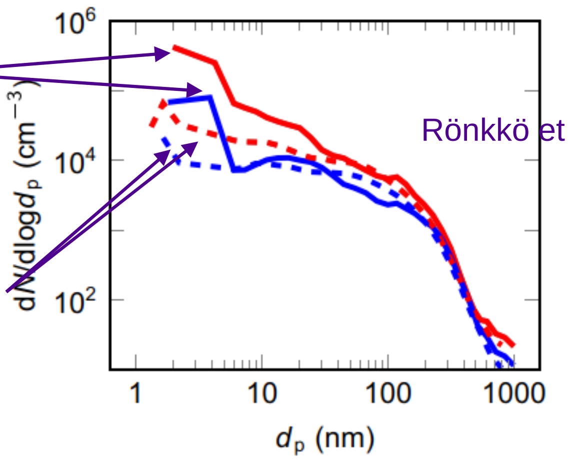


Kuuluvainen et al., 2016

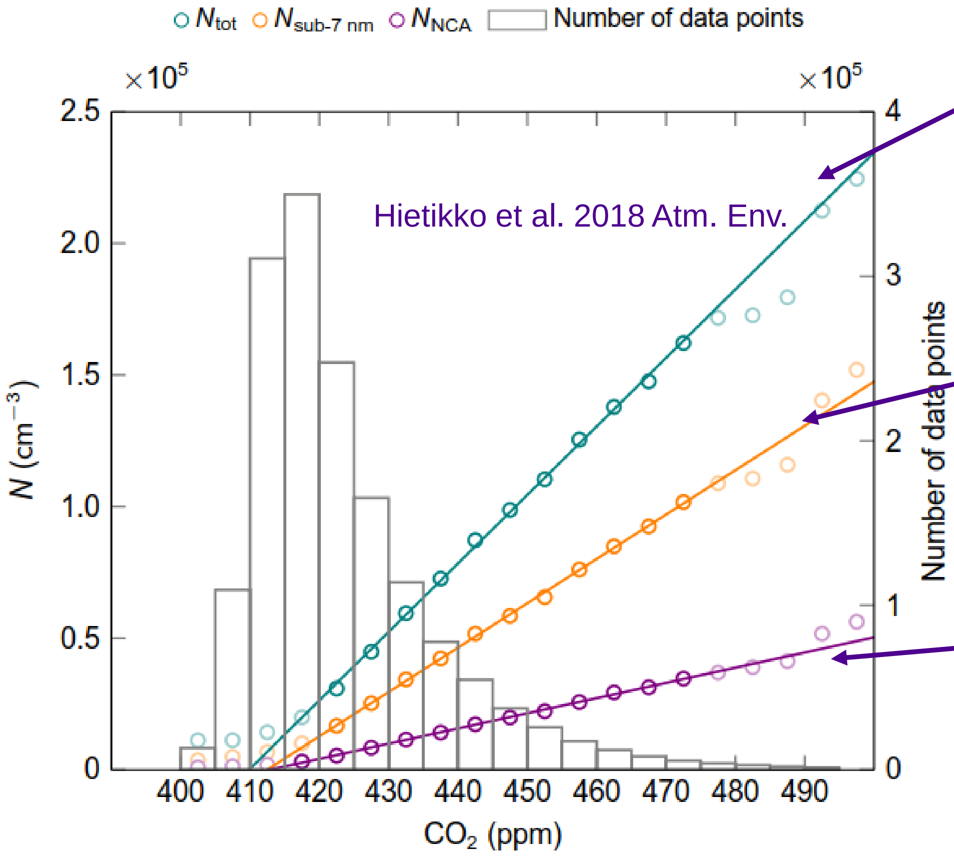
Nanoclusters and determination of particle emission factors of traffic

Road

Urban background



Rönkkö et al., PNAS, 2017



Hietikko et al. 2018 Atm. Env.

