Characterizing Sampling and Detection Properties of AMLD

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MOTIVATION

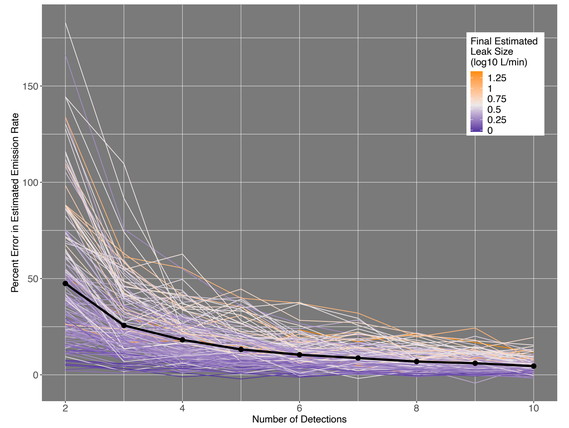
- Natural gas (NG) leaks are a potential safety hazard, economic loss, and climate change contributor because NG is mainly composed of the greenhouse gas methane (CH_4).
- Advanced mobile leak detection (AMLD) using highly sensitive CH_4 analyzers has developed in recent years for surveying local NG distribution systems in urban areas.
- However, recommendations for driving survey protocols and the effects of driving effort on quantifying and detecting CH_4 point source emissions remain open questions.

METHODS

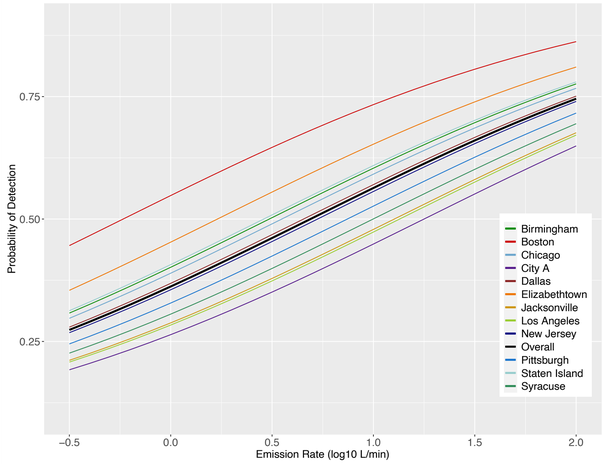
- We analyzed mobile survey data from 15 U.S. cities to inform driving survey protocols and performance.
- Data included
  - *Observed peaks*: locations with a rise and fall in CH_4 concentrations, suggesting detection of a leak.
  - *Verified peaks*: locations with 2+ observed peaks.
  - Location detection and drive-by (sampling) history.
- We conducted three analyses
  - **Analysis 1: Error in Size Estimates**
  - **Analysis 2: Detection and Verification Probability**
  - **Monte Carlo Synthesis**

ANALYSIS 1: ERROR IN SIZE ESTIMATES

- Use a resampling technique to estimate the percent error in estimated leak emission rate as a function of the number of times a leak is detected.
- More detections of a leak improve estimates of leak emission rates.
- Positive bias in emissions estimates occurs due to occasional large overestimates of leak size and the thresholds in place for flagging the detection of a leak.



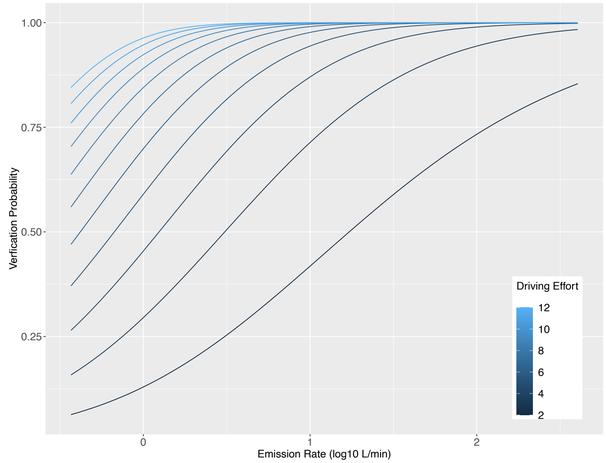
ANALYSIS 2: DETECTION AND VERFICATION PROBABILITY



Statistical Model:

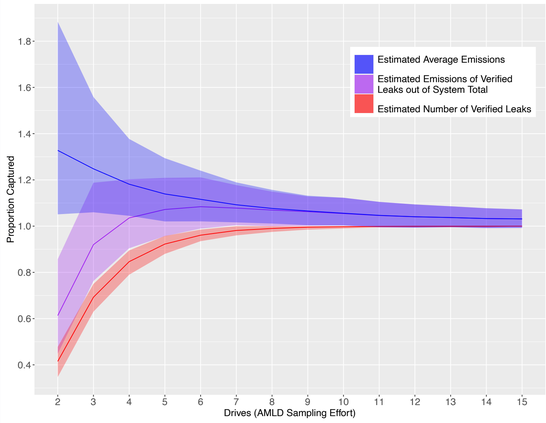
$$logit(p_{ij}) = \alpha_i + \beta_0 + \beta_1 x_{ij}$$

- α_i: city specific RE
- $\alpha_i \sim N(0, \sigma_\alpha^2)$
- x_{ij}: estimated emission rate for city i, methane source j



- Model the probability of detecting a leak on a single drive-by as a function of leak size using logistic regression.
- Estimate the probability of verifying a leak (2+ detections) as a function of sampling effort.
- Larger leaks are easier to detect and are more likely to be verified with increasing sampling effort relative to small leaks.
- Different levels of sampling effort may be needed to achieve similar leak capture proportions across cities.

MONTE CARLO SYNTHESIS



- Combