Greenhouse Gas Emission Estimate Using a Fully-automated Permanent Sensor Network in Munich

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Objectives

- Creating an GHG emission map based on concentration measurements
- Improving the emission inventories
- Finding and quantifying unknown emission sources
- Evaluating existing and planned GHG mitigation policies

- **Approach**:
  - Differential column measurements (*Chen et al. 2016*)
  - $E \propto C_{downwind} - C_{upwind}$

- **Fully-automated sensor network necessary**

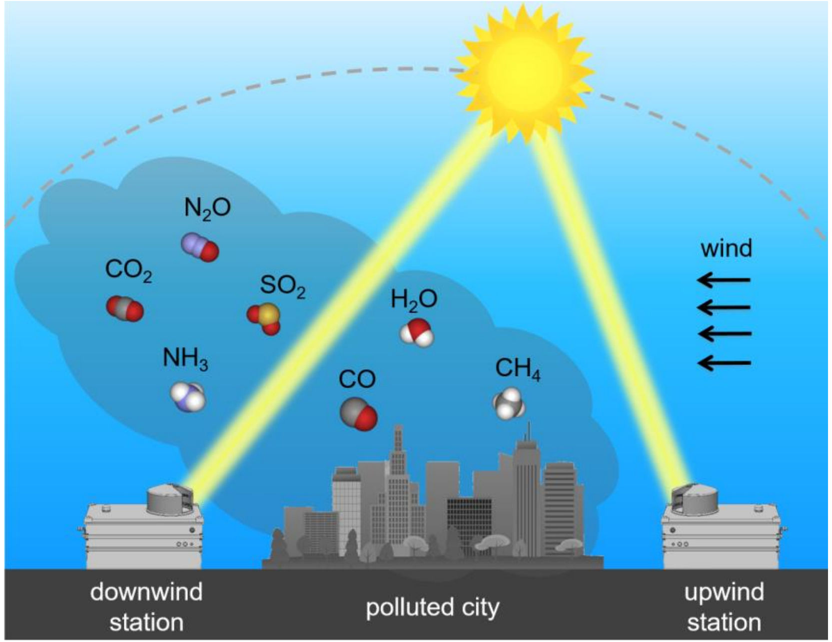

Fig. 1: Principle of the differential column measurements

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Enclosure System

(Heinle and Chen, 2018; Dietrich et al. 2019)

- Fully-automated system
  - Rain/sun detection
  - Automatic start/stop of measurements
  - Remote control
  - Fail-safe → reliable protection of the instrument
  - Easy to transport
- Deployed in Munich (5 stations), Finland and Uganda

→ Our system reduces the personnel costs to a minimum and increases the amount of measurement data to a maximum

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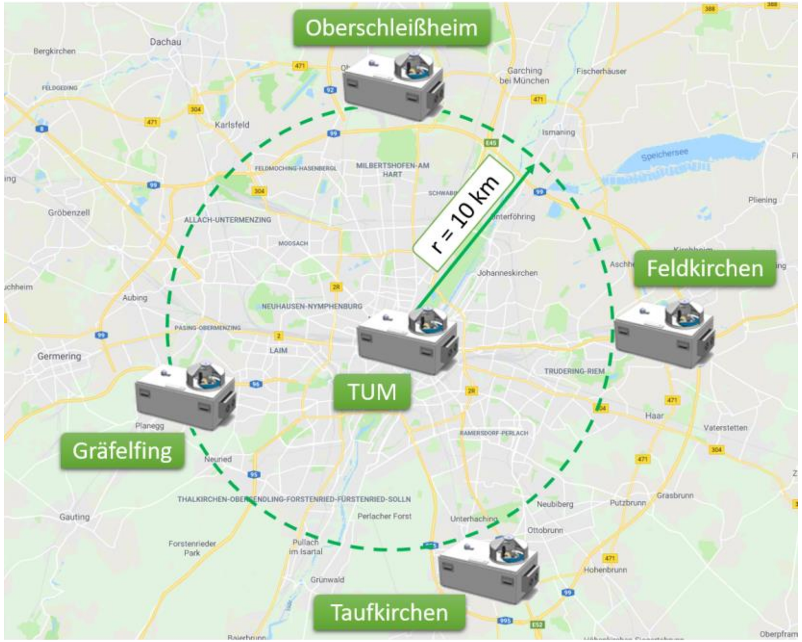
Sensor Network Setup



