2023 International Emissions Inventory Conference
Sep 28, 2023

DETECTION EFFICIENCIES FOR CONTINUOUS METHANE MONITORING SYSTEMS AT OIL AND GAS PRODUCTION SITES

Qining Chen, Colette Schissel, Yosuke Kimura, Gary McGaughey, Elena McDonald-Buller, and David T. Allen

Center for Energy and Environmental Resources
The University of Texas at Austin

Links to Publication

Detection efficiency: *10.1021/acs.est.2c06990*

Times to detection: *10.26434/chemrxiv-2023-p8lfk*

Overview

- **Continuous monitoring systems can not detect all emission events**

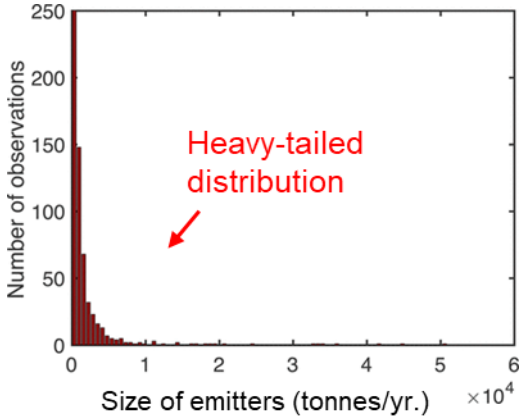
- **Framework to assess efficiency of continuous methane monitoring systems** on oil and gas production sites for detecting
  - Continuous emission events with infinite durations
  - Intermittent emission events with fixed durations

- **Significant improvement in detection efficiency** by continuous monitoring systems lead to more accurate estimates of annual emission inventories, compared to periodic sampling techniques

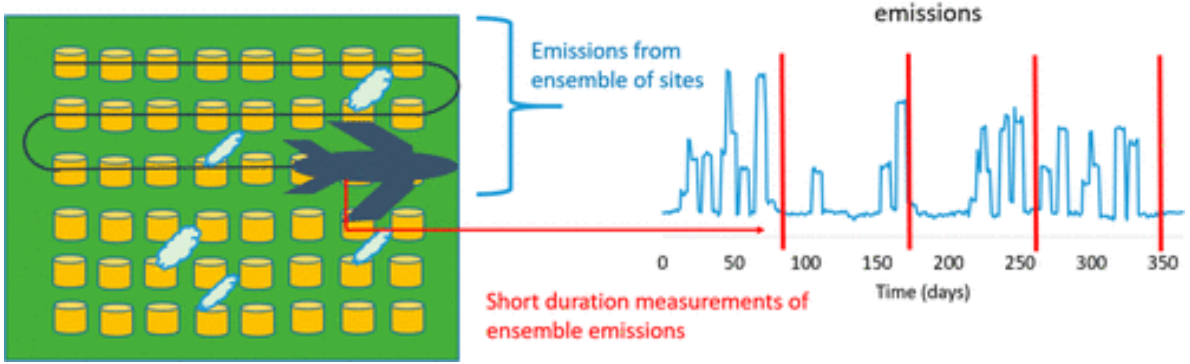
INTRODUCTION

Heavy-tailed distribution of methane emitters → **Intermittency of large emission sources** → **Periodic measurements introduce errors in annual emission estimates**

- The top **5% emitters contribute >50%** of total emissions *(Brandt et al., 2016)*



- **26% persistence** observed from ≥3 aircraft overflights for 1100 distinct sources in the Permian Basin *(Cusworth et al., 2021)*



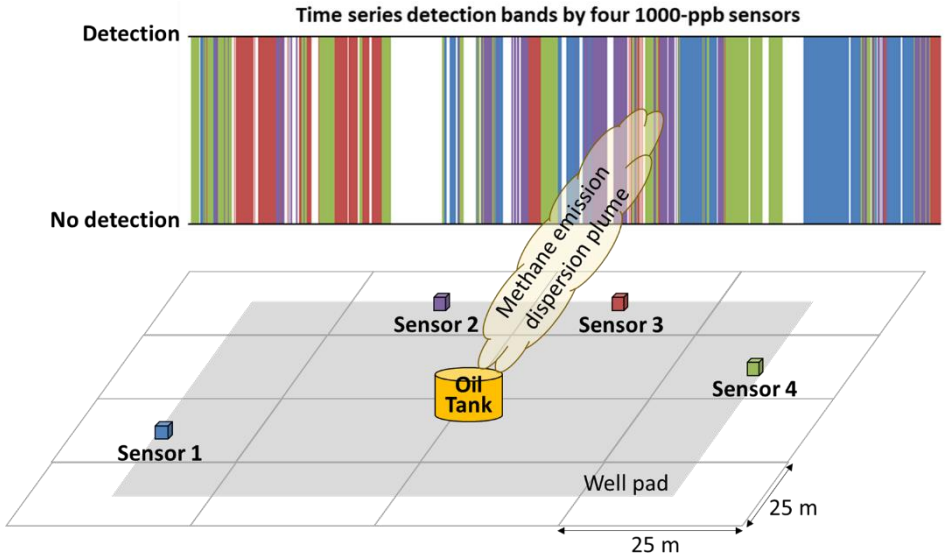
- For emission events that persist for ≤1 month, quarterly sampling had **sampling error >30%** *(Schissel and Allen, 2022)*

Deploy continuous methane monitoring systems at oil and gas sites

Continuous Monitoring Systems

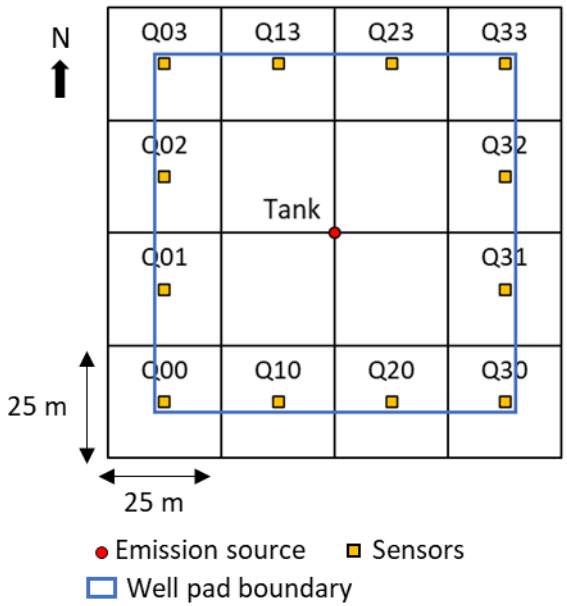
- Typically with 1 to 4 sensing systems per site (*Chen et al., 2021*), providing more rapid detection of emission events than periodic screening
- Efficiency in detections depend on source characteristics, meteorological conditions, sensor detection limits, and sensor placement strategies

This work describes a framework to assess the efficiency of continuous monitoring networks in detecting emission events

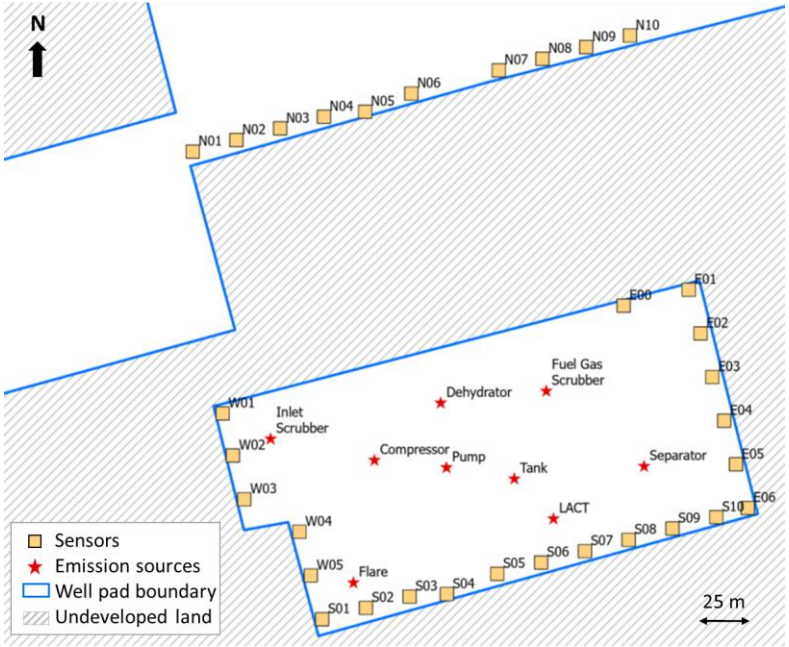


Site Scenarios and Potential Sensor Placements

(a) Idealized site with single emission source surrounded by sensors



(b) Nine different sources surrounded by sensors representing an active site in the Permian Basin



