Title: Detection, localization, and quantification of single-source methane emissions on oil and gas production sites using point-in-space continuous monitoring systems

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ABSTRACT

We propose a modular framework for methane emission event detection, localization, and quantification on oil and gas production sites that uses concentration and wind data collected by point-in-space continuous monitoring systems. The framework uses a gradient-based spike detection algorithm to estimate emission start and end times (event detection) and pattern matches simulated and observed concentrations to estimate emission source location (localization) and rate (quantification). The framework was evaluated on a month of non-blinded, single-source controlled releases from METEC. Potential uses for the proposed framework include near real time alerting for rapid emission mitigation and emission quantification for data-driven inventory estimation on production sites.

1. Background

- Oil and gas sites are a promising avenue for methane emission reduction, as leaks can be mitigated if detected quickly.
- Continuous monitoring systems (CMS) measure methane concentrations in near real time, and hence can provide rapid alerts to operators when an emission is detected.
- An analytical framework is required to translate raw CMS concentration observations into emission start and end time estimates (event detection), source estimates (localization), and rate estimates (quantification).

2. DLQ framework

Step 1. Background removal and event detection
Remove background from the raw concentration data and identify time periods during which we think emissions are occurring using a gradient-based spike detection algorithm.

Step 2. Simulation
Use the Gaussian puff atmospheric dispersion model to simulate concentrations at each sensor location given different potential emission sources and the observed wind data.

Step 3. Localization
Compare the simulated concentrations to the actual concentration observations to identify the most likely source.

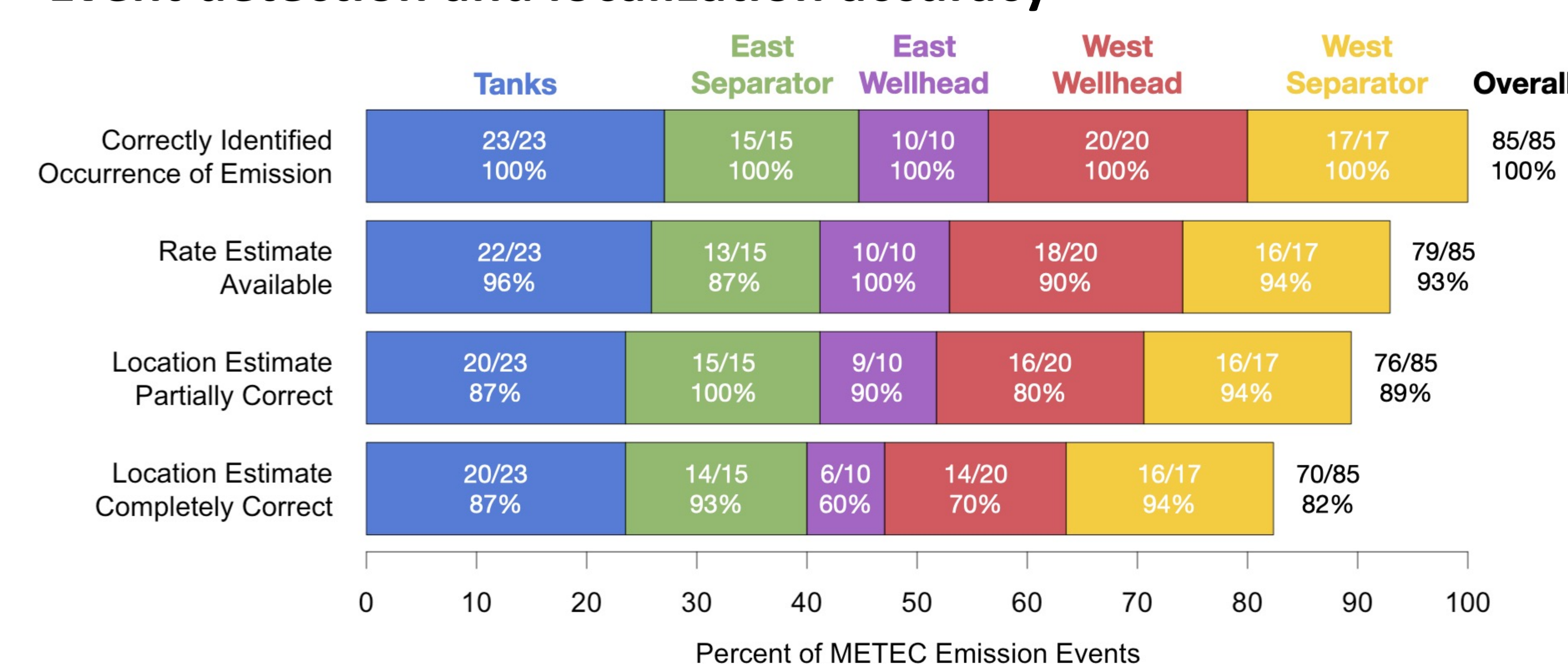
Step 4. Quantification
Scale the simulated concentrations from the most likely source identified in the previous step to optimally match the actual observations, which provides an emission rate estimate.