- 5 FTIR spectrometer in our fully-automated enclosures
- Distributed in and around Munich
  - Always at least one upwind/downwind station for arbitrary wind conditions
  - Center station is the downwind of half the city
- Running permanently since September 2019 with 5 stations
- Center station is operating since summer 2015

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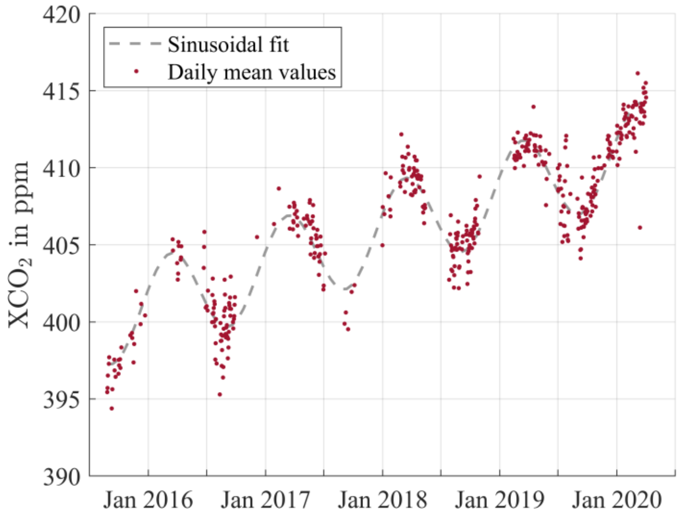
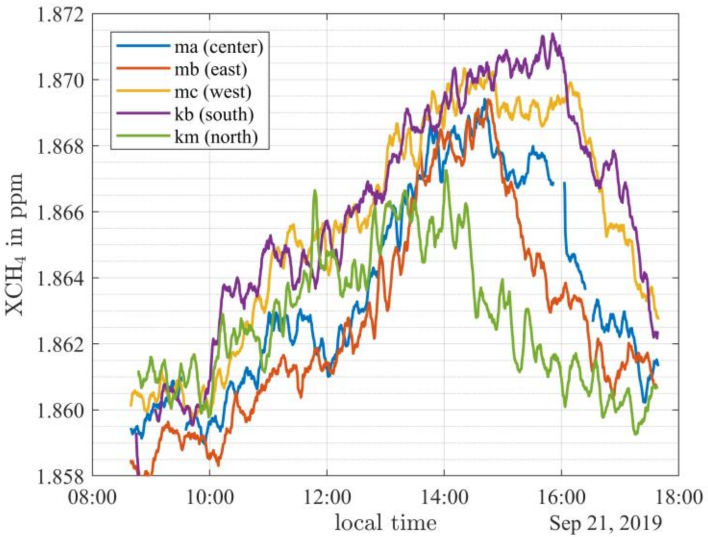
Measurement Results





→ Inner-city station captures the seasonal cycle of CO_2 for the last 4.5 years

→ Sensor network can sense the concentration gradients of CH_4 to quantify the emissions

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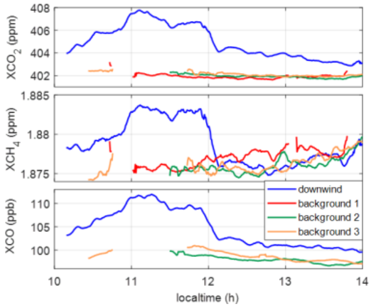
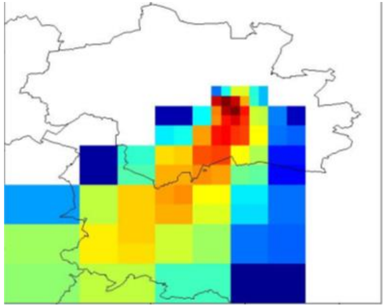
Framework for Estimating Emission (Bayesian Inversion)

(Jones et al. 2020)

$$\min_{x,\,b} \| y - (Hx + Bb) \|_2$$





y: *observations*

H: *footprint matrix*

x: *emissions*

B: *background influence matrix*

b: *background concentration*

→ Approach: Minimizing a cost function to determine the emissions and the background influence

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Inverse Modeling Results

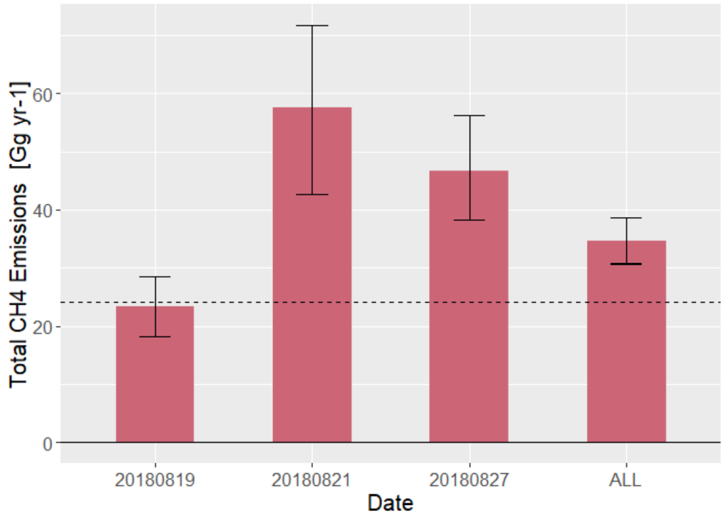

Fig. 2: Methane emission results of the inversion framework

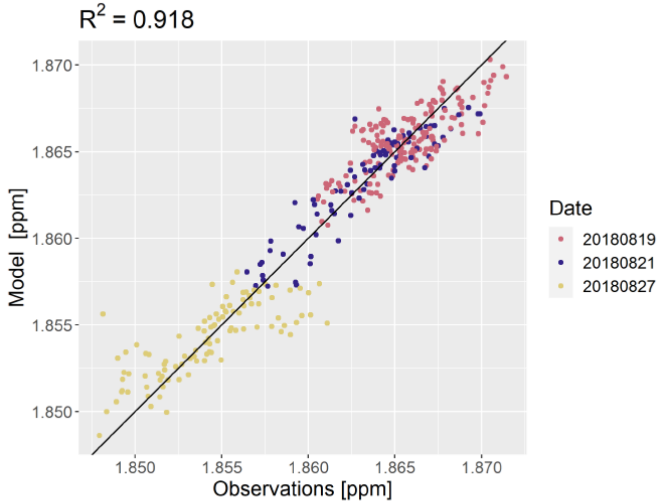

Fig. 3: Correlations between measurements and the model

→ Emission number 1.5 times higher than the emission inventory
→ Inventory mistakenly characterized gas-fired power plant as a hotspot

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Conclusion

- First urban GHG network worldwide based on the principle of differential column measurements
- Fully-automated to minimize the personnel effort and maximize the data amount
- Long-term inner-city measurements since 2015, city gradients since 2019
- New inversion framework to determine urban GHG emissions based on column measurements
- Emission inventory (TNO-MACC) underestimates Munich emission, but overestimates gas fired power plant

Fig. 4: Our 5 sensor systems on the roof of the university building during the calibration measurements 2018

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References

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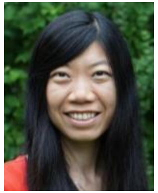

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