# Investigation of UFP-Distributions with Stationary and Mobile Measurements at the Düsseldorf Airport

**Laboratory for Environmental Measurement Techniques**
**Düsseldorf University of Applied Sciences**

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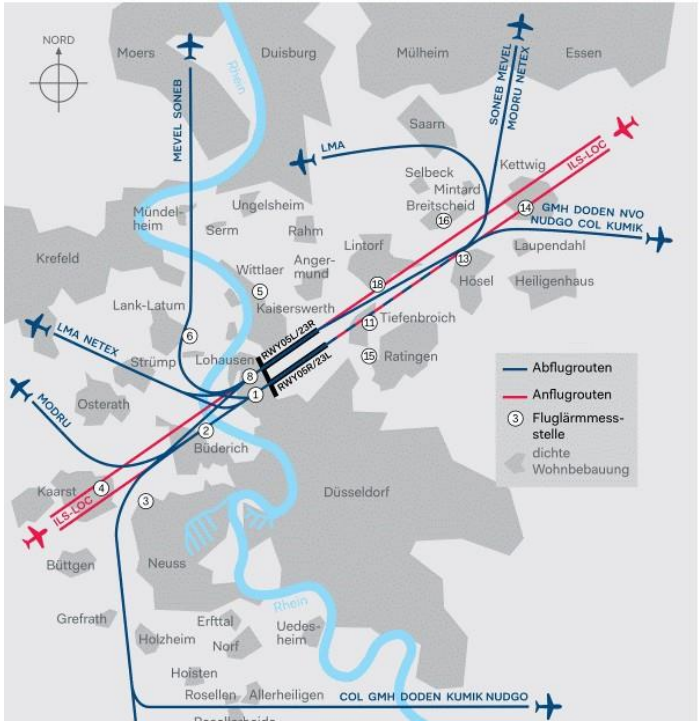
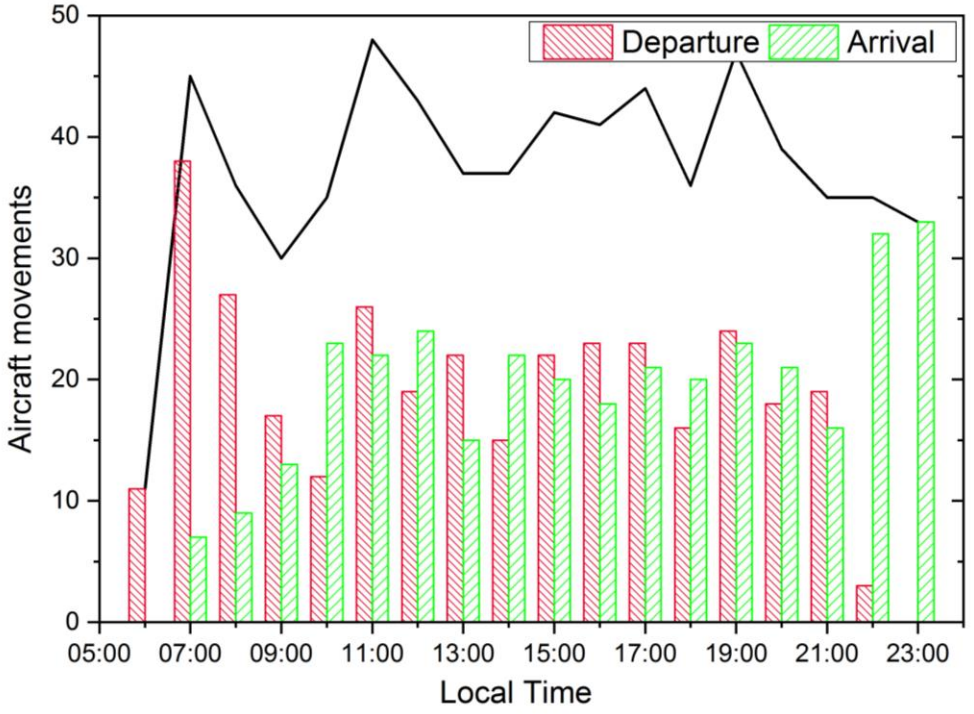
# Scope

- Study-design
- Intercomparison measurements at Mülheim Styrum measurement station
- Düsseldorf Airport location
- Results of the mobile investigations
- Results of the stationary measurements
- Conclusion

# Düsseldorf Airport DUS - Runway system and daily aircraft movements

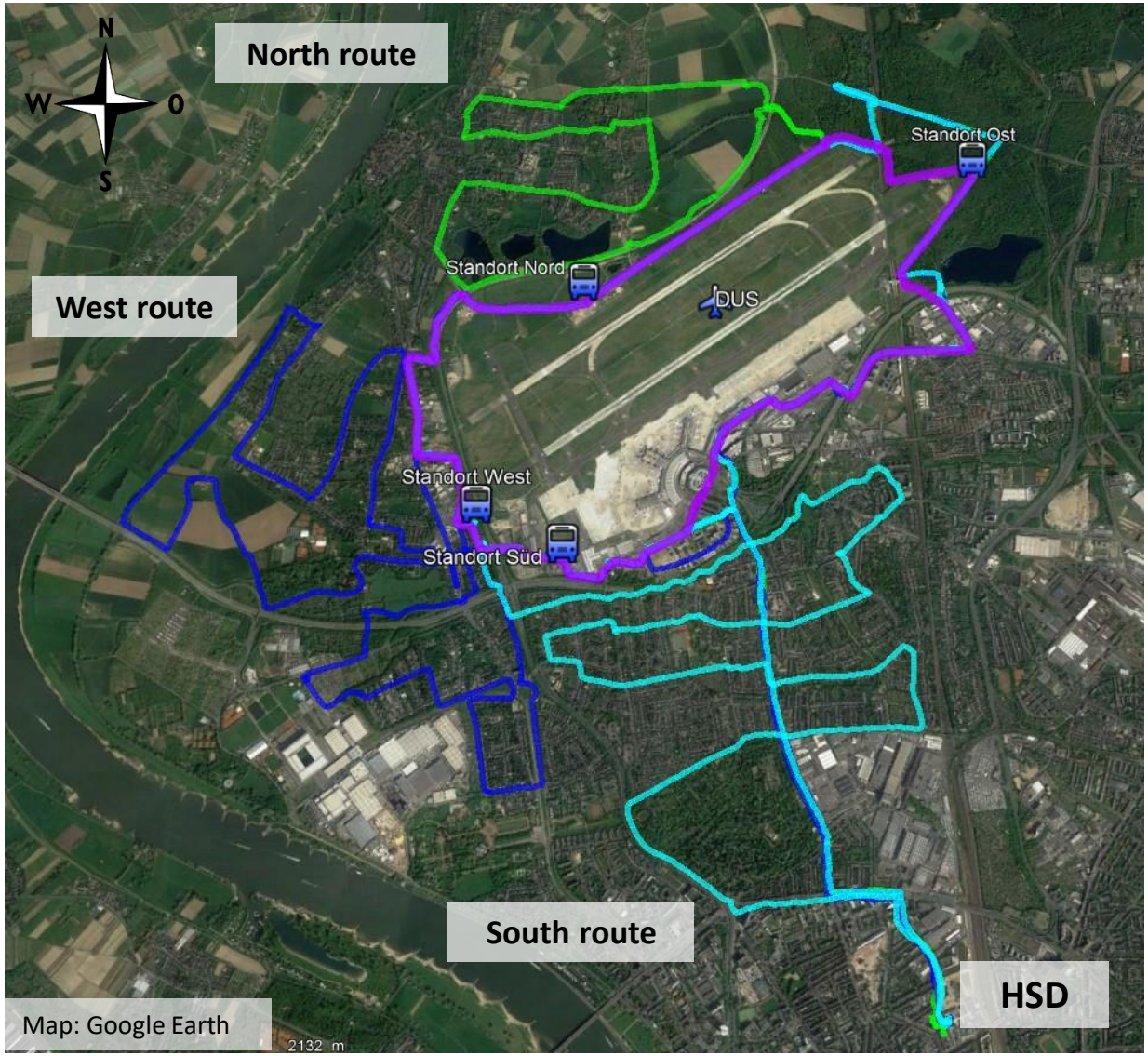



Source: Düsseldorf Airport

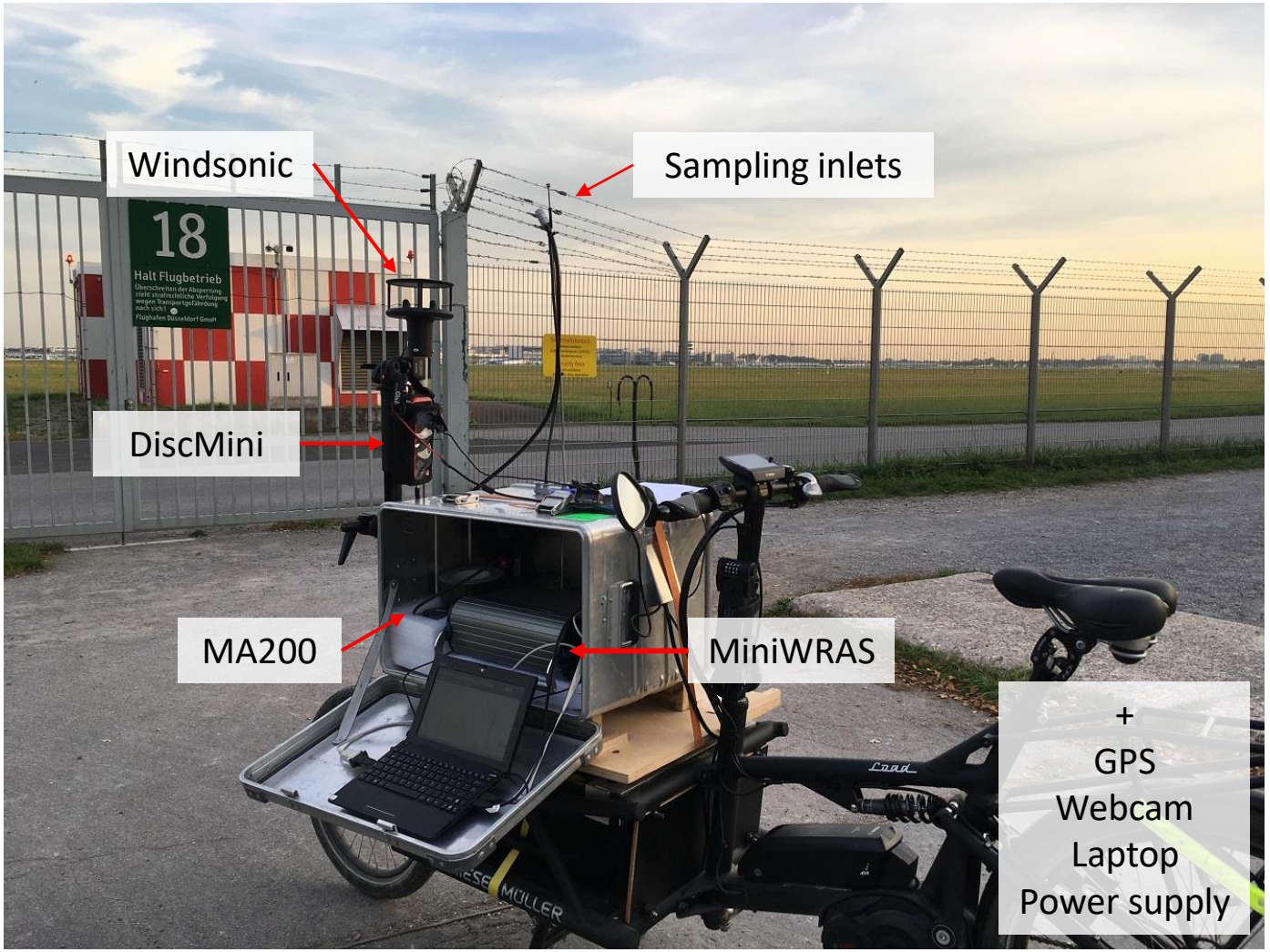


# Locations of the stationary measurements

- **Cycling-Routes for mobile investigation**



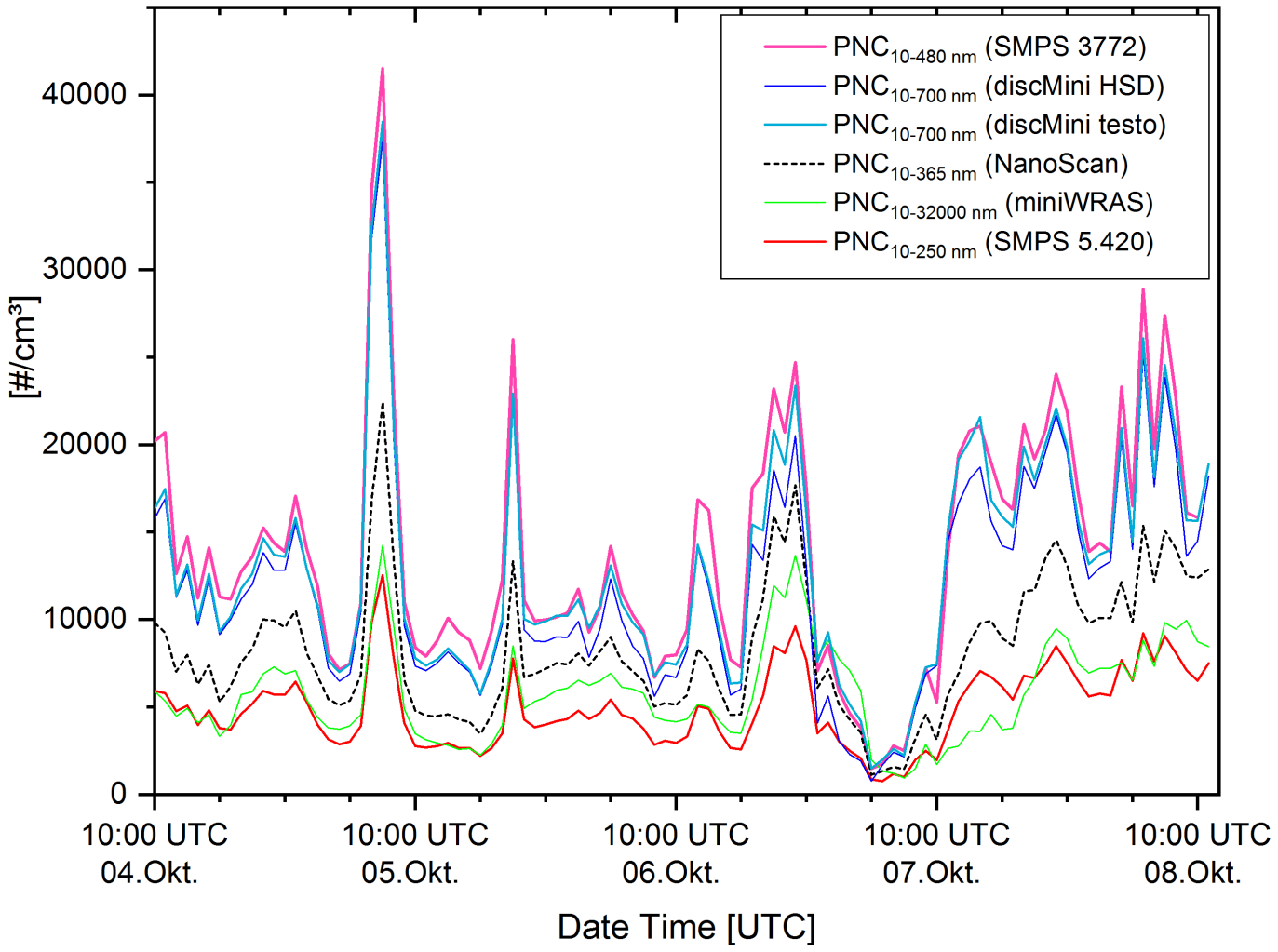
- **Equipped measurement bike**



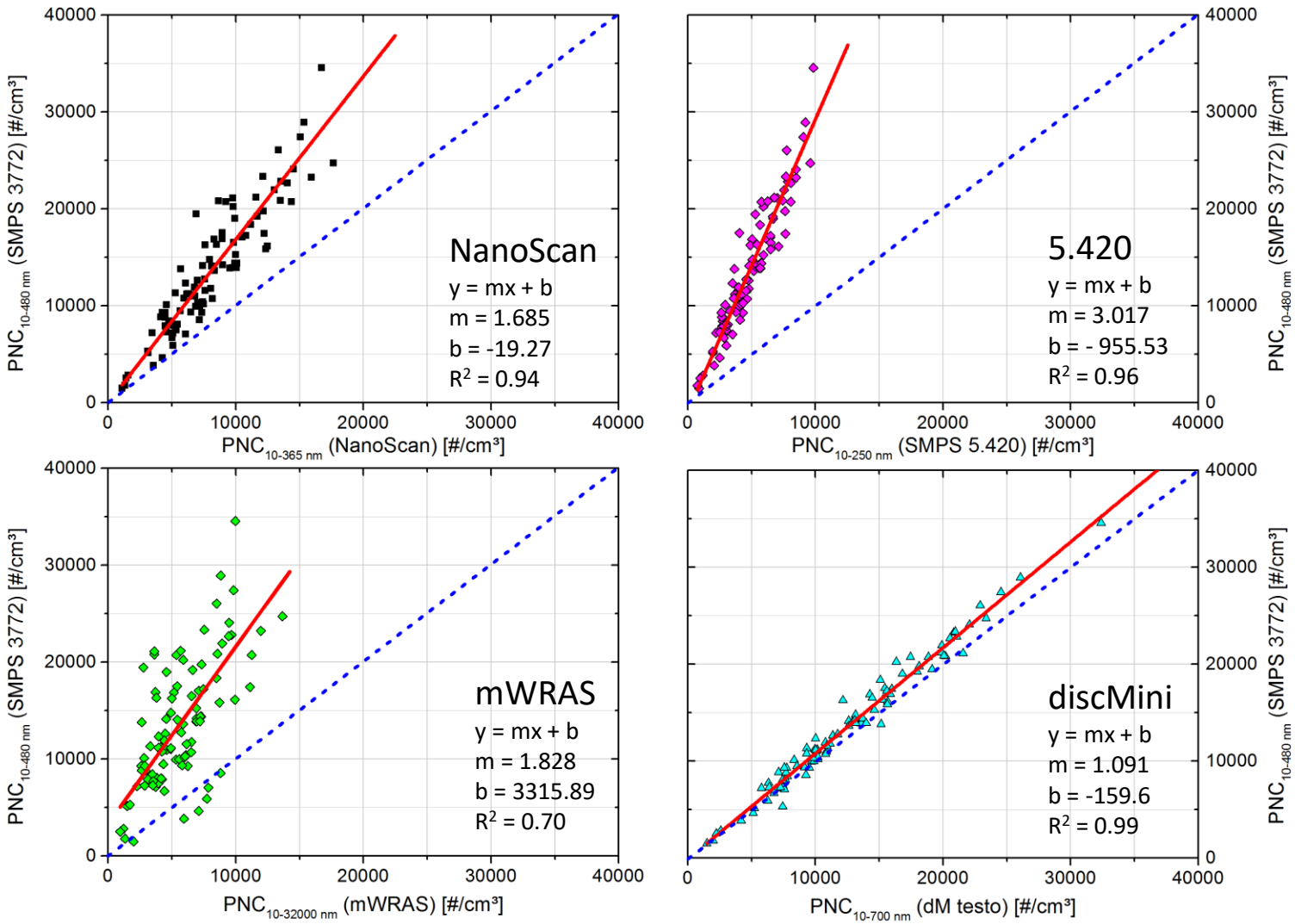
## Comparative measurements in Mülheim Styrum

- From 22.Oct. till 29.Oct.2018
- Comparison between SMPS+C (Durag/Grimm), miniWRAS (Durag/Grimm), NanoScan (TSI), 2 x DiscMini (Testo/HSD) and SMPS (TSI) operated by LANUV/IUTA e.V.

- **Results of the comparative measurements**



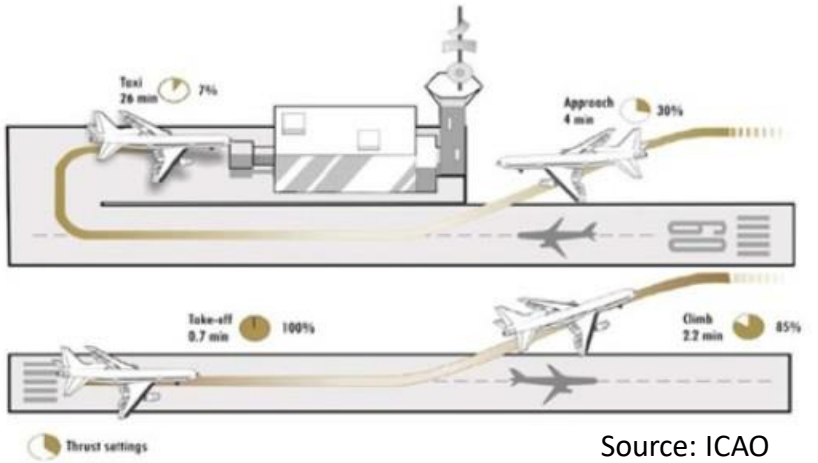
# Regression Analysis



# Different air-pollution sources at the airport

- Landing- Take-Off (LTO) by International Civil Aviation Organization (ICAO)

**Taxi:**
**26 min; 7 % Thrust**




**Approach:**
**4 min; 30 % Thrust**

**Take-off:**
**0.7 min; 100 % Thrust**

**Climb:**
**2.2 min; 85 % Thrust**

Source: ICAO

Additional sources:

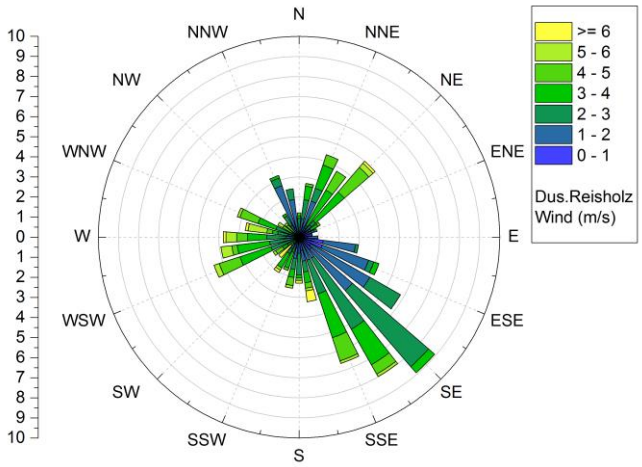
- Auxiliary power units (APU) and ground power units (GPU) for maintenence of the on-board systems during standby
- Groundhandling (supply vehicles, buses for the transport of passengers)

In the area of the airport:

- Road traffic (arrival and departure, buses, highway access)
- Supply vehicles and kerosene gas station

# Overview mobile measurements

| Date | Time | Route | Winddirection | | Windspeed | Status | Aircraft movements |
|---|---|---|---|---|---|---|---|
| | UTC | | | [°N] | [m/s] | | (Departure / Arrival) |
| 09.10.2018 | 15:00 | DUS | ENE | 60 | 0,7 | West | |
| 12.10.2018 | 12:30 | DUS + North route | S | 177 | 4,3 | West | 172 (89 / 83) |
| 17.10.2018 | 15:20 | DUS + South route | NNW | 334 | 1,5 | West | 148 (75 / 73) |
| 18.10.2018 | 12:00 | DUS + South route | NNE | 27 | 3,4 | East | 137 (70 / 67) |
| 19.10.2018 | 07:20 | DUS + West route | NNE | 26 | 1,4 | East | 161 (77 / 84) |
| 20.10.2018 | 12:30 | DUS + South route | N | 13 | 1,9 | East | 113 (59 / 54) |
| 21.10.2018 | 08:30 | DUS + North route | SSE | 154 | 1,9 | West | 112 (61 / 51) |
| 29.10.2018 | 04:00 | DUS + West route | NNE | 24 | 3,4 | East | 113 (84 / 29) |
| 31.10.2018 | 07:00 | DUS + North route | SE | 144 | 3,3 | West | 123 (57 / 66) |

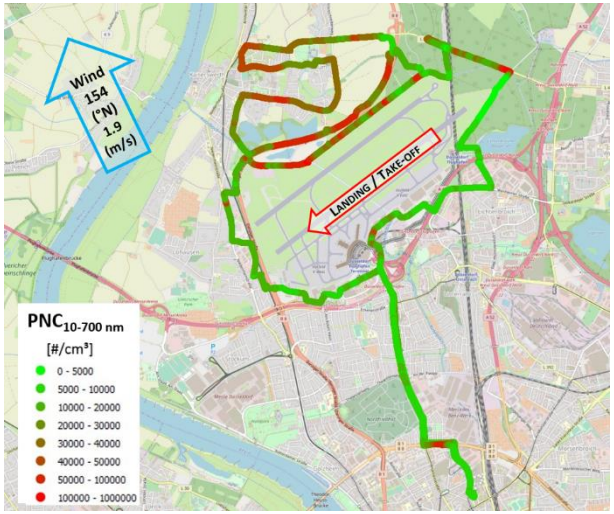


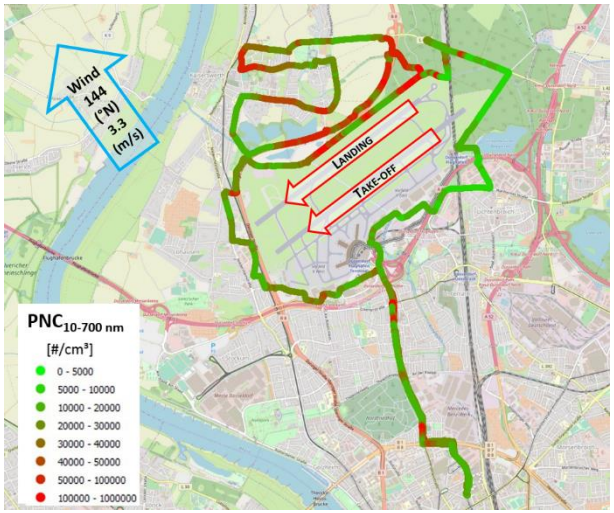
# North routes - overview

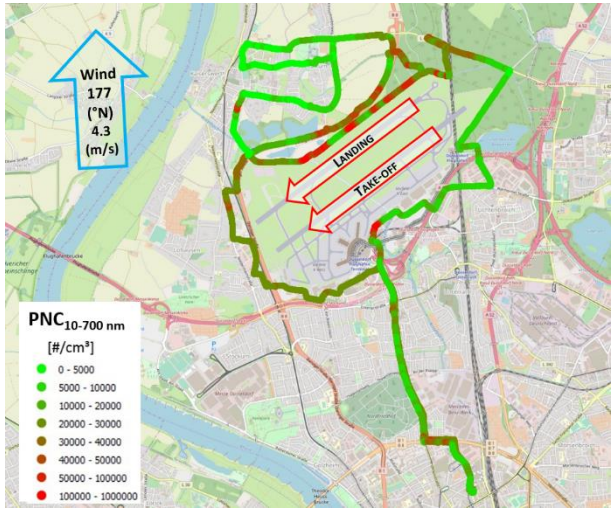
Sun. 21.Oct.
154 °N - 1.9 m/s
112 (61 - 51)

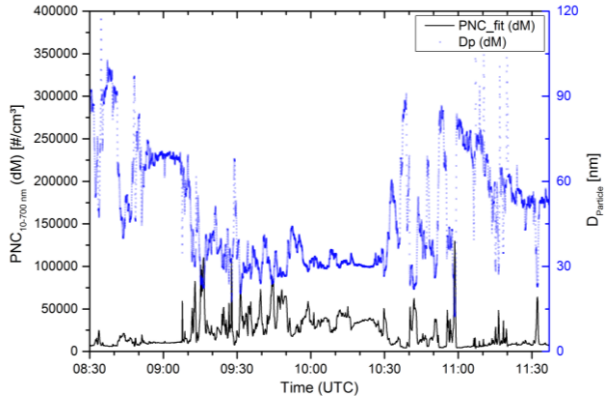
Wed. 31.Oct.
144 °N - 3.3 m/s
123 (57 - 66)

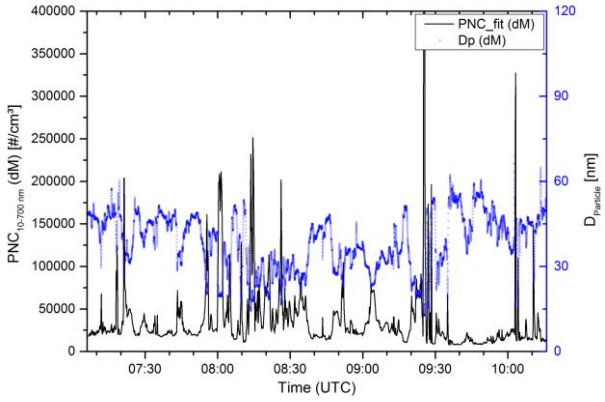
Fri. 12.Oct.
177 °N - 4.3 m/s
172 (89 - 83)

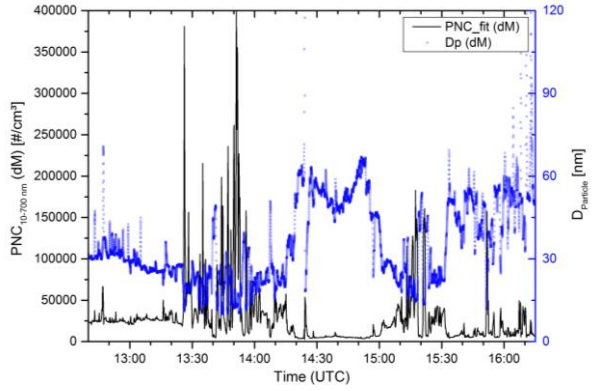


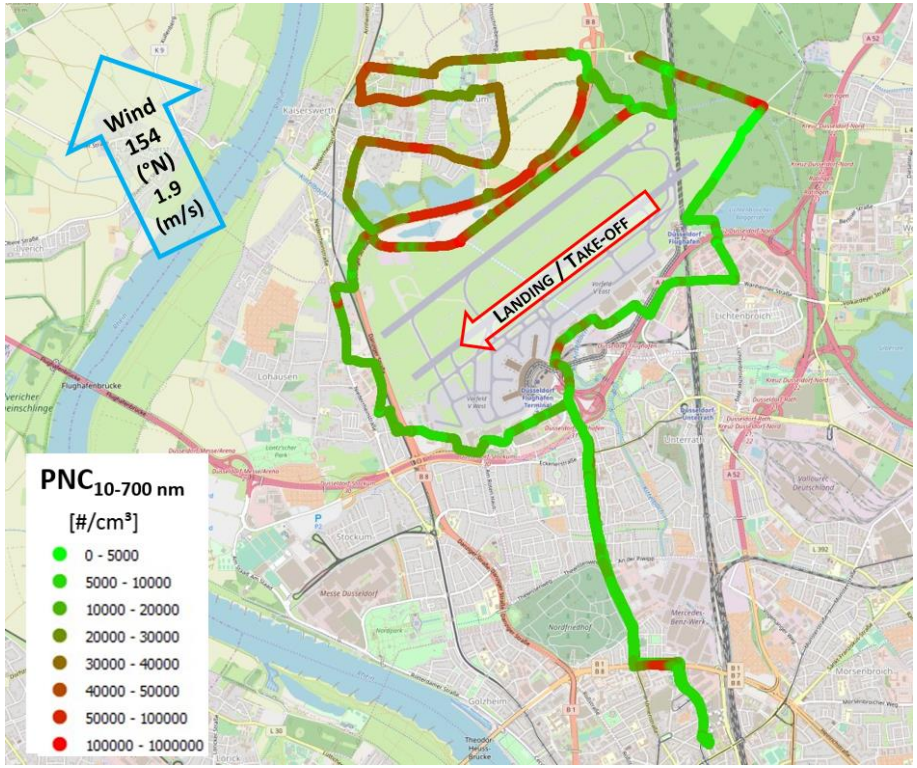



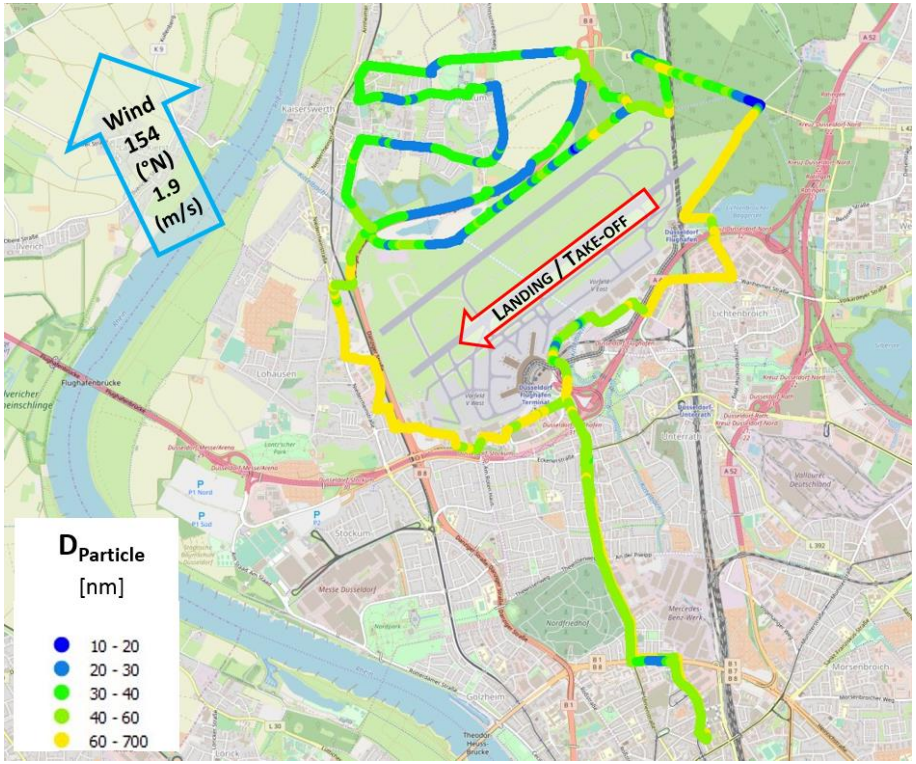



- **North route - particle number concentration and avarage particle diameter**

Sun. 21.Oct.
154 °N - 1.9 m/s
112 (61 - 51)



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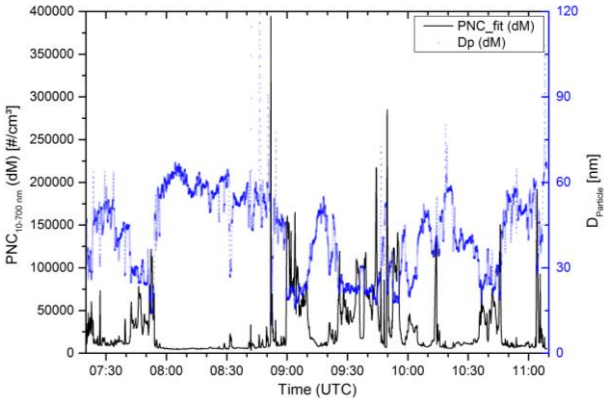
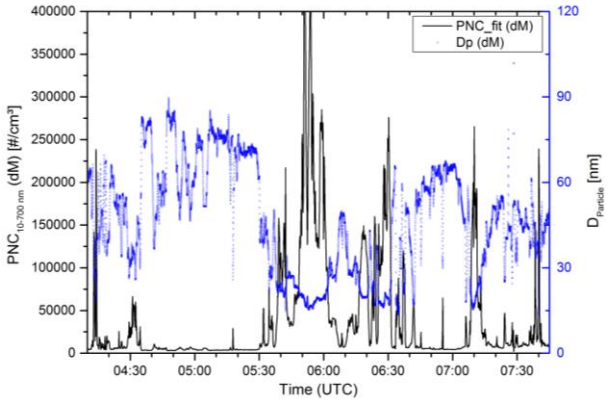
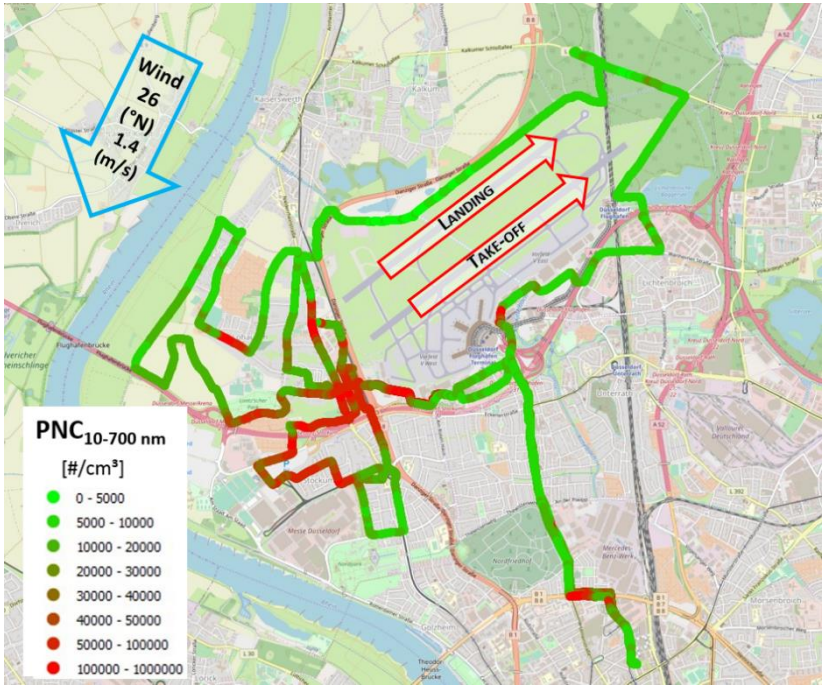
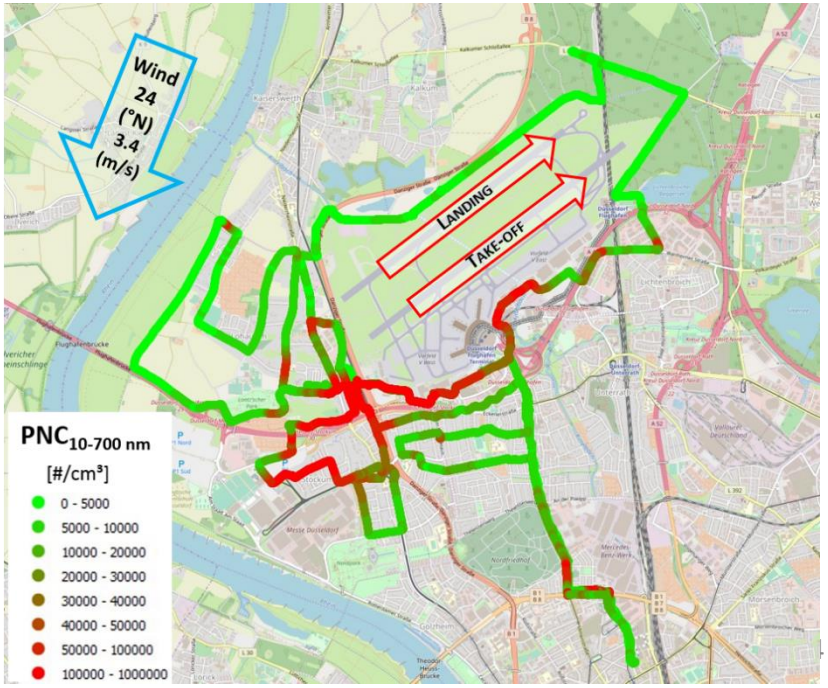
Fri. 19.Oct.
26 °N - 1.4 m/s
161 (77 - 84)




Mon. 29.Oct.
24 °N - 3.4 m/s
113 (84 - 29)



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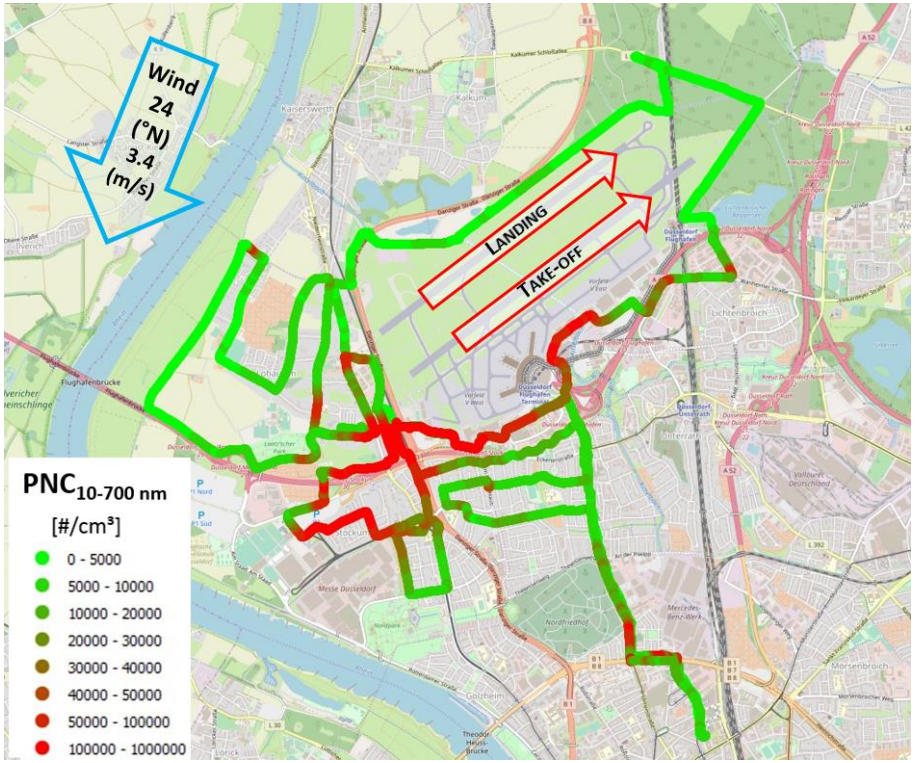
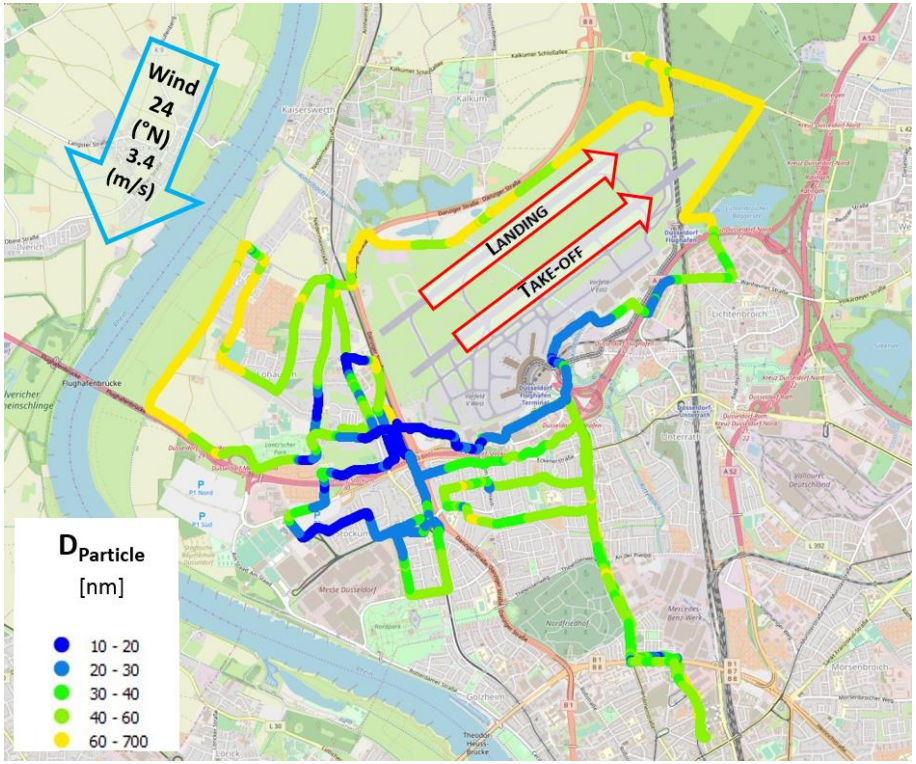


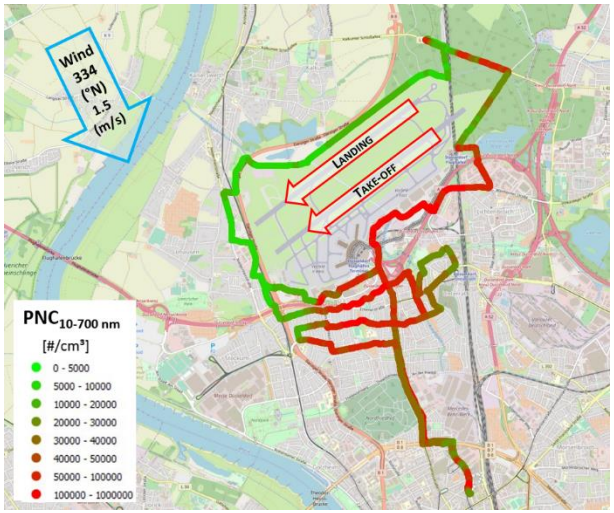



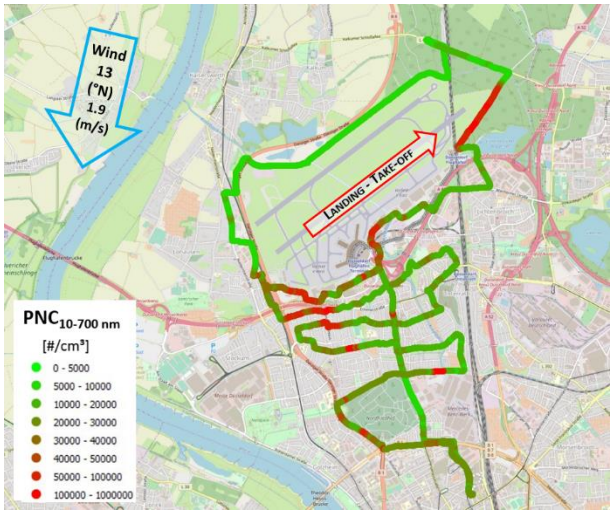
# South routes - overview

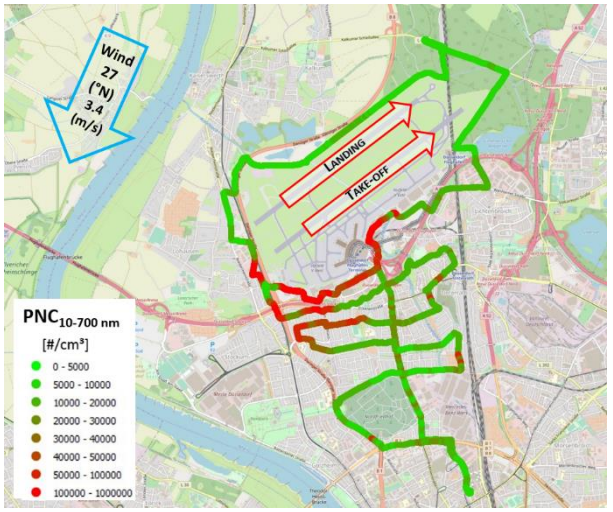
Wed. 17.Oct.
334 °N - 1.5 m/s
148 (75 - 73)

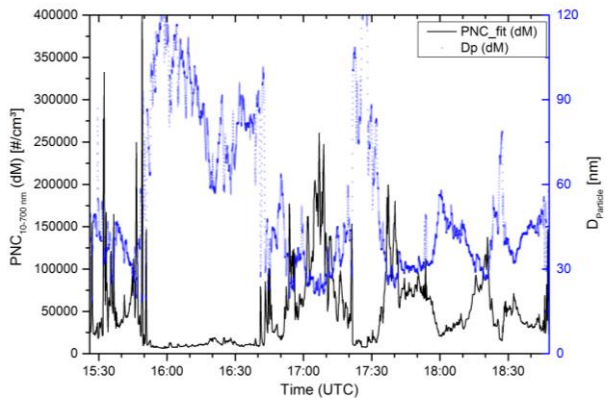
Sat. 20.Oct.
13 °N - 1.9 m/s
113 (59 - 54)

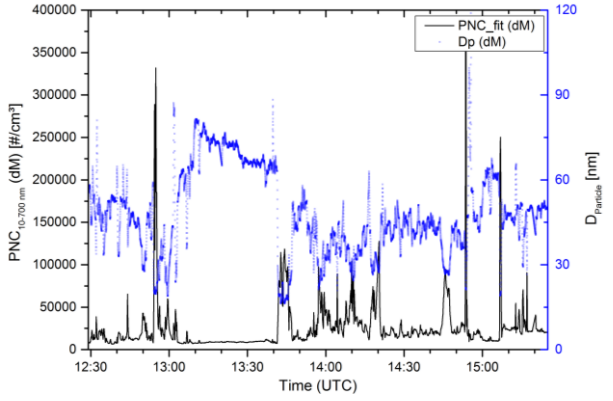
Thu. 18.Oct.
27 °N - 3.4 m/s
137 (70 - 67)

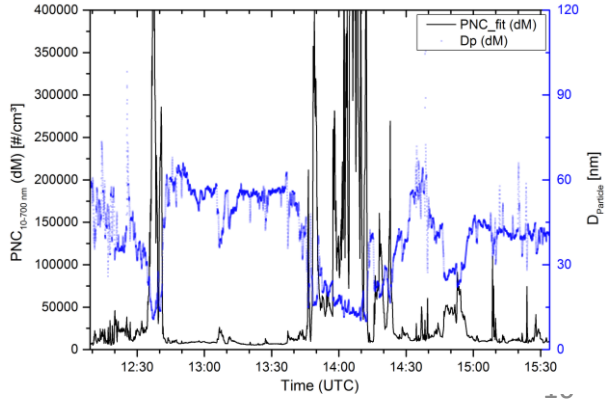


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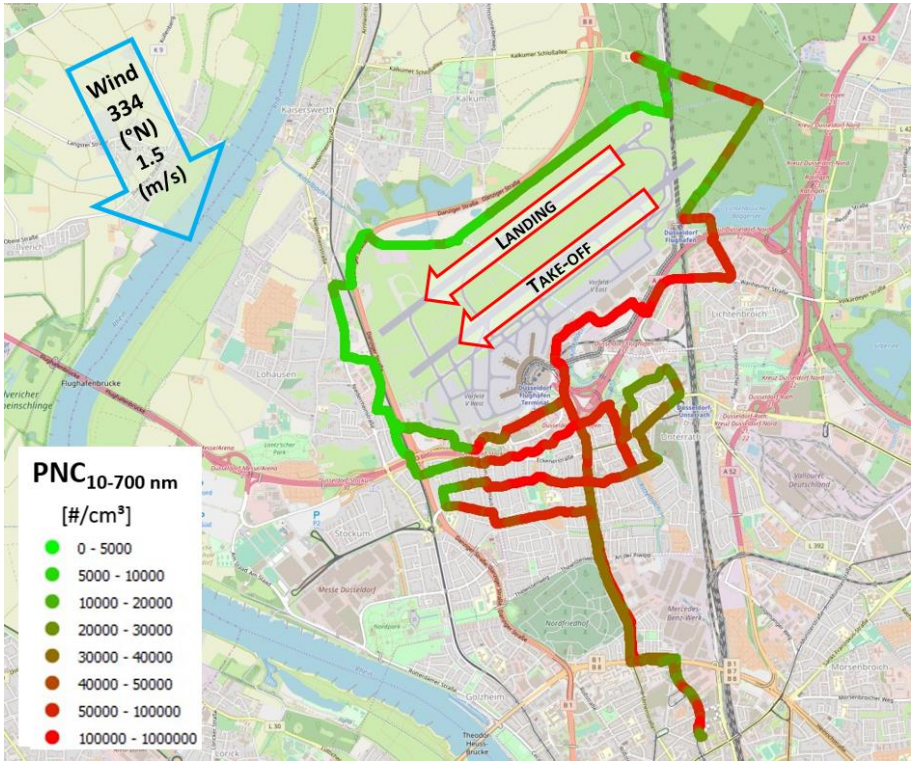
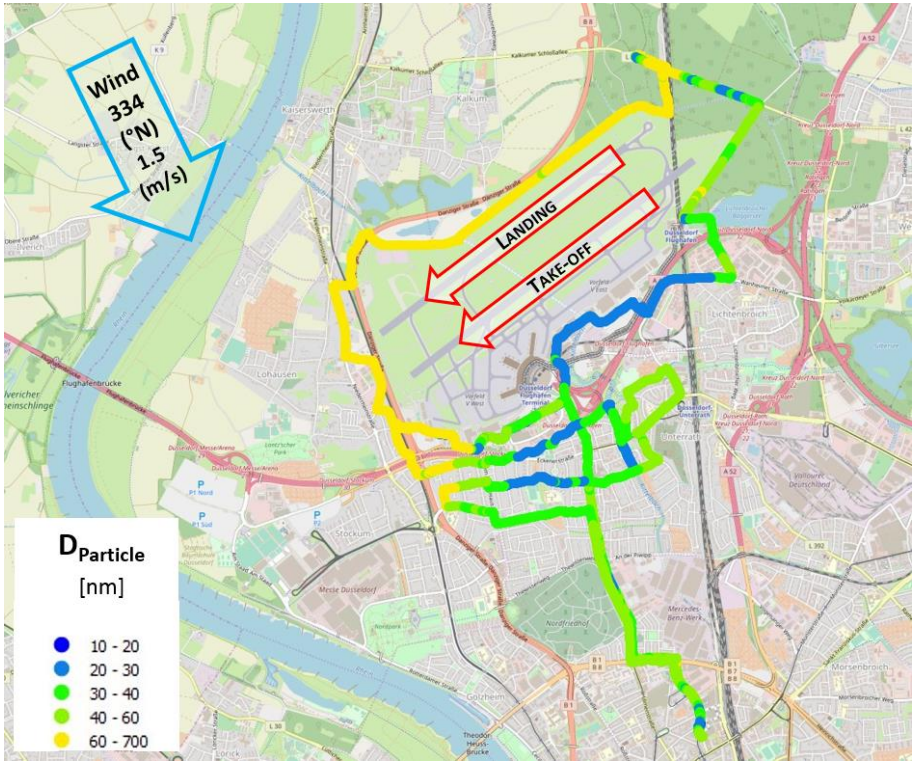


## Research flight on the 31.10.2018

How far can we measure the Airport emissions?


Twin engine aircraft

Endurance up to 2000 km

All kind of instrumentation

Volcano ash plume flights

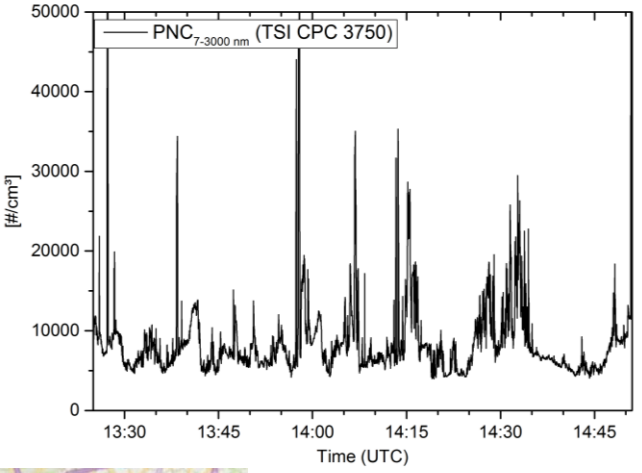
Research aircraft standby for DWD for volcanic eruptions

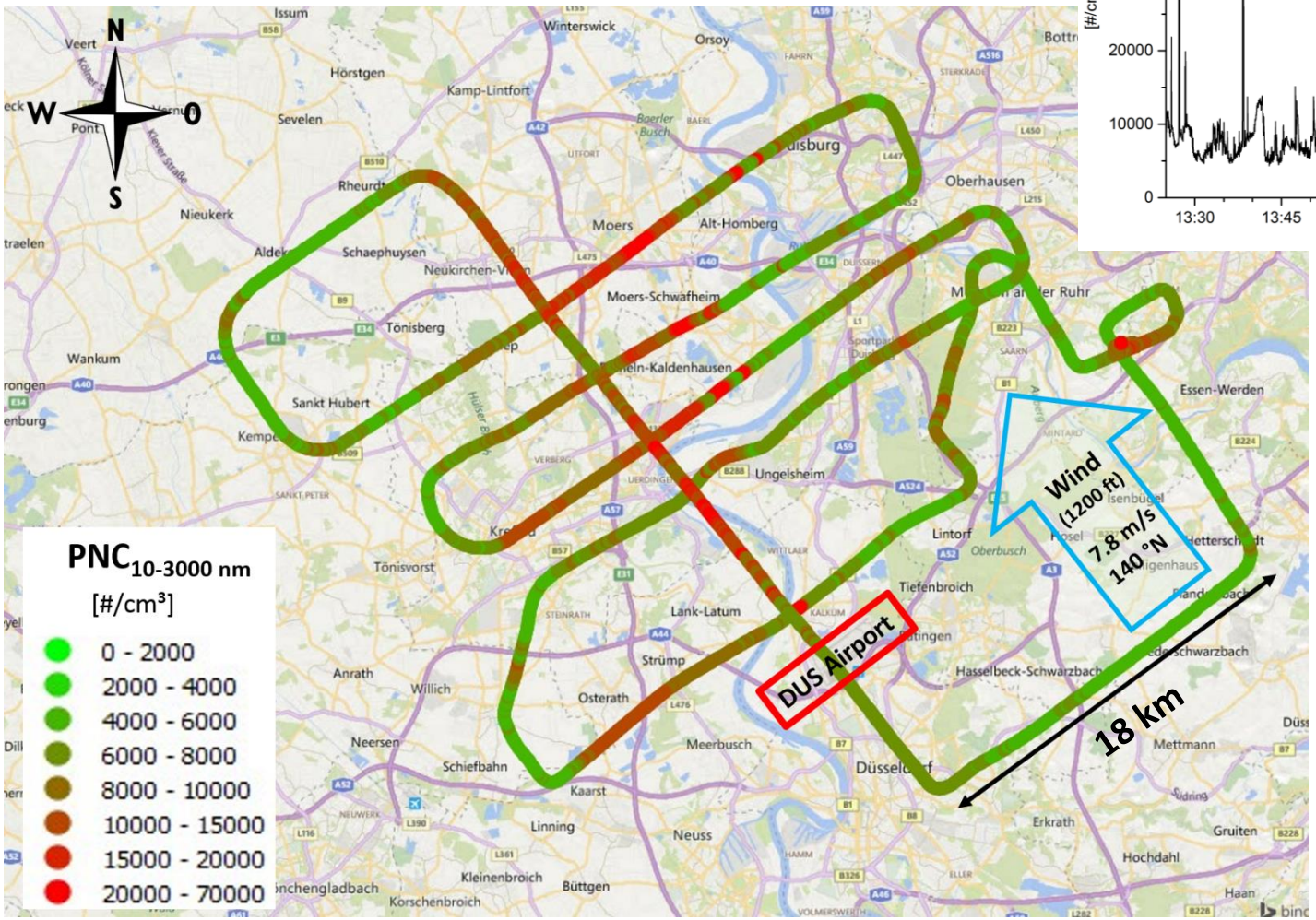
Flights over industrial areas

Transboundary air pollutant fluxes

- **Research flight on the 31.10.2018**

  How far can we measure the Airport emissions?

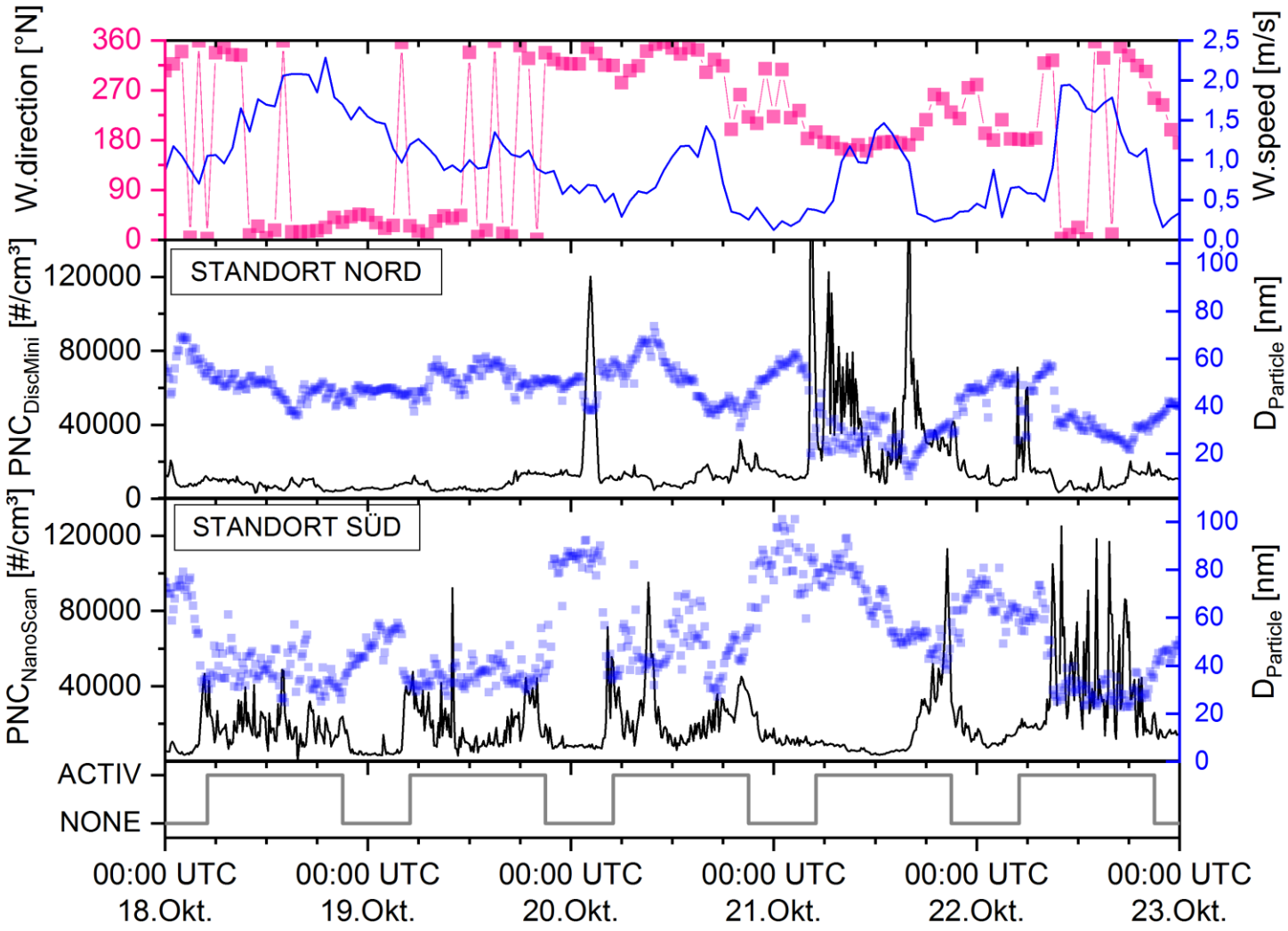


# Locations of the stationary measurement

## Stationary measurments

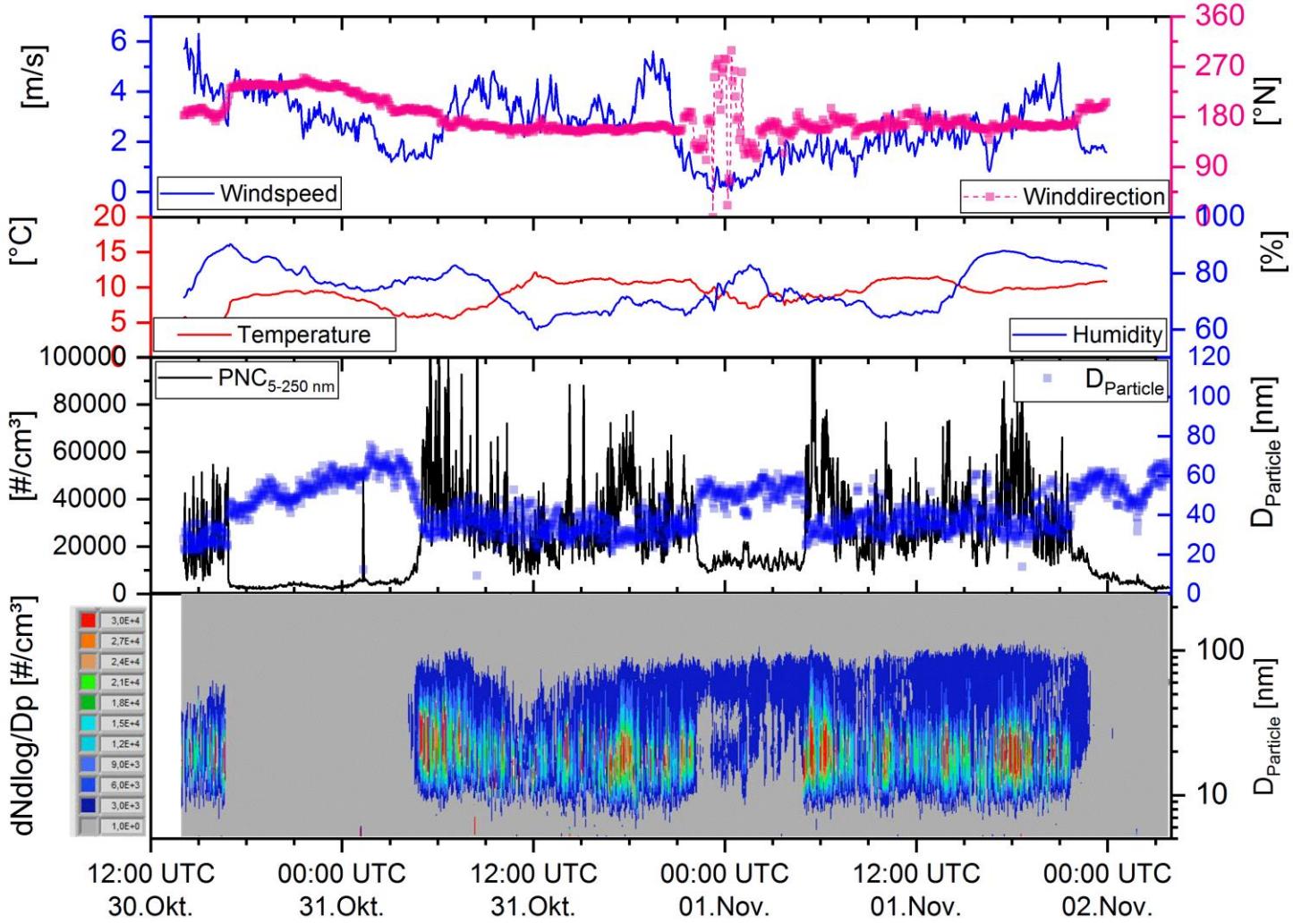
Temporal distribution of UFP-emission depending on meteorological conditions and Airport activity



# Locations of the stationary measurement

- **Stationary measurements**

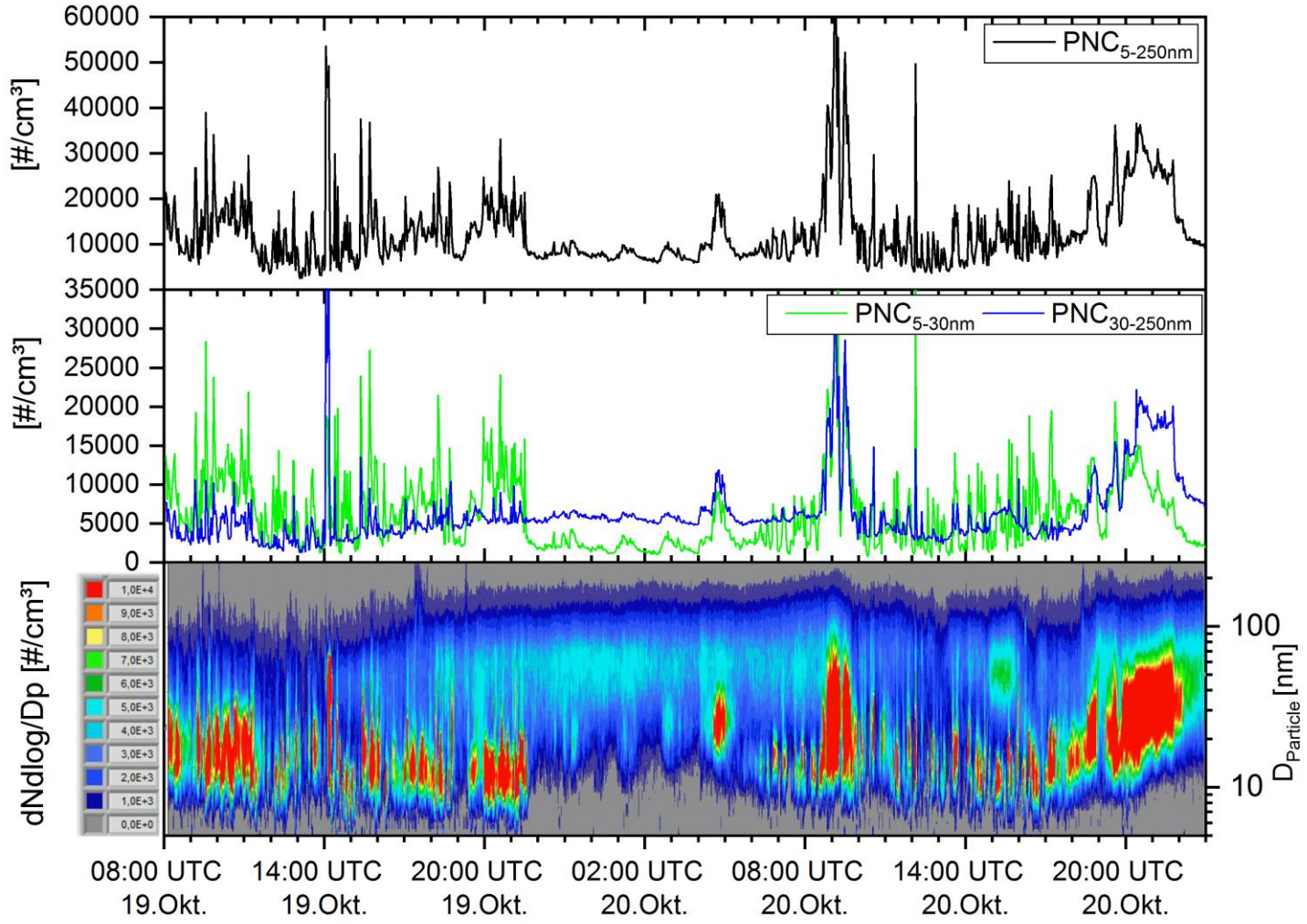
Location: center north



# Locations of the stationary measurement

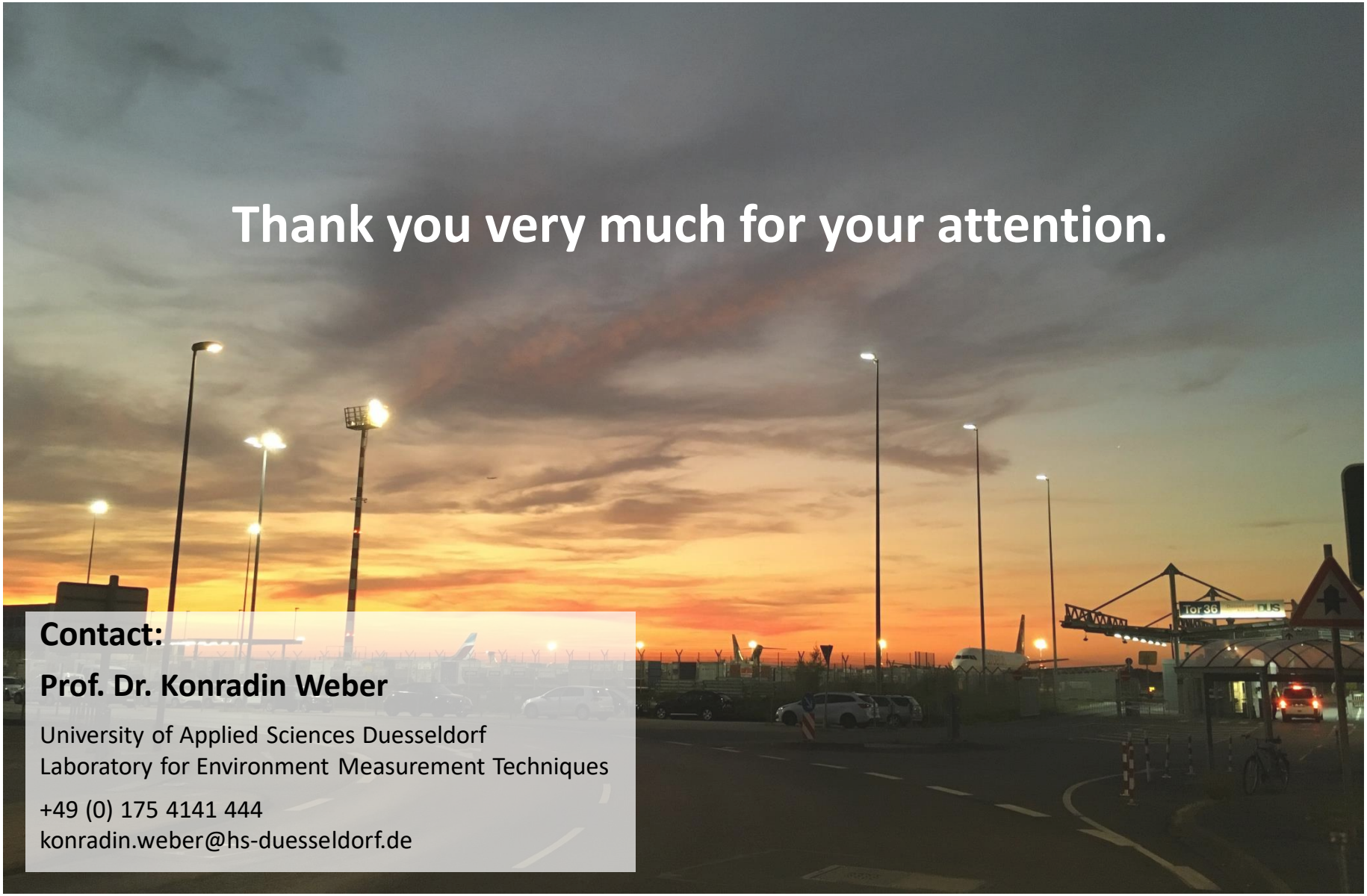
- **Stationary measurements**

Location: west



## Conclusion

- We could measure the UFP emissions released at the Airport DUS
- The UFP released by the jet engines have a small particle mean diameter ($D_P$ ~ 10-20 nm)
- There is a strong correlation between aircraft movements and the particle number concentration which leads to a typical diurnal trend in the data
- The spatial distribution could be measured clearly with the bike-measurements up to several kilometers downwind to the Airport
- With the research flight we could measure the plume of the Airport up to ten kilometers away downwind
- The mean particle diameter can be used as an auxiliary quantity to distinguish between emissions released from aircraft or roadtraffic.
- **The funding of this study by the Environmental State Agency of NRW in Germany is very much appreciated**
- **More measurements planned with: bicycle, aircraft, drones, low cost sensors**




# Thank you very much for your attention.

**Contact:**

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Laboratory for Environment Measurement Techniques

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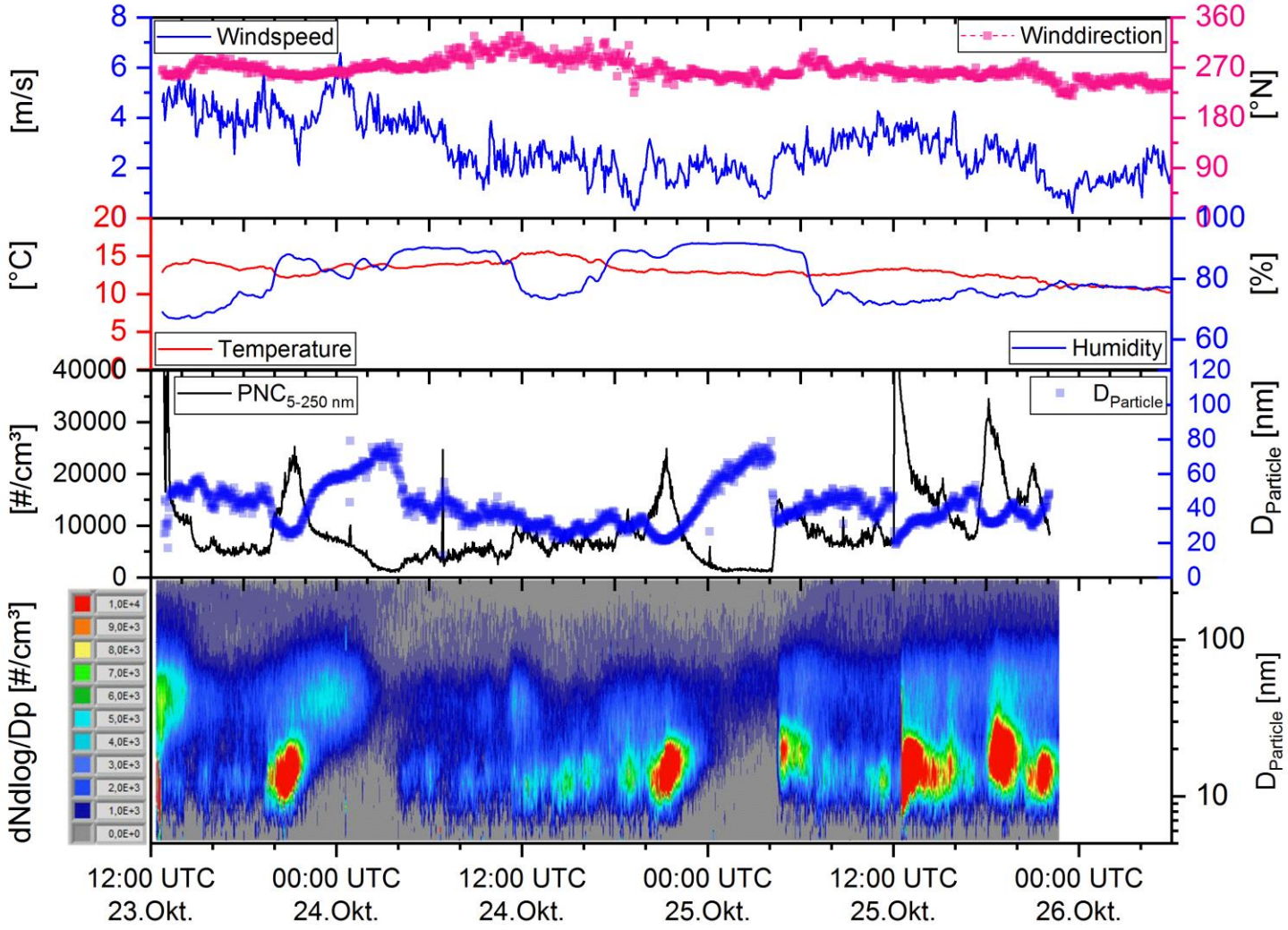
konradin.weber@hs-duesseldorf.de

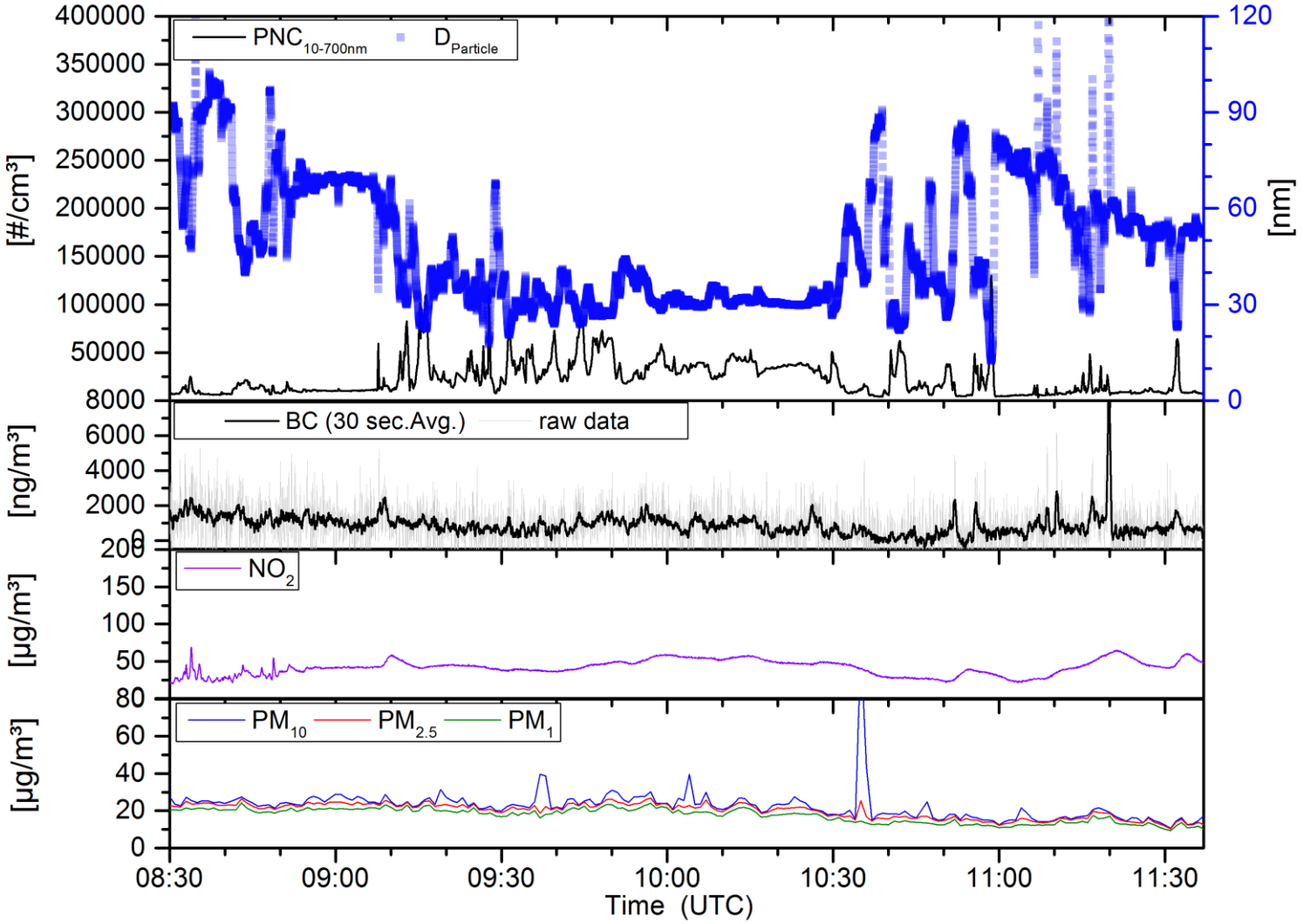
- **Stationary measurements**

Location: east

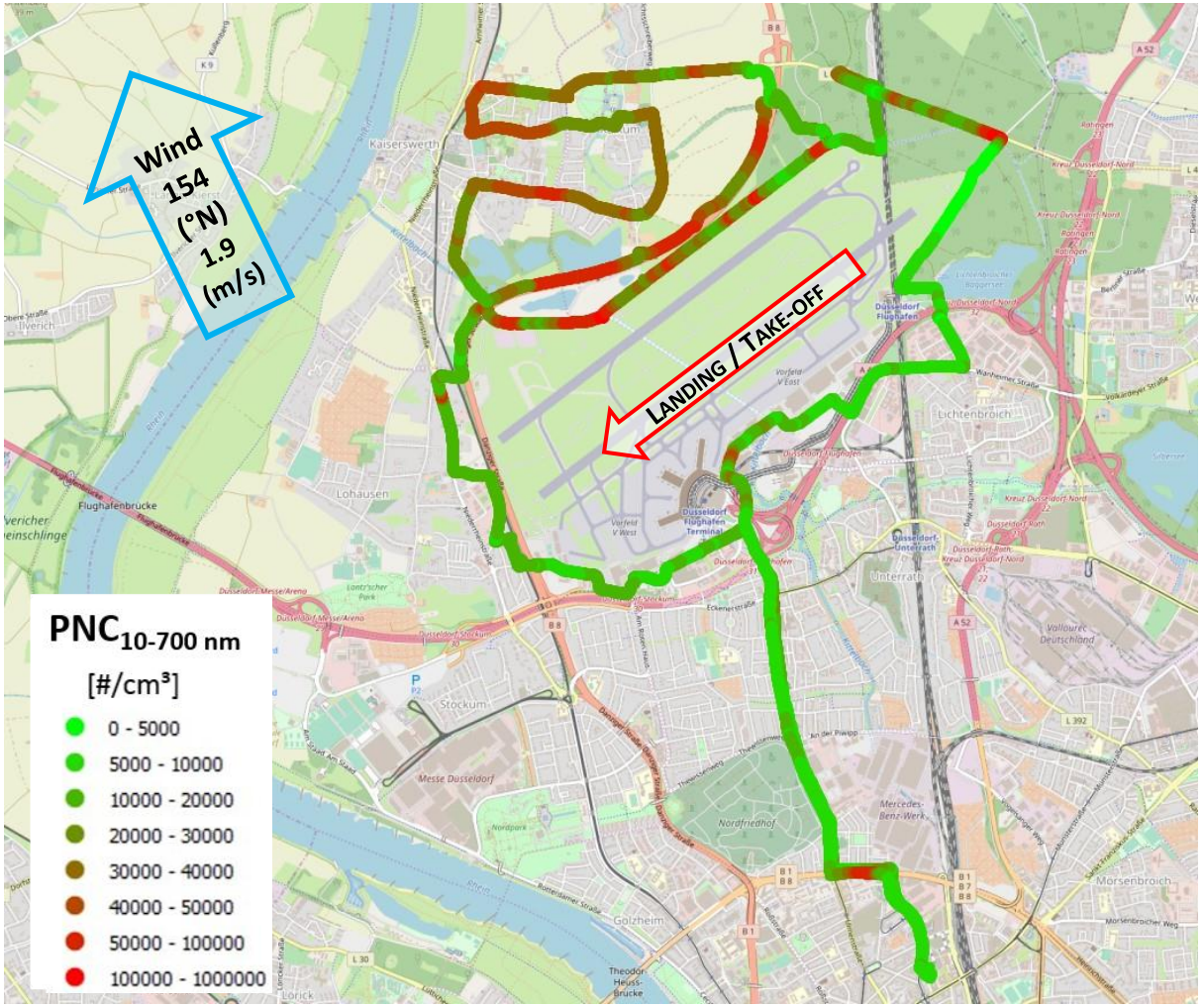


- **North routes**

- **North route 21.10.2018 (Sun.) - concentration plots**

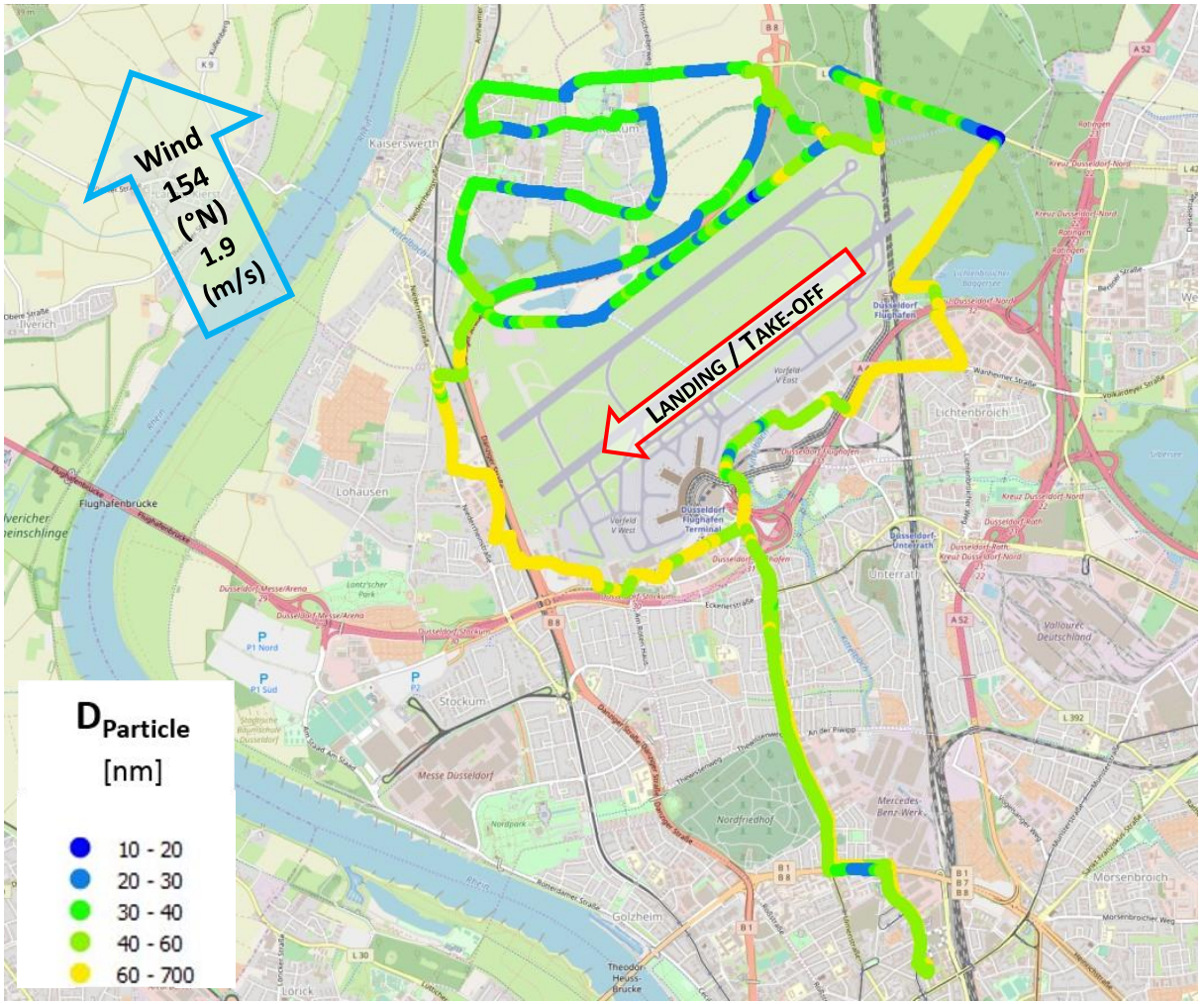


- **North route - 21.10.2018 (Sun.) - spatial distribution $PNC_{10\text{-}700}$ (dM)**



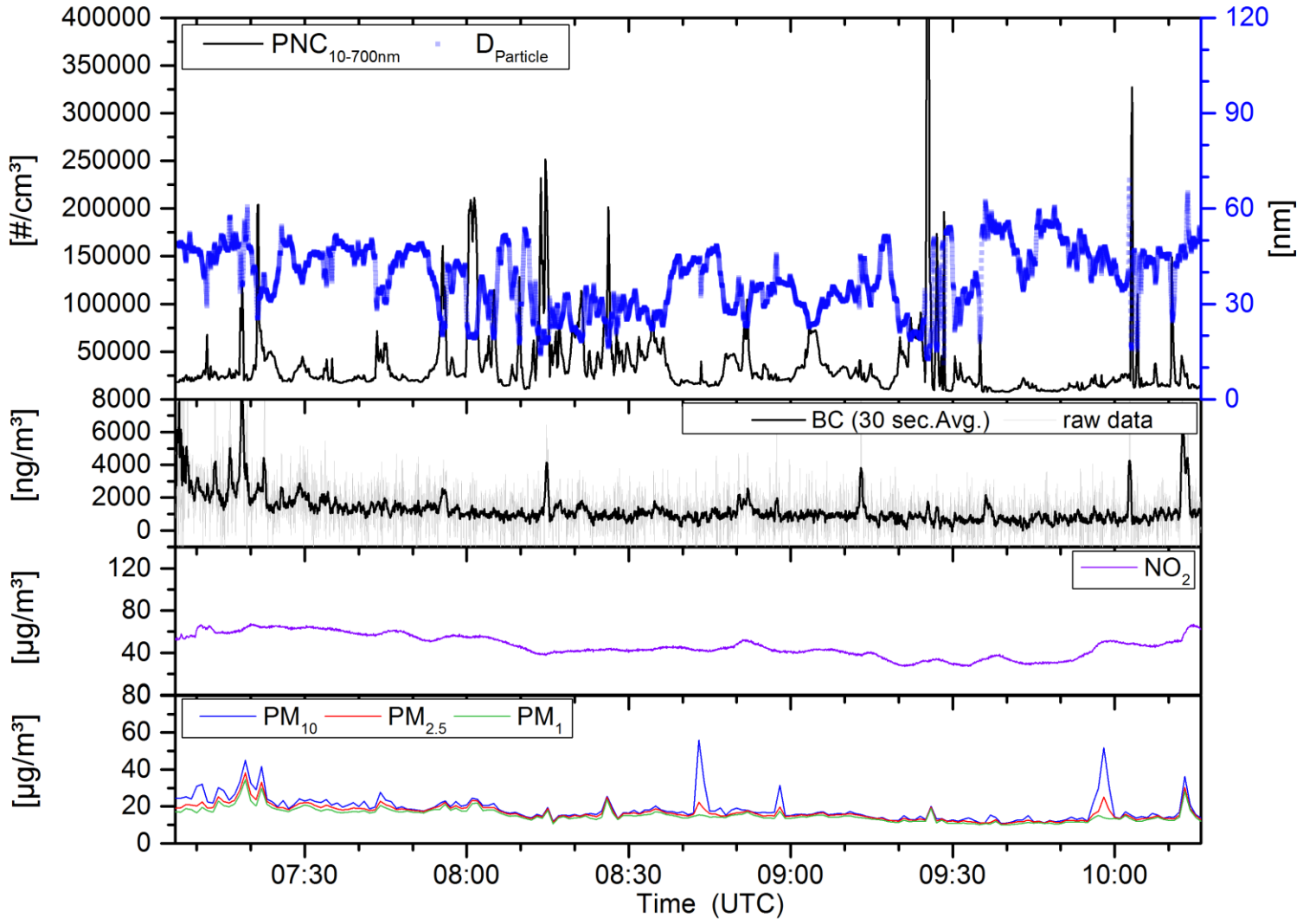

Source: Open Street Map

- **North route - 21.10.2018 (Sun.) - spatial distribution - $D_{Particle}$ (dM)**




Source: Open Street Map

- **North route - 31.10.2018 (Wed.) - concentration plots**



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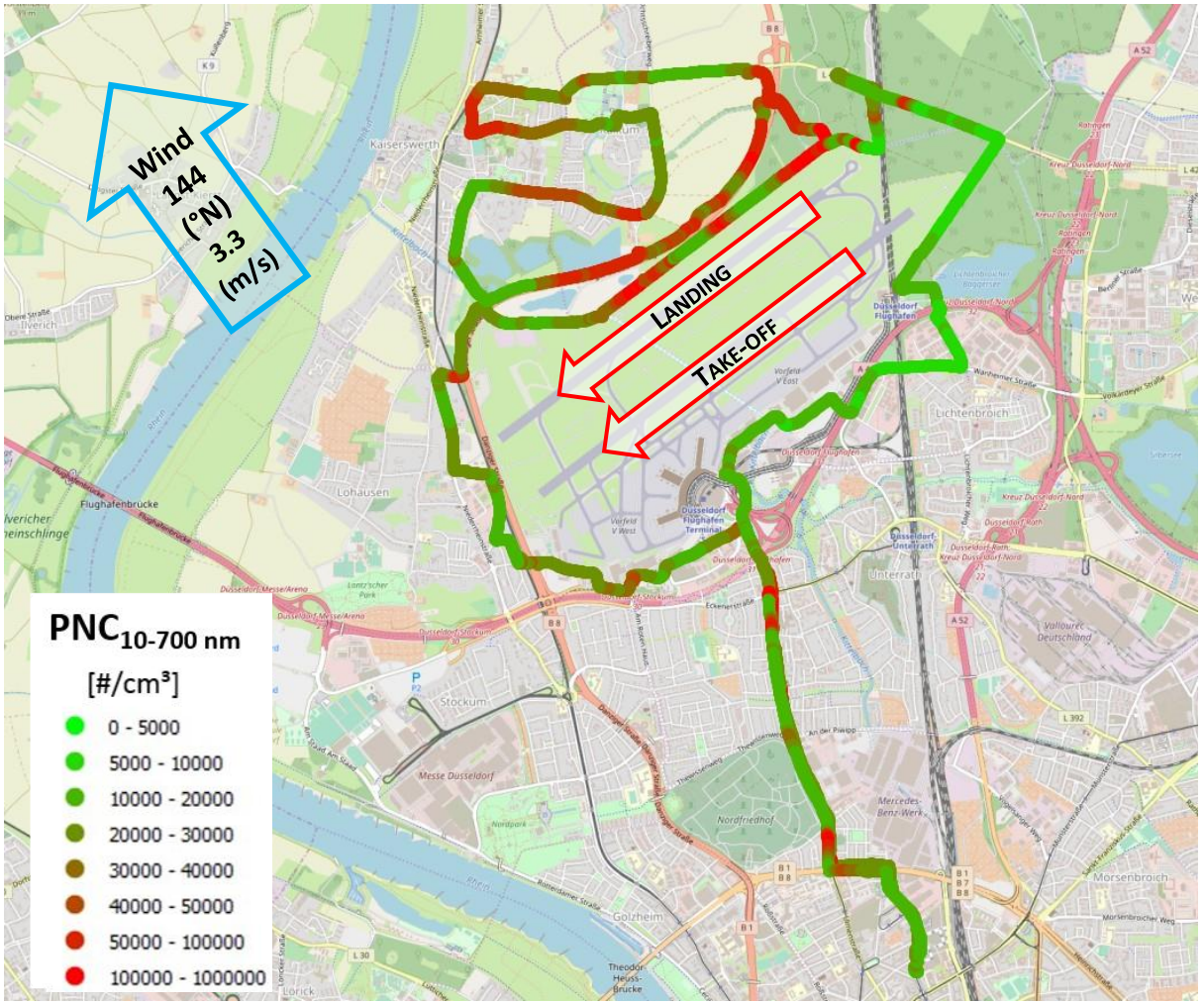
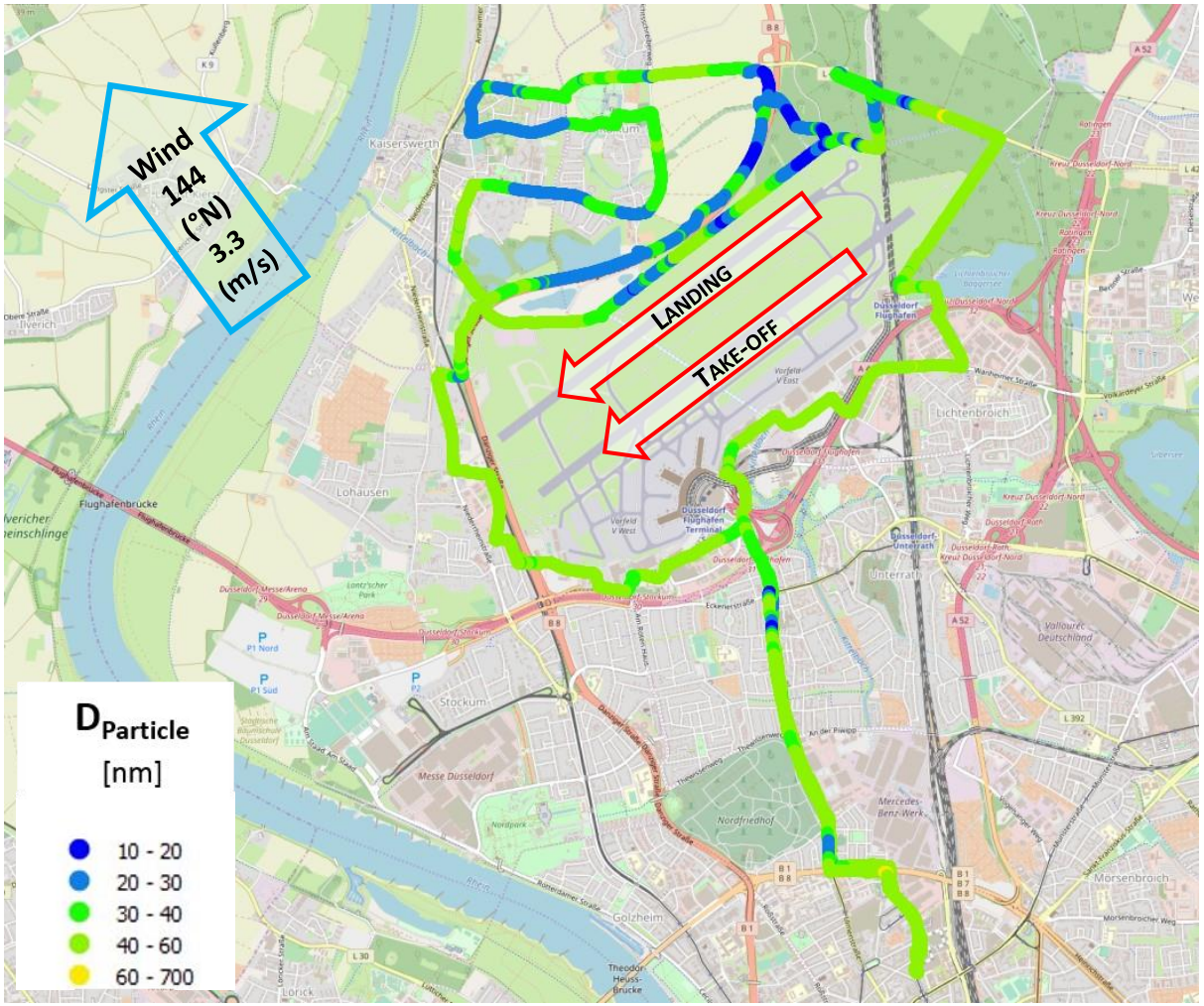


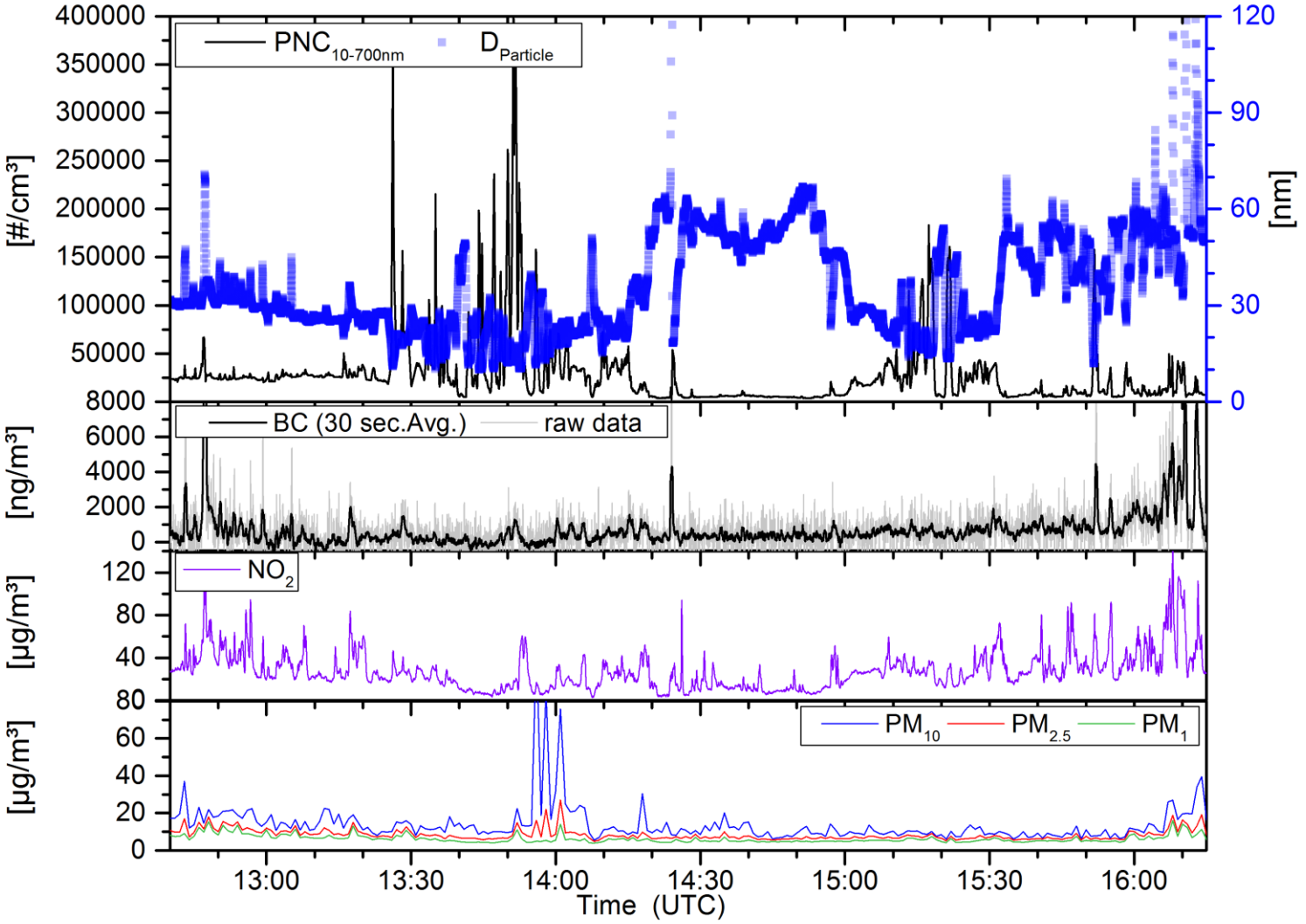

Source: Open Street Map

- **North route - 31.10.2018 (Wed.) - spatial distribution - $D_{Particle}$ (dM)**




Source: Open Street Map

- **North route - 12.10.2018 (Fri.) - concentration plots**



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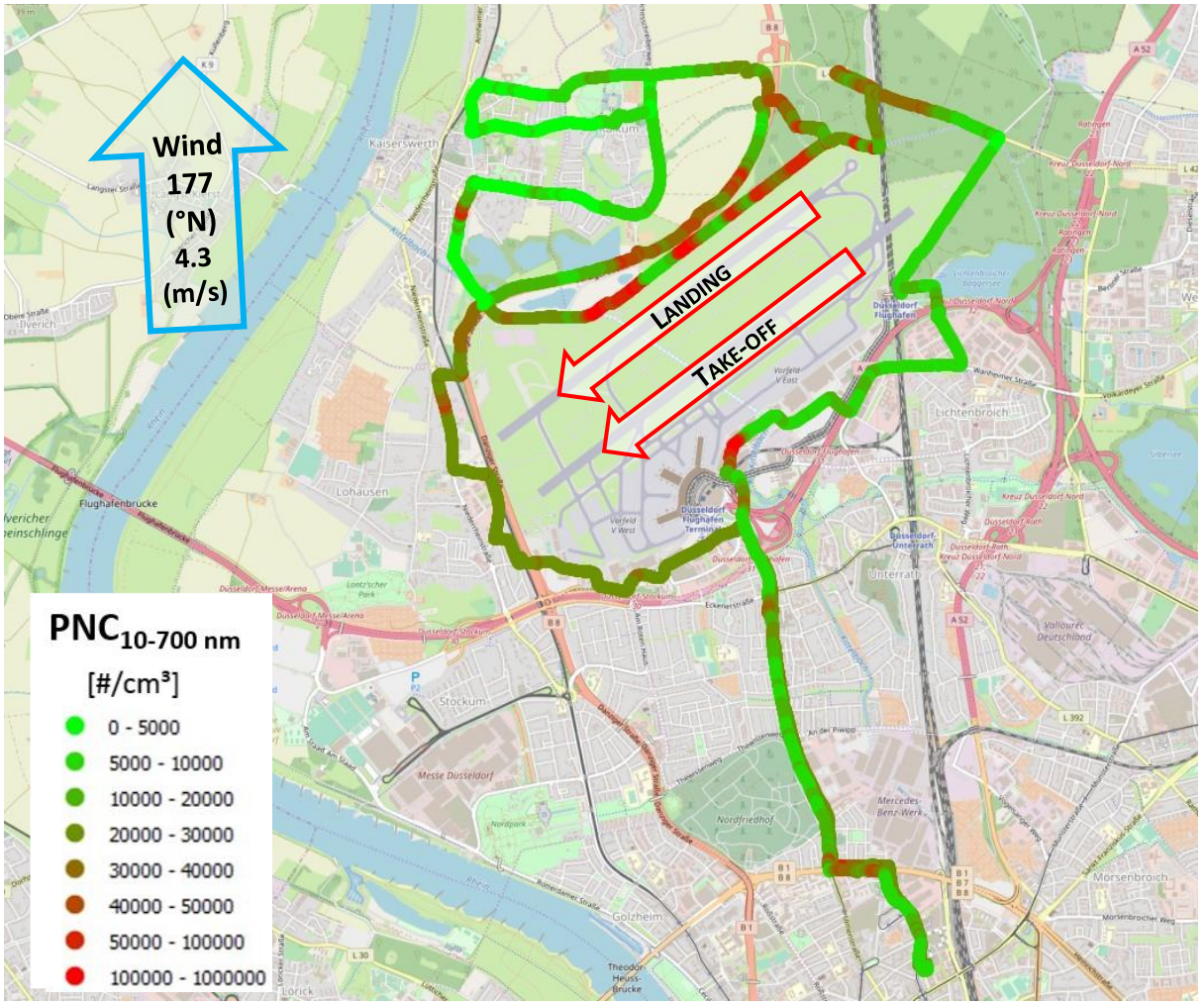
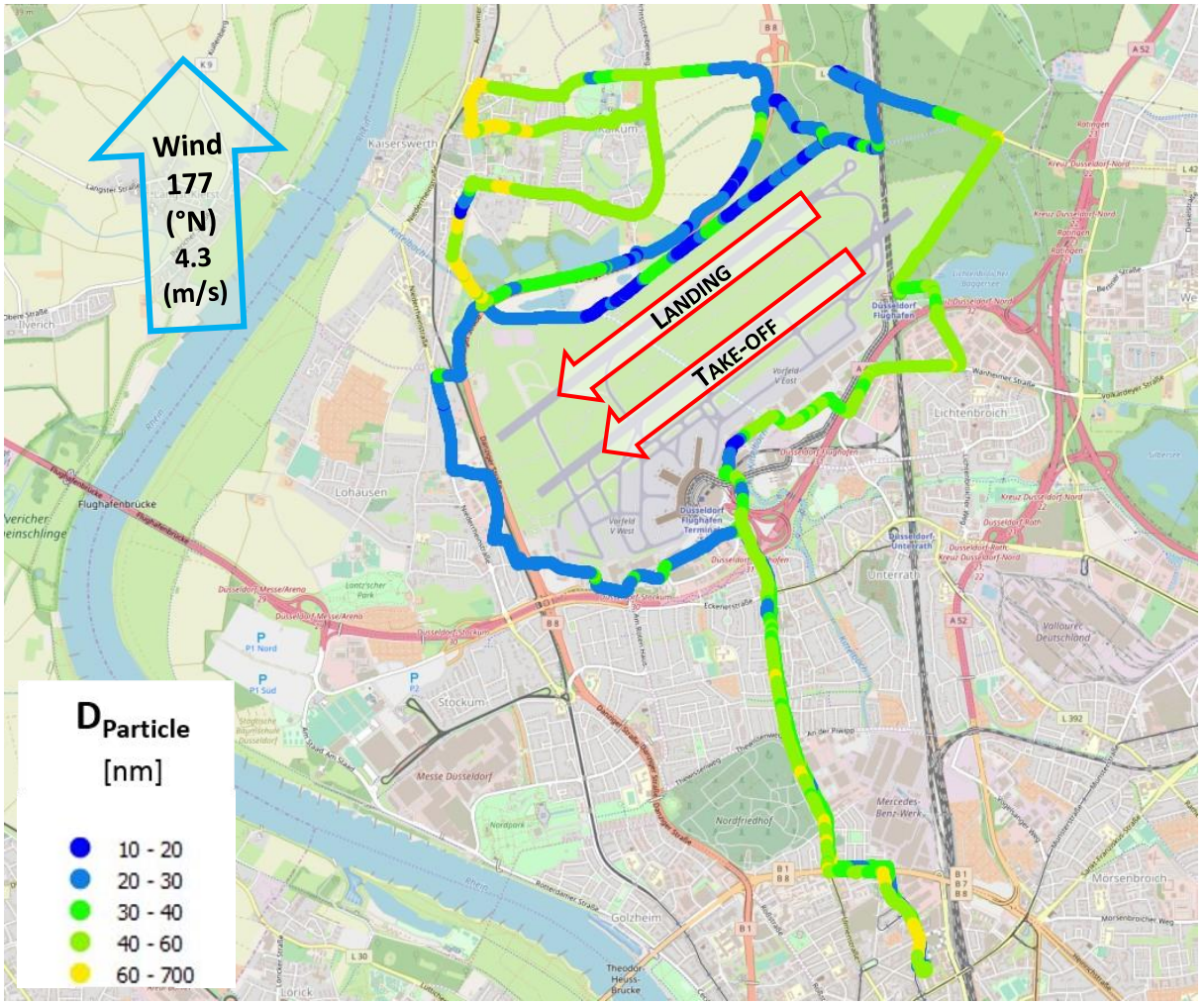



Source: Open Street Map

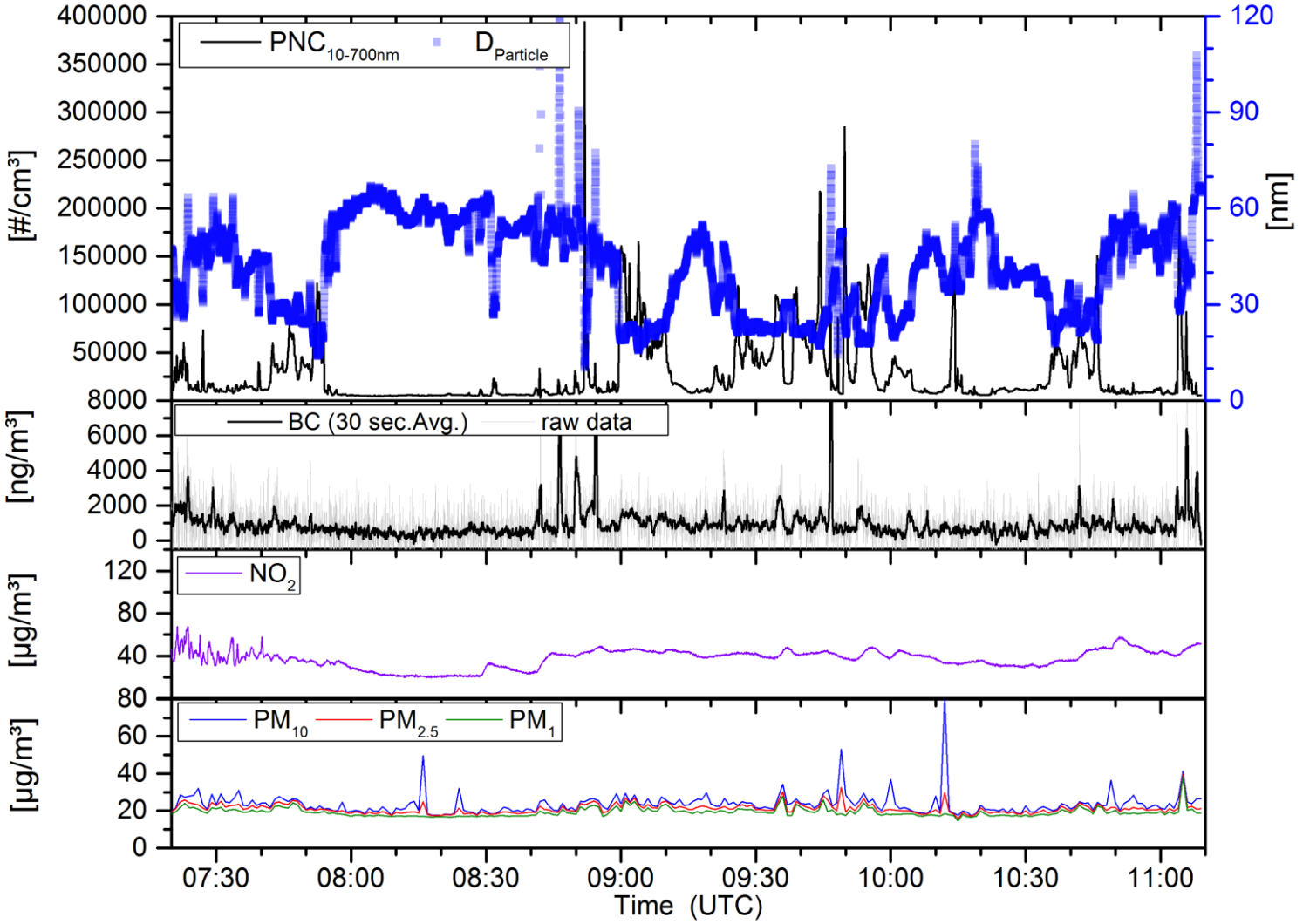
- **North route - 12.10.2018 (Fri.) - spatial distribution - $D_{Particle}$ (dM)**



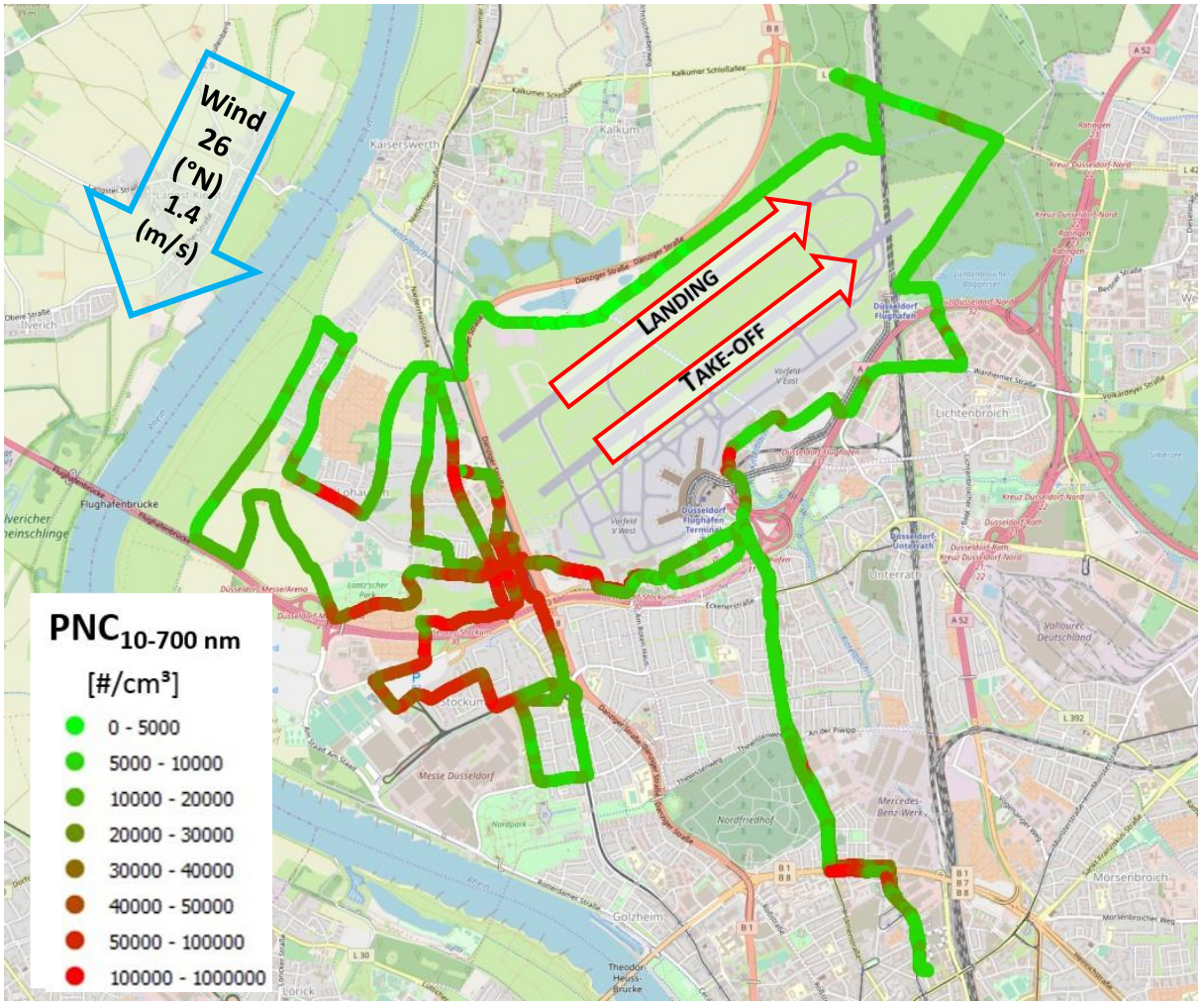

Source: Open Street Map

- **West routes**

- **West route - 19.10.2018 (Fri.) - concentration plots**

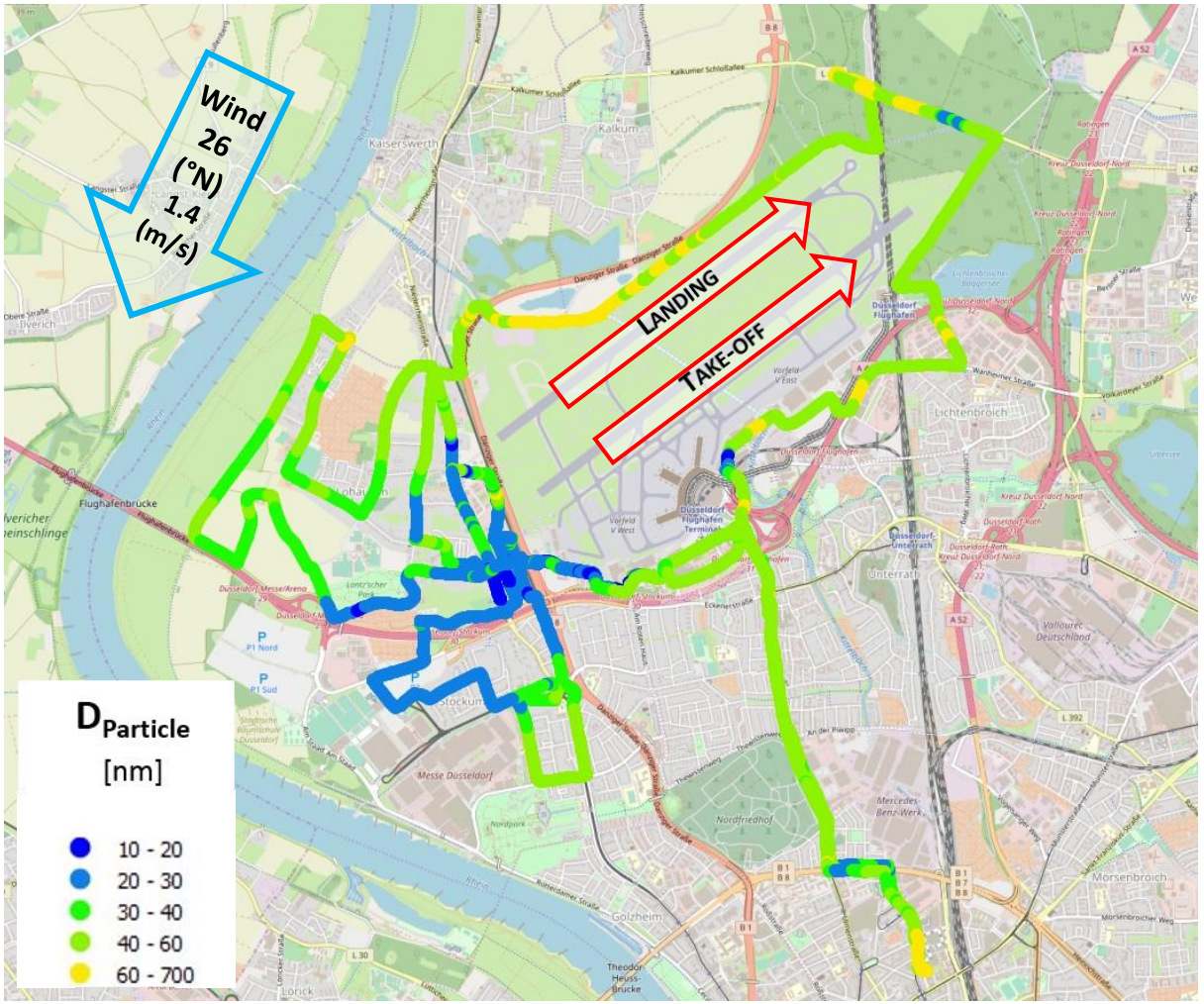


- **West route - 19.10.2018 (Fri.) - spatial distribution - $PNC_{10\text{-}700}$ (dM)**



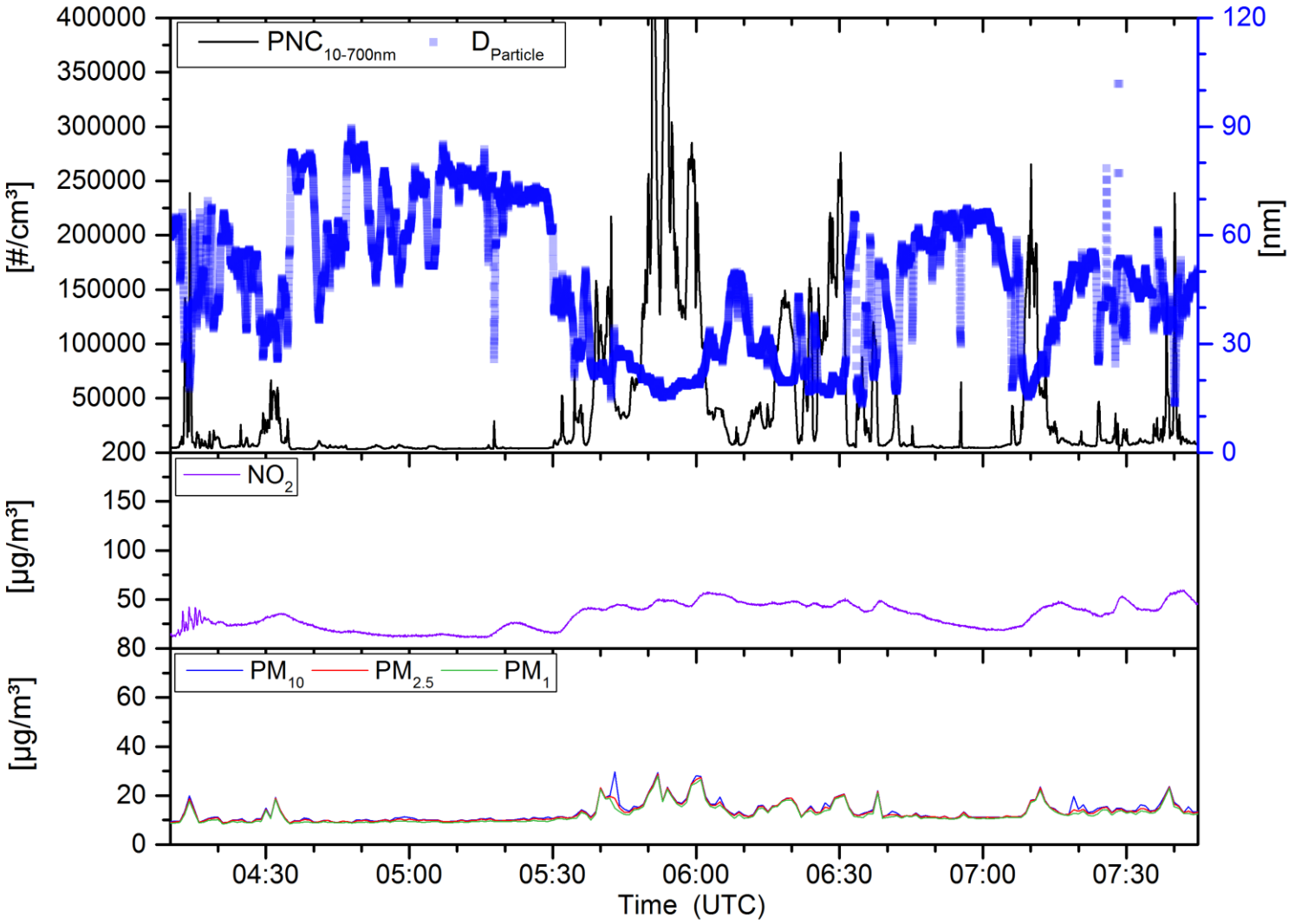

Source: Open Street Map

- **West route - 19.10.2018 (Fri.) - spatial distribution - $D_{Particle}$ (dM)**

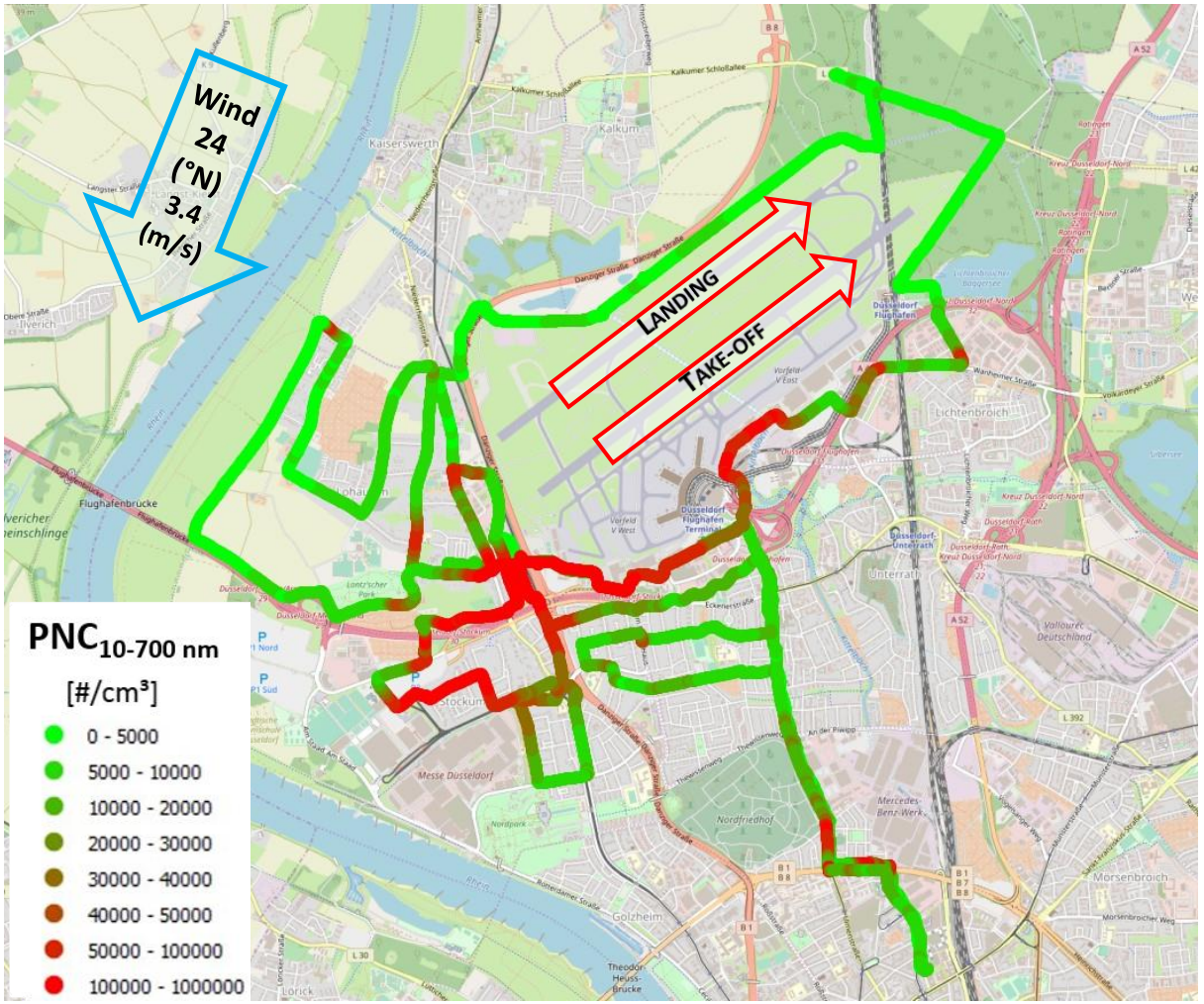



Source: Open Street Map

- **West route - 29.10.2018 (Mon.) - concentration plots**

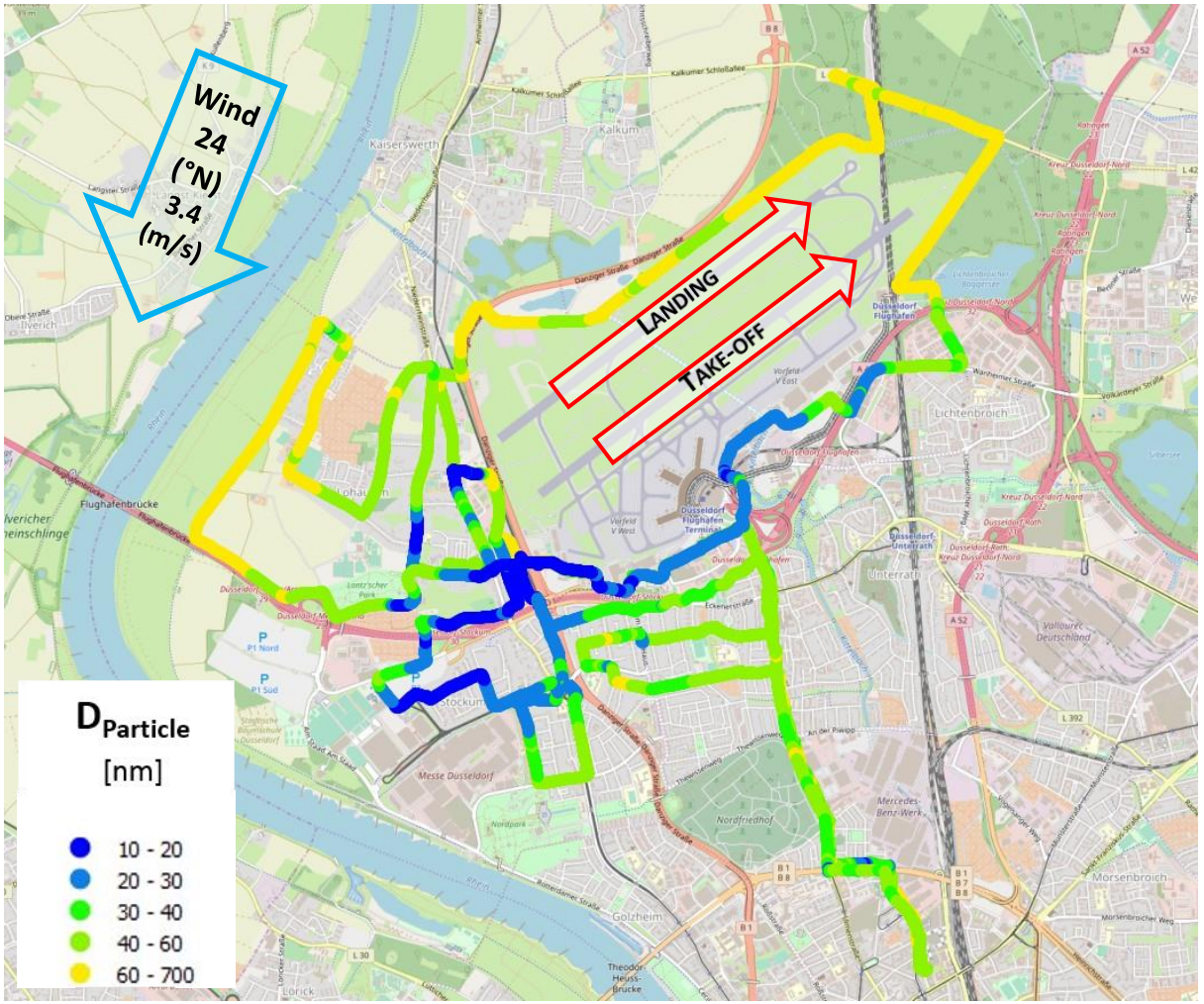


- **West route - 29.10.2018 (Mon.) - spatial distribution - $PNC_{10\text{-}700}$ (dM)**




Source: Open Street Map

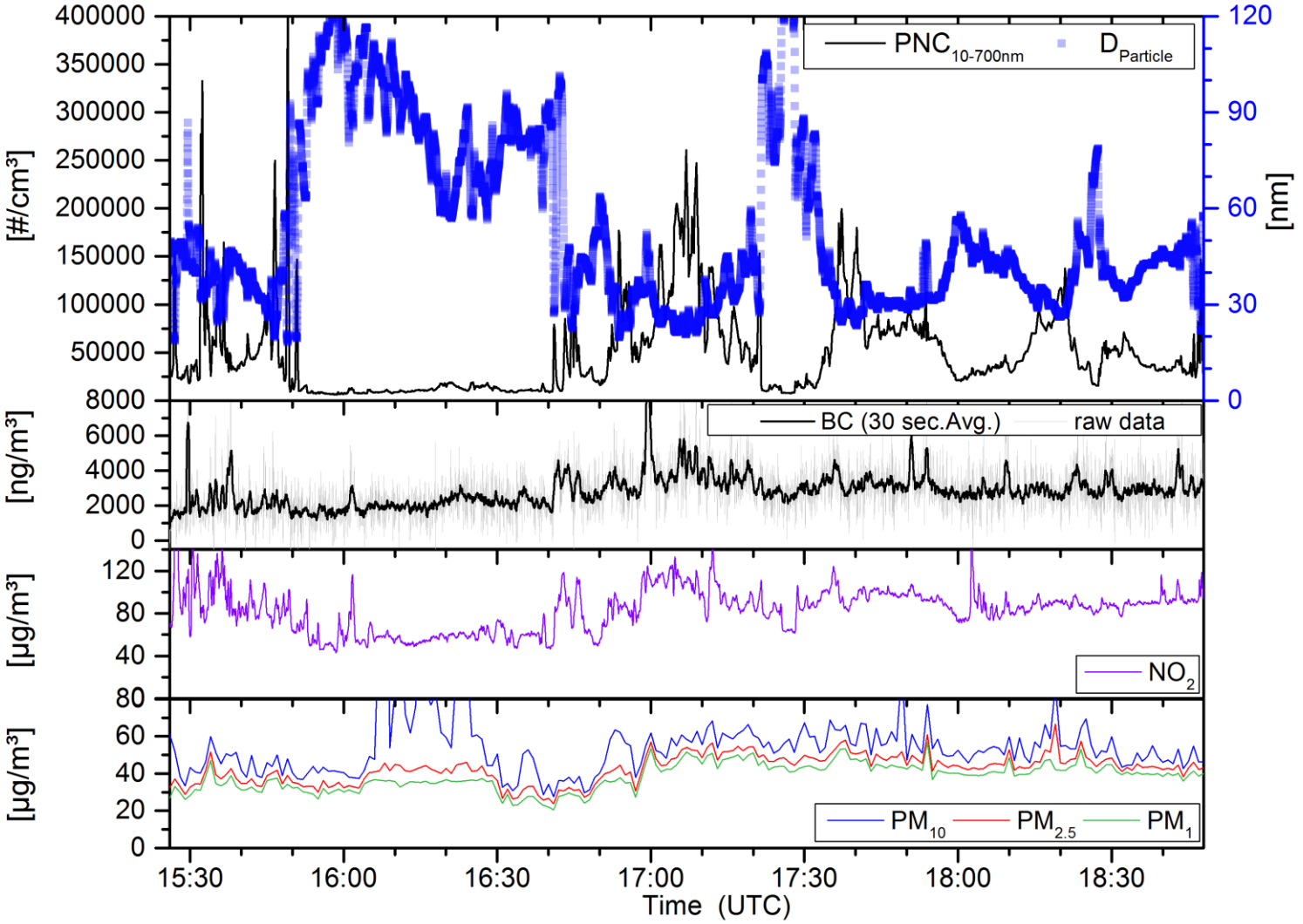
- **West route - 29.10.2018 (Mon.) - spatial distribution - $D_{Particle}$ (dM)**



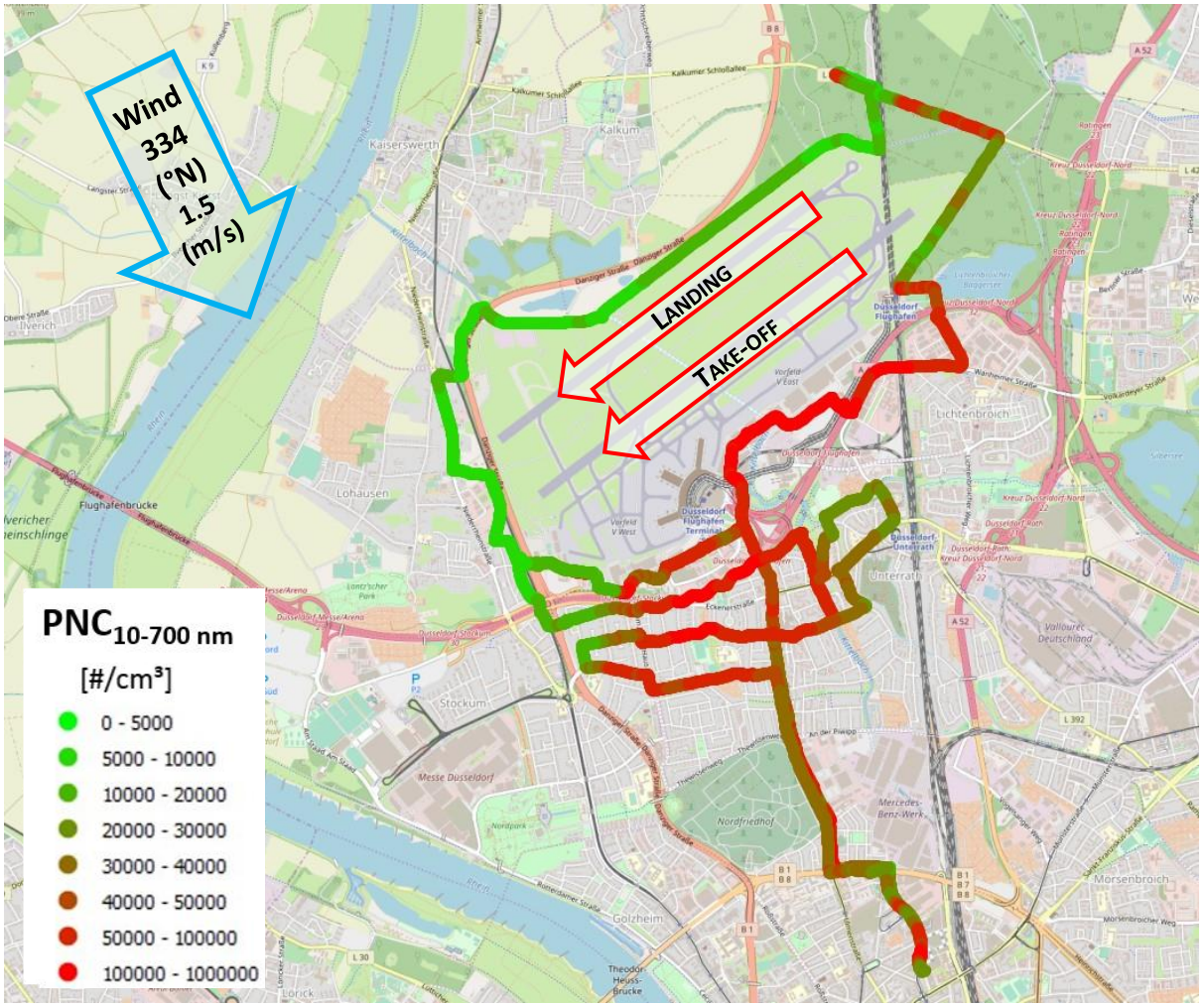

Source: Open Street Map

- **South routes**

- **South route - 17.10.2018 (Wed.) - concentration plots**

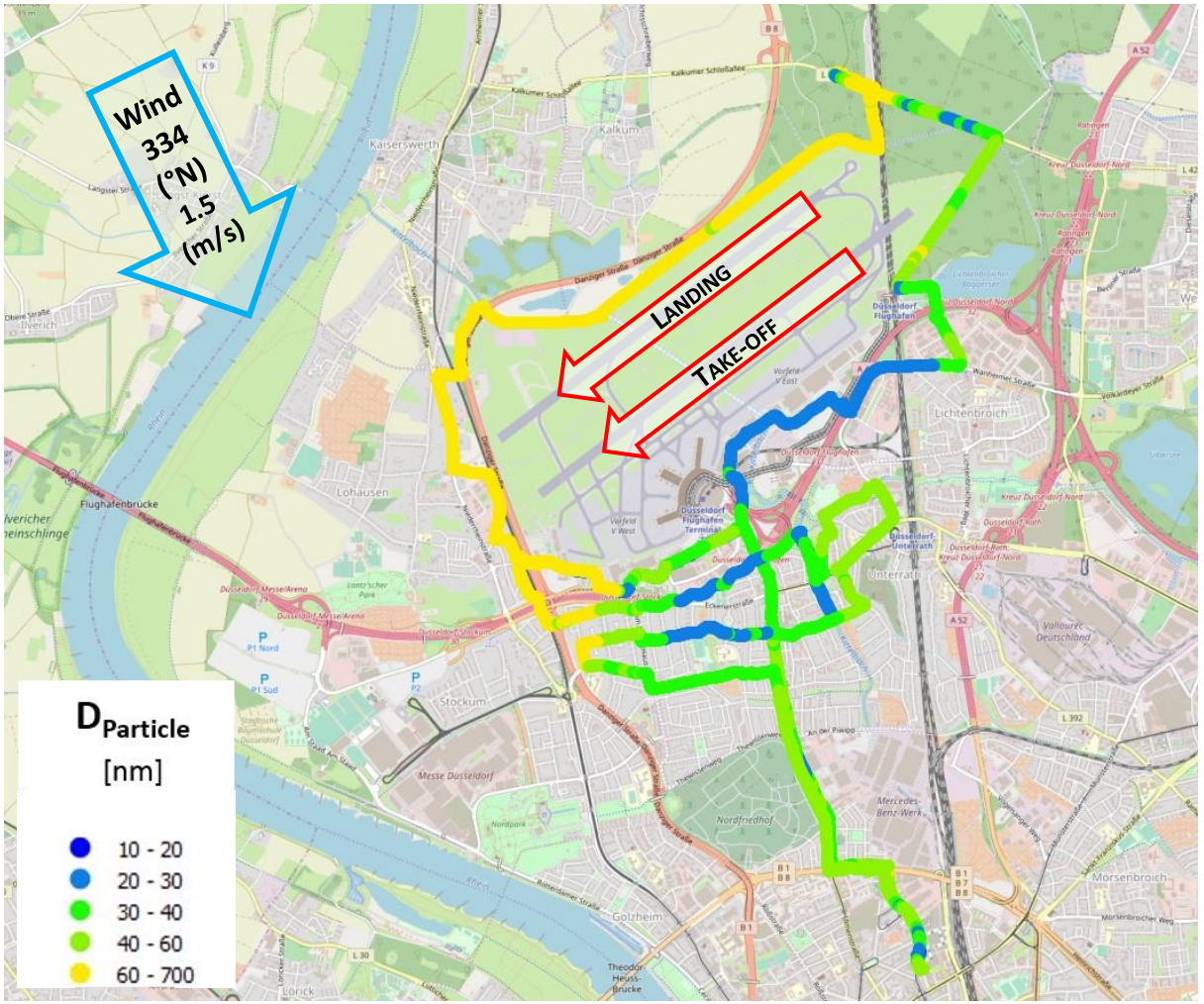


- **South route - 17.10.2018 (Wed.) - spatial distribution - $PNC_{10\text{-}700}$ (dM)**



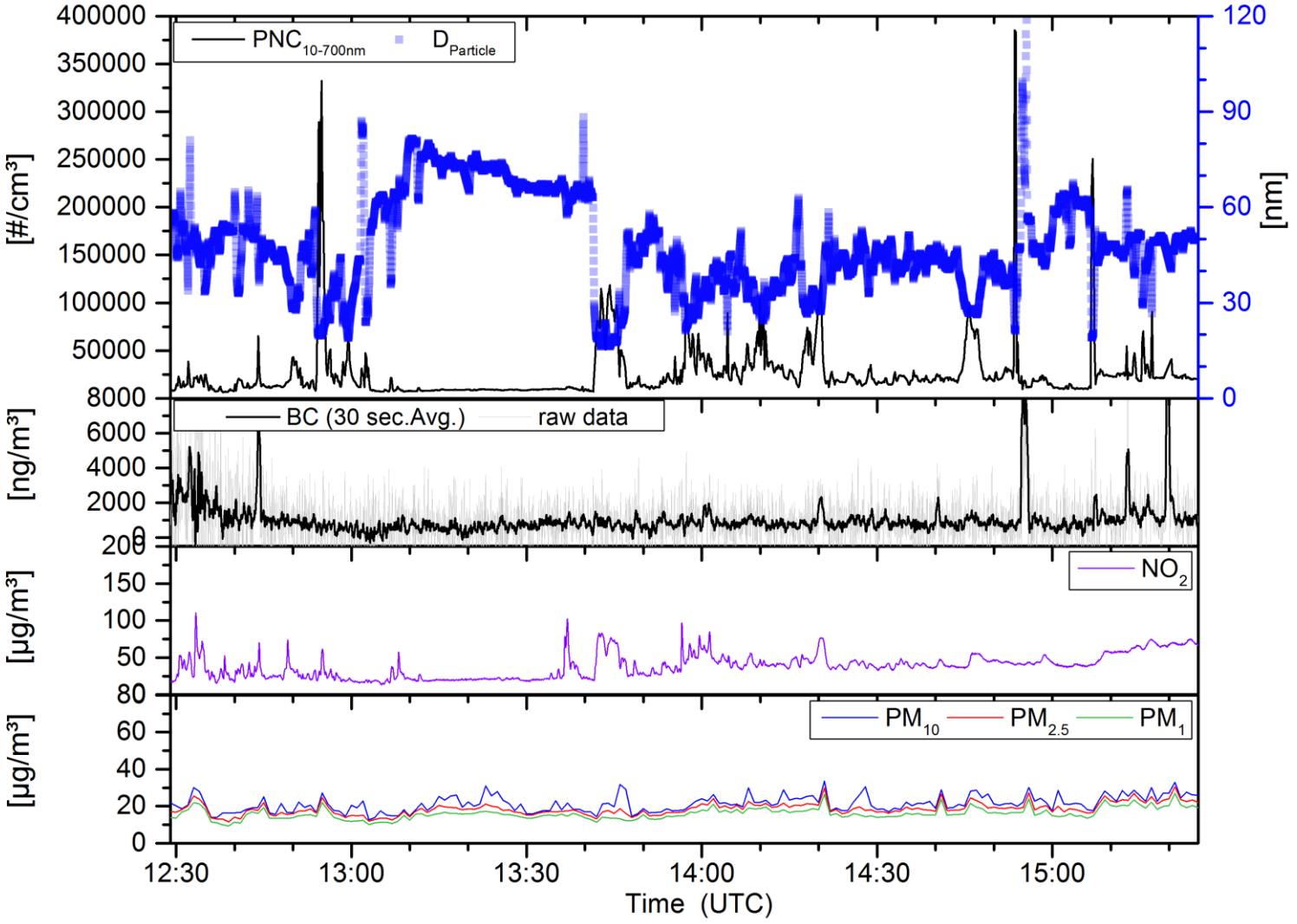

Source: Open Street Map

- **South route - 17.10.2018 (Wed.) - spatial distribution - $D_{Particle}$ (dM)**

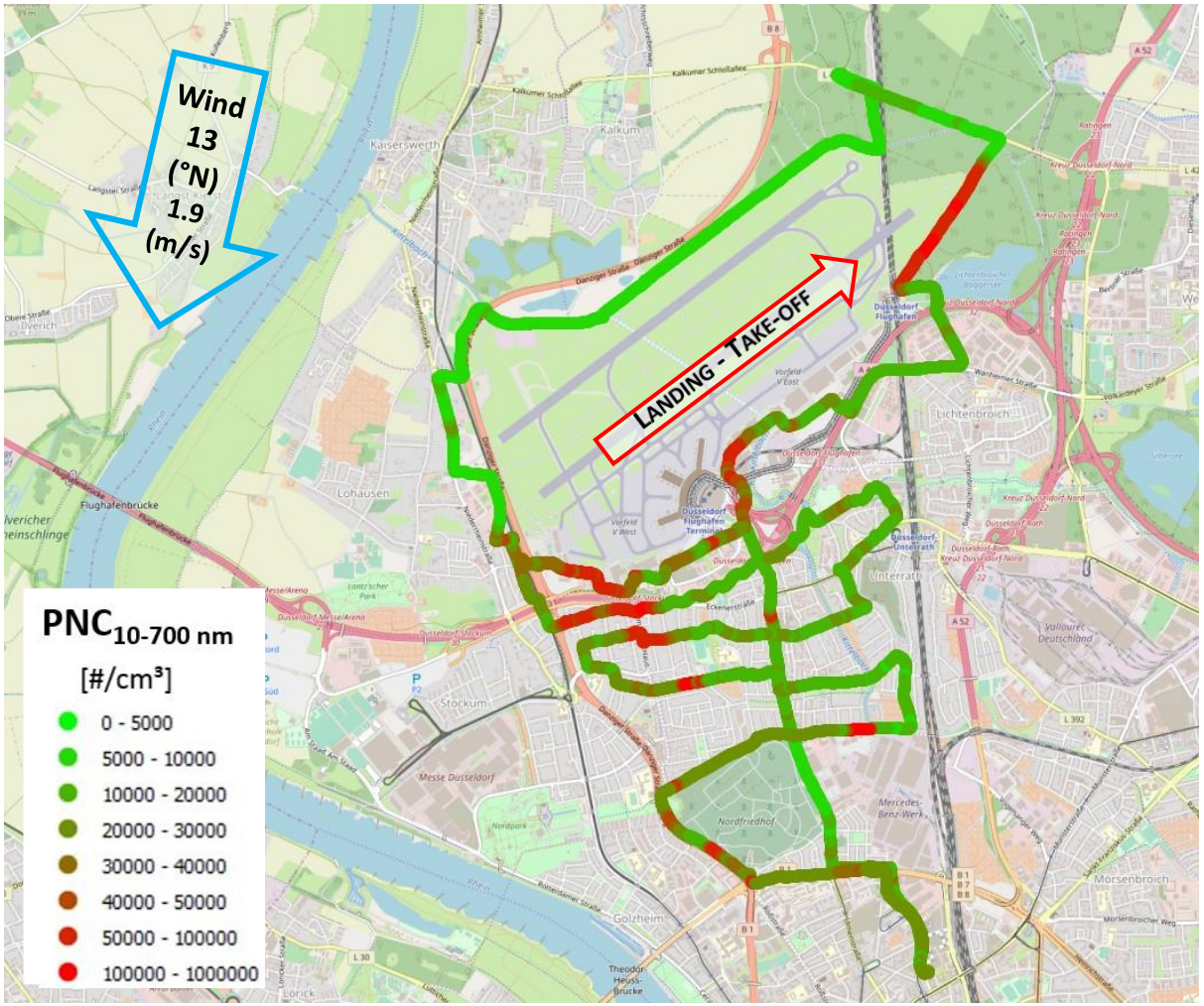



Source: Open Street Map

- **South route - 20.10.2018 (Sat.) - concentration plots**

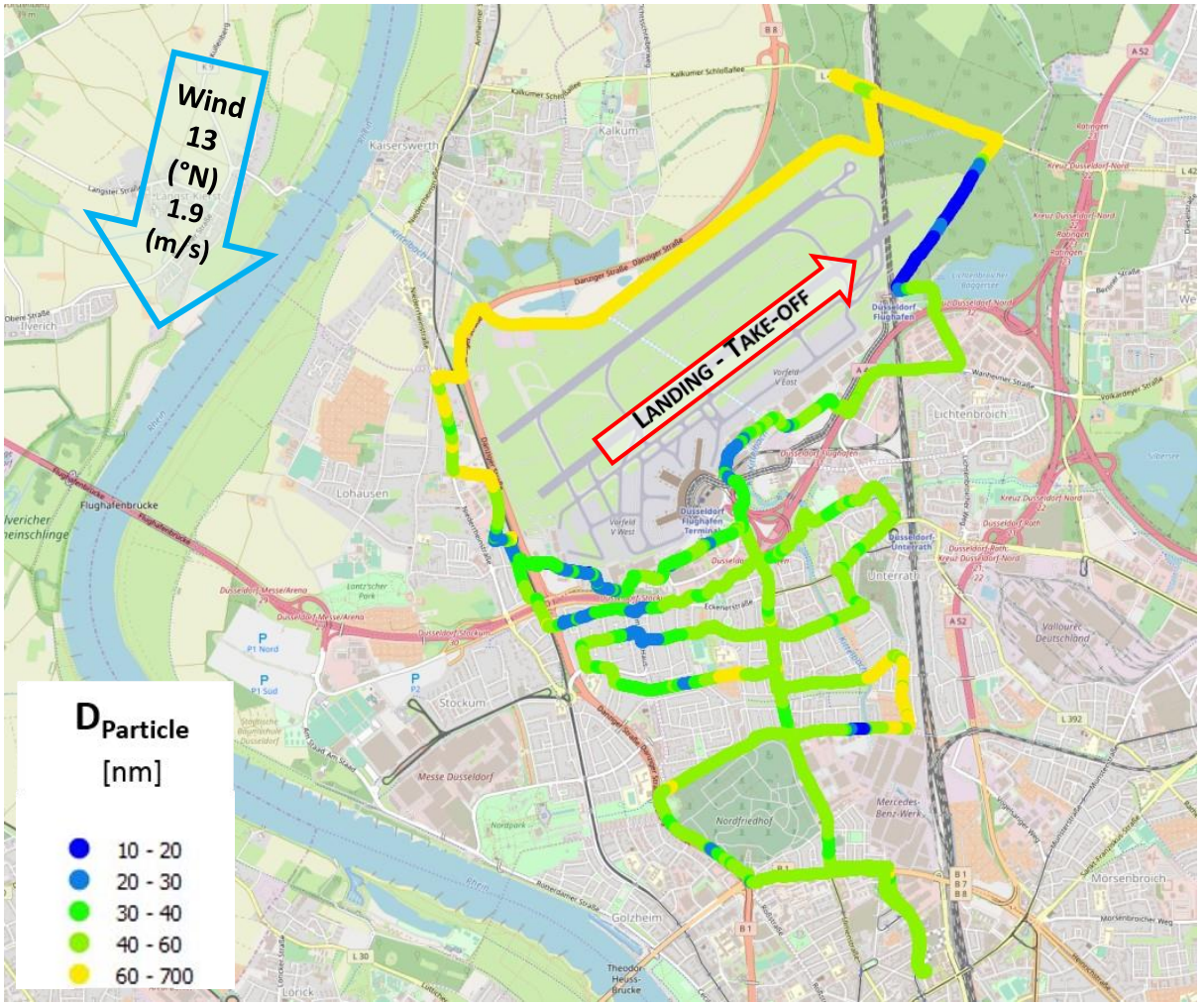


- **South route - 20.10.2018 (Sat.) - spatial distribution - $PNC_{10\text{-}700}$ (dM)**



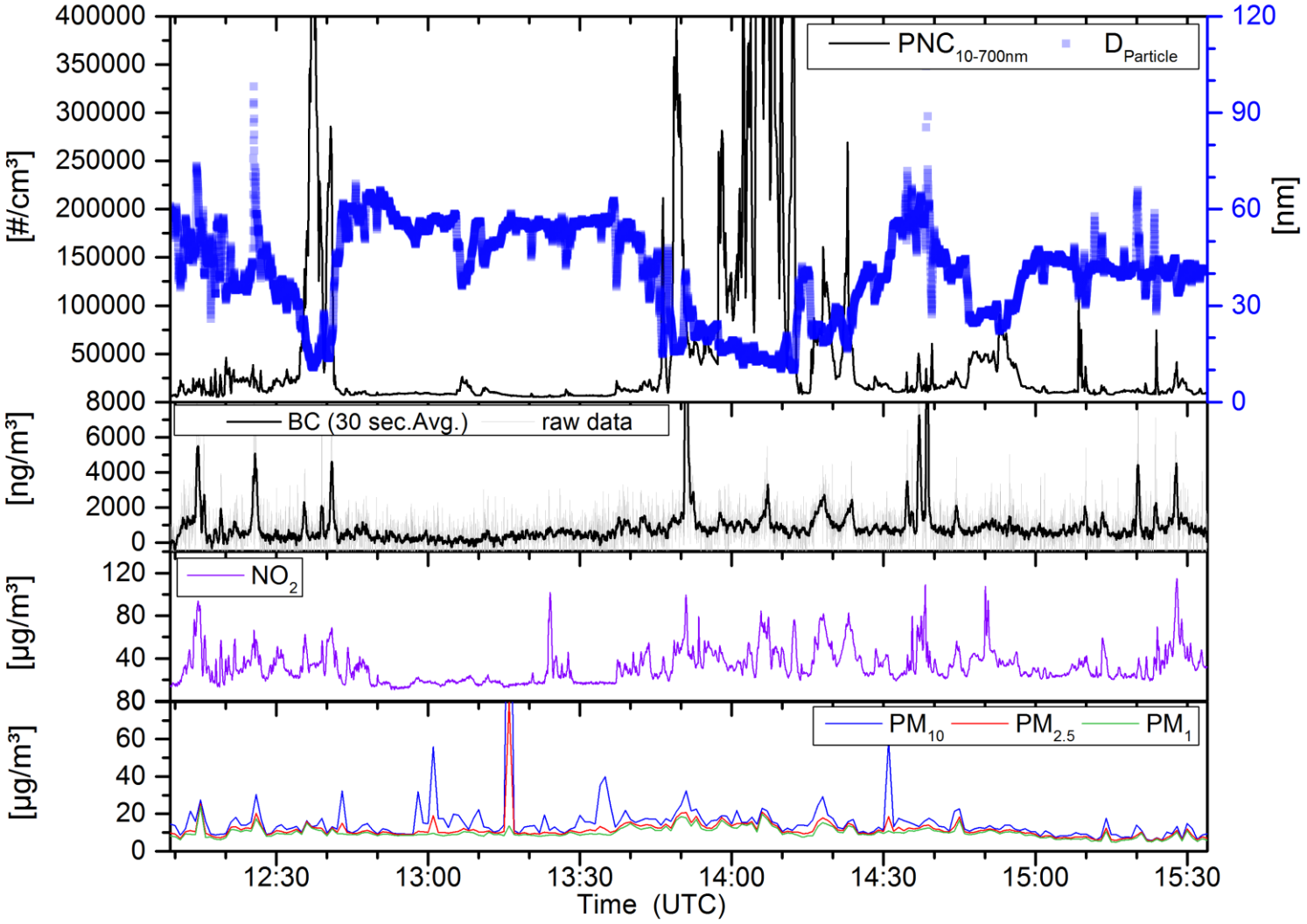

Source: Open Street Map

- **South route - 20.10.2018 (Sat.) - spatial distribution - $D_{Particle}$ (dM)**

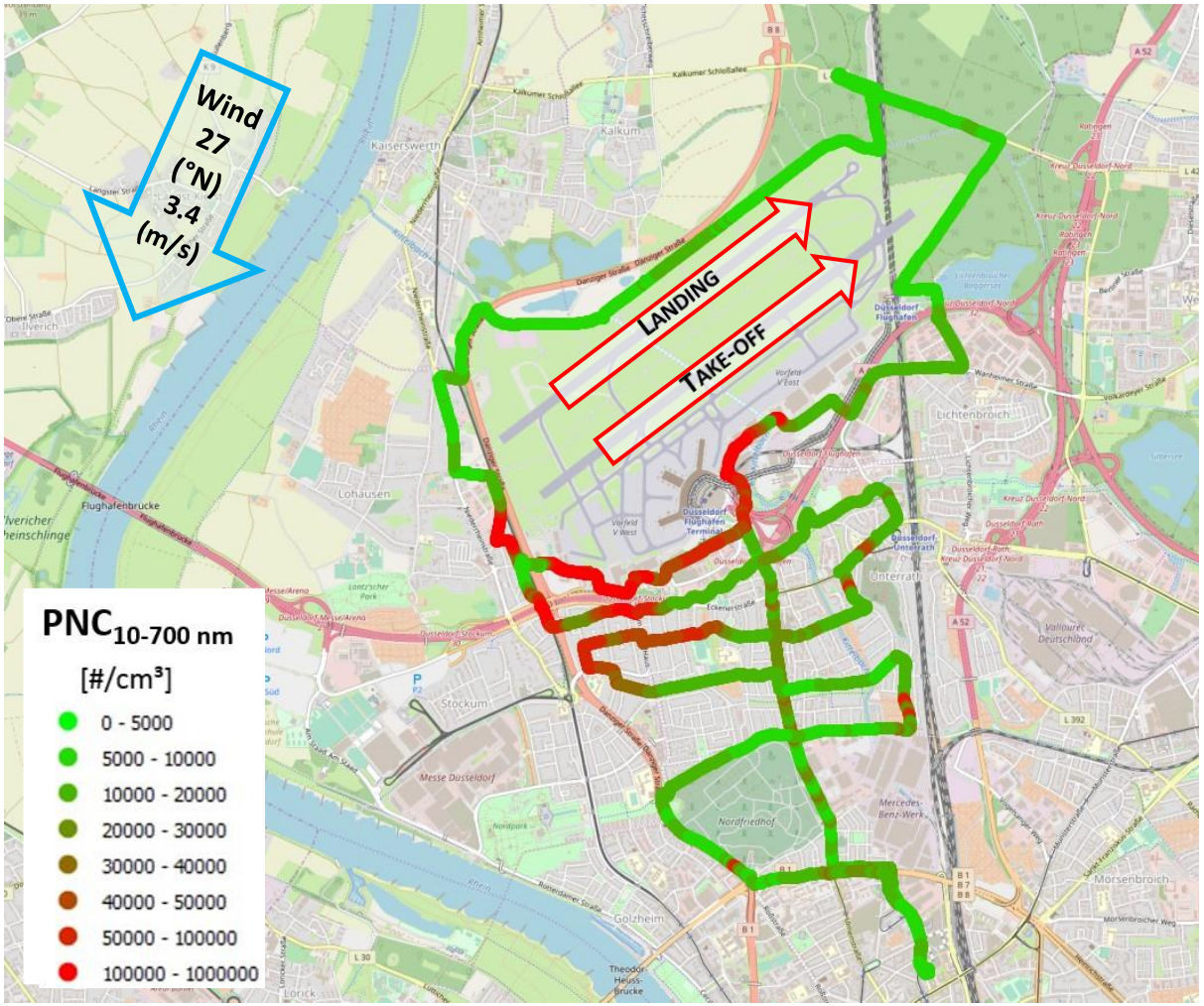



Source: Open Street Map

- **South route - 18.10.2018 (Thu.) - concentration plots**

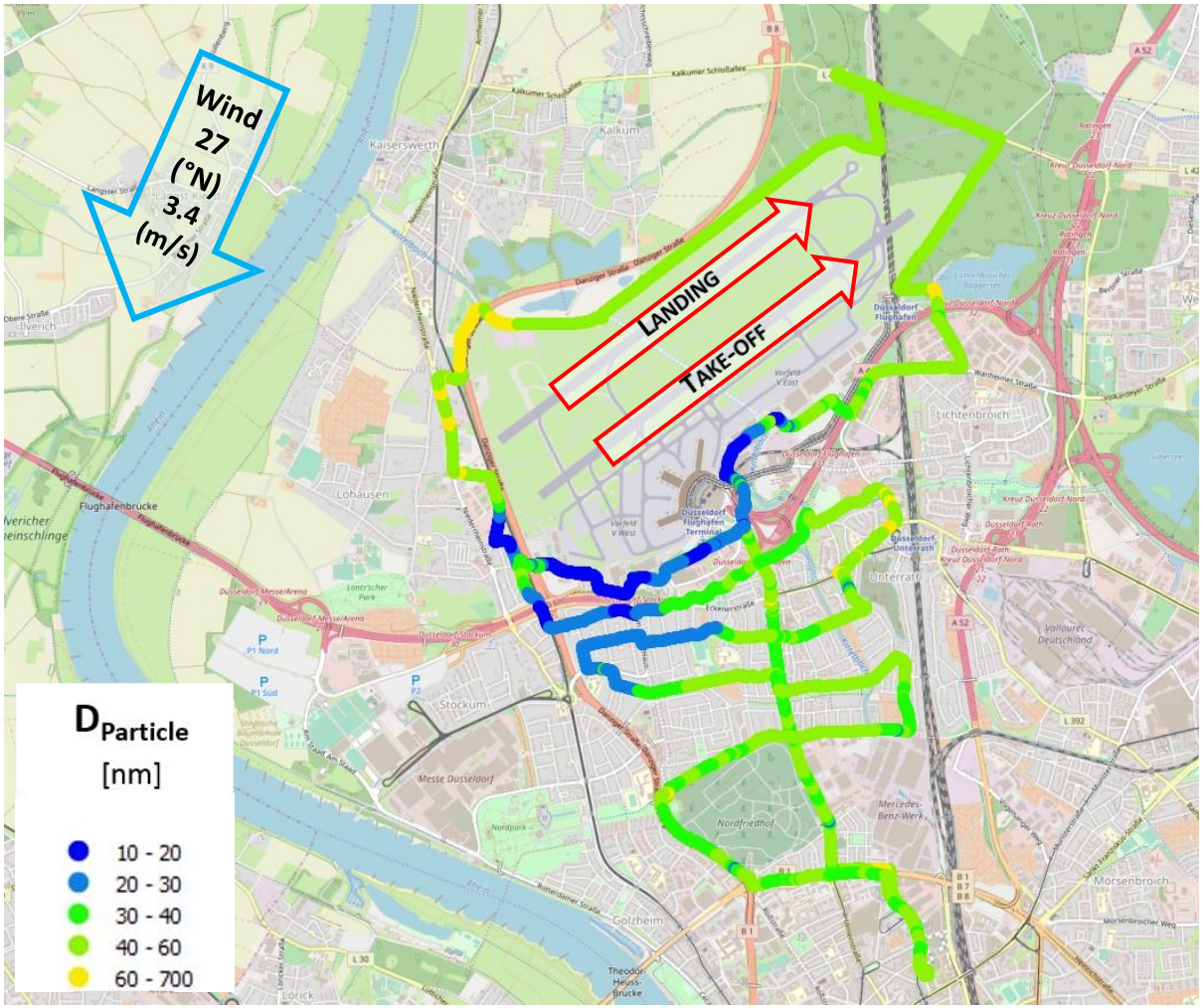


- **South route - 18.10.2018 (Thu.) - spatial distribution - $PNC_{10\text{-}700}$ (dM)**



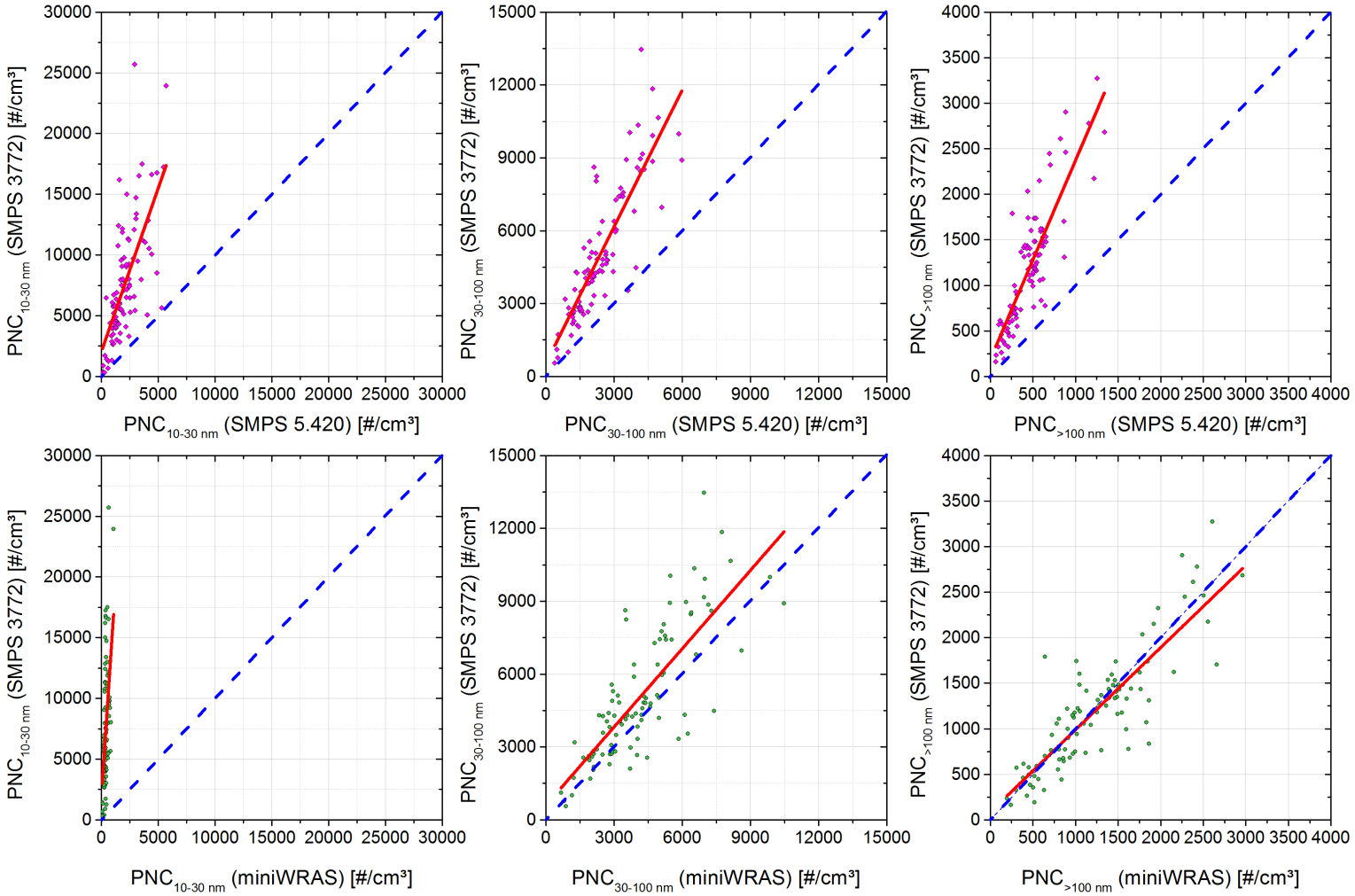

Source: Open Street Map

- **South route - 18.10.2018 (Thu.) - spatial distribution - $D_{Particle}$ (dM)**

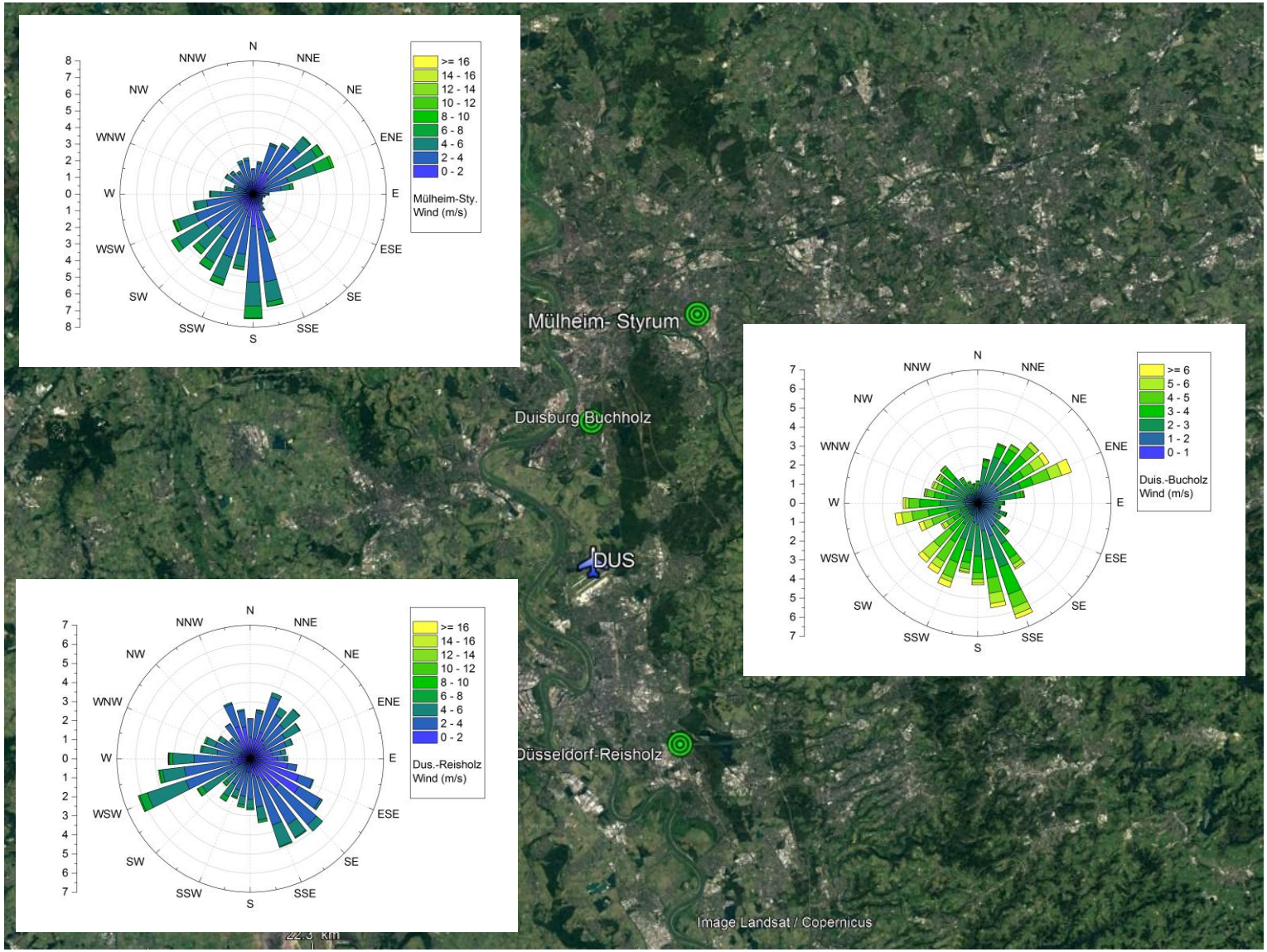



Source: Open Street Map

# Size-dependend correlation



# Windroses from different stations



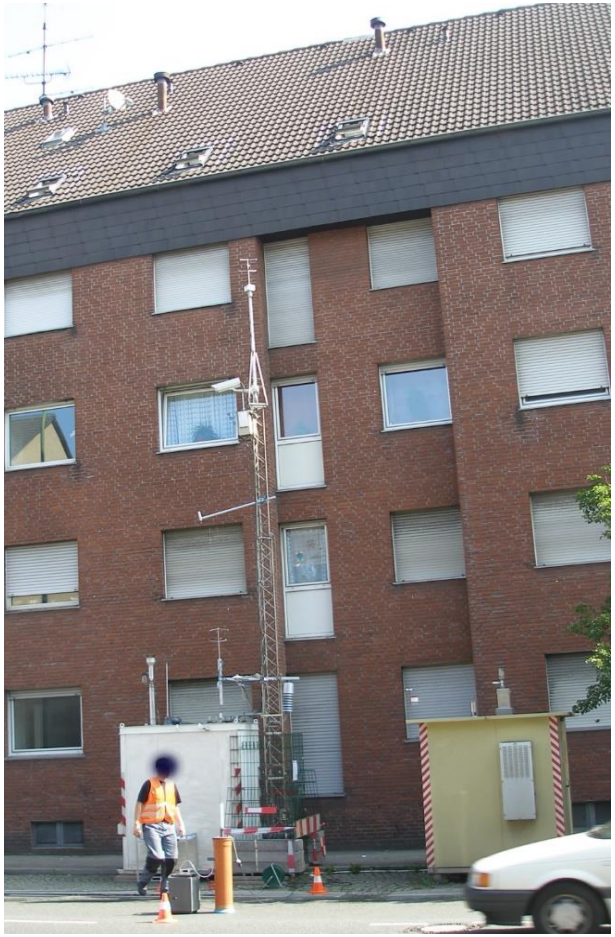
# Stationary measurement platforms

Measurement Truck

Small Measurement Container

Big Measurement Container

# Stationary measurement Platforms



Measurement Tower

Measurement Tower

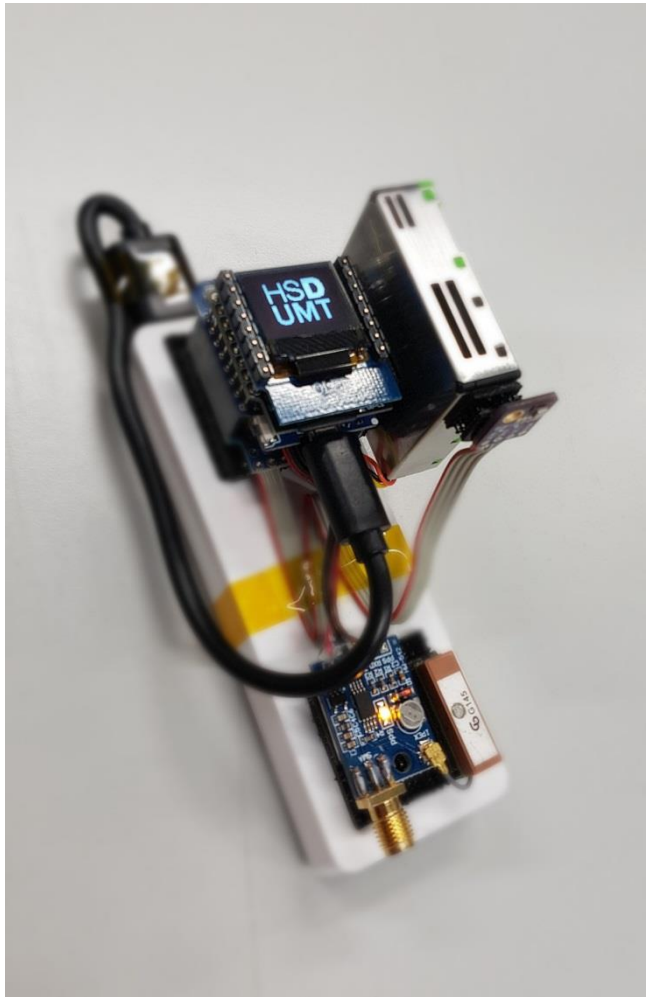
# Mobile Measurement Platforms

Aircraft

Measurement Drones

Measurement Car


Electric Measurement Bicycle




# Complete electronic module based on Sensirion SPS30 developed by HSD

Data are stored continuously on micro-SD card

- PM10
- PM2.5
- PM1
- PM4
- Particle Number concentrations in four classes
- Temperature
- Humidity
- Velocity
- GPS position

**Under development at HSD: LTE-module, WLAN, IRIDIUM for online transmission of data , e.g. during flights with multicopter**