$4{,}22 \cdot 10^{15}$ particles / kg fuel

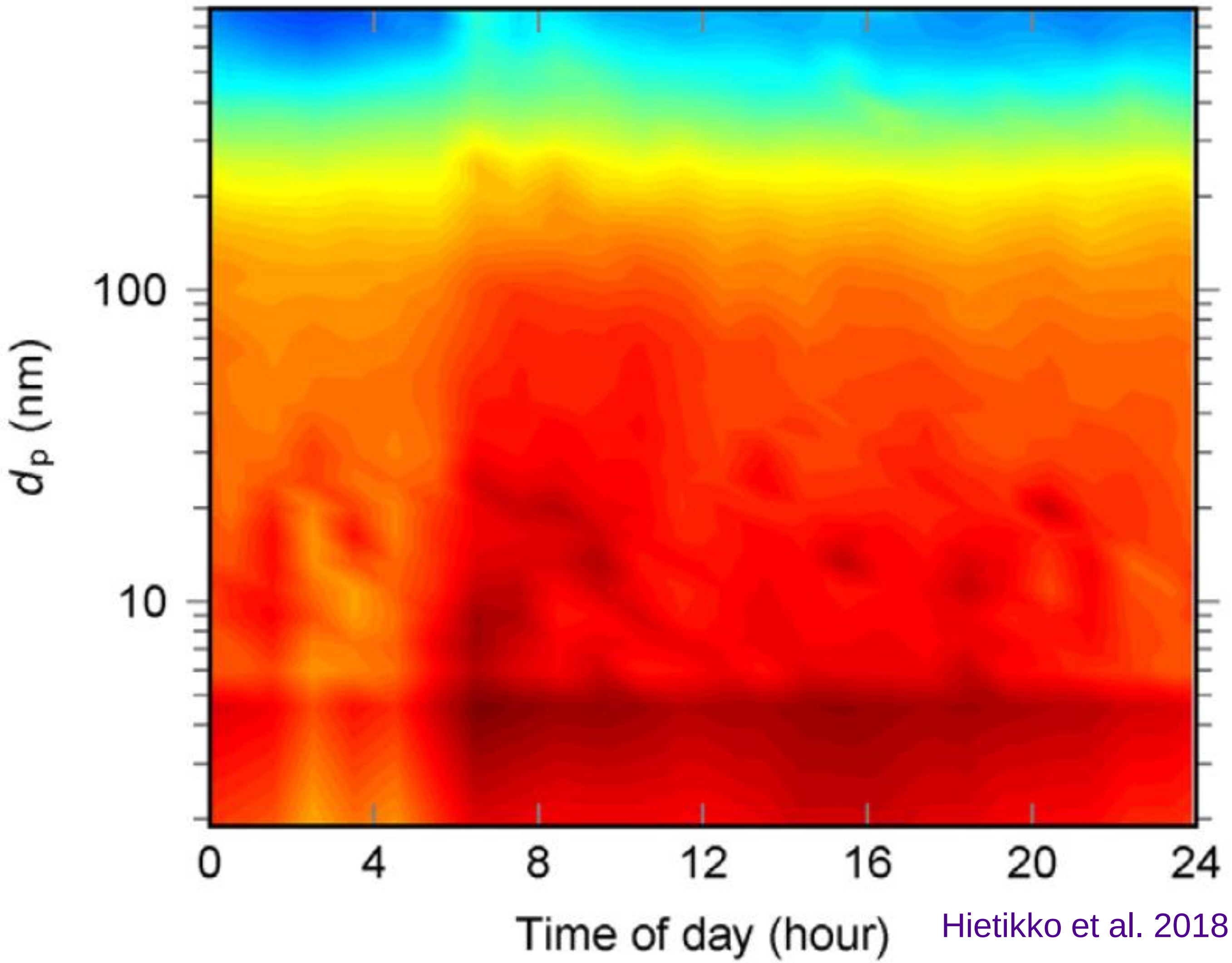
$2{,}73 \cdot 10^{15}$ sub-7 nm particles / kg fuel

$9{,}36 \cdot 10^{14}$ sub-3 nm particles / kg fuel

Diurnal variation of particle number size distribution

Particle number size distribution in Mäkelänkatu when wind was blowing from road to monitoring station.