Dispersion Modeling and Meteorology Episode

- Emission rates: 10 kg/hr
- Dispersion model: CALPUFF v7.2
- Meteorological data: March 26th to April 8th in 2019 in the Permian Basin, broadly representative of annual meteorology conditions
- Output: time series detection and non-detection binaries based on sensor detection thresholds of 200, 500, 1000 ppb, per sensor location per source
- Sensitivity analyses available at: https://doi.org/10.1021/acs.est.2c06990

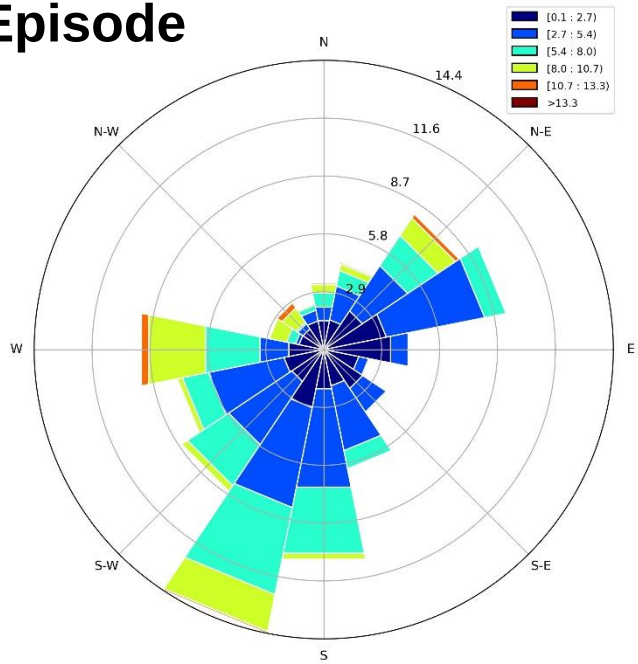


Figure: wind rose during the 2-week simulation period; predominant wind directions from the south

Emission Events Simulations

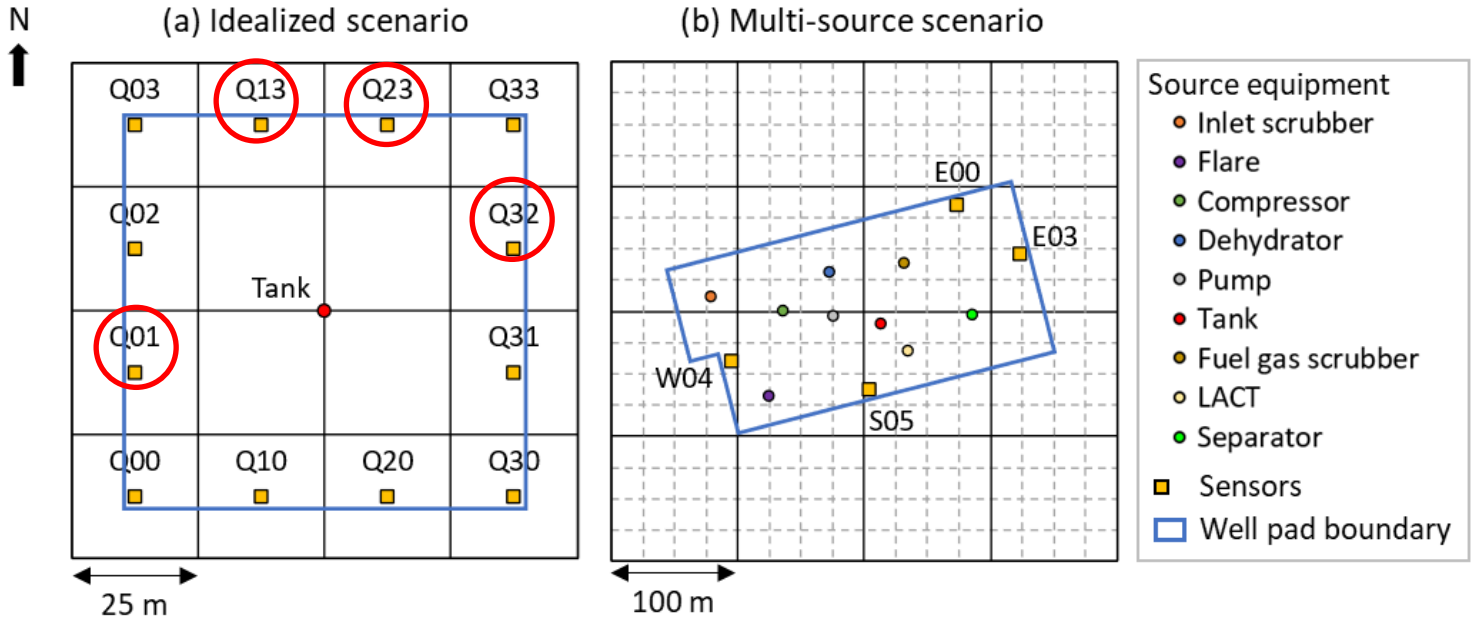
- 2 Types of emission events:
  - Infinite-duration events: events continue until the end of the simulation
  - Fixed-duration events: with durations of 10 min, 30 min, 60 min (1 h), 180 min (3 h), 360 min (6 h), 720 min (12 h), and 1440 min (24 h)
- Start times:
  - Randomly selected during the 2-week simulation period
  - 10,000 Monte Carlo iterations conducted

Event Detections

- Detection definition: methane concentration enhancements at the sensor site above the sensor threshold for at least one minute
- Sensor detection thresholds: 200 ppb, 500 ppb, 1000 ppb

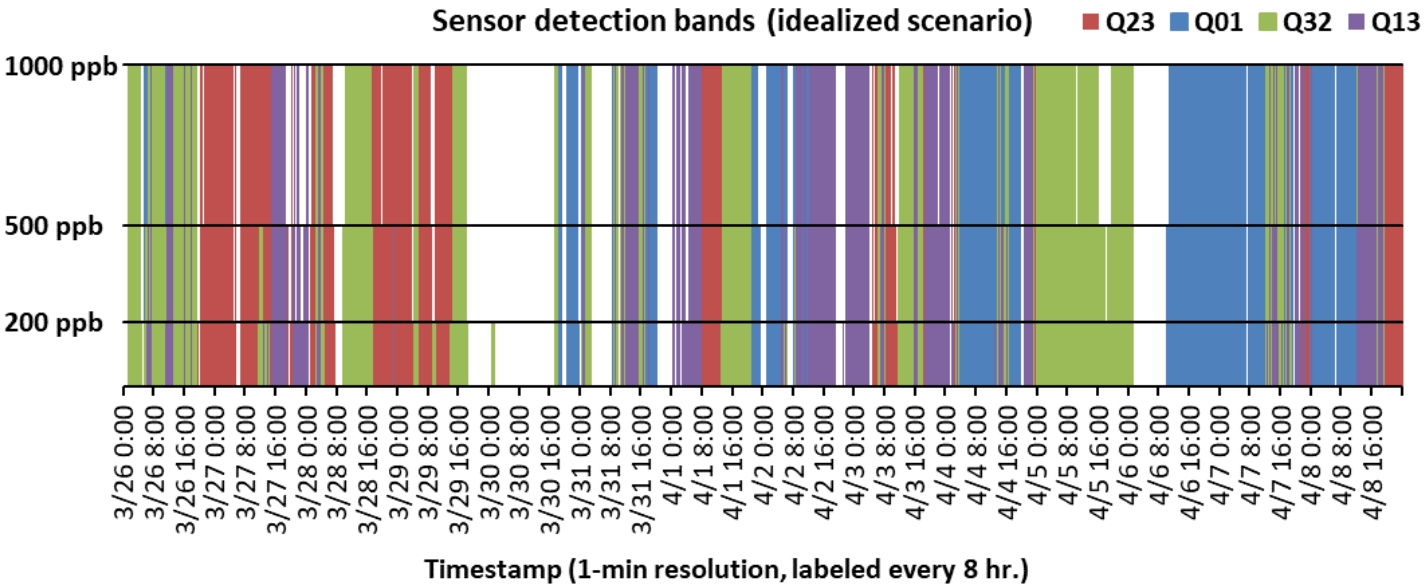
Optimize Sensor Placements

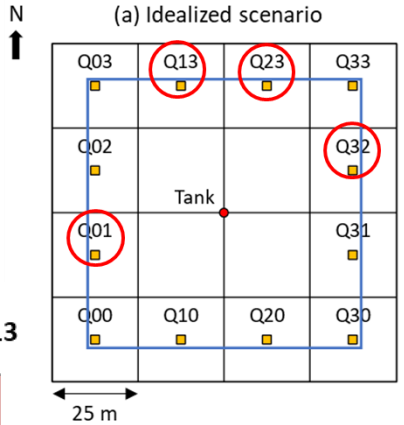
- Combinations of 1, 2, 3, and 4 sensors with highest averaged detection frequency across all sources on the site



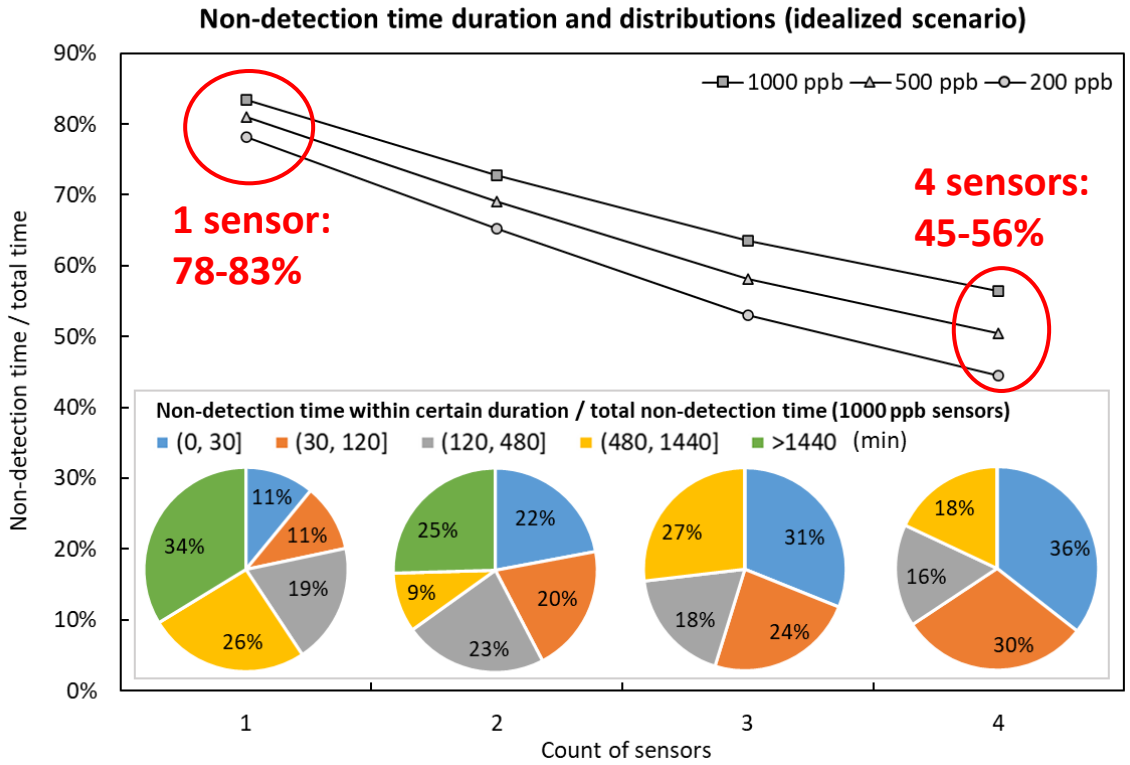
Detection Time Series

- Detection thresholds had limited impacts on distributions of detect / non-detect intervals
- Longest non-detection interval lasted for > 16.3 hours (on March 30)





Non-detection Time Durations and Distributions



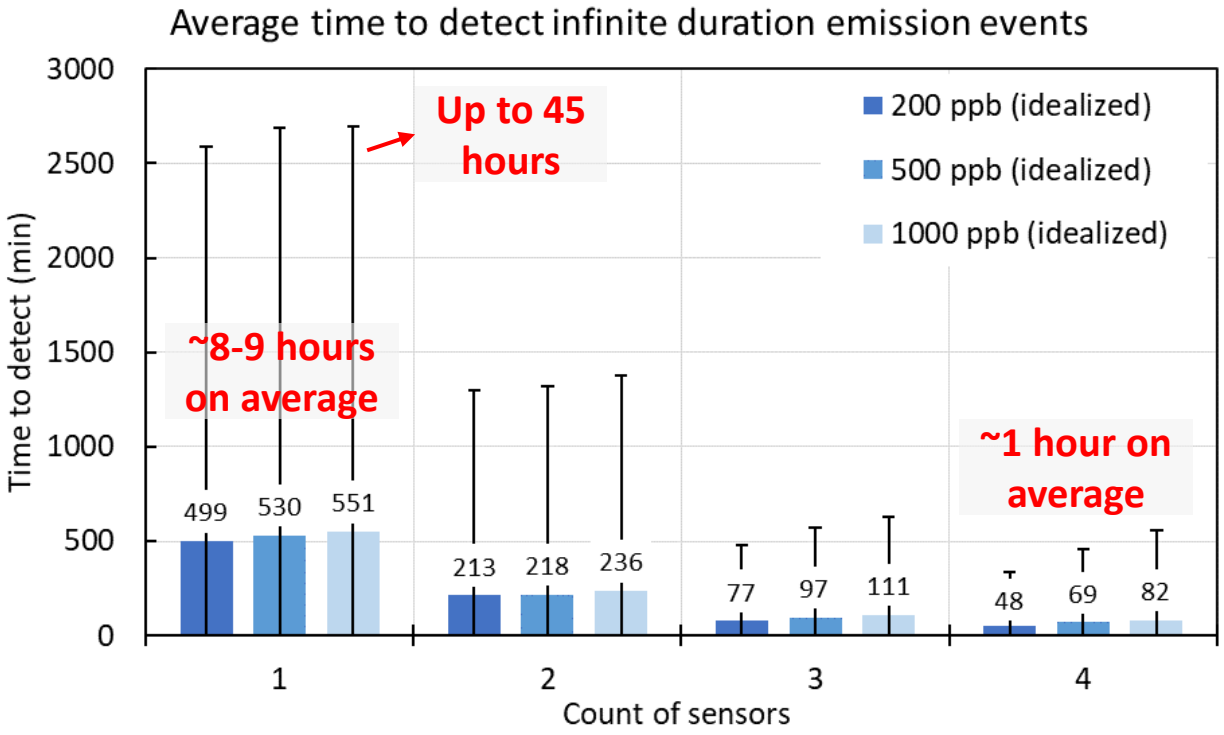
- Increasing counts of sensors were more important than improving sensor detection thresholds
- Even with 4 sensors, non-detect times account for ~50% of the time
- With more sensors being placed, fraction of longer non-detection periods (> 8 hrs.) decrease

Understanding Detect / Non-detect Times is Important for…

- **Estimating durations of continuous events based on time to detection**
  - Emission duration information needed to estimate emission inventory from concentration detections
  - EPA propose rules on modifying Greenhouse Gas Reporting Program (August 2023) include important provisions related to determining durations of emission events

- **Predicting detection probability of intermittent events**

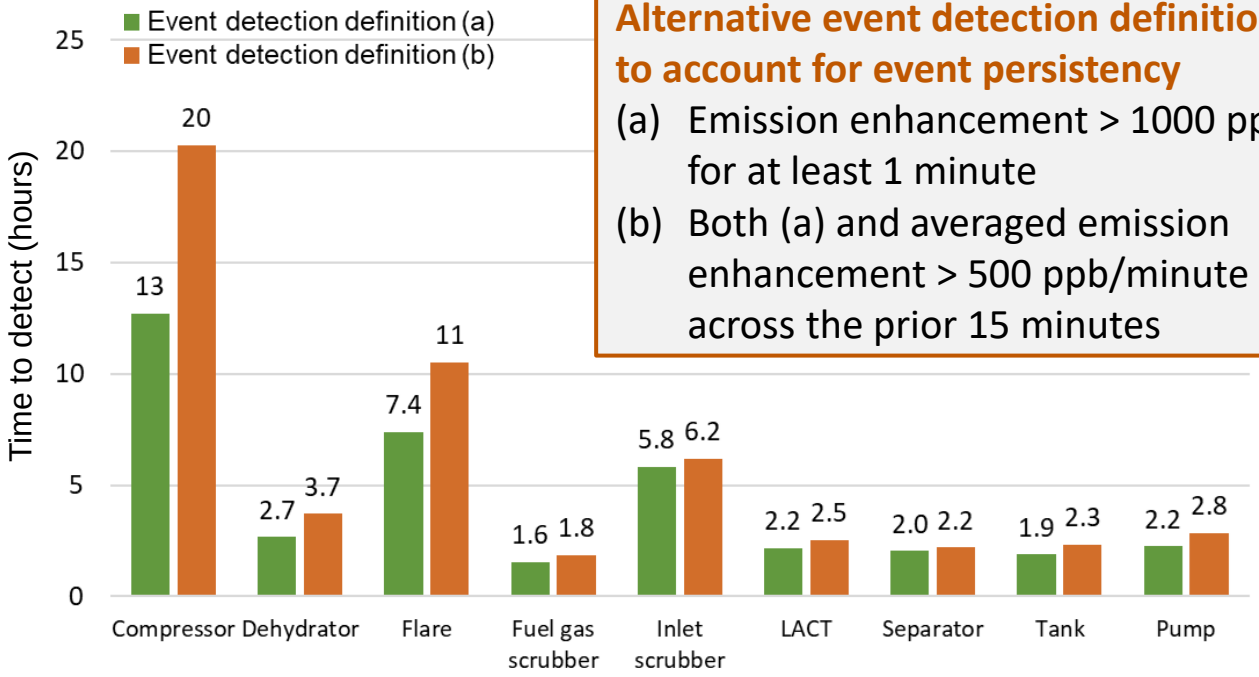
Time to Detect Continuous Events: Idealized Scenario



- Average time to detection decreased from ~8-9 hours by 1 sensor to ~1h by 4 sensors
- Time to detection per event depends largely on start time of the event
- Maximum time to detection: ~45 hours

Time to Detect Continuous Events: Multi-Source Scenario

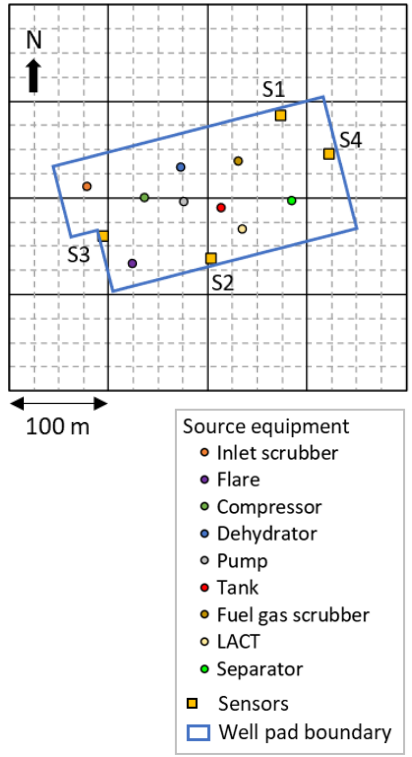
Average time to detect infinite duration emission events with 4x1000 ppb sensors



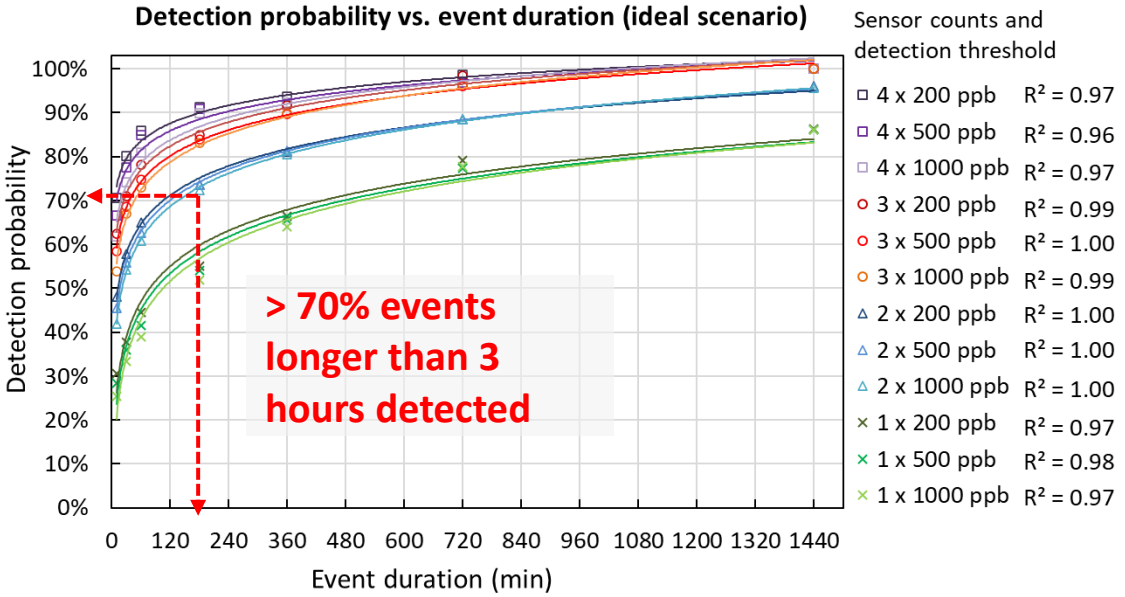
Alternative event detection definitions to account for event persistency

(a) Emission enhancement > 1000 ppb for at least 1 minute

(b) Both (a) and averaged emission enhancement > 500 ppb/minute across the prior 15 minutes



Detection Efficiency of Intermittent Events: Idealized Scenario



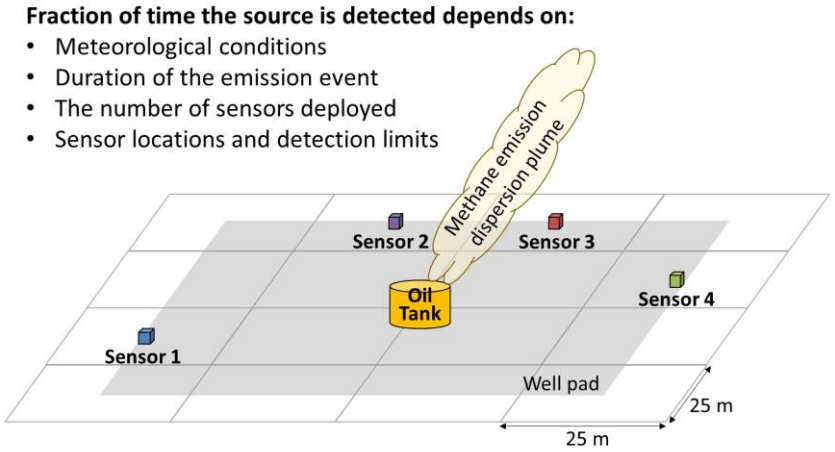
- Detection probability is a strong function of emission event duration (natural logarithm, $R^2 > 0.9$)
- Sensor detection thresholds are less important on the detection probabilities compared to sensor counts
- With 4 ideally located sensors, 60-70% of emission events lasting for 10 minutes are detected; 100% of emission events lasting > 24 hours are detected

Implications and Conclusion

- Detection efficiencies depend on source characteristics, meteorological conditions, sensor detection limits, and sensor placement strategies

- Significant improvement in detection efficiencies by continuous monitoring systems compared to periodic samplings

- More accurate estimates of annual emission inventories with extrapolation considering temporal coverage of detections based on dispersion modeling



Thank you!

2023 International Emissions Inventory Conference
Sep 28, 2023

PROJECT ASTRA | TEXAS The University of Texas at Austin

DETECTION EFFICIENCIES FOR CONTINUOUS METHANE MONITORING SYSTEMS AT OIL AND GAS PRODUCTION SITES

Qining Chen, Colette Schissel, Yosuke Kimura, Gary McGaughey, Elena McDonald-Buller, and David T. Allen

Center for Energy and Environmental Resources
The University of Texas at Austin

Links to Publication

Detection efficiency: *10.1021/acs.est.2c06990*

Times to detection: *10.26434/chemrxiv-2023-p8lfk*

Acknowledgement

Funding provided by Collaboratory to Advance Methane Science

PROJECT ASTRA

CH4 COLLABORATORY TO ADVANCE METHANE SCIENCE

ASTRA members

TEXAS The University of Texas at Austin
GTI ENERGY
Chevron
Microsoft
EDF ENVIRONMENTAL DEFENSE FUND
PIONEER NATURAL RESOURCES
ExxonMobil
Schlumberger

Prediction of Percentage of Emissions Detected

Correlation between event detection efficiency and natural logarithm of event duration

Distribution of event durations

- Assume a lognormal event duration distribution with a mean of 2 hours and a 90% confidence interval of 5.3 hours

Emissions detected (per event)

$= Detection\ efficiency \times Event\ duration \times Emission\ rate$

A collection of 10,000 emission events

Percentage of emissions detected

$$= \frac{\sum Emissions\ detected\ per\ event}{\sum (Event\ duration \times Emission\ rate)}$$

Prediction of Percentage of Emissions Detected

- Longer duration events have a higher probability of detection and higher total emissions
- Detection probability of total emissions higher than detection probability of total events