3. Experimental data

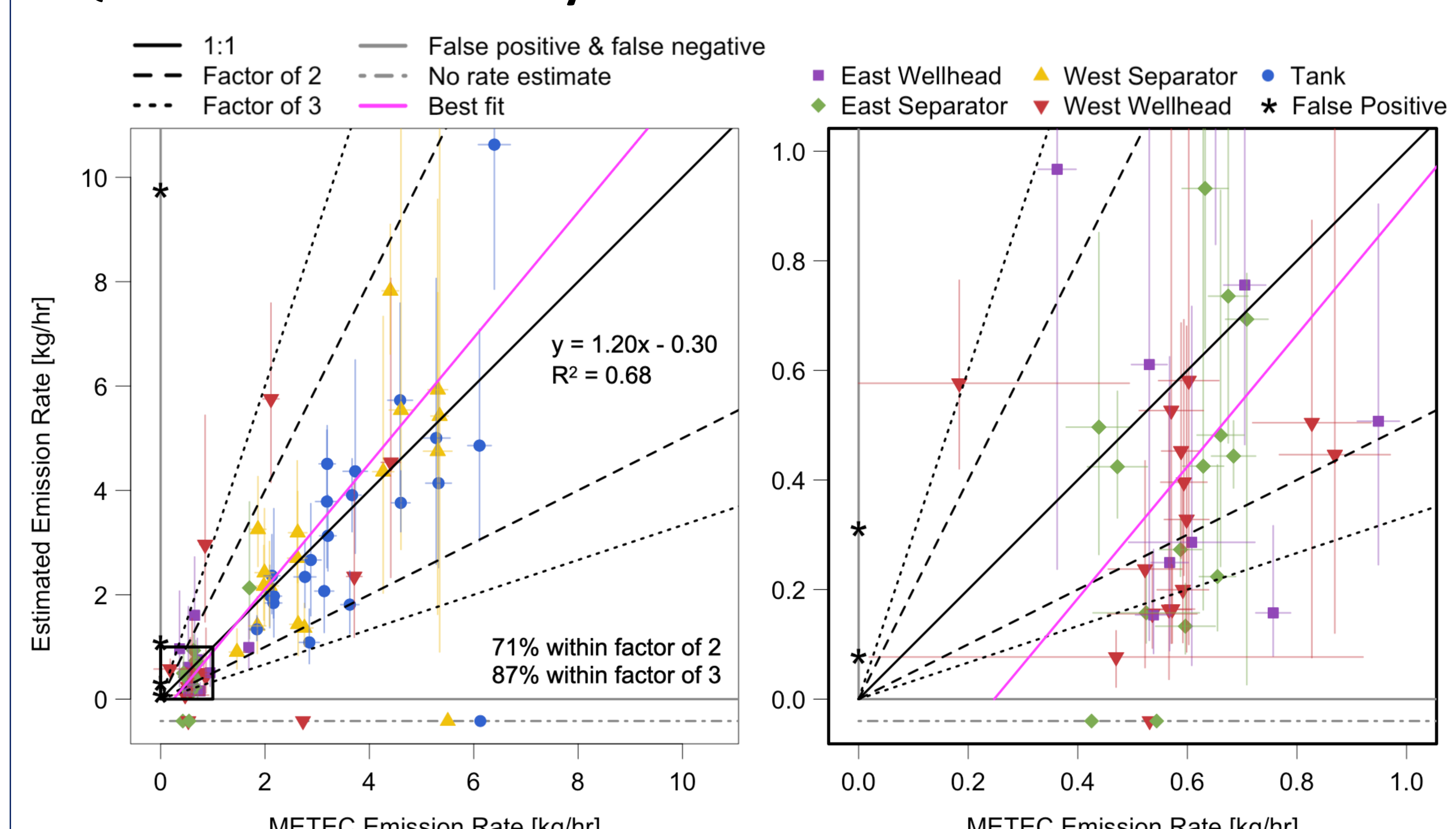
We evaluate the framework on 85 single-source controlled releases at the Methane Emissions Technology Evaluation Center (METEC)

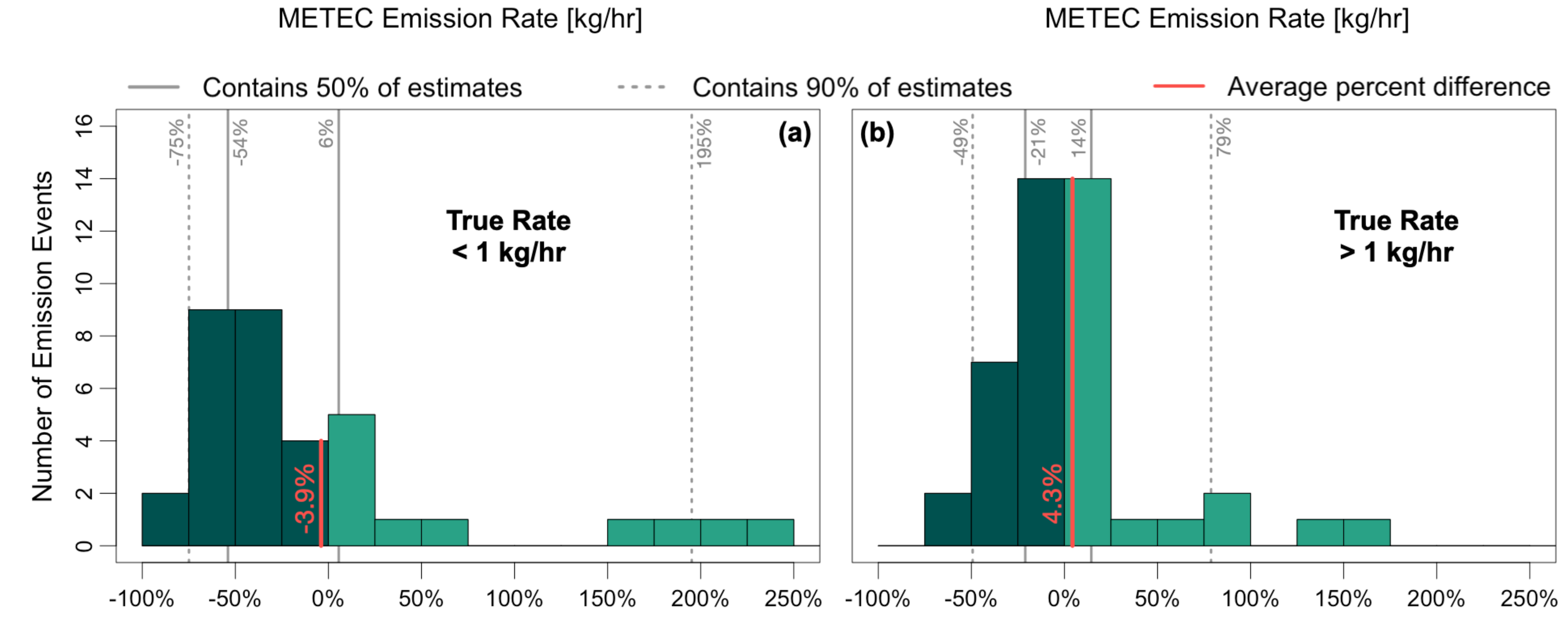
4. Framework performance on single-source controlled releases

Event detection and localization accuracy



Quantification accuracy

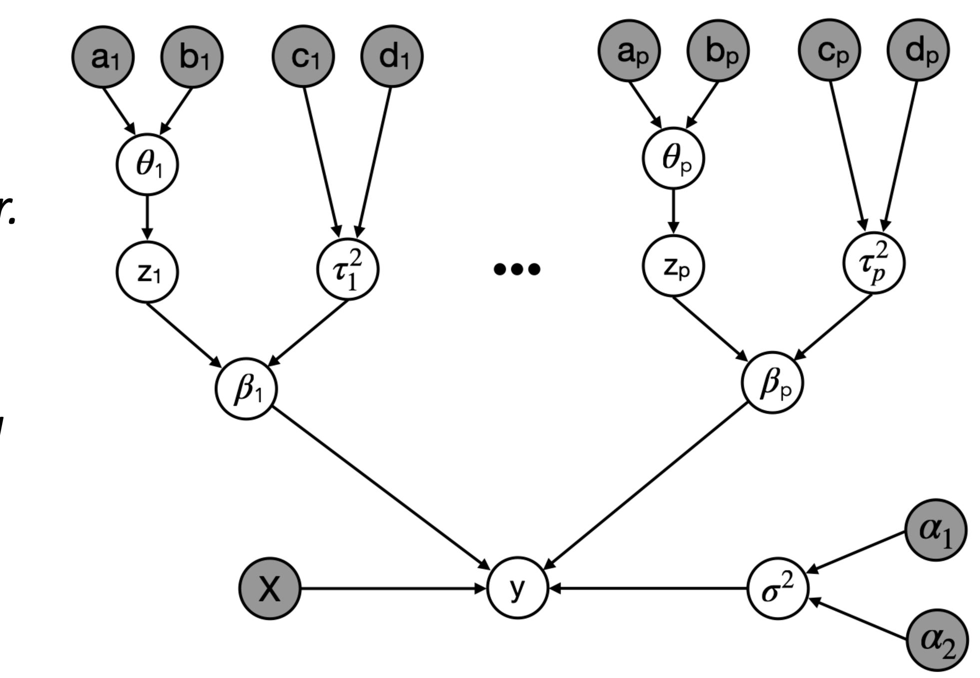




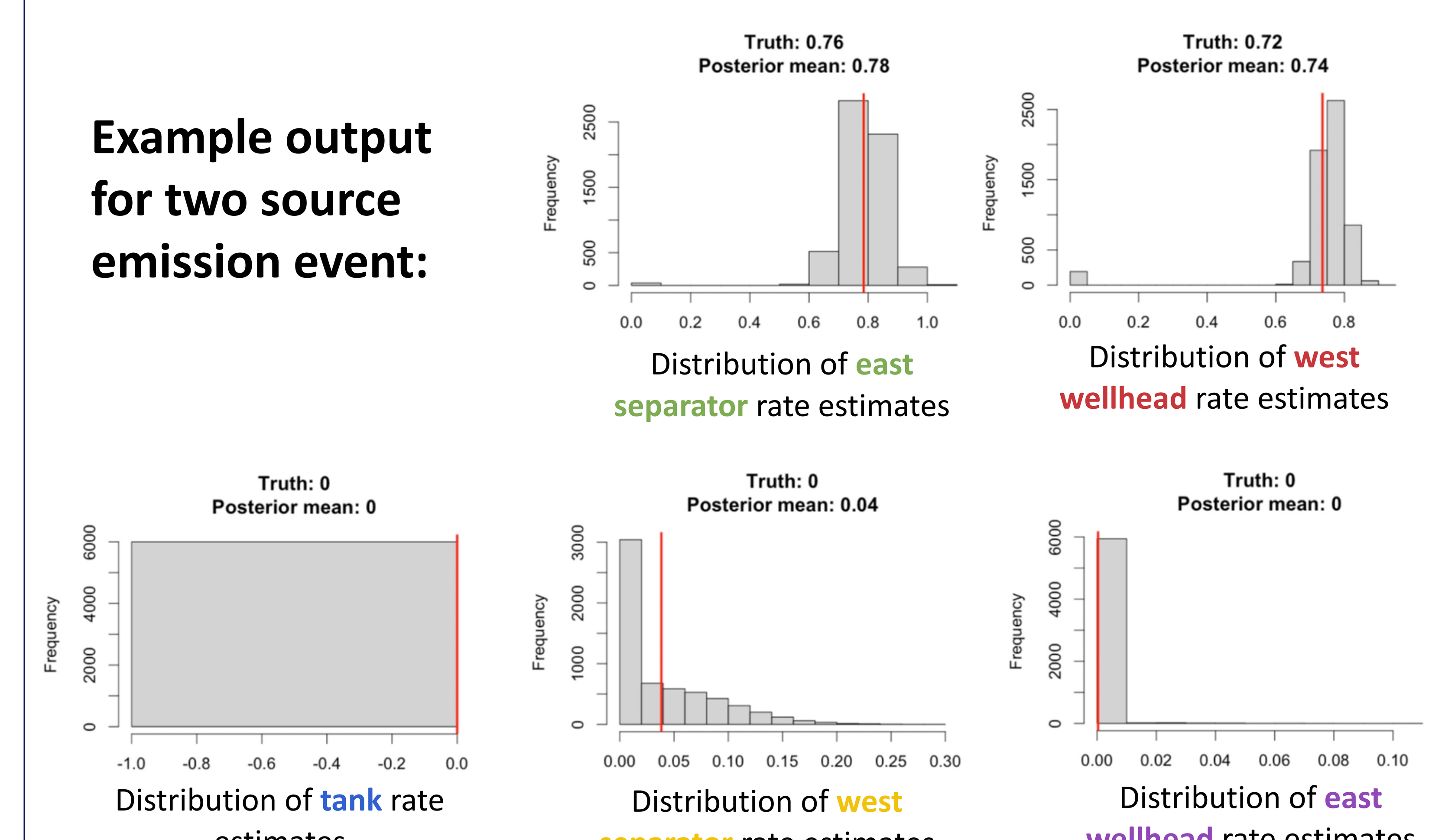
5. Future work: multisource emissions

- Bayesian hierarchical model in development to estimate multisource emissions.
- Advantages of Bayesian modeling framework:

1. Small emission rate estimates shrunk to identically zero. *Makes alerting easier.*
2. Include operator insight via priors. *Often well known if a particular source will be emitting based on various operating conditions.*



Example output for two source emission event:



References

William S. Daniels, et al. (2024). Detection, localization, and quantification of single-source methane emissions on oil and gas production sites using point-in-space continuous monitoring systems. *Elementa: Science of the Anthropocene.* DOI: 10.1525/elementa.2023.00110

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