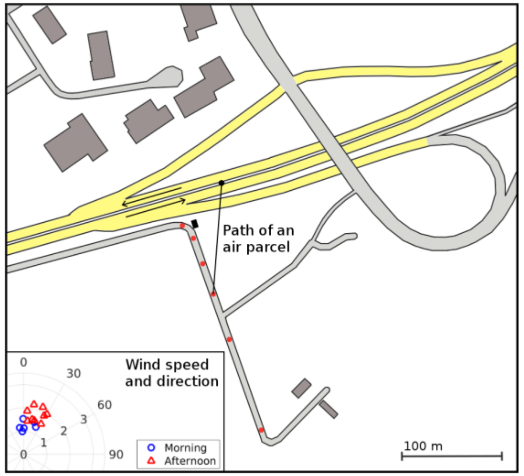
Weekdays, April 2017.

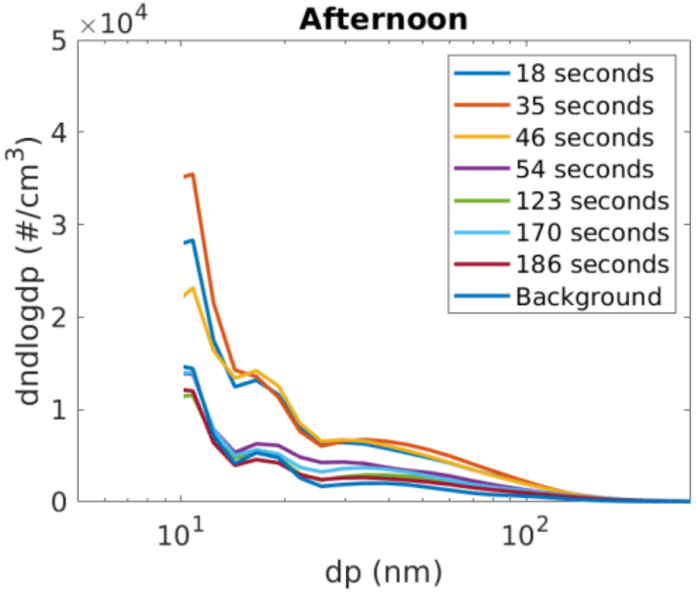


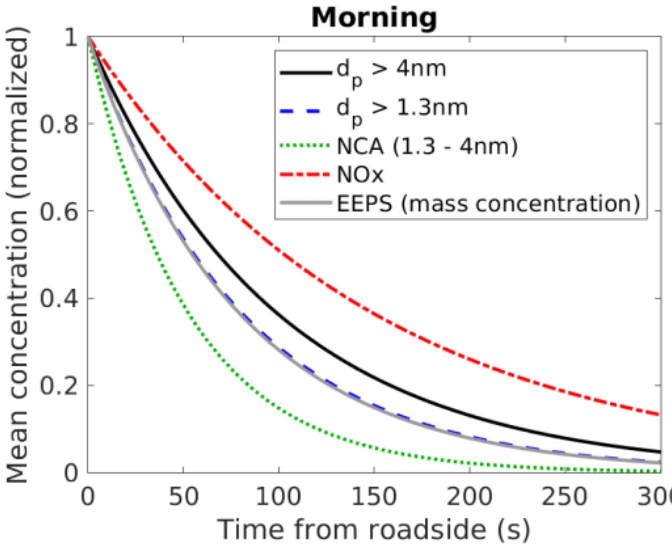
Hietikko et al. 2018, Atm Env

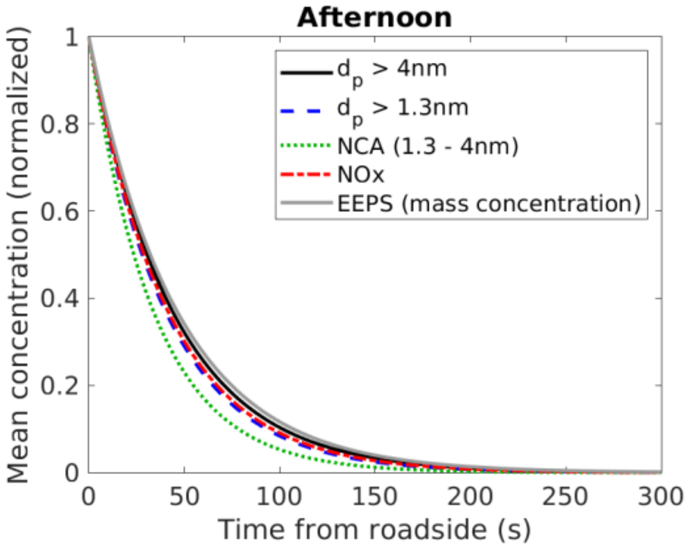
Tampere University

Dispersion of particles in traffic environment



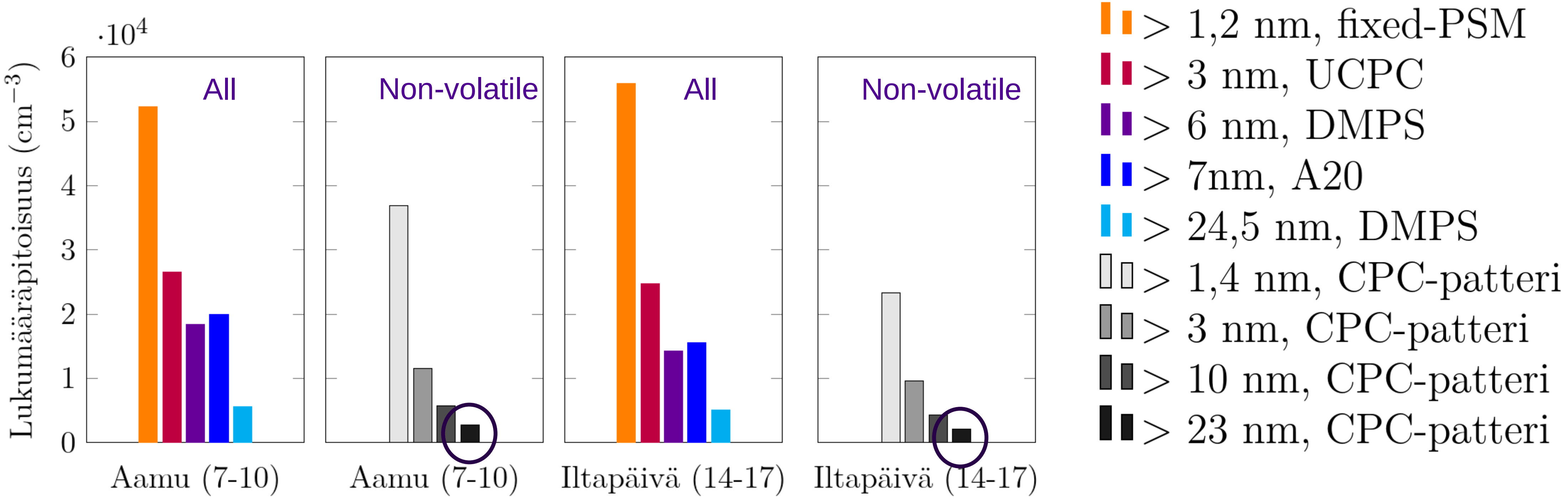






Kangasniemi et al. 2019, Atmosphere

Particle number concentrations in street canyon

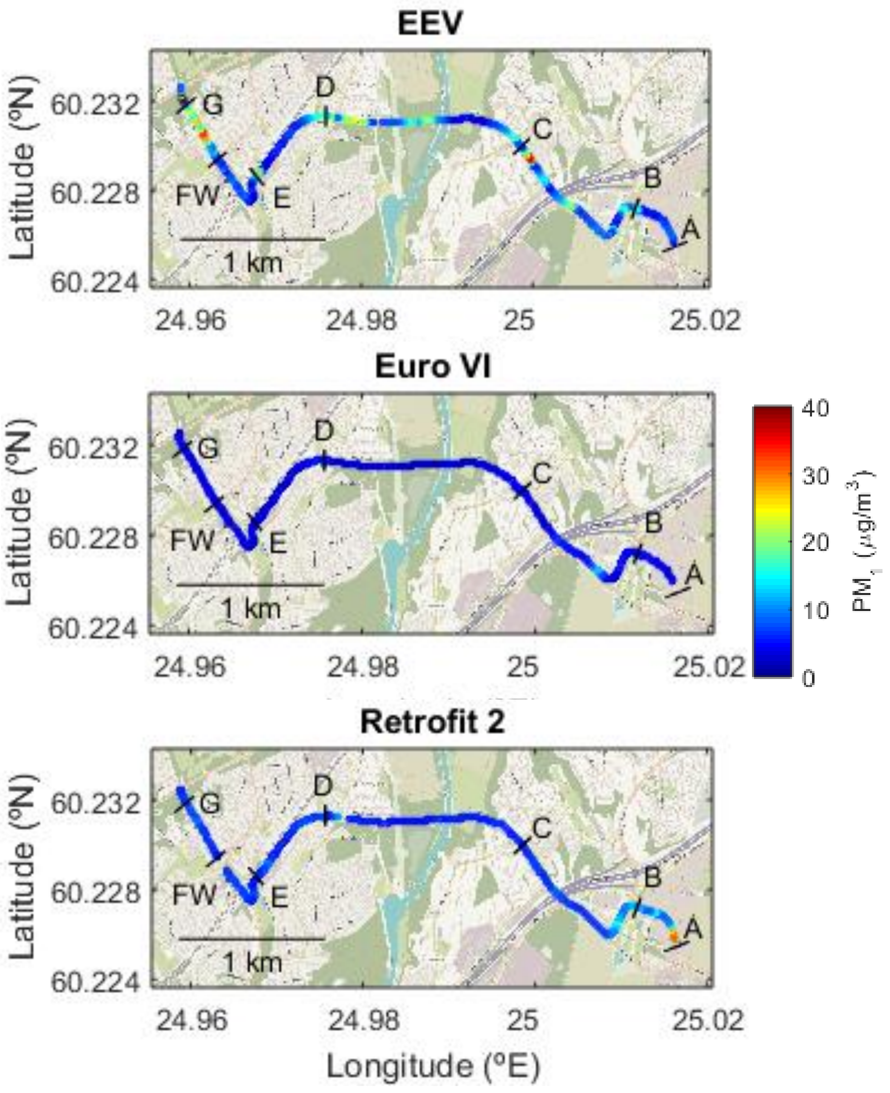


Measured in April-May, 2018

Henna Lintusaari, Diplomityö, 2019

Particle emissions from city buses depends on exhaust aftertreatment

Benefits of technology changes seen especially near bus stops



Summary

- Exhaust aerosol is a complex mixture of particles and gases
- Exhaust aerosol tranforms during its life cycle
  - Formation of new particles, condensation of semi-volatile compounds; changes of particle size distribution, chemical composition, and volatility
- Traffic exhaust particle emission reduction is efficient way to improve urban air
- To monitor particle number, take following into account:
  - Measurement location
  - Particle size range to be measured, and sampling to be used
  - Time resolution
  - All particles or non-volatile fraction only?
  - Trace gas measurements

Thank you for your attention!

topi.ronkko@tuni.fi

Tampere University

All Cityzer collaborators and co-authors of following studies are acknowledged:

Alanen, J., Simonen, P., Saarikoski, S., Timonen, H., Kangasniemi, O., Saukko, E., Hillamo, R., Lehtoranta, K., Murtonen, T., Vesala, H., Keskinen, J., Rönkkö, T. (2017) Comparison of primary and secondary particle formation from natural gas engine exhaust and of their volatility characteristics. Atmospheric Chemistry and Physics, 17 (14), pp. 8739-8755. DOI: 10.5194/acp-17-8739-2017. (https://www.atmos-chem-phys.net/17/8739/2017/) OPEN ACCESS

Arnold, F., Pirjola, L., Rönkkö, T., Reichl, U., Schlager, H., Lähde, T., Heikkilä, J., Keskinen, J. (2012) First on-line measurements of sulphuric acid gas in modern heavy duty diesel engine exhaust: Implications for nanoparticle formation. Environmental Science and Technology, 46, 11227-11234.

Hietikko, R., Kuuluvainen, H., Harrison, R.M., Portin, H., Timonen, H., Niemi, J.V., Rönkkö, T. (2018) Diurnal variation of nanocluster aerosol concentrations and emission factors in a street canyon. Atmospheric Environment, 189, pp. 98-106. DOI: 10.1016/j.atmosenv.2018.06.031

Järvinen, A., Timonen, H., Karjalainen, P., Bloss, M., Simonen, P., Saarikoski, S., Kuuluvainen, H., Kalliokoski, J., Dal Maso, M., Niemi, J.V., Keskinen, J., Rönkkö, T. (2019) Particle emissions of Euro VI, EEV and retrofitted EEV city buses in real traffic. Environmental Pollution, 250, 708-716. DOI: https://doi.org/10.1016/j.envpol.2019.04.033

Kangasniemi, O., Kuuluvainen, H., Heikkilä, J., Pirjola, L., Niemi, J.V., Timonen, H., Saarikoski, S., Rönkkö, T., Dal Maso, M. (2019) Dispersion of Traffic Related Nanocluster Aerosol Near a Major Road. Accepted to Atmosphere.

Karjalainen, P., Pirjola, L., Heikkilä, J., Lähde, T., Tzamkiozis, T., Ntziachristos, L., Keskinen, J., Rönkkö, T. (2014). Exhaust particles of modern gasoline vehicles: A laboratory and an on-road study. Atmospheric Environment, 97, 262-270.

Karjalainen, P., Timonen, H., Saukko, E., Kuuluvainen, H., Saarikoski, S., Aakko-Saksa, P., Murtonen, T., Bloss, M., Dal Maso, M., Simonen, P., Ahlberg, E., Svenningsson, B., Brune, W.H., Hillamo, R., Keskinen, J., Rönkkö, T. (2016) Time-resolved characterization of primary particle emissions and secondary particle formation from a modern gasoline passenger car. Atmos. Chem Phys., 16 (13), pp. 8559-8570, doi: 10.5194/acp-16-8559-2016.

Kuuluvainen, H., Rönkkö, T., Järvinen, A., Saari, S., Karjalainen, P., Lähde, T., Pirjola, L., Niemi, J.V., Hillamo, R., Keskinen, J. (2016) Lung deposited surface area size distributions of particulate matter in different urban areas. Atmos. Environ., 136, pp. 105-113, doi: 10.1016/j.atmosenv.2016.04.019.

Kuuluvainen, H., Poikkimäki, M., Järvinen, A., Kuula, J., Irjala, M, Dal Maso, M., Keskinen, J., Timonen, H., Niemi, J.V., Rönkkö, T. (2018) Vertical profiles of lung deposited surface area concentration of particulate matter measured with a drone in a street canyon. Environmental Pollution, 241, pp. 96-105. https://doi.org/10.1016/j.envpol.2018.04.100.

Lintusaari, Henna. Diplomityö, 2019.

Lähde, T., Niemi, J.V., Kousa, A., Rönkkö, T., Karjalainen, P., Keskinen, J., Frey, A., Hillamo, R., Pirjola, L. (2014) Mobile particle and NOx emission characterization at Helsinki Downtown: Comparison of different traffic flow areas. Aerosol and Air Quality Research, 14, 1372-1382. (http://www.aaqr.org/article/detail/AAQR-13-10-OA-0311)

Rönkkö, T., Lähde, T., Heikkilä, J., Pirjola, L., Bauchke, U., Arnold, F., Rothe, D., Yli-Ojanperä, J., Keskinen, J. (2013). Effects of gaseous sulphuric acid on diesel exhaust nanoparticle formation and characteristics. Environmental Science and Technology, 47, 11882−11889. (http://pubs.acs.org/doi/abs/10.1021/es402354y)

Rönkkö, T., Pirjola, L., Ntziachristos, L., Heikkilä, J., Karjalainen, P., Hillamo, R., Keskinen, J. (2014). Vehicle engines produce exhaust nanoparticles even when not fueled. Environmental Science and Technology, 48, 2043–2050. (http://pubs.acs.org/doi/abs/10.1021/es405687m)

Rönkkö, T., Kuuluvainen, H., Karjalainen, P., Keskinen, J., Hillamo, R., Niemi, J.V., Pirjola, L., Timonen, H.J., Saarikoski, S., Saukko, E., Järvinen, A., Silvennoinen, H., Rostedt, A., Olin, M., Yli-Ojanperä, J., Nousiainen, P., Kousa, A., Dal Maso, M. (2017) Traffic is a major source of atmospheric nanocluster aerosol. Proceedings of the National Academy of Sciences of the United States of America, 114 (29), pp. 7549-7554. DOI: 10.1073/pnas.1700830114 (http://www.pnas.org/content/114/29/7549.full)

Emission and air quality research conducted by Aerosol Physics Laboratory





- Measurement methods, instrument development, field tests
- Air quality, traffic emissions, stack emissions
- Characteristics of exhaust aerosol
- Transformation of emissions in the atmosphere

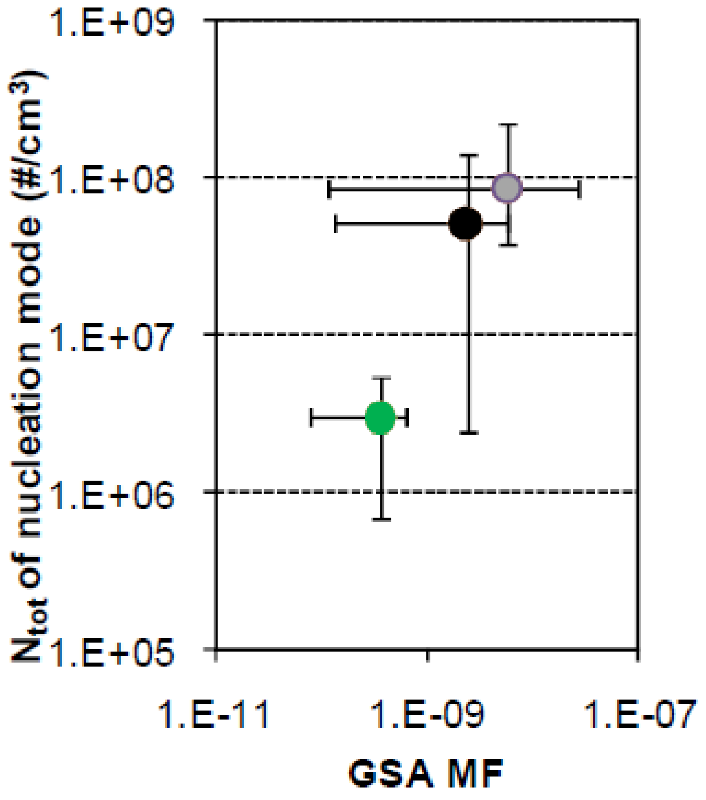





E.g. fuel affects nanoparticle emissions (i.e., particle number emissions)

Heavy duty diesel engine
DOC and DPF
Different fuels
Partial flow sampling of exhaust mimicking real-world dilution process
SMPS, CIMS

100 % load



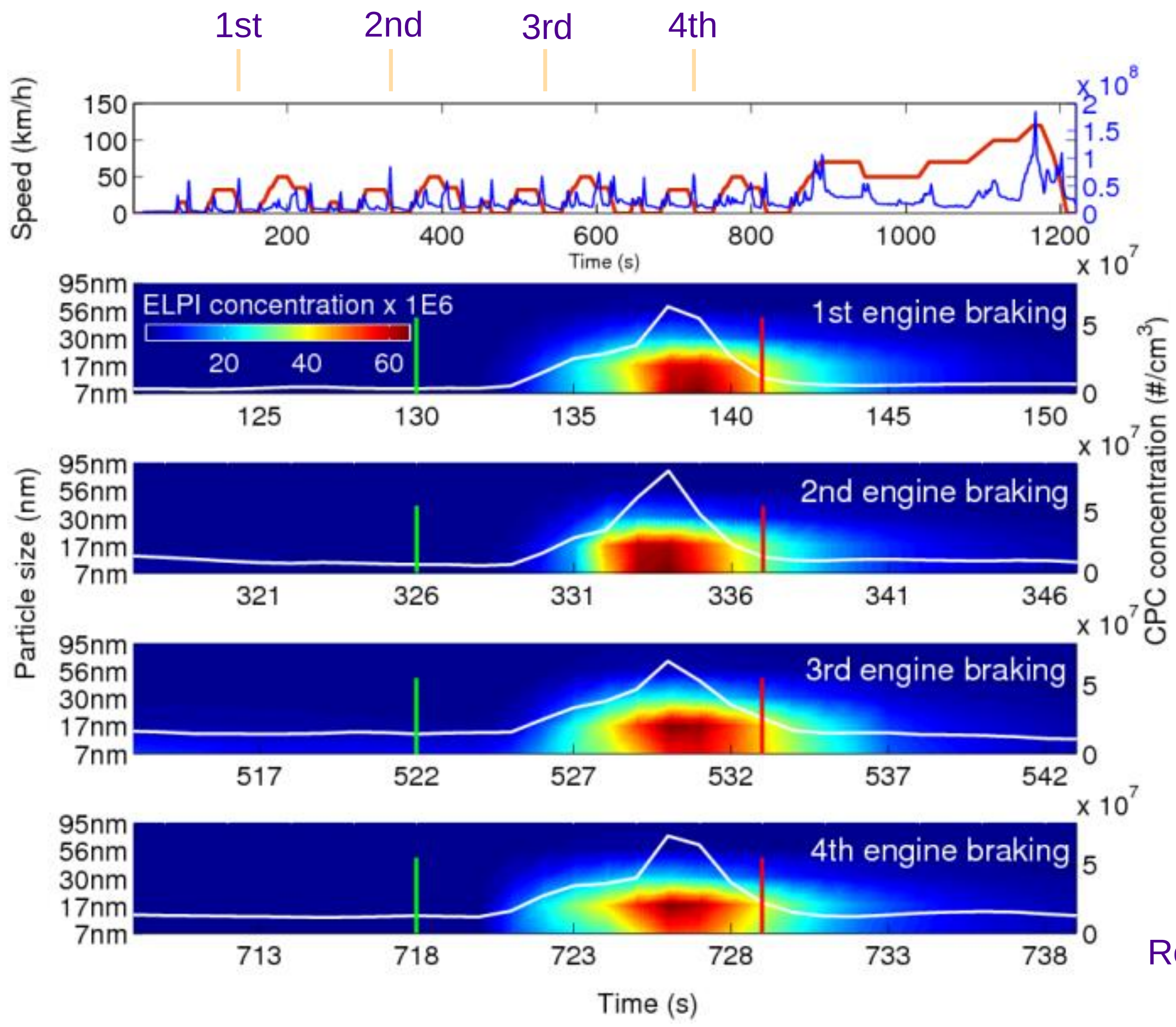
= different fuels, engine oils, catalysts

Large variations exist both in gaseous sulfuric acid (GSA) and nucleation particle concentrations

GSA from Arnold et al. 2012

Vehicles emit exhaust particles also during deceleration

GDI car
E10 gasoline
NEDC



Rönkkö et al. 2013