Investigations of Methane Emissions from the Munich Oktoberfest 2018

Jia Chen (1), Florian Dietrich (1), Hossein Maazallah (2,4), Dominik Winkler (1), Andreas Forstmaier (1), Magdalena Hofmann (3), Hugo Denier van der Gon (4), and Thomas Röckmann (2)

(1) Environmental Sensing and Modeling, Technical University of Munich, Munich, Germany (jia.chen@tum.de),
(2) Institute for Marine and Atmospheric Research, Utrecht University, Utrecht, The Netherlands,
(3) Picarro B.V., ’s-Hertogenbosch, The Netherlands,
(4) Netherlands Organisation for Applied Scientific Research (TNO), Utrecht, The Netherlands
**Oktoberfest facts:**

- > 6 Mio. Visitor
- Visitor density: ≈ 1 pers/m²
- 40% of total energy provided by natural gas \( \rightarrow \text{CH}_4 \)
- 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 → CH₄
- 4 km of temporal constructed gas pipelines

→ Due to those numbers Oktoberfest could be a potential CH₄ 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

<table>
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<tr>
<th>Before</th>
<th>During Oktoberfest</th>
<th>After</th>
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<tbody>
<tr>
<td><img src="before.png" alt="Graph" /></td>
<td><img src="during.png" alt="Graph" /></td>
<td><img src="after.png" alt="Graph" /></td>
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- 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)
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
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

Total distribution

- Gaussian shaped emission distribution
- Overall emissions: $7.3 \pm 0.6 \, \mu g/(m^2 s)$

Comparison weekend vs. weekday

- 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