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Dispersion of ultrafine particles originated from a medium-large international airport

ETH Nanoparticles 2026

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Ultrafine particles (UFPs)

- Particles smaller than 100 nm
- Emitted from various pollution sources in urban areas
  - ➢ Strong temporal and spatial variation
- Dominate particle number concentration (PNC)
  - But low effect on mass (e.g. $PM_{2.5}$)

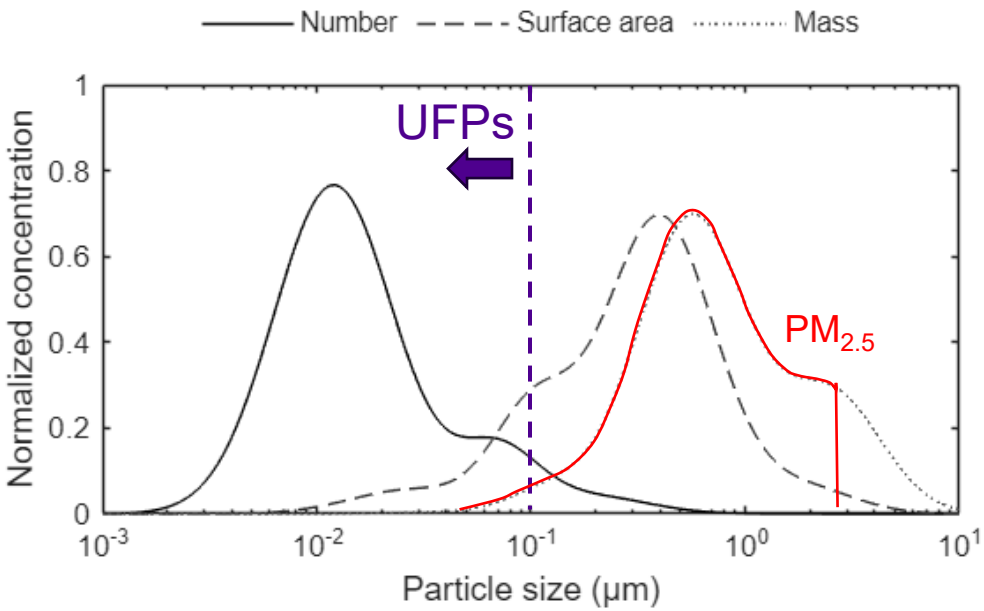
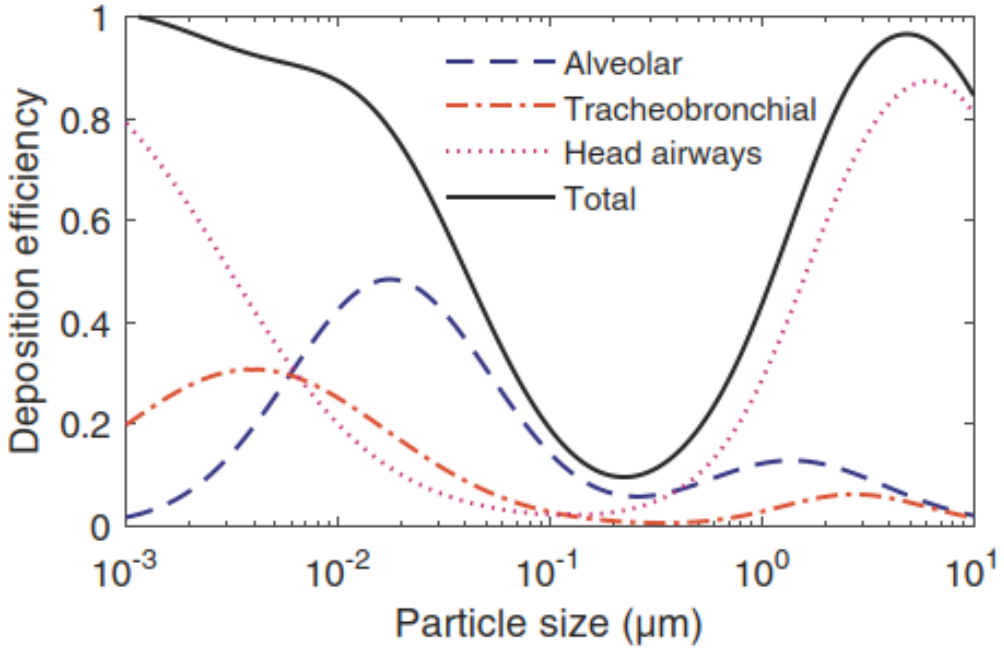


Illustration of a typical particle size distribution in urban air

UFPs and health

ICRP (1994). Human respiratory tract model for radiological protection. Vol. 66. 24.



- Still need for research…, but:
  - UFPs linked to respiratory, pulmonary, neurological effects on health and premature deaths [e.g., 1,2,3]
  - UFPs deposit efficiently in the human respiratory tract

➢ **EU air quality directive: Mandatory measurements of PNC (> 10 nm) near particle pollution hotspots and in supersites**

[1] Vallabani, et al. (2023). Toxicity and health effects of ultrafine particles: Towards an understanding of the relative impacts of different transport modes. Environmental Research, 231.
[2] Mussalo et al. (2025). Traffic-related ultrafine particles influence gene regulation in olfactory mucosa cells altering PI3K/AKT signaling. Environment International, 199.
[3] Hänninen et al. (2025). Health risks related to air pollution by transport categories and vehicle types: Comparison by mortality indicators. Environment International, 202.

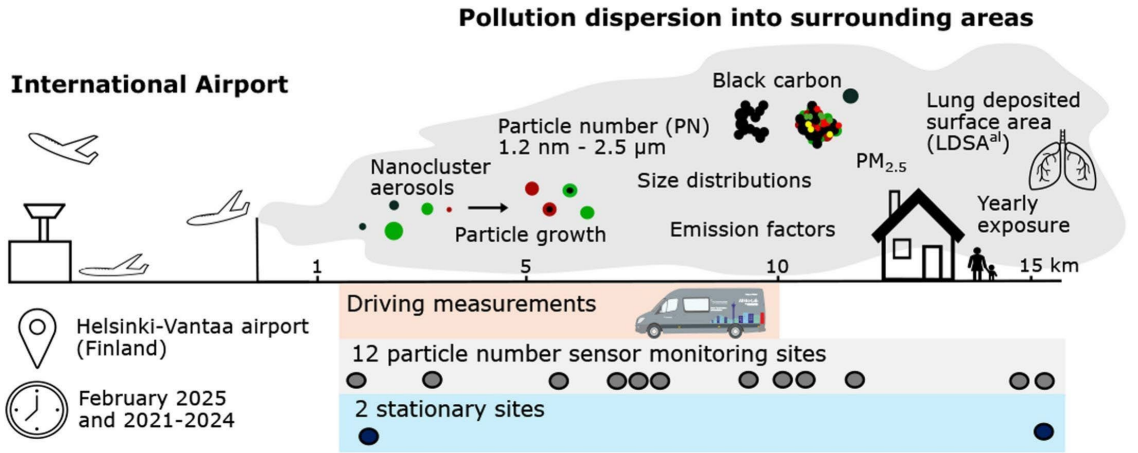
Lepistö et al. (2026). Dispersion of ultrafine particle pollution from an international airport: Characteristics and short- and long-term effects in surrounding areas. Environment International, 208.

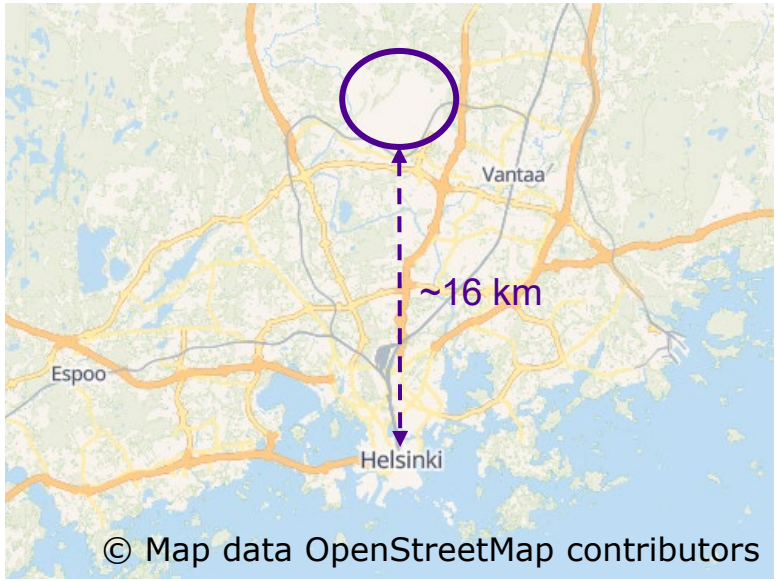
Our study

- Aim: understand the UFP characteristics and dispersion near a medium-large international airport

- Helsinki-Vantaa Airport (Finland)
  - 32nd busiest airport in Europe in 2024 (the number of commercial flights)

- Intensive measurement campaign in February 2025
- Long-term data 2021–2024



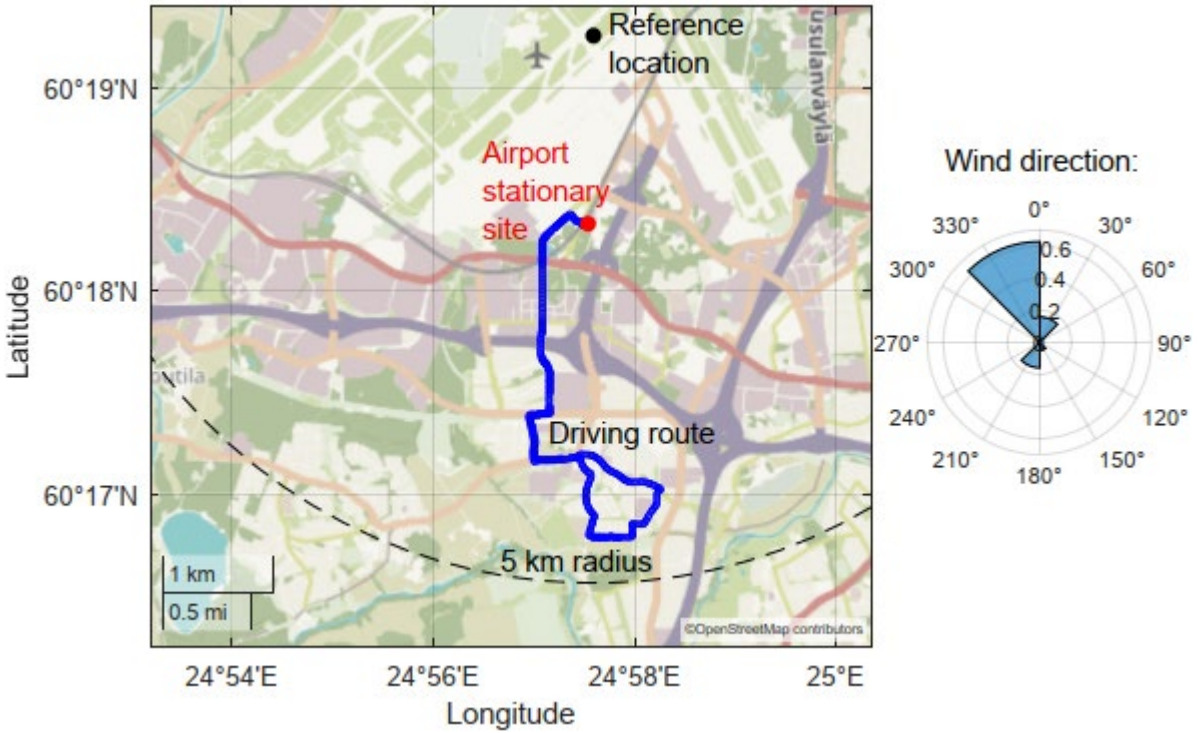


Location of Helsinki-Vantaa airport

Intensive measurement campaign

- Driving measurements with the ATMo-Lab
  - ➢8 driving routes radially outwards to the airport (~1–10 km distance)
- Stationary measurement site
  - Approx. 1.3 km from the nearest runway

Aerosol and Trace gas mobile laboratory (ATMo-Lab)



An example driving measurement route and the location of the stationary site

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CPC: Condensation particle counter (Airmodus, TSI)
ELPI+: Electrical low pressure impactor (Dekati)
AE33: Aethalometer (Magee Scientific)
nCNC: Nano condensation nucleus counter (Airmodus)
PSM: Particle size magnifier (Airmodus)
SMPS: Scanning mobility particle sizer (TSI)

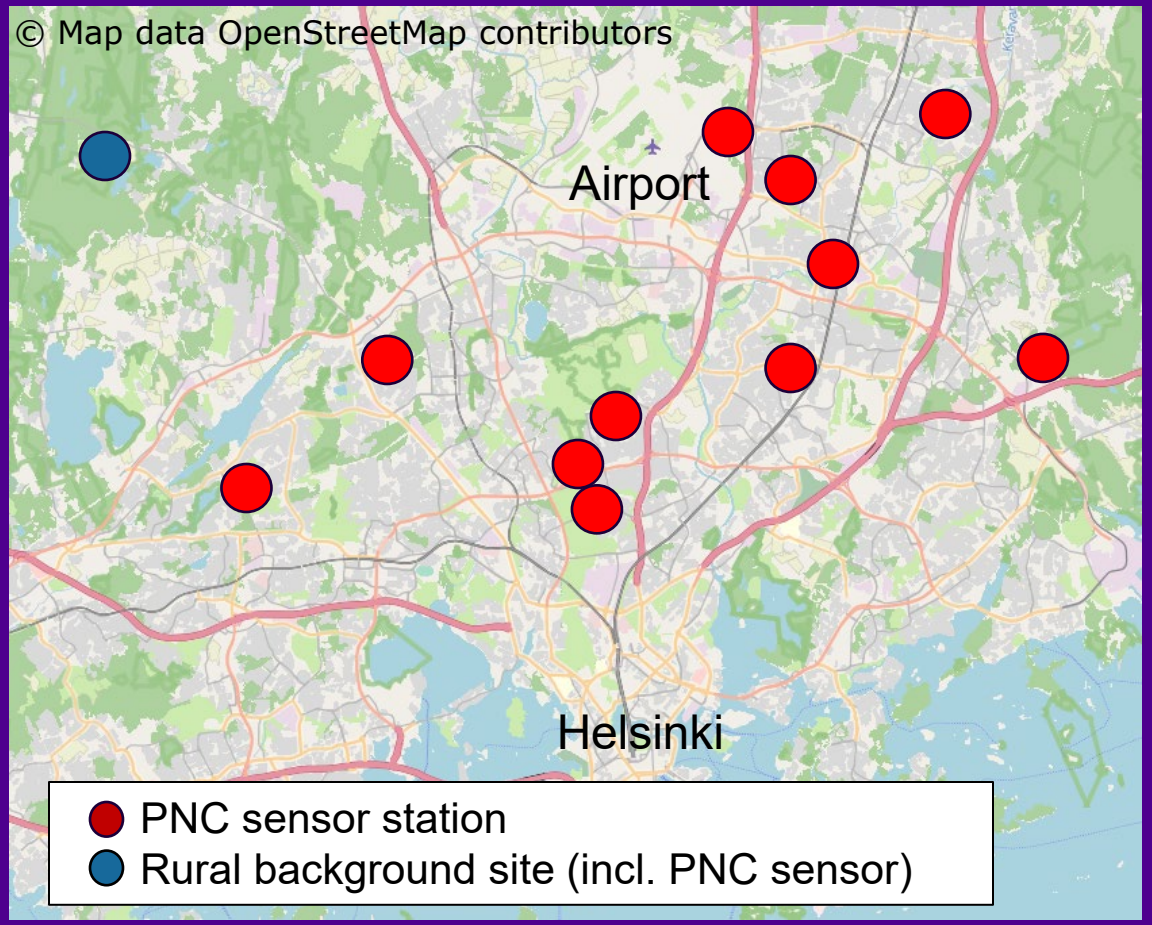
Instruments

- **ATMo-Lab:**
  - 4 CPCs: $PNC_{> 2.5\ nm}$, $PNC_{> 4\ nm}$, $PNC_{> 10\ nm}$, $PNC_{> 23\ nm}$
  - ELPI+: Particle number size distributions, $PM_{2.5}$, lung deposited surface area ($LDSA^{al}$)
  - AE33: Black carbon (BC)
  - Partector 2 Pro: Indicative PNC, $LDSA^{al}$, size distributions
  - LI-COR LI-840A: CO_2

- **Stationary site:**
  - CPC: $PNC_{> 10\ nm}$
  - A12 nCNC (incl. PSM 2.0): Size distributions 1–12 nm, $PNC_{> 1.2\ nm}$
  - SMPS and ELPI+: Particle number size distributions
  - LI-COR LI-850A: CO_2, Emission factors

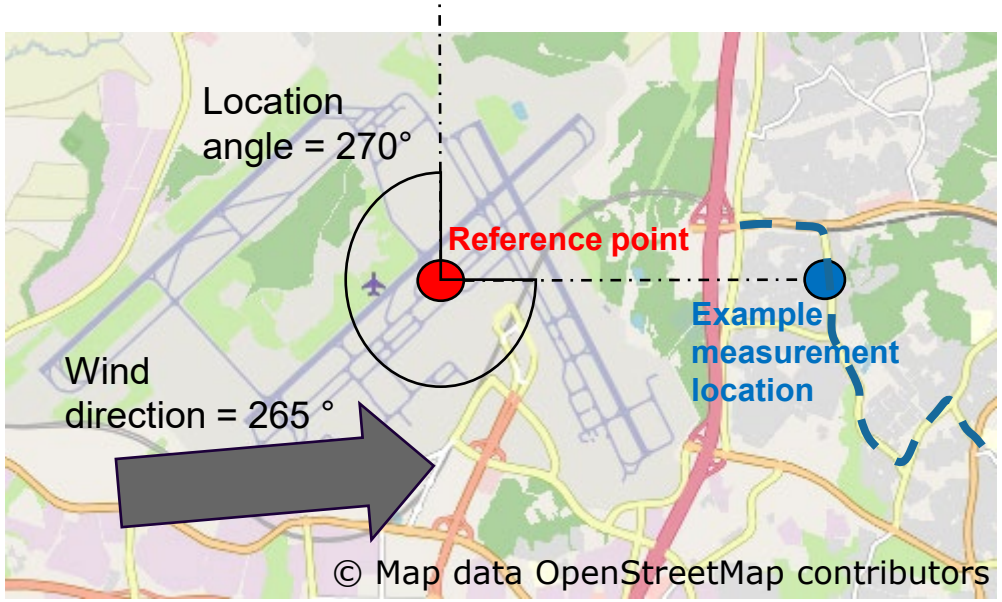
Long-term data

- Rural background site
  - 15 km west from the airport
  - Data 2022-2024
  - PNC, $PM_{2.5}$, size distribution, BC, NO_x, SO_2…
- 12 PNC sensor monitoring sites
  - 0.7–15 km from the airport
  - Data 2021–2024
    - At least 1 year of data from each location
  - Pegasor AQ Urban



Chosen approaches (mobile laboratory)

- Airport covers a large area
  - ➢ Need to choose a reference point
  - ➢ **Reference point**: The location which resulted in highest median PNC in all driving routes together (downwind)



Example of a downwind measurement during driving measurements (difference between wind direction and location 5°)

- To categorize wind direction:
  - ➢ Compare the angle between wind direction and the measurement location (with respect to the reference location)
    - **Downwind**: Difference between wind and location < 10°
    - **Partial wind**: Difference 10-25°
    - **Other wind**: Difference > 25°

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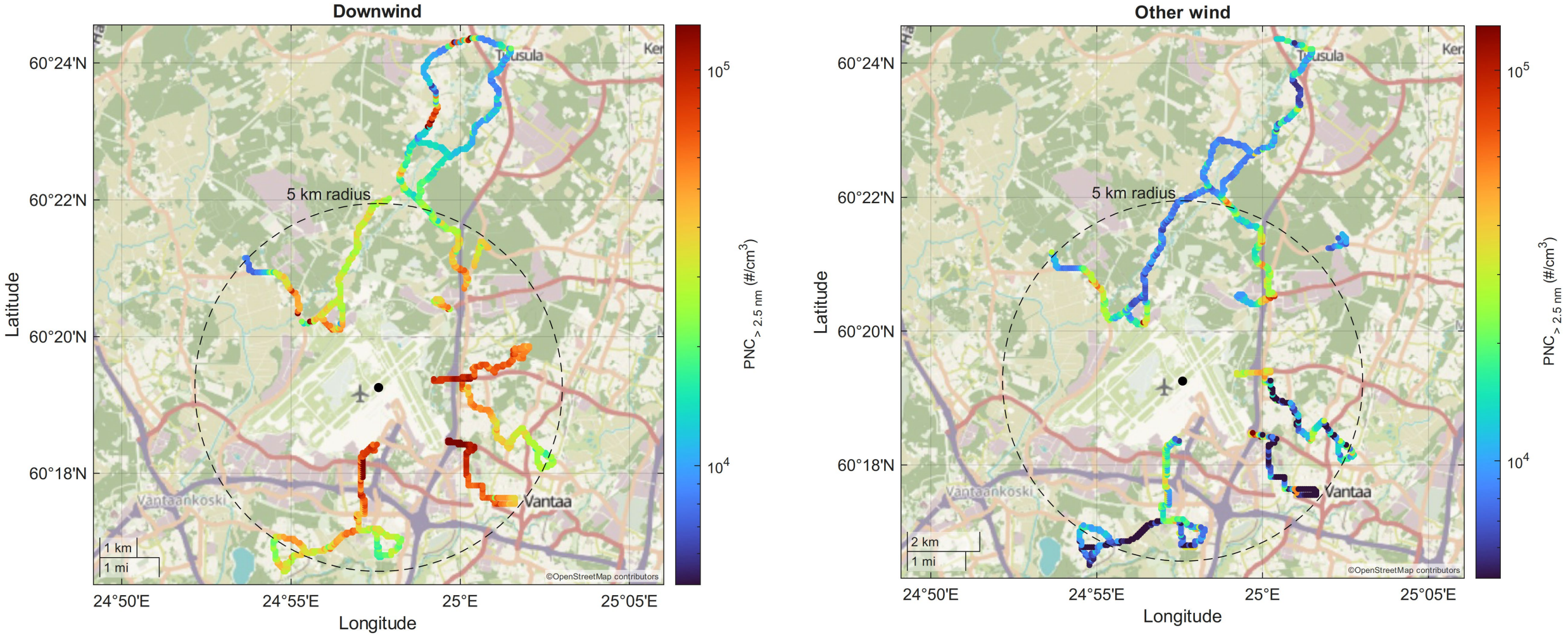
Median $PNC_{> 2.5\ nm}$ measured on the driving routes



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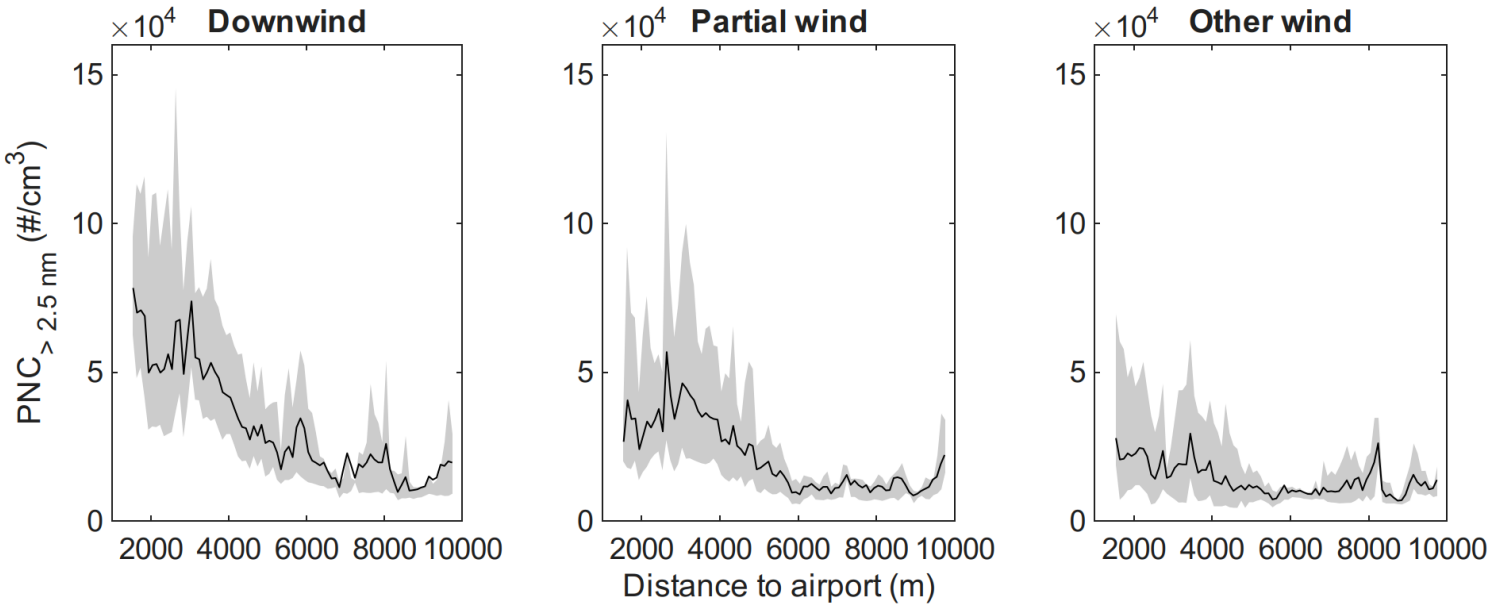
Ultrafine particle dispersion

Downwind:
Clear exponential trend observable (airport)

Other wind:
Contribution of road traffic



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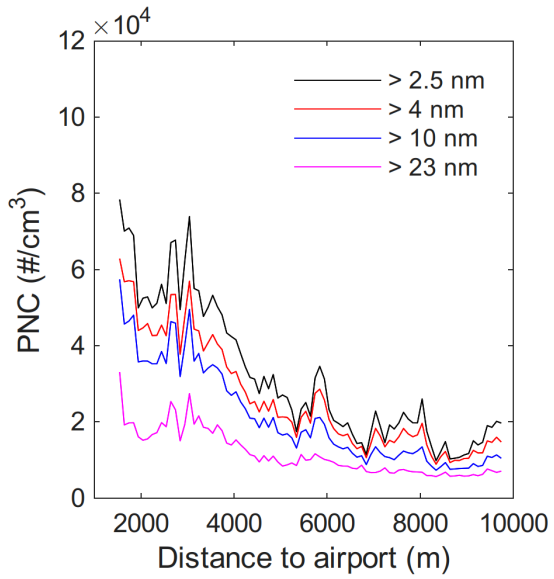
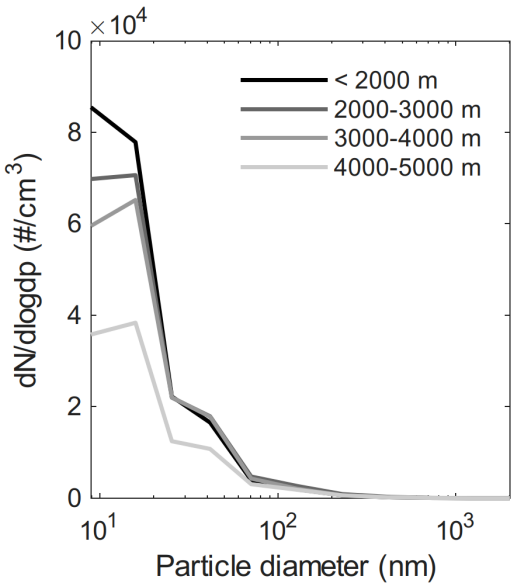
Ultrafine particle dispersion

Downwind:





- Effect of airport seen especially with particles smaller than 23 nm
  - Minimal effect on BC or $PM_{2.5}$
- $PNC_{> 10\ nm}$ exceeded 20 000 #/cm^3 at 4.4 km distance (WHO's definition for high short-term concentration)

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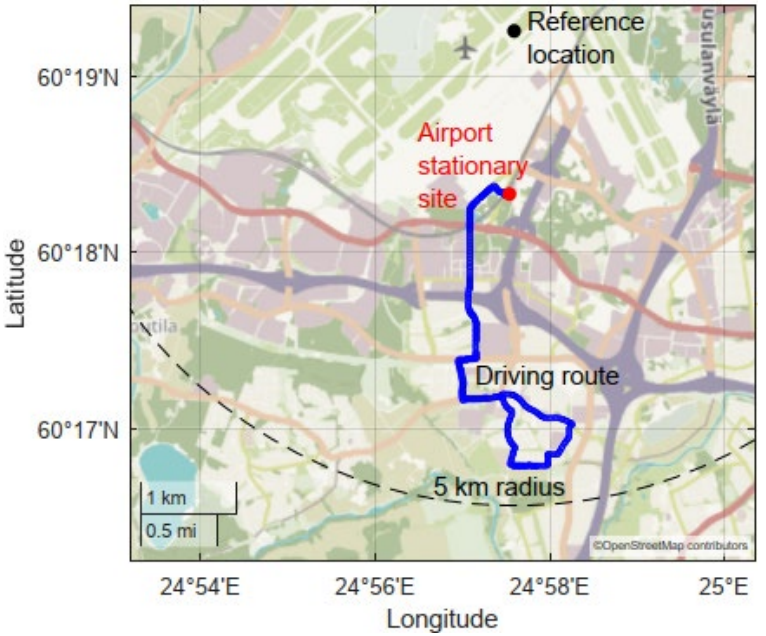
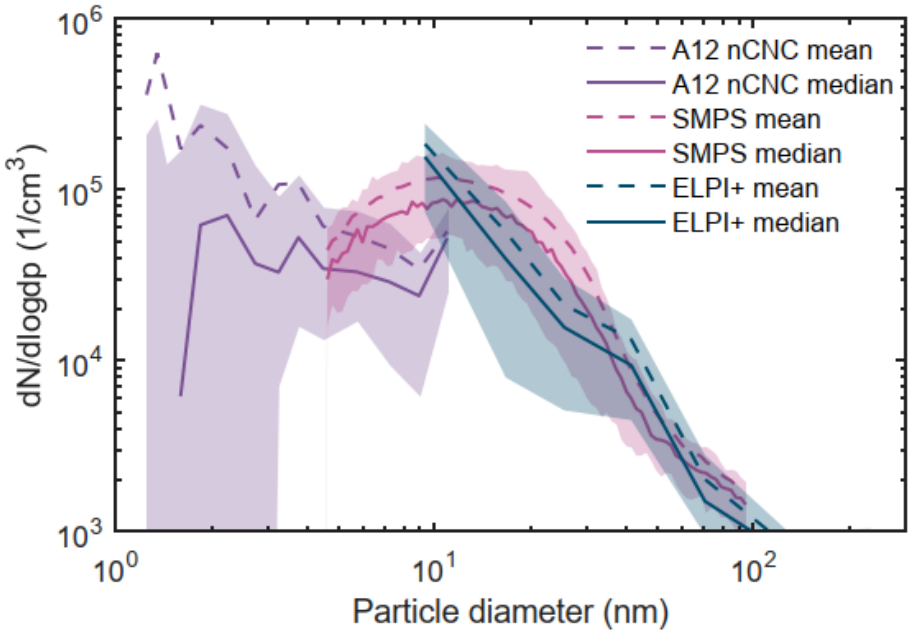
Stationary site: Size distribution during airport wind





- A12 measurement with retrofitted PSM 2.0 + SMPS and ELPI+ data

➢ Geometric mean diameter ~ 10 nm
➢ Effects of airport extend down to size of nanocluster aerosols (< 3 nm)

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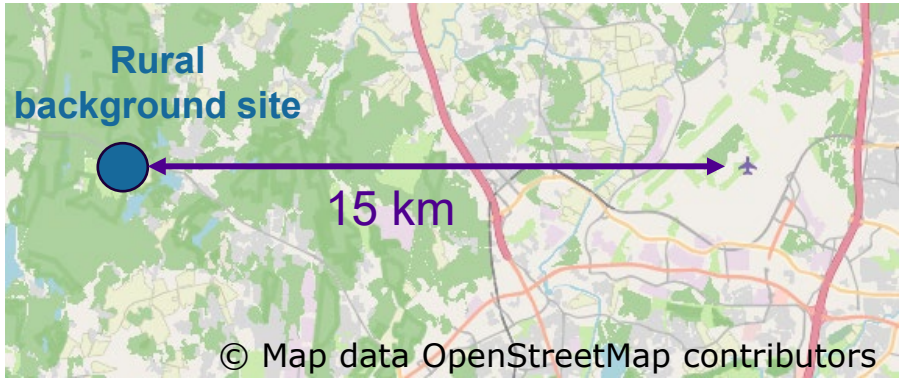
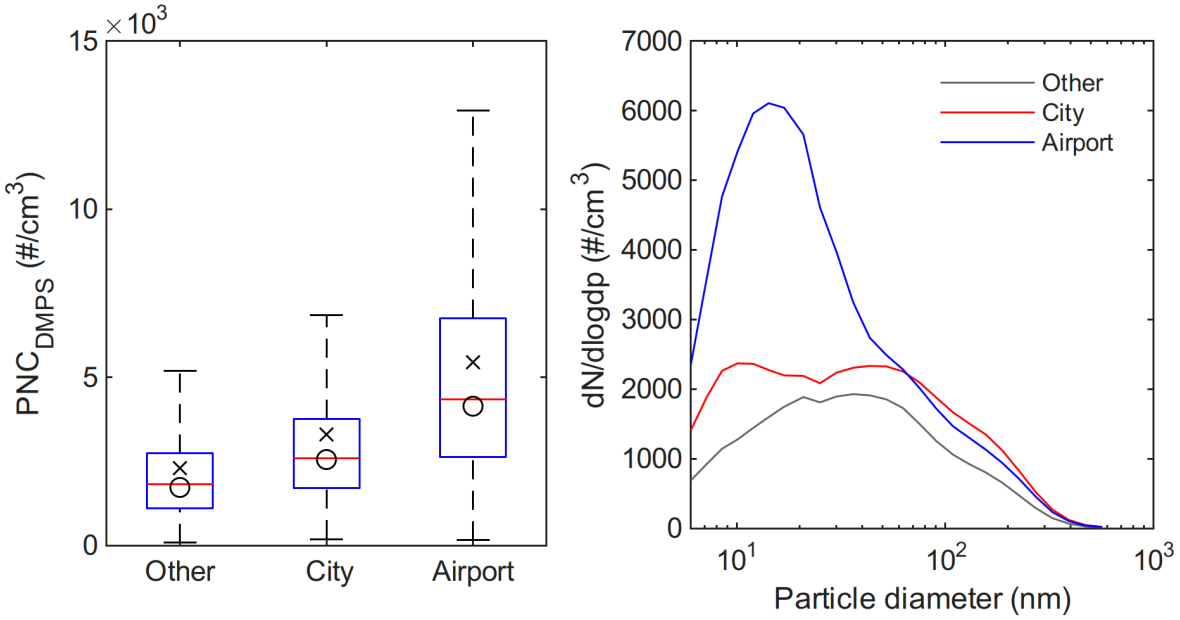
Long-term data

Rural background site





- Effects of airport observable even 15 km away from the airport
- Still, small average size (< 20 nm)

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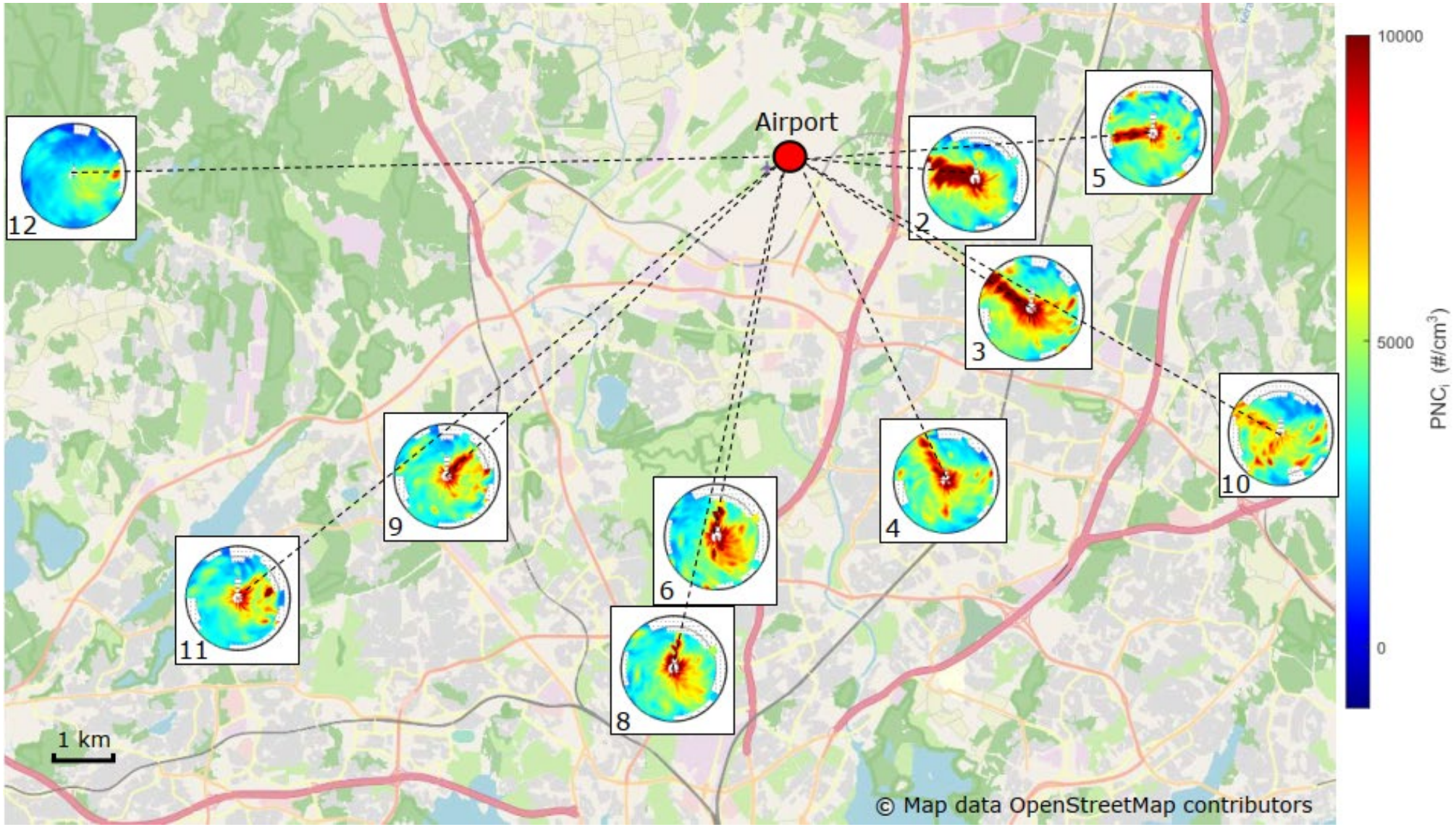
PNC sensor network



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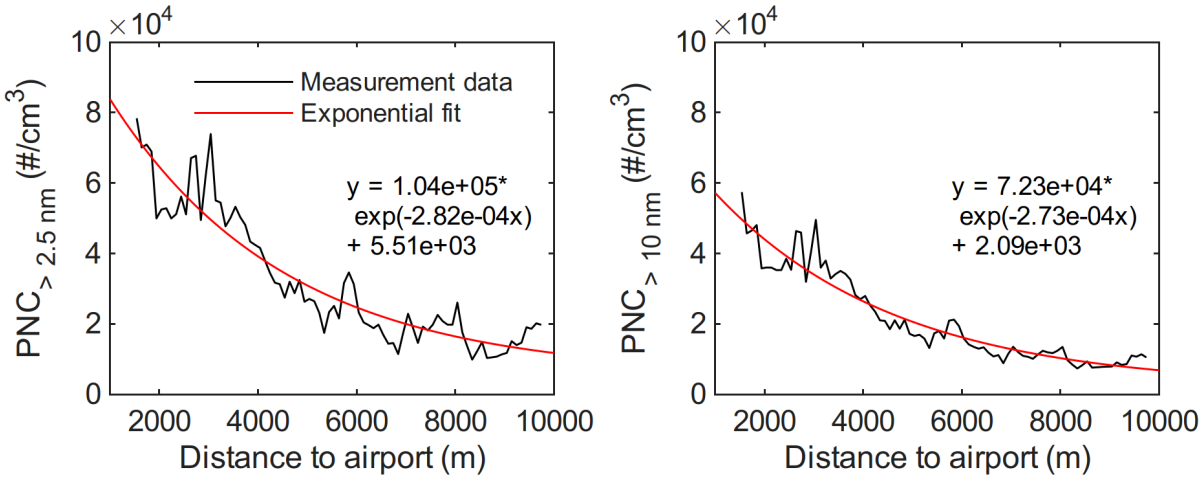
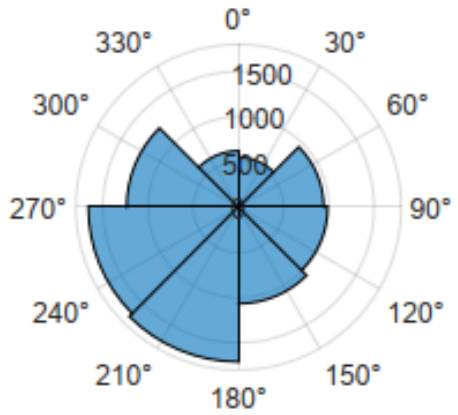
Estimation of yearly concentration increase due to the airport

Exponential fits based on the downwind measurements



Long term wind data measured at the airport



= Indicative estimation of the effects of airport on the yearly averaged concentrations in the surrounding areas

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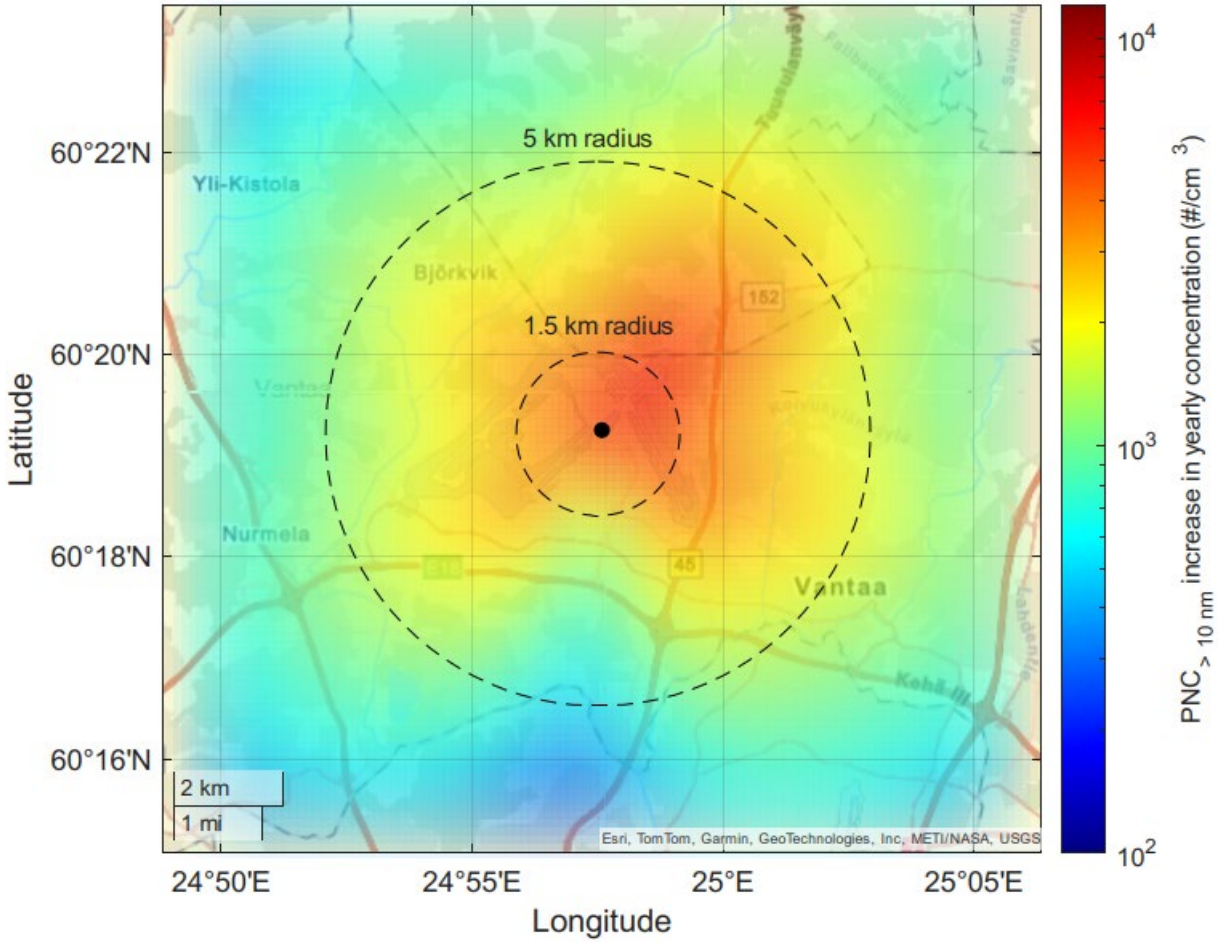
Contribution to yearly averaged PNC



- Yearly contribution ~2 000–3 000 #/cm^3 to $PNC_{>10\ nm}$ at 5 km away (prevailing wind)
  - Roughly 30–50 % of typical urban background concentrations in Helsinki

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Summary

- Airports are major sources of ultrafine particles (but not BC or $PM_{2.5}$)
  - ➢ Downwind $PN_{>10\ nm}$ exceeded WHO's high concentration "limit" at 4.4 km distance
  - ➢ Effects observable over 15 km
  - ➢ Under prevailing wind: Significant effect on yearly PNC at 5 km distance

- Something to consider:
  - Helsinki-Vantaa only the 32nd busiest airport in Europe in 2024
  - Global trends of increasing aviation and urbanisation

➢ Need for regulatory actions to reduce UFP pollution from airports

➢ Airports should not be forgotten when considering the pollution hotspot measurements required by the EU

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Collaborators:

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Questions?

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