Investigations of Methane Emissions from the Munich Oktoberfest 2018

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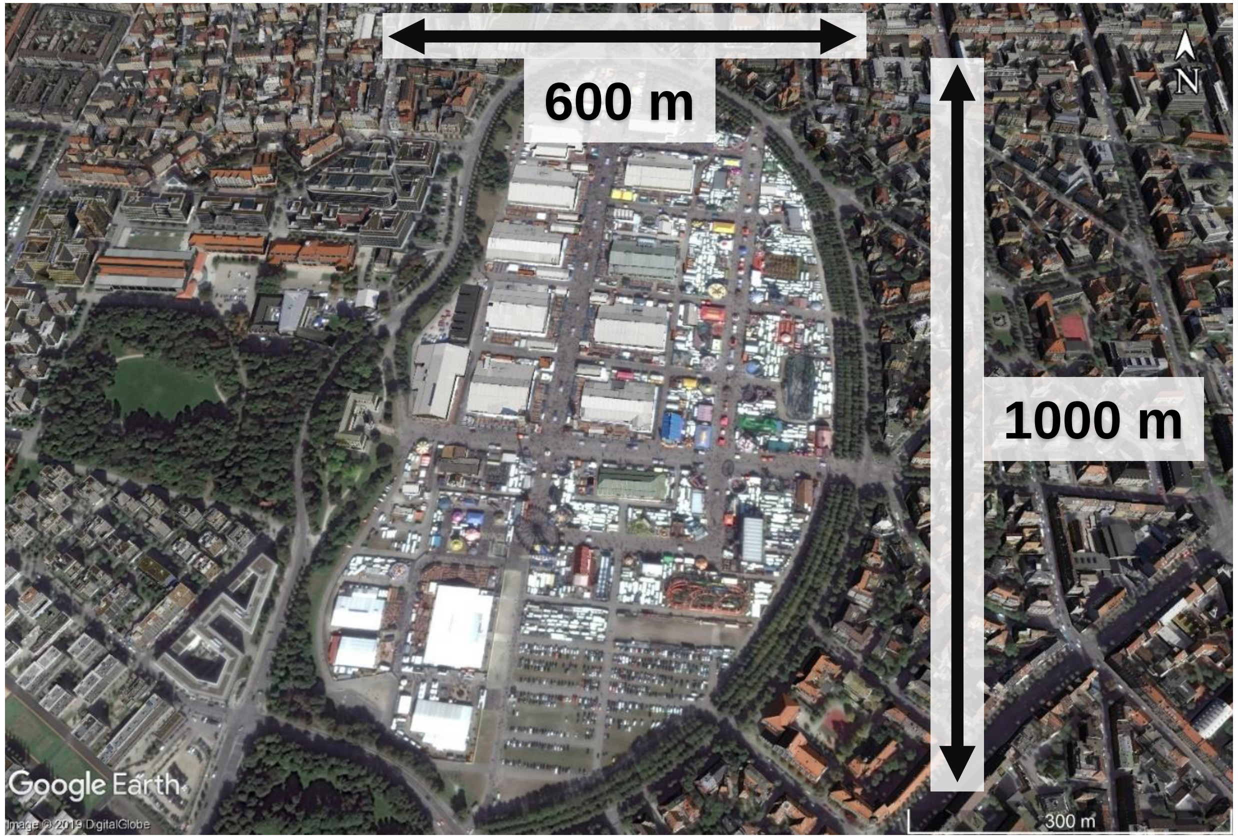
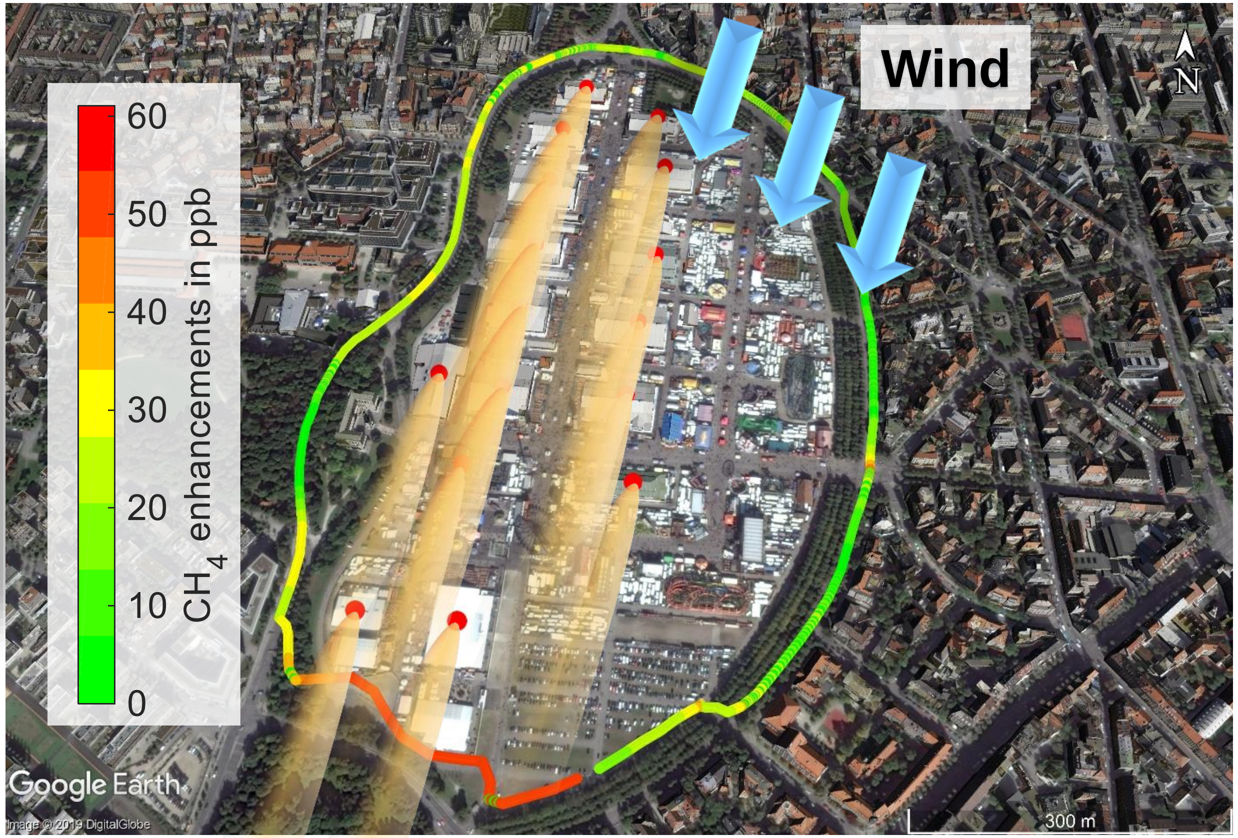
Oktoberfest facts:

- > 6 Mio. Visitor
- Visitor density: ≈ 1 pers/m²
- 40 % of total energy provided by natural gas → CH_4
- 4 km of temporal constructed gas pipelines



Oktoberfest investigations 2018



→ Quantification of the emission number including a daily emission cycle of the Oktoberfest

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Motivation

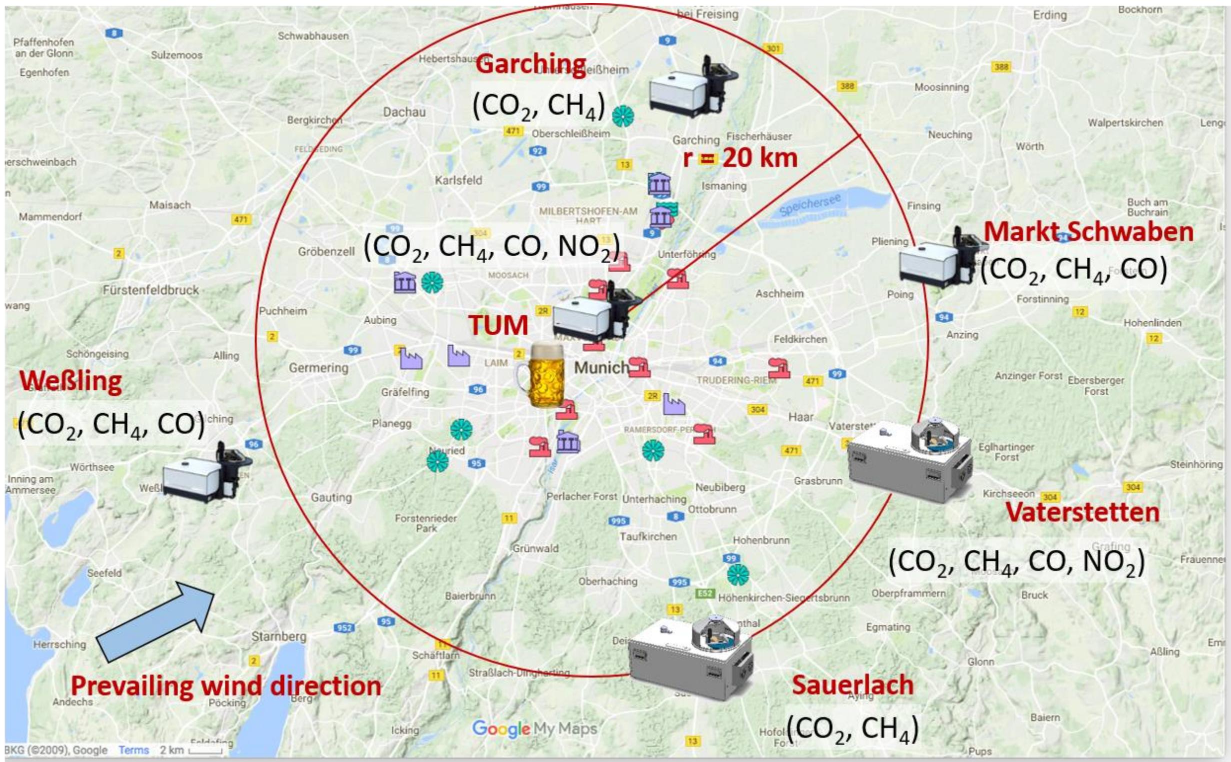
Oktoberfest facts:

- > 6 Mio. Visitor
- Visitor density: ≈ 1 pers/m²
- 40 % of total energy provided by natural gas → CH_4
- 4 km of temporal constructed gas pipelines

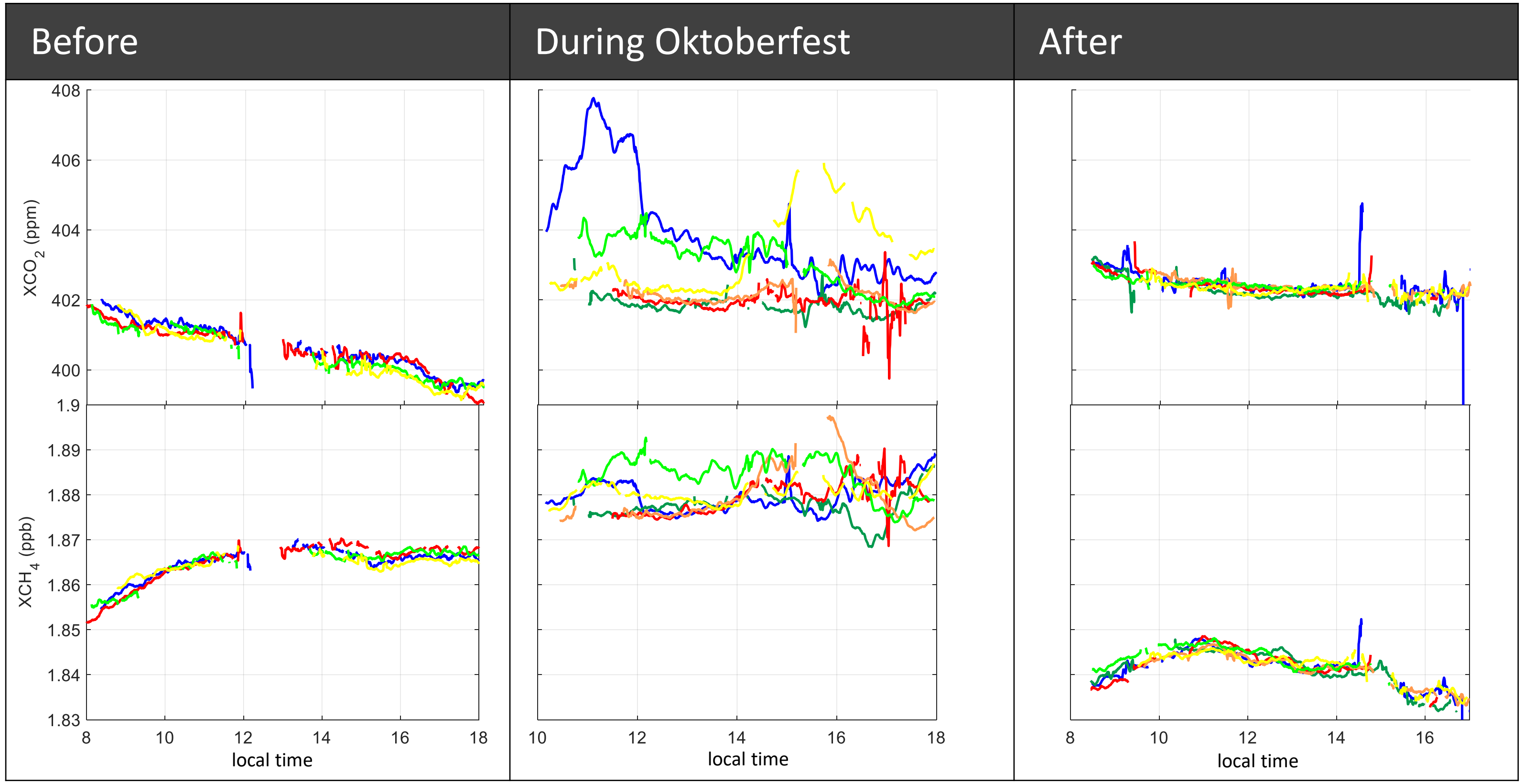
→ Due to those numbers Oktoberfest could be a potential CH_4 source

Motivation – Measurement campaign 2017 setup

- Ground-based remote sensing
- FTIR spectrometer (EM27/SUN)
- Differential column method
- Covering Oktoberfest period



Motivation – Measurement campaign 2017 results



→ Higher absolute GHG values and higher enhancement during the time of the Oktoberfest compared to the period before and after

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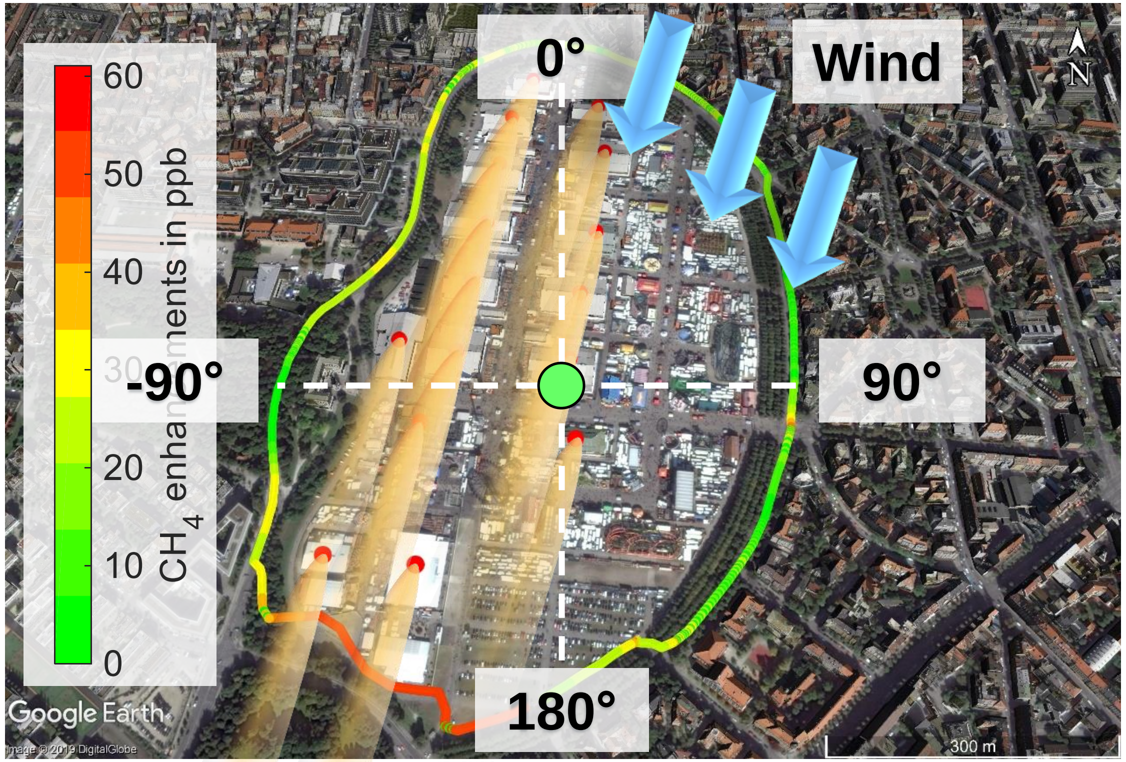
Measurement approach

- → Waking and biking around the area of the Oktoberfest
- → Sensor: Picarro GasScouter G4302 (cavity-ring-down laser spectrometer)

Motivation >
Approach v
Measurement
Multiple Gaussian plume model
Plume selection algorithm
Forward and inverse model
Results >

Modeling approach – Multiple Gaussian plume model

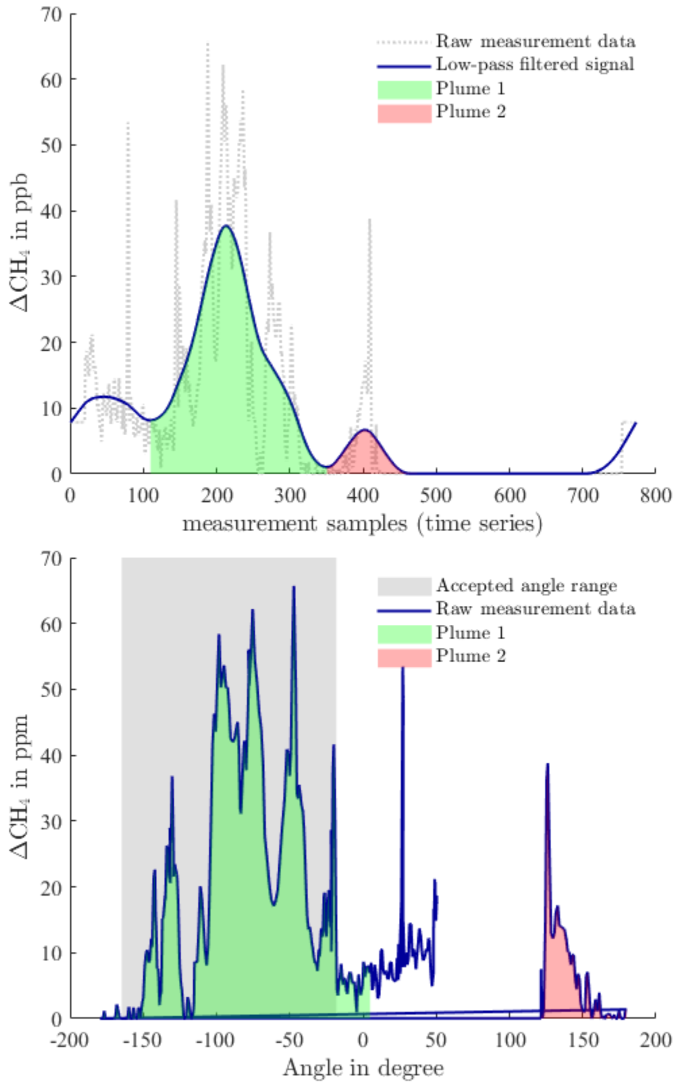
- Tents as sources
- Every tent as Gaussian plume source
- Overlapping plumes of the 16 biggest tents with each other



→ Framework to determine the emission number of an area source

Modeling – Plume selection

- Raw data: Possibility that several plumes exist within a single round
- Plume detection by low-pass filtering (Kaiser window)
- Separating into plumes
- Comparing plume angle range with forward model: the plume with the higher overlapping ratio is chosen



→ Determining best suited plume for each round
→ Less sensitive to wind errors

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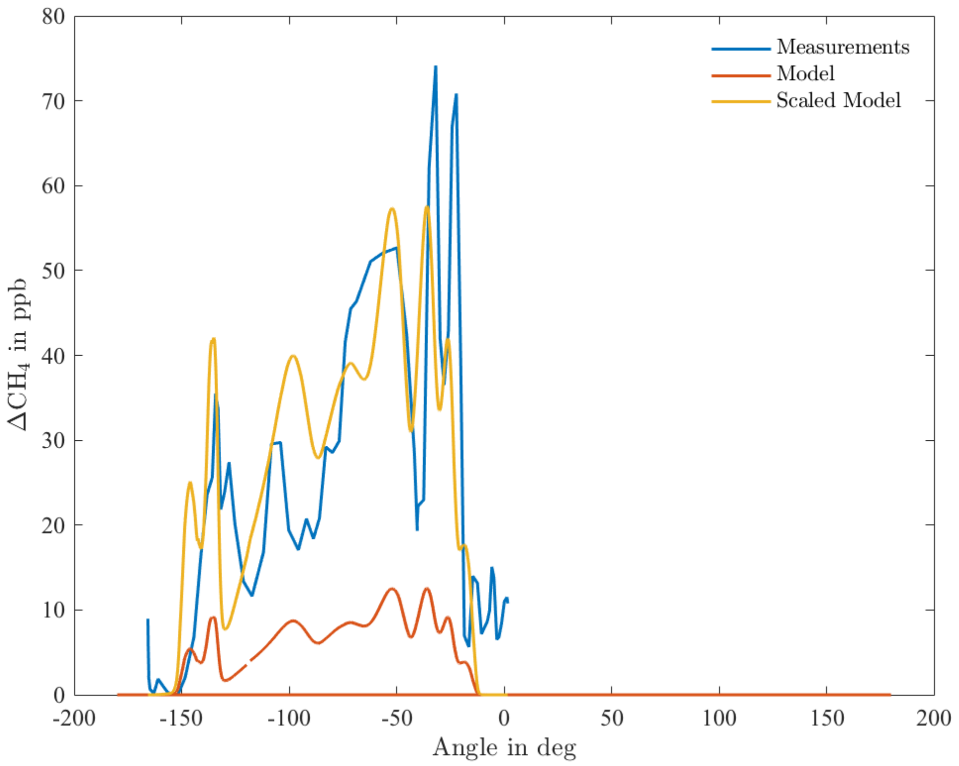
Modeling approach – Forward and inverse model

- CH_4 concentrations with respect to the angle
- Forward model consisting of 16 overlapping Gaussian plumes
- Scale the model such that the area underneath model and measurements curve is equal
- $E_{Oktoberfest} = E_{prior} \cdot k_{scaling}$

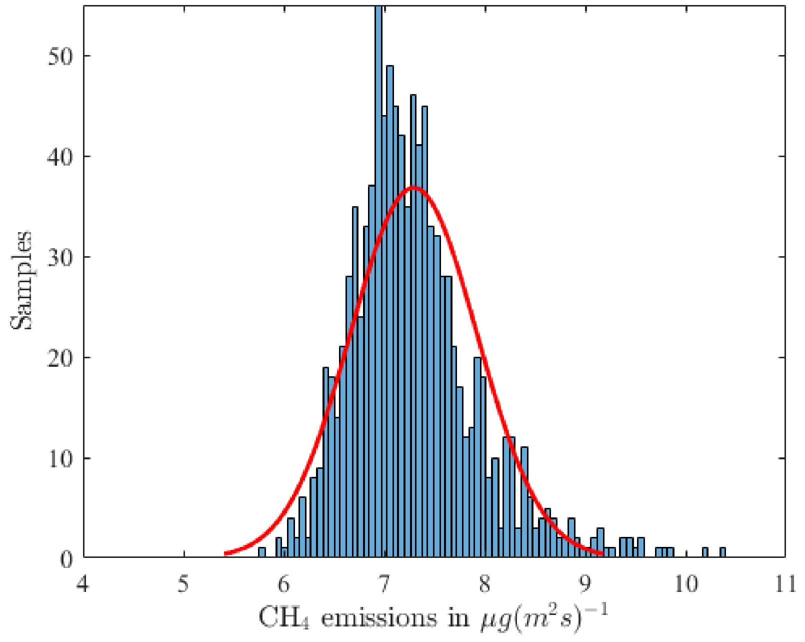


→ Forward model is agreeing well with the measurements

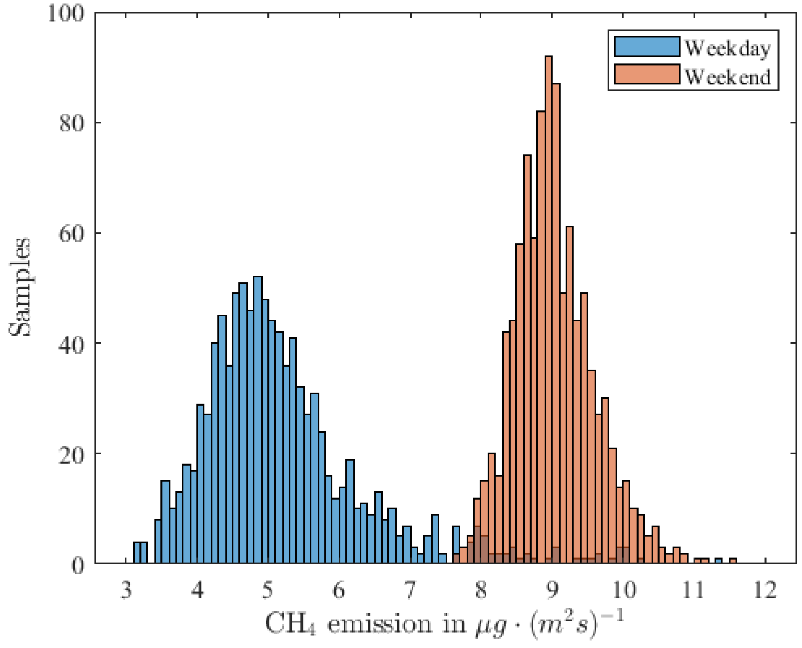
Results – Emission distribution

Motivation >
Approach >
Results v
Emission distribution
Source attribution
Study comparison

Total distribution



Comparison weekend vs. weekday

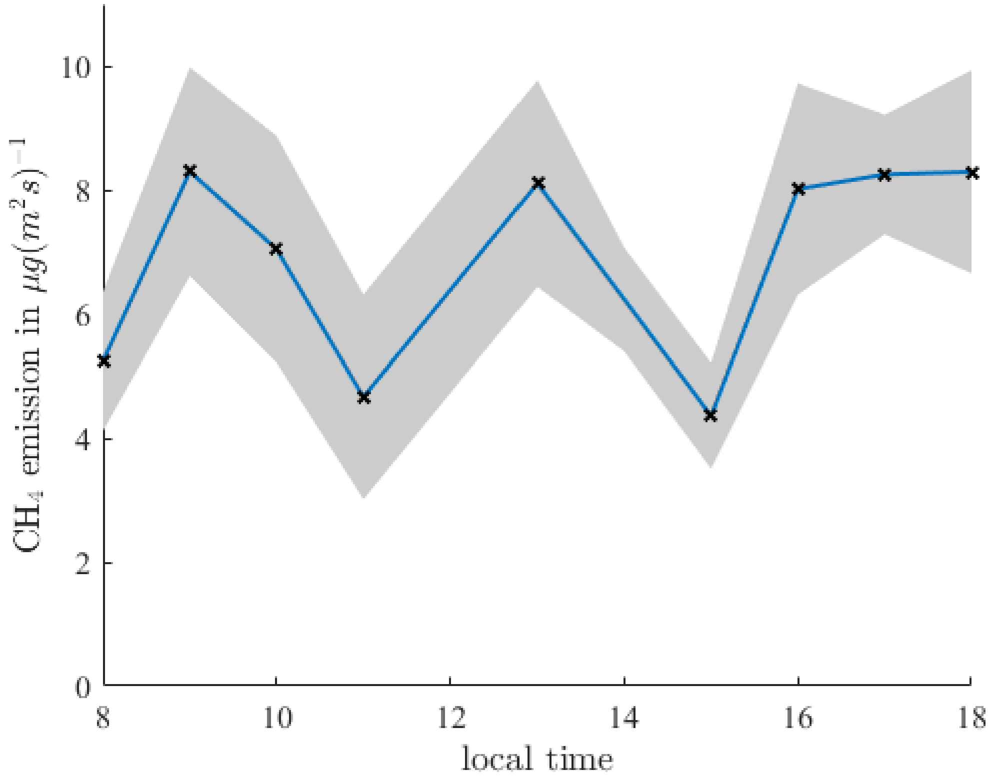


→ Gaussian shaped emission distribution
→ Overall emissions: **7.3** ± 0.6 µg$(m^2s)^{-1}$

→ Weekend emissions significantly higher than weekday emissions

Results – Source attribution

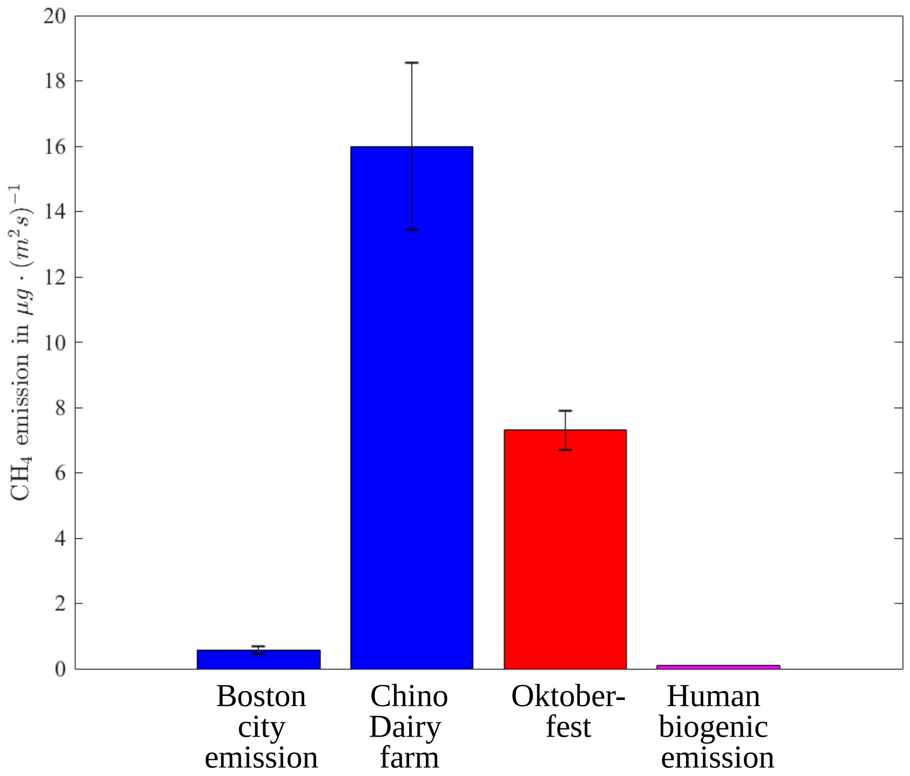
- Emission trend is not directly correlated with amount of visitors
- Tents seem to be the emission sources (good correlation between measurement and model)
- Biogenic human emissions are too weak to explain the total emission numbers



→ Emissions likely related to gas leakages, incomplete combustion, etc.

Results – Comparison to other studies

- Boston: 0.59 µg/(m²s) (McKain et al. 2015)
- Chino: 16 µg/(m²s) (Chen et al. 2016)
- Human biogenic: 0.04 µg/(m²s) (Keppler et al. 2016)



→ Oktoberfest is a significant methane source