Including aerosol dynamic processes in LES: evaluation and application

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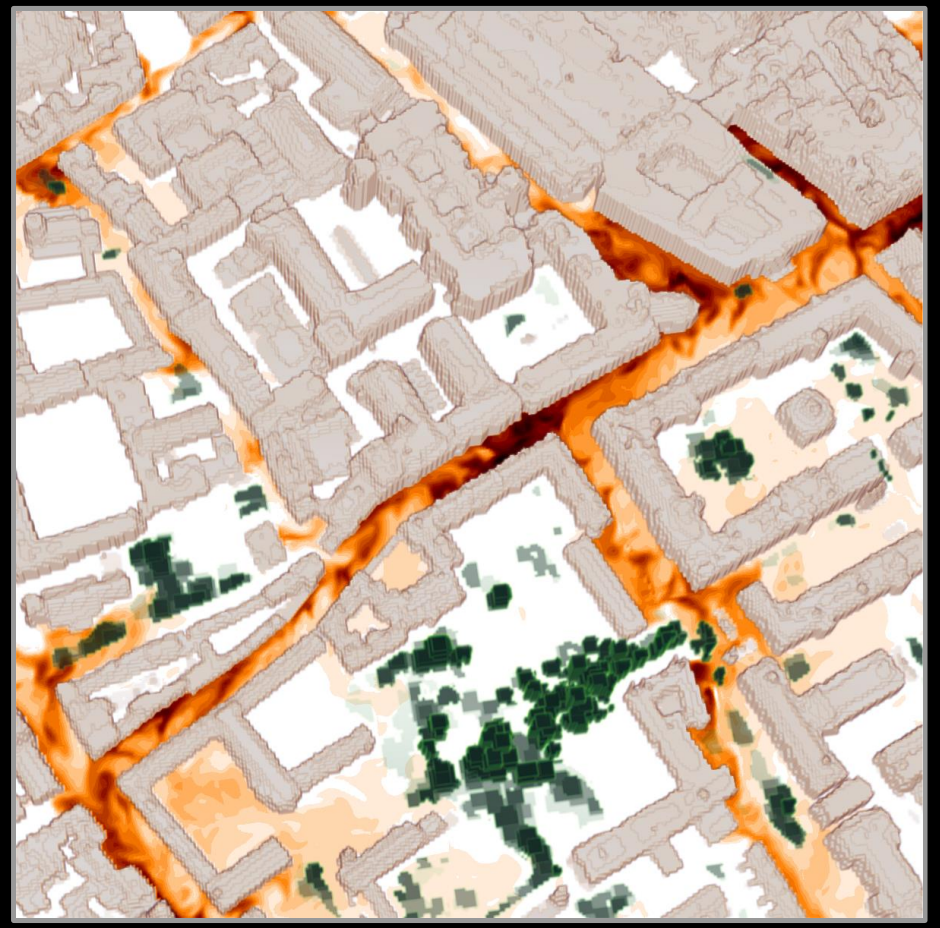
Street-level air quality is an outcome of complex interactions

meteorology

background

local emissions



Cambridge, UK

urban morphology

chemistry

aerosol dynamics

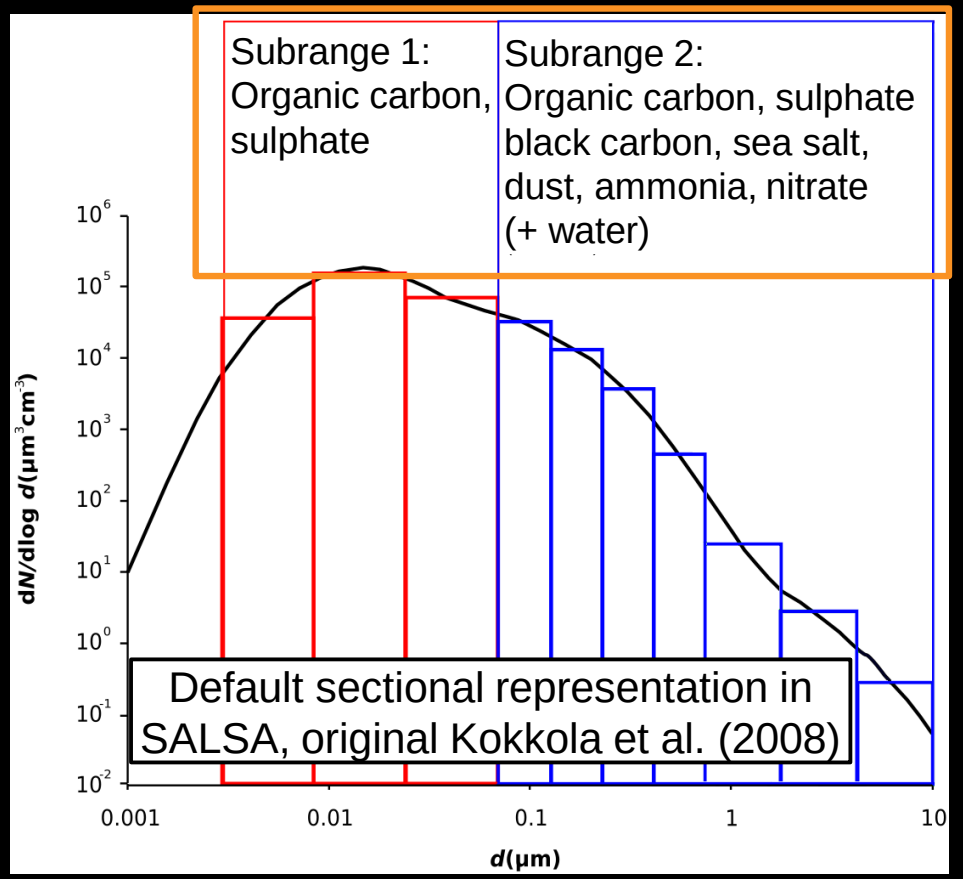
- Coagulation
- Condensation
- Nucleation
- Deposition (wet and dry)

Air pollutant concentration

Aerosol module SALSA embedded into the LES model PALM

- LES: PALM modelling system (Maronga et al., 2015, GMD)
- Sectional aerosol module SALSA (Kokkola et al., 2008, ACP; Kurppa et a., 2019, GMD)
  - PSD in ~10 size bins + chemical composition
  - Processes:
    - ➢ Coagulation
    - ➢ Condensation and dissolutional growth: H_2SO_4, HNO_3, NH_3, SVOCs, LVOCs
    - ➢ Nucleation (several parametrisations)

    + Dry deposition (also on resolved vegetation)
  - Coupled with an online chemistry module (see Maronga et al., 2019, GMDD)
  - Eulerian approach

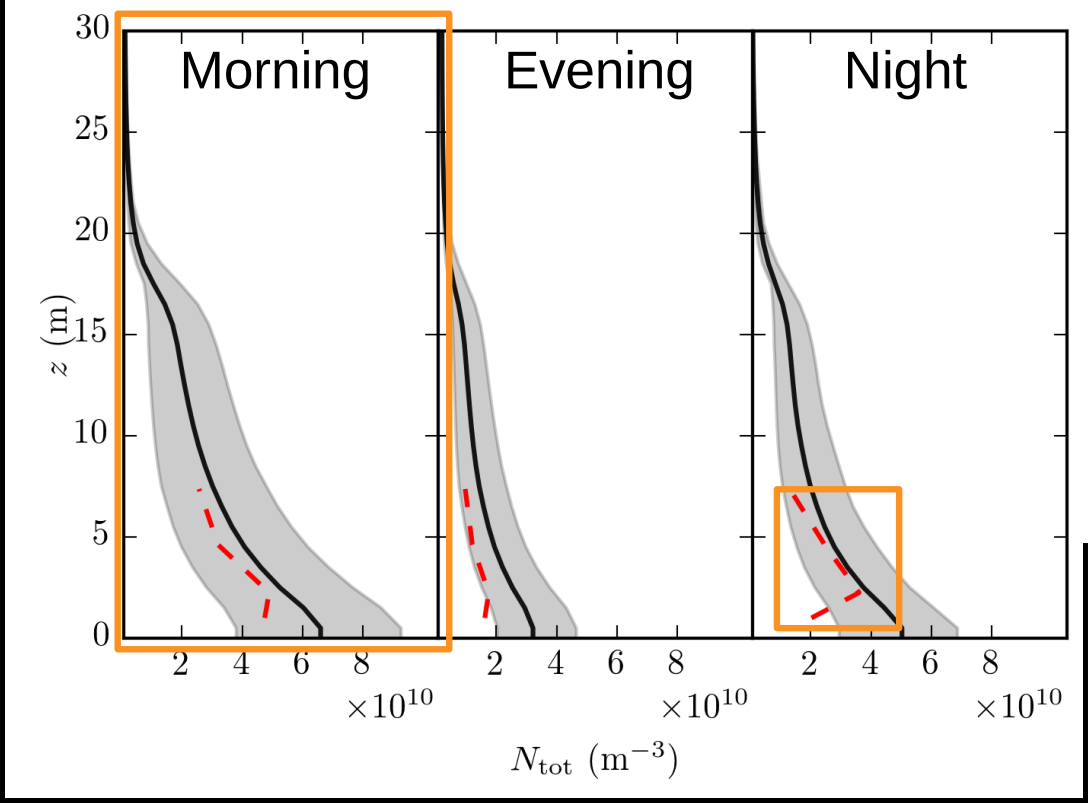


LES = large-eddy simulation
PSD = particle size distribution
SVOC = semi-volatile organic compound
LVOC = low-volatile organic compound

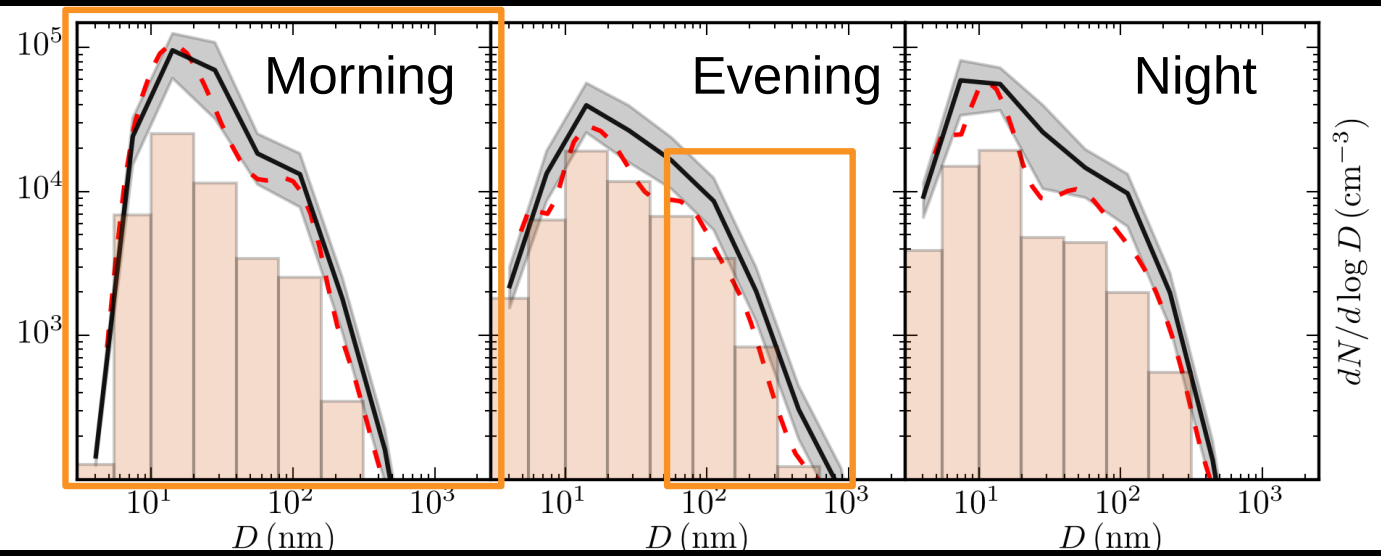
Evaluation against pseudo-simultaneous measurements (Kumar et al. 2008) on the vertical variation of PSD within a street canyon in Cambridge, UK, in March 2007 (Kurppa et al., 2019).

Simulations agree well with measurements

Total number concentration N_{tot} (m^{-3})



Aerosol number size distribution (PSD) at z = 1.0 m

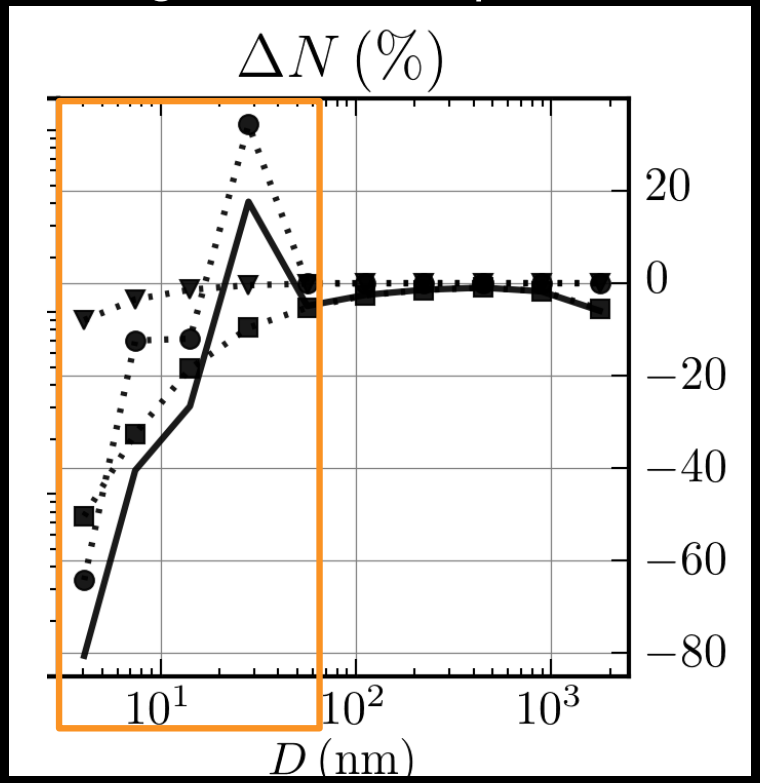


Measured
Modelled
Emission PSD shape

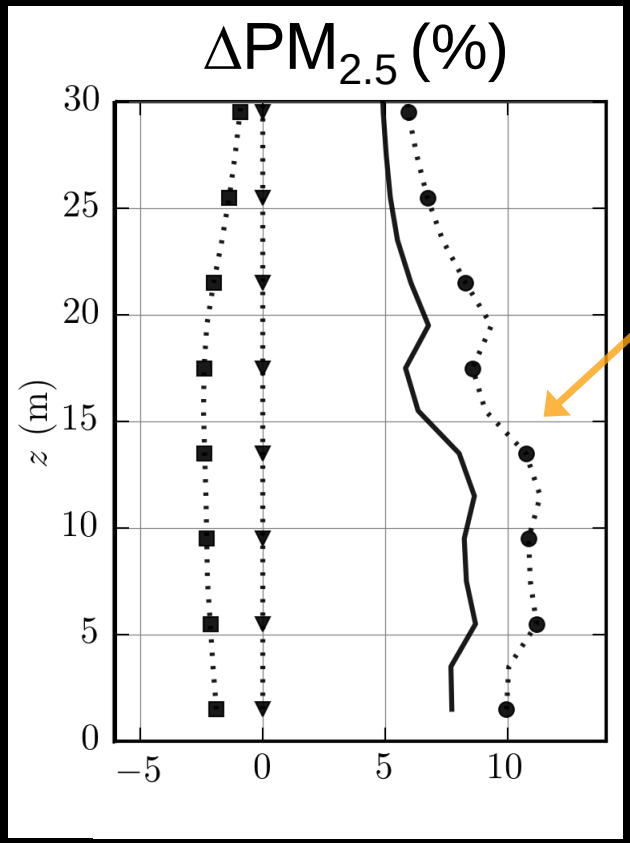
Kurppa et al. (2019, GMD)

Aerosol processes most important for the number of small particles and condensation for mass

Change in number per size bin



Vertical profile of the change in mass

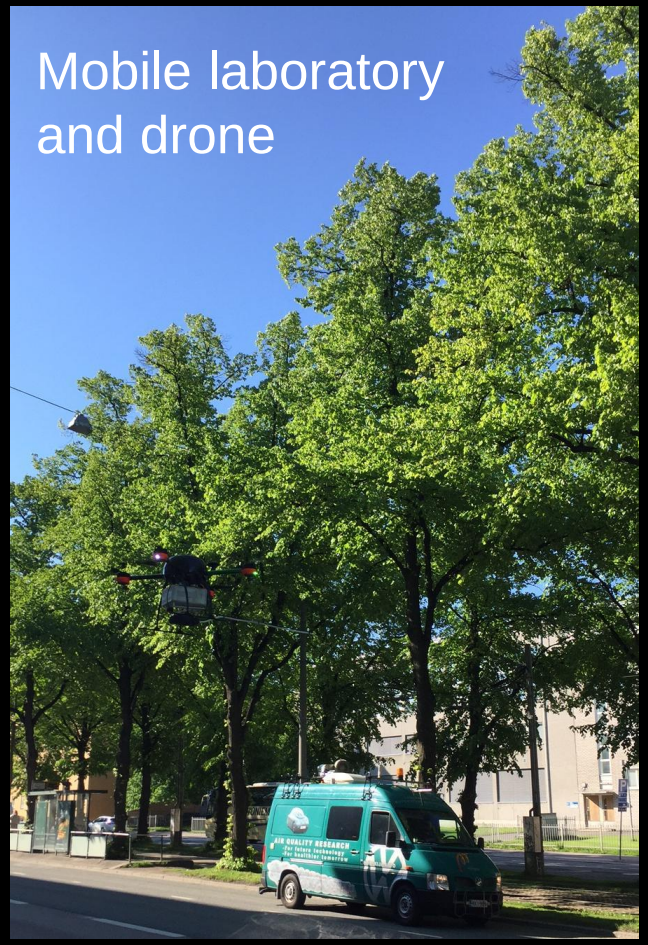


Condensation!

Coagulation Condensation Dry deposition All processes

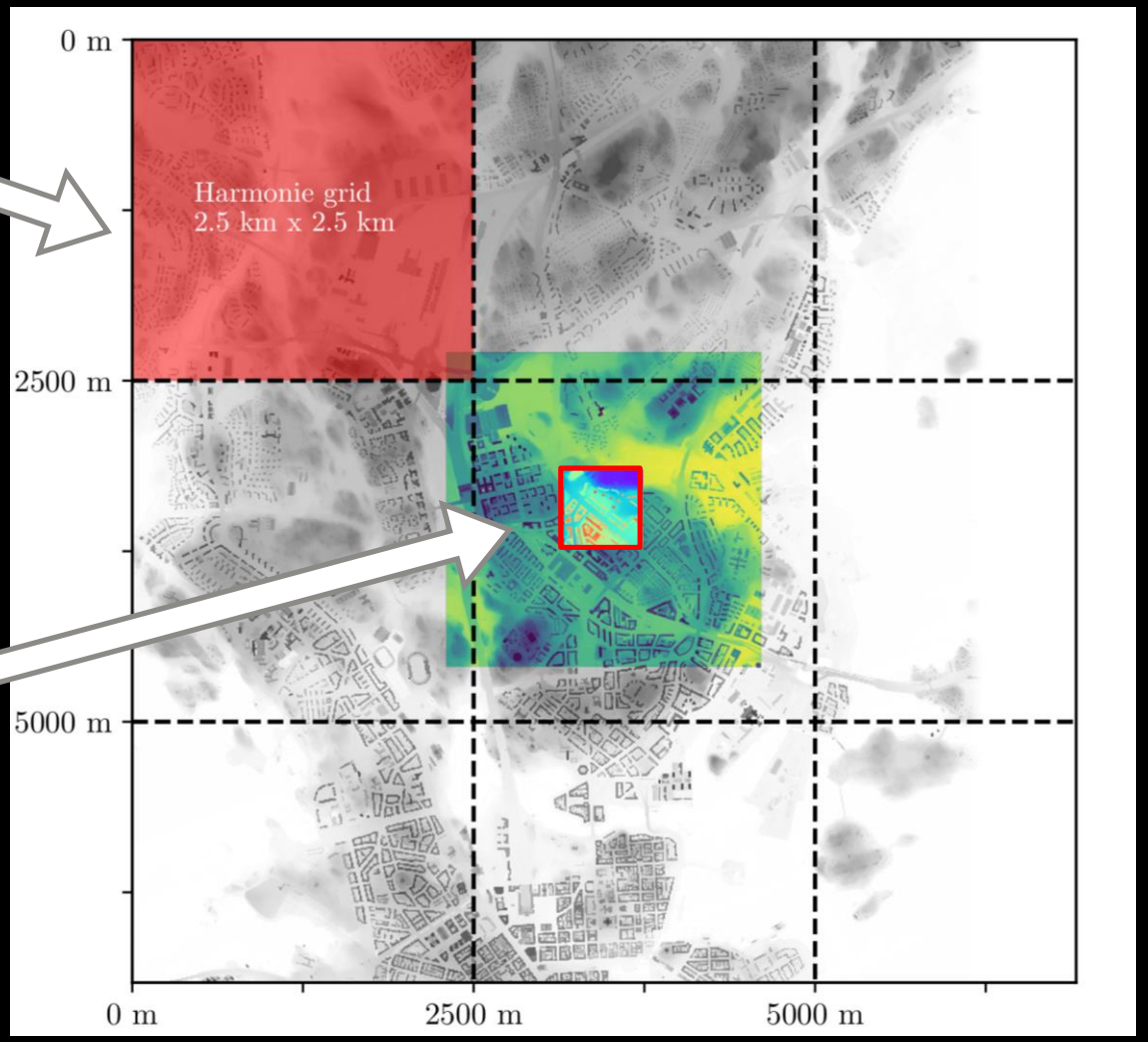
Kurppa et al. (2019, GMD)

More extensive model evaluation in Helsinki



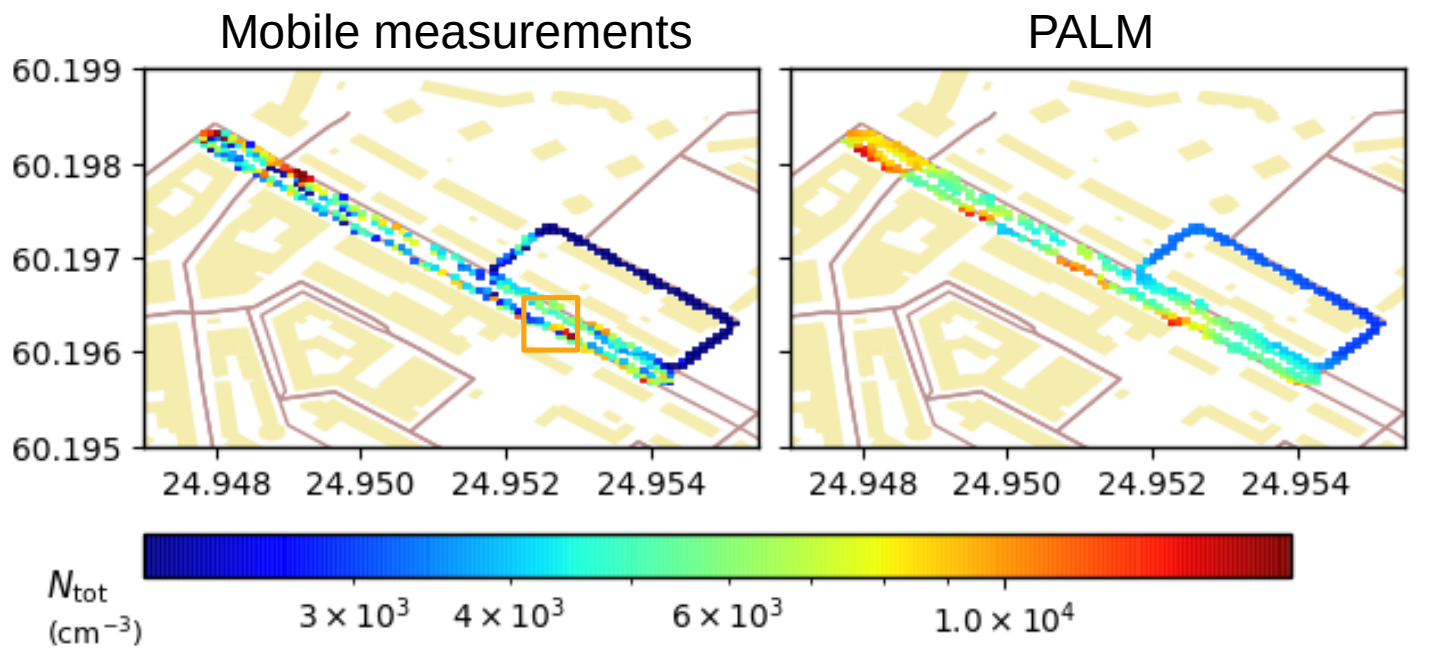
Meteorological boundary conditions from the NWP model Harmonie

Background concentrations from ADCHEM (Roldin et al. 2011, ACP)

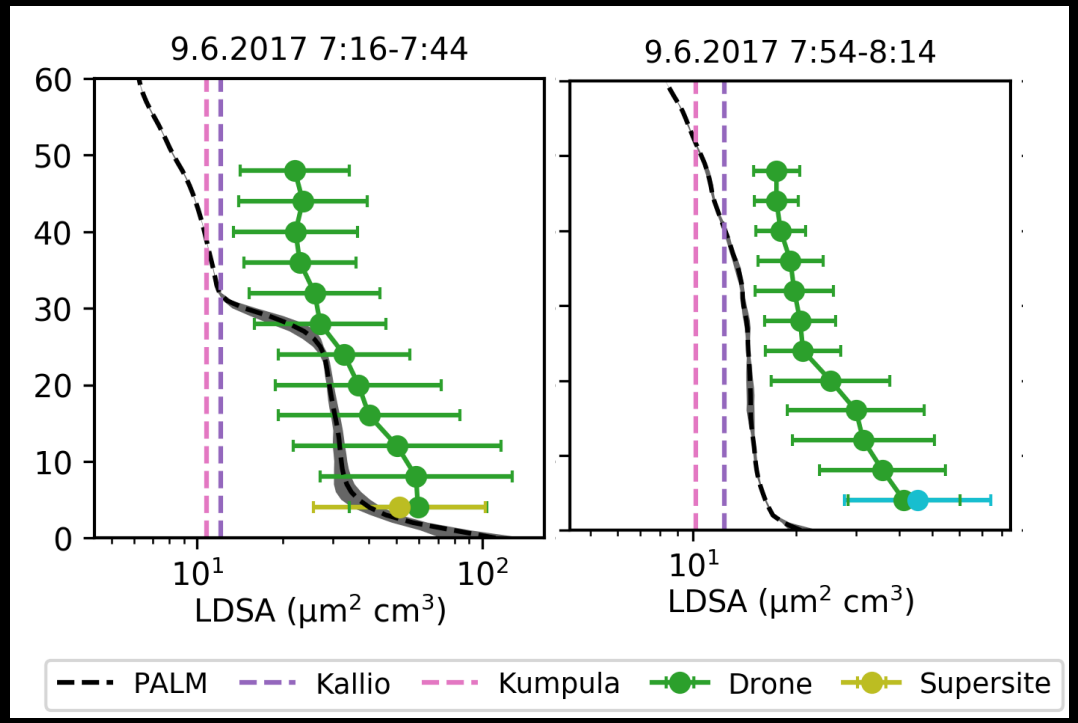


First results emphasize the importance of correct boundary conditions

9 June 2017, 7:16-8:14 am

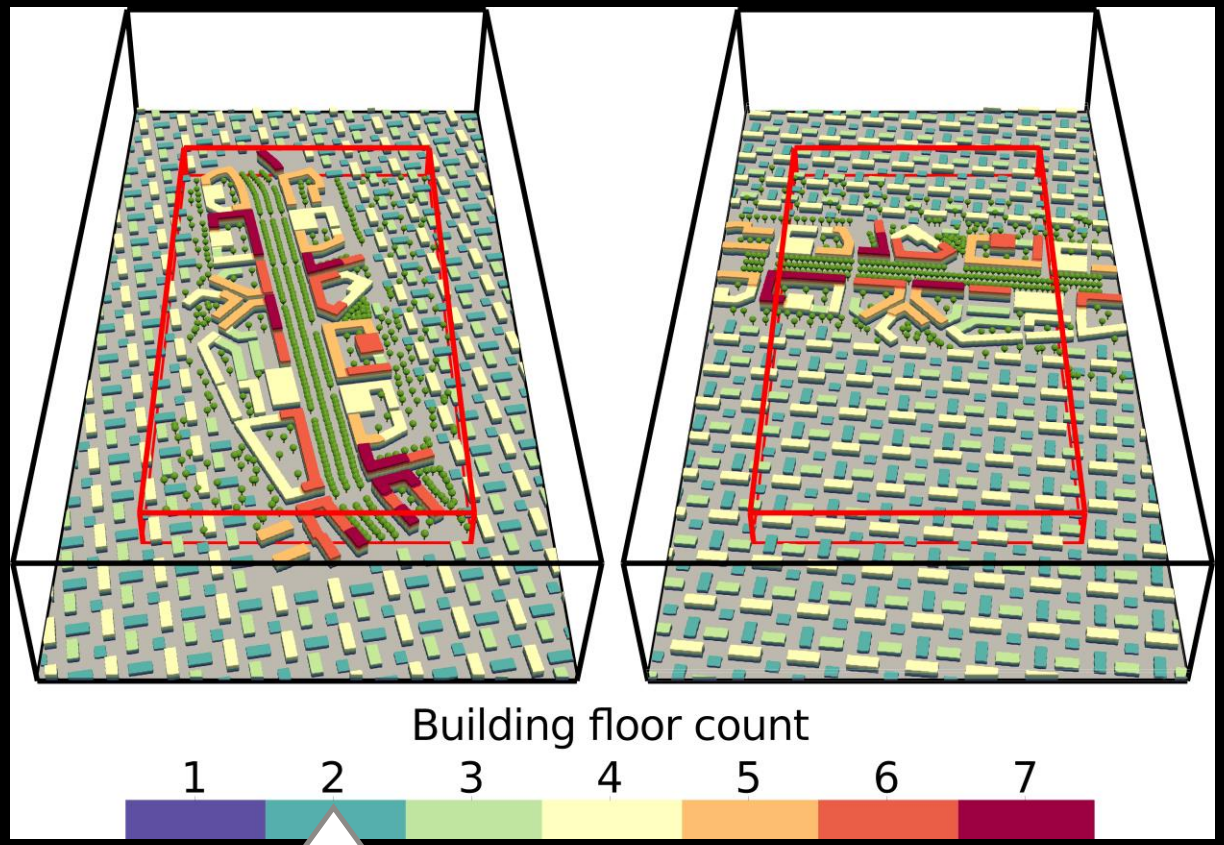


Southern side Northern side

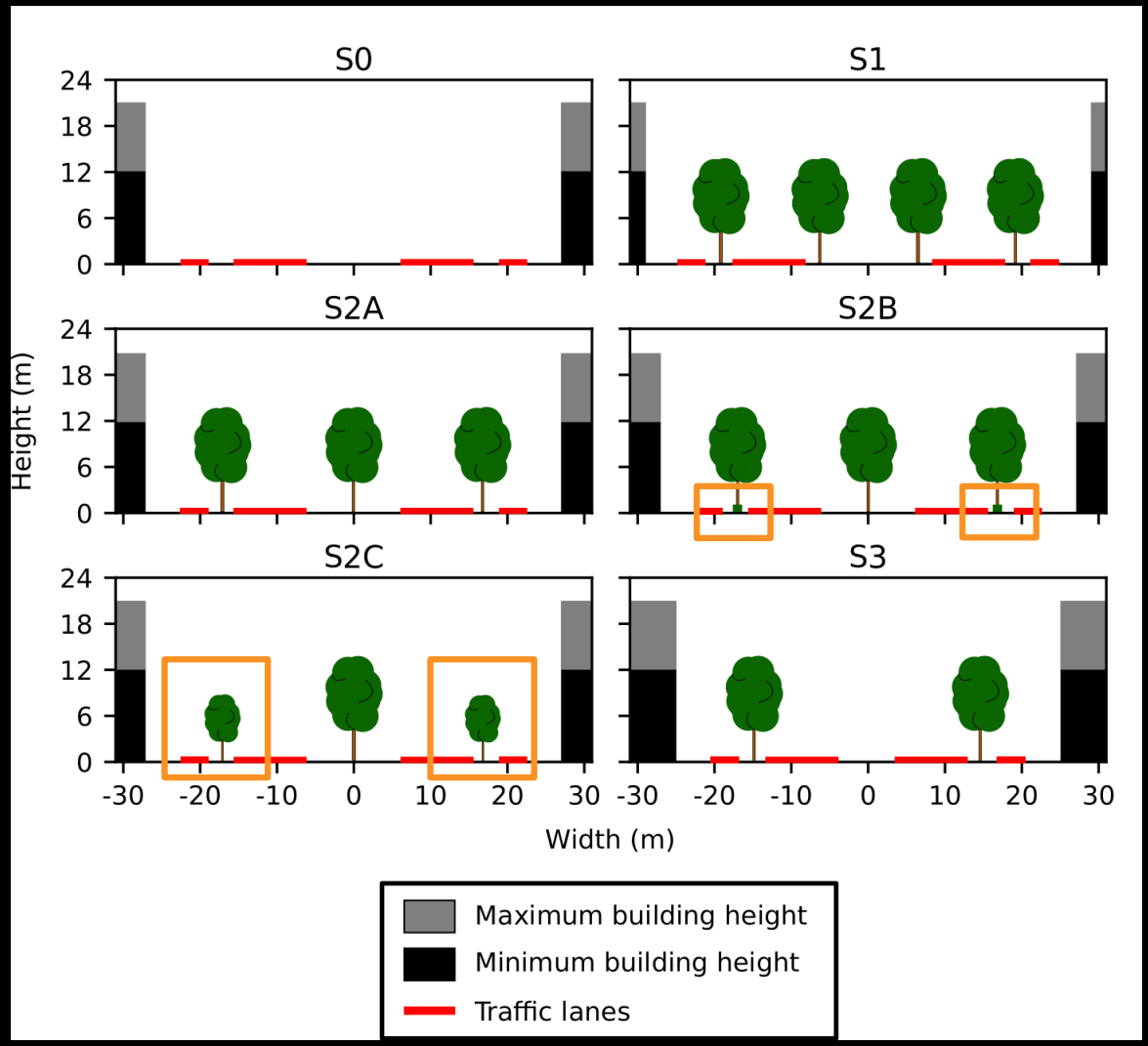


N_{tot} = total aerosol number concentration
LDSA = total lung-deposited surface area of aerosol particles

Application: what is the best (and realistic) layout for street trees?

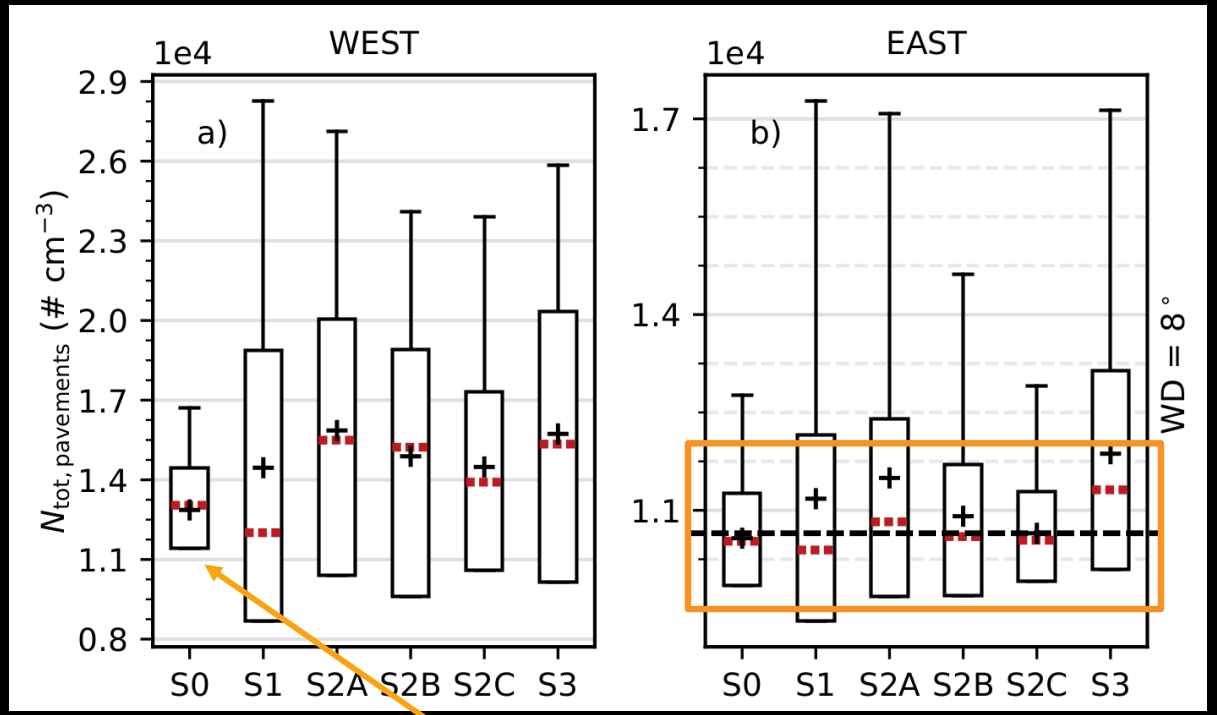


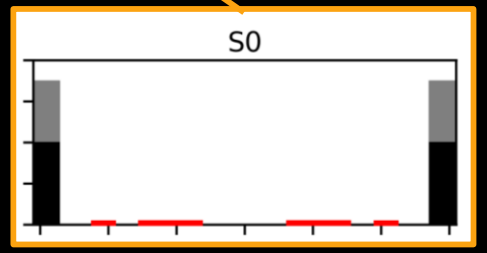
Karttunen and Kurppa et al. (submitted)



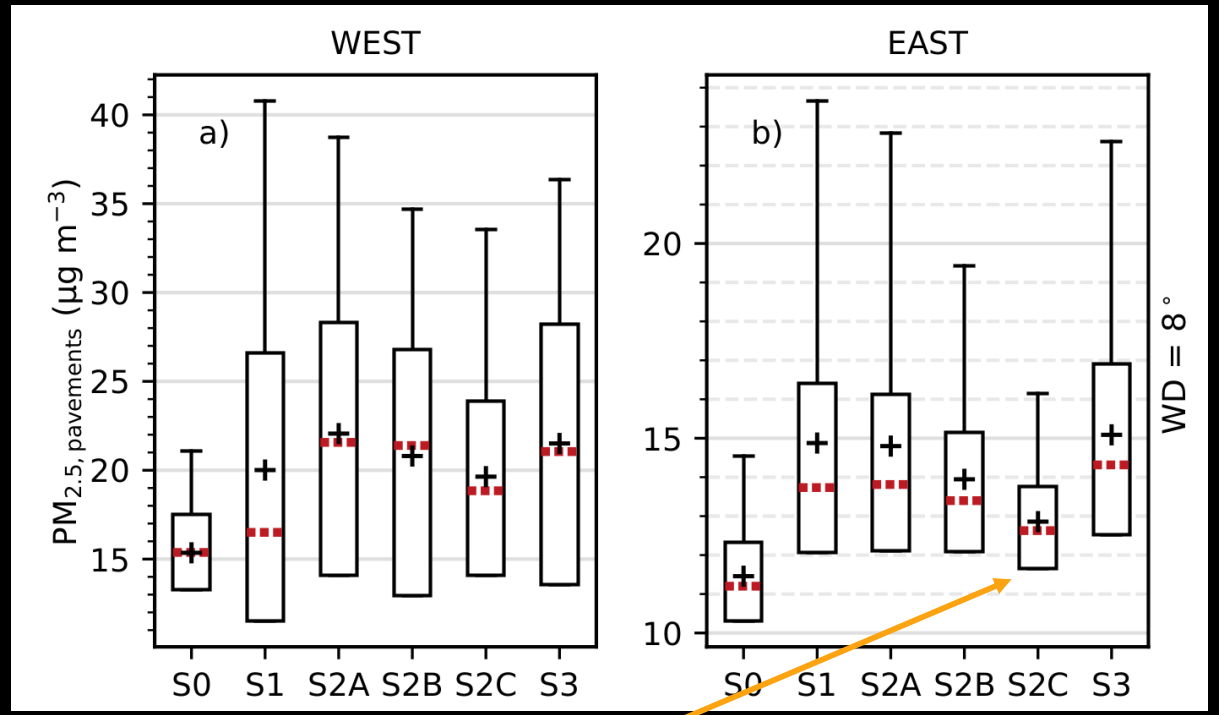
In general, trees increase concentrations on pavements (i.e., side walks)

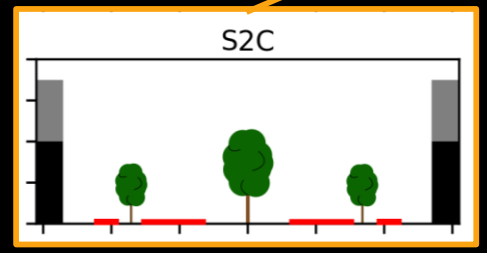
Total number concentration N_{tot}



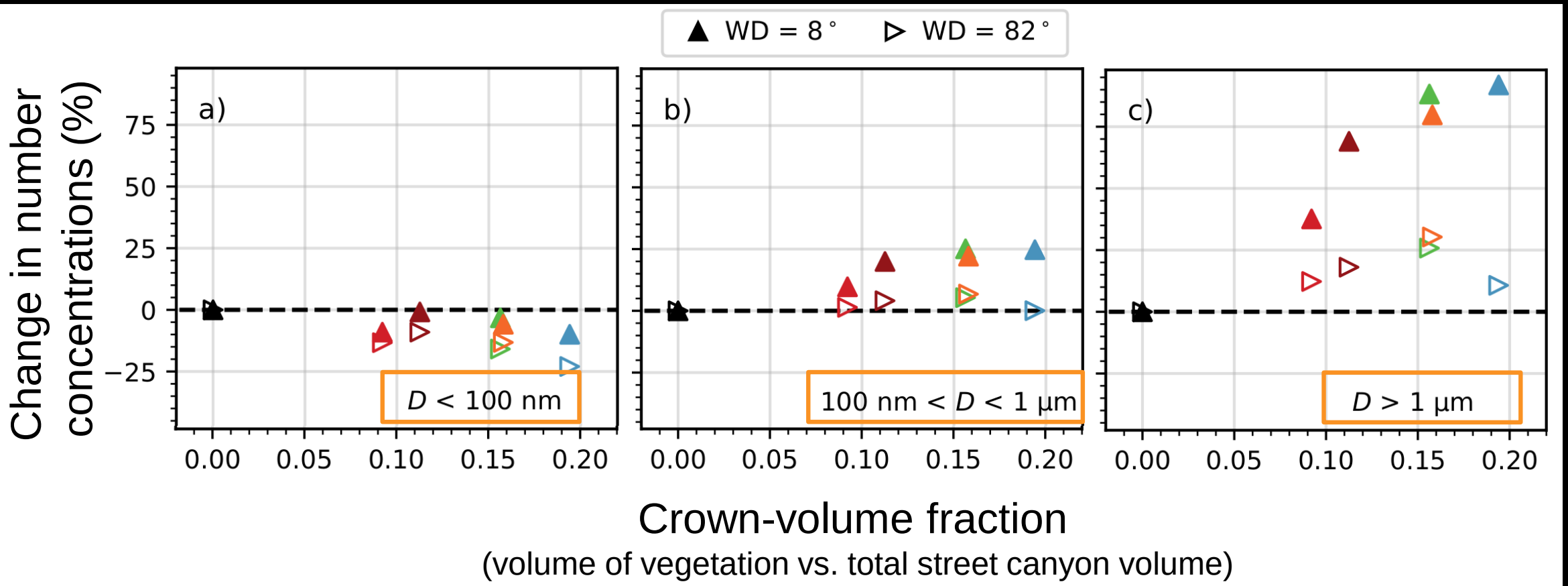


Mass concentration $PM_{2.5}$





Dry deposition on vegetation can be important for the smallest particles



Conclusions

- PALM currently includes an aerosol module
- Aerosol processes are relevant for urban air quality
  - Dry deposition decreases number concentrations by ~ 20 %
  - Condensation grows particles and increases mass by ~10 %
    - Studying the formation of secondary aerosols requires further model development
- Trees inside a street canyon increase air pollutant concentrations
  - Dry deposition can balance the aerodynamic impact for small particles
- Still, correct boundary conditions (flow, background concentrations, emissions) are of major importance for successful simulation

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