Assessment of heterogeneity of air pollution within an urban canopy

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DER FORSCHUNG | DER LEHRE | DER BILDUNG

UNIVERSITÄT LEIPZIG

TIB

Motivation

- Air quality is an important factor for the health of inhabitants and vegetation within urban areas.
- Local authorities are responsible for monitoring the urban air quality.
  - high running costs
  - coarse network   } hot spot measurements

- Citizen science networks
  - low-cost sensors + many volunteers -> covering a large area
    -> overcome the data sparsity.

a) **Are these data of sufficient high quality to provide results comparable to those of the quality assured networks?**

b) **Is the network density sufficient to determine concentration patterns within the urban canopy layer?**

Measurements

Luftmessnetz Hamburg

Air Monitoring Network

- 4 stations measuring traffic emissions.
- 3 background measuring stations.
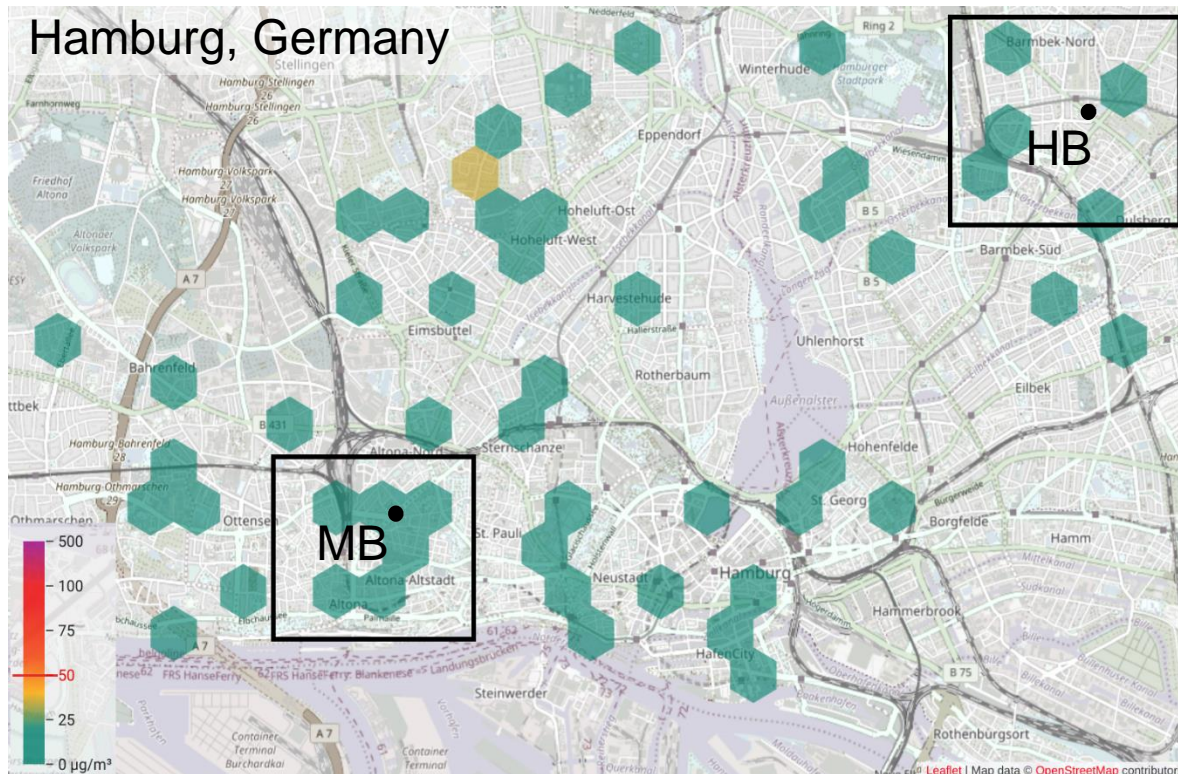
2 traffic emission stations were analysed.
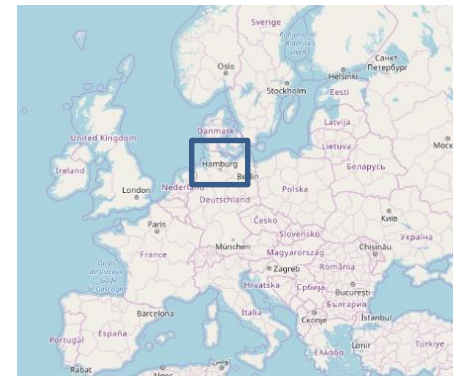
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Citizen Science Network

- Established in 2015.
- Thousand volunteers are participating in this project.
- Usage of low-cost-sensor SDS11.
- Website: luftdaten.info

SDS011 - Sensor

Research Area

AtMoDat

Hamburg, Germany

HB

MB

Screenshot taken on 01.05.2018, source: https://deutschland.maps.luftdaten.info/

Luftmessnetz Hamburg
HB: Habichtstraße
MB: Max-Brauer-Allee

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(Luftdaten.info)

= min. one sensor

Data Selection Criteria

Component: PM2.5 and PM10

1. Data covering the period from 03.2017 – 03.2018.
2. Citizen science stations:
   a) have been active during the period.
   b) located within an area of 3 km distance to the reference site.
   c) were not moved during the period.
3. Must have more measurements than a specific threshold
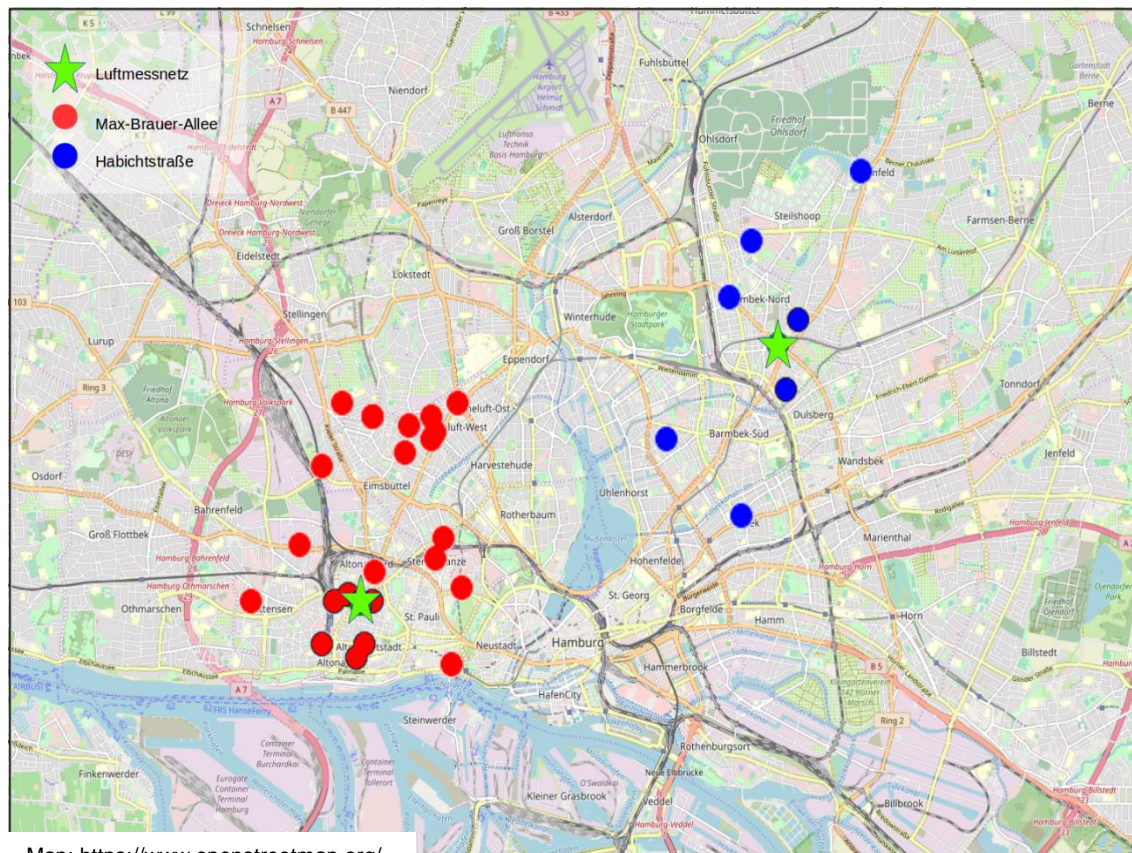   -> min. 6000 hourly mean values.

Selected Stations

Map: https://www.openstreetmap.org/

Legend:
- ⭐ Luftmessnetz
- 🔴 Max-Brauer-Allee
- 🔵 Habichtstraße
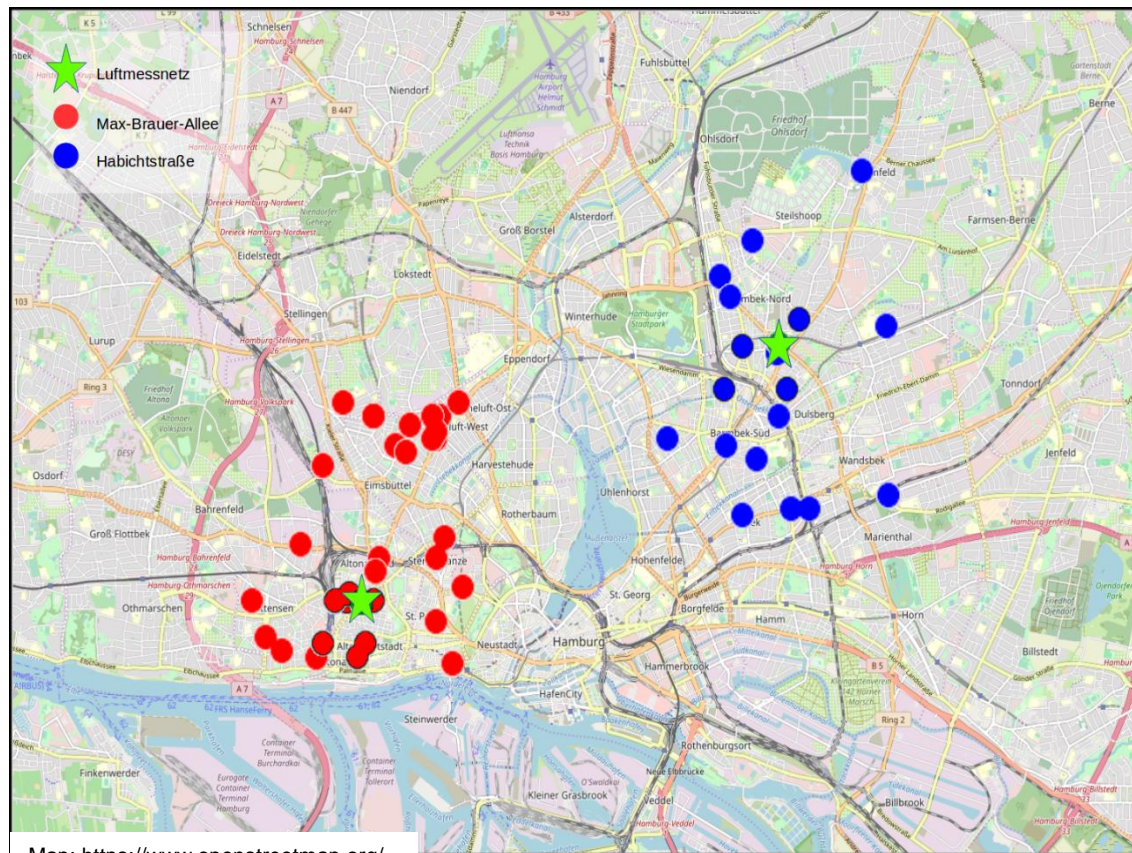
Before applying threshold:

All stations within a radius of 3 km around the reference station.

50 Stations available.

Selected Stations

Map: https://www.openstreetmap.org/

Legend:
- ★ Luftmessnetz
- ● Max-Brauer-Allee
- ● Habichtstraße

After applying threshold:

All stations within a radius of 3 km around the reference stations.
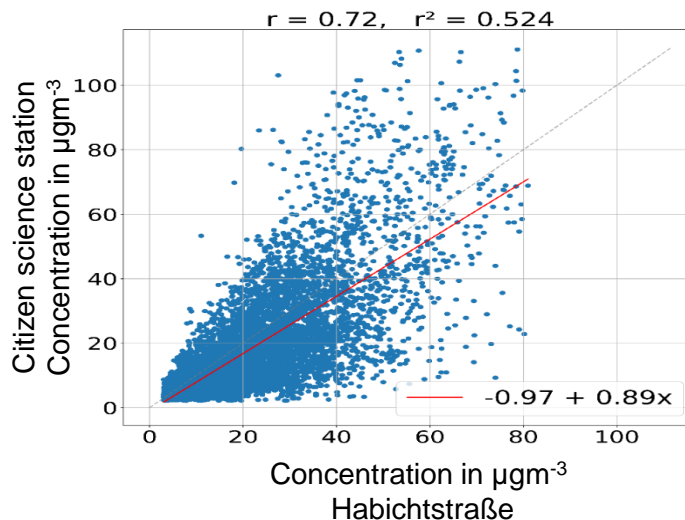They **provide a minimum amount of hourly data.**
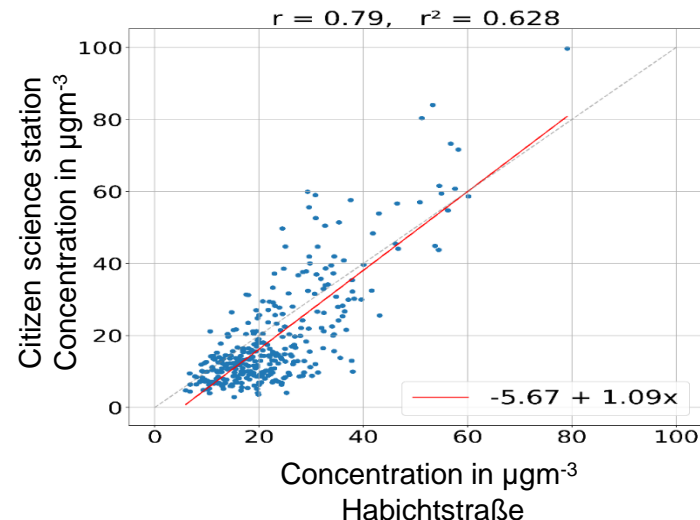
25 Stations available.

Results: Measurements

AtMoDat

Scatter plots and regression for PM10
Station nearby Habichtstraße (North East Hamburg)

The comparison between the reference and low-cost-sensor shows a slight overestimation of the values by the low-cost-sensor.

Hourly mean values

$r = 0.72, \quad r^2 = 0.524$

Citizen science station Concentration in μgm^{-3}

$-0.97 + 0.89x$

Concentration in μgm^{-3}
Habichtstraße

Daily mean values

$r = 0.79, \quad r^2 = 0.628$

Citizen science station Concentration in μgm^{-3}

$-5.67 + 1.09x$

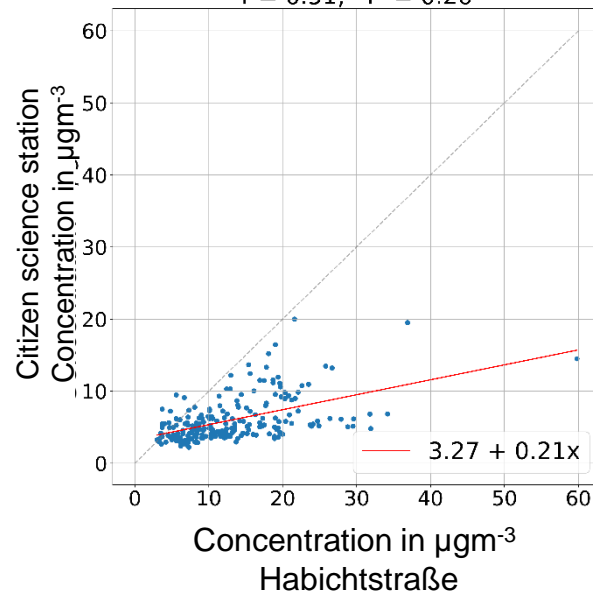Concentration in μgm^{-3}
Habichtstraße

At almost every station this behaviour occured.

Results: Measurements

The measurements of the low-cost sensor are affected by humidity.
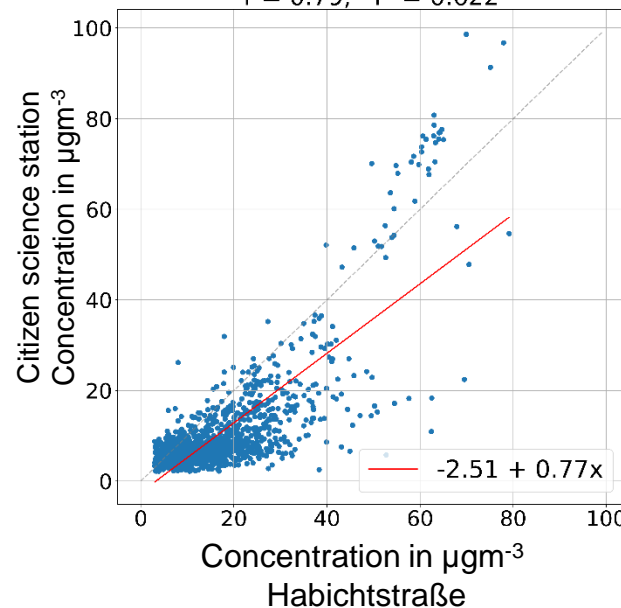PM10, hourly mean values during the occurance of specific RH values.
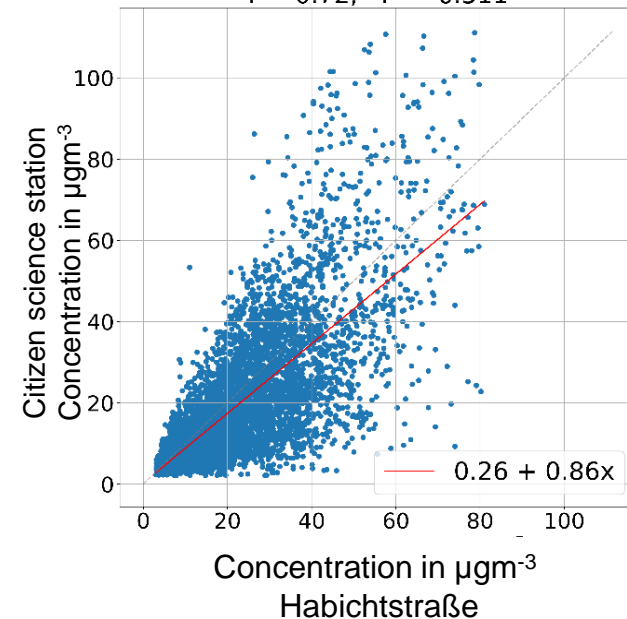

RH below 50 %   RH 50 - 70 %   RH above 70 %

r = 0.51, r² = 0.26   r = 0.79, r² = 0.622   r = 0.72, r² = 0.511

3.27 + 0.21x   -2.51 + 0.77x   0.26 + 0.86x
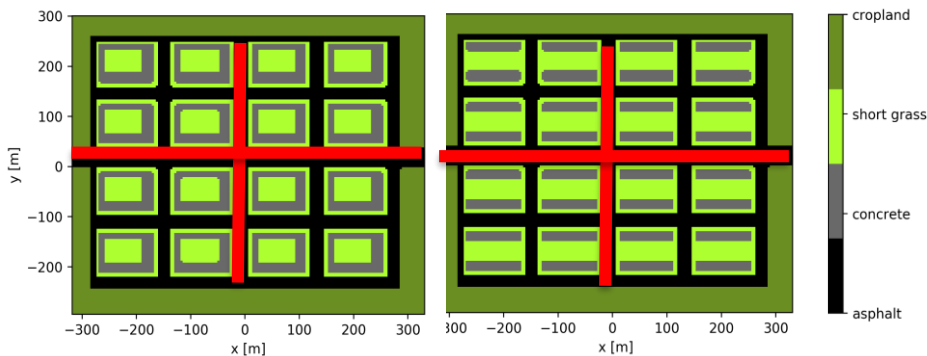
Results: Measurements
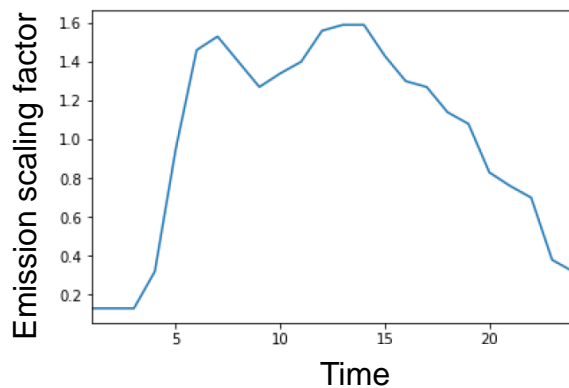
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PM10

All Data
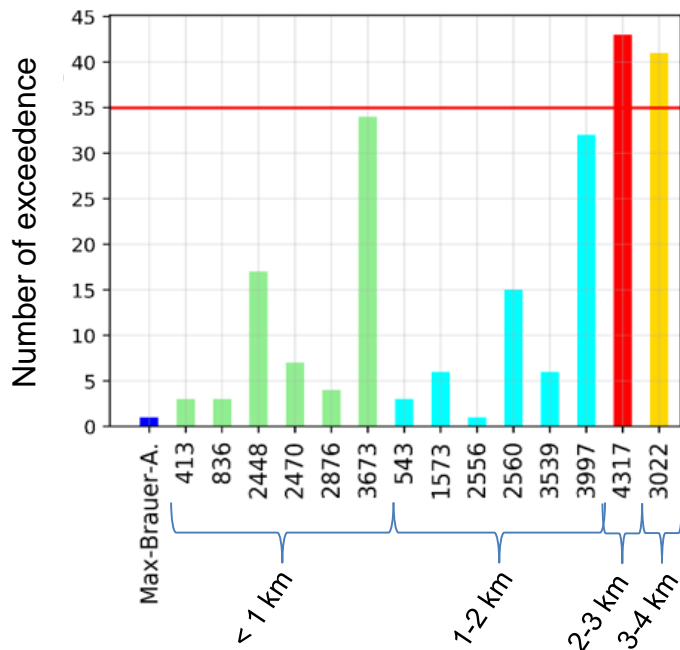
Data during RH 50% - 70%
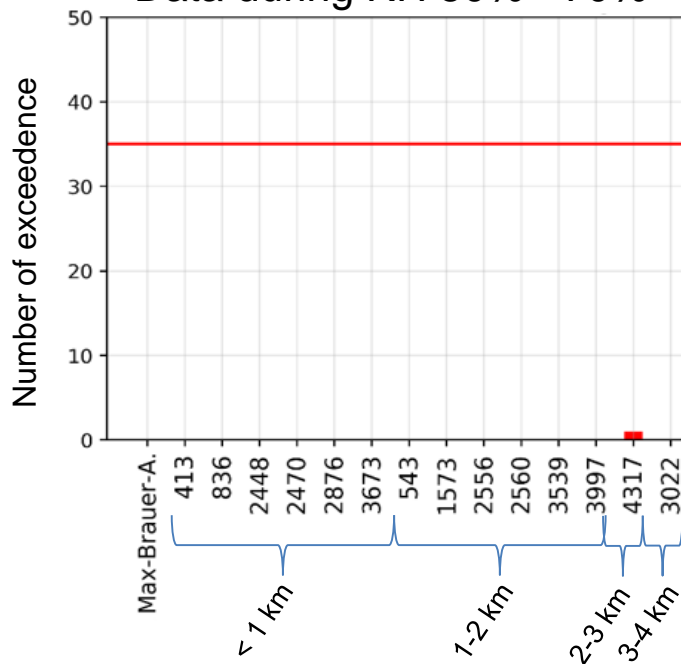
Threshold:
Max. 35 days per year with a daily average concentration
> 50 μg/m³.

Only considering data during the recommended RH provides not enough data for the analysis.

Model Simulation - Model Domain


cropland
short grass
concrete
asphalt

= Area of traffic emission

- **MITRAS** (**MI**cro-scale **TRA**nsport and **S**tream Model).

- Model simulation with two idealized model domains.

- Different wind, stratification and season.

- Emission in both domains at the same streets.

- Passive tracer handling = no chemical reactions.
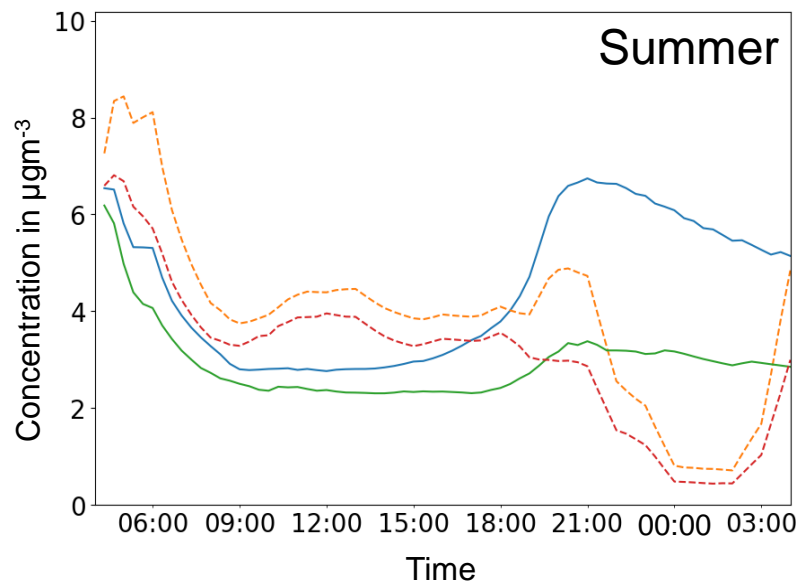
- With and without time dependent release of tracer

Results: Model
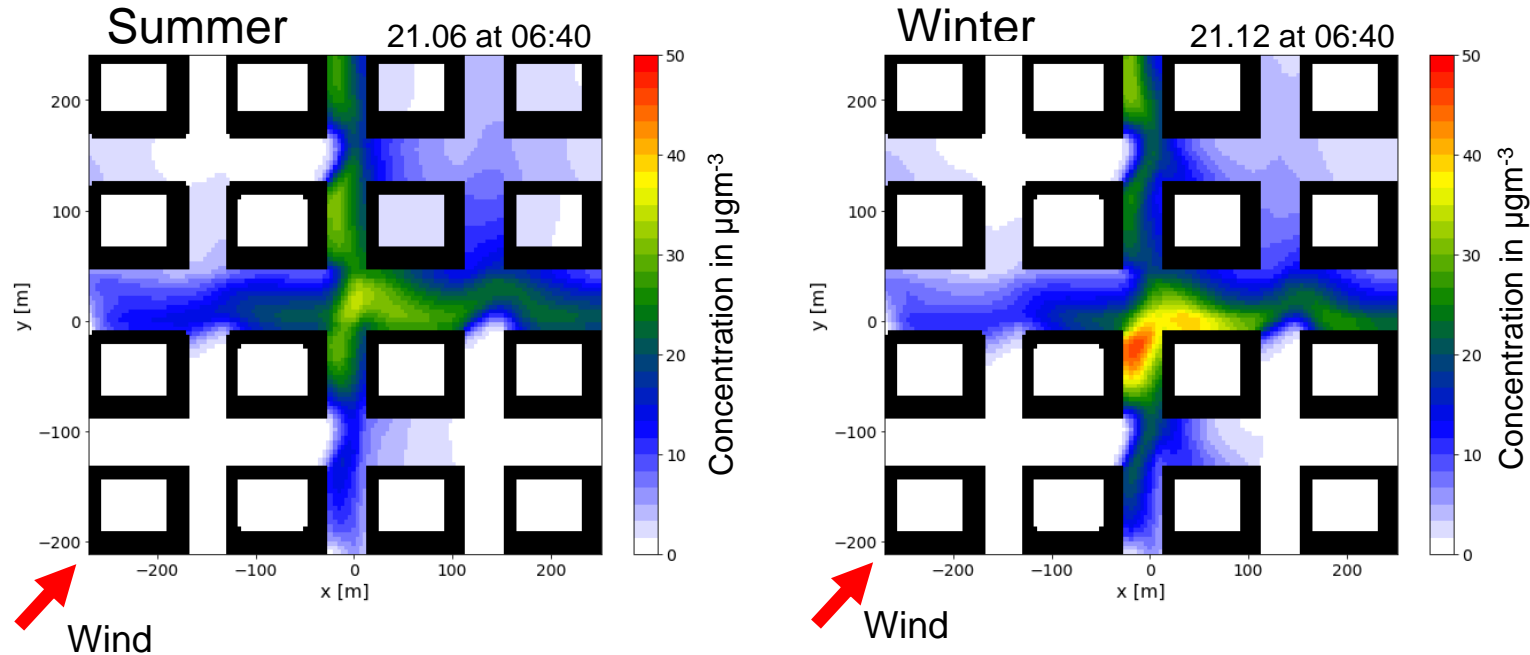
Higher concentration values in winter because of the stable stratification, hinders the dispersion of the tracer.

Results: Model

AtMoDat

Temporal changes of the area mean concentration values

Summer

Level k=1
- b4-Sl-oT } Block Buildings
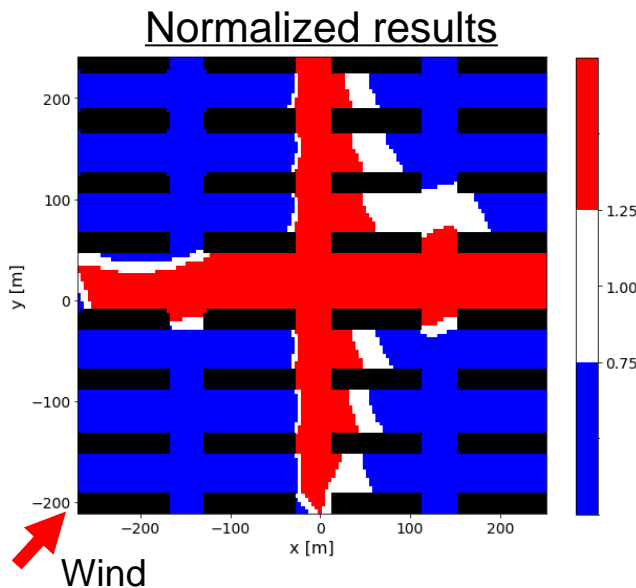- b4-Sl-mT
- t4-Sl-oT } Terraced Buildings
- t4-Sl-mT

oT: without time function
mT: with time function

- Block building simulation: higher mean concentration values.
- Course of the time function clearly visible.

Results: Model

AtMoDat

Where are the measurements representative for the domain?

24 hour mean

Wind

Normalized results

Wind
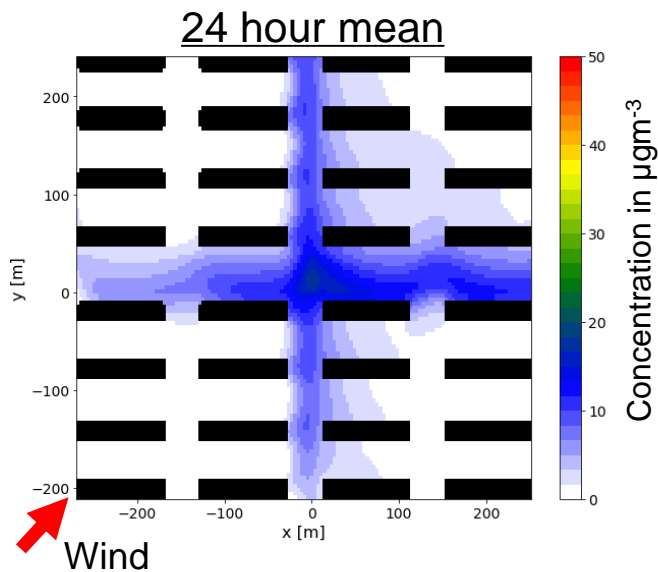
White areas provide values similar to the area mean value.

Measurements in the areas would provide:
Red = overestimated
Blue = underestimated
⎤ Measurements

Conclusion

a) **Are these data of sufficient high quality to provide results comparable to those of the quality assured networks?**
   - Citizen science devices sensitive to humidity.
   - High correlation between the reference and the low-cost-sensors data.
   - Stations provide not enough data for proper analysis.

   Due to the issue with the rel. humidity and due to the lack of long-term measurements during this study, the network does not provide sufficient high quality data.

b) **Is the network density sufficient to determine concentration patterns within the urban canopy layer?**
   - Small amount of data compared to the amount of sensors in the area.
   - Model results: a much denser network is needed.

   During this study, the density of the network was too coarse to estimate concentration pattern.

Thank you for your attention.

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Special Thanks to:

- OK LAB Stuttgart (luftdaten.info)
- Hamburger Luftmessnetz, (luft.hamburg.de)

For providing data and information about the measurement system.

This work contributes to the Project **AtMoDat,** which develops a data standard for microscale, obstacle resolving model data.

For further Information please visit our website (www.atmodat.de) and contribute in our survey! (QR-Code) or via **uhh.de/orm-survey**

About AtMoDat

AtMoDat (short for Atmospheric Model Data) aims to create a model data standard which:

- consider specific features of micro scale model and the model output data.
- should enhance the exchange of data between modeler and user.
- increase the reusability of data and improve the publication process.
- Be based on the Climate and Forecast (CF) convention, that are used by CMIP.

Further information on our website (www.atmodat.de) or visit the presentation by Daniel Neumann, entitled:

AtMoDat: Improving the reusability of ATmospheric MOdel DATa with a DataCite DOIs paving the path towards FAIR data. (EGU2020-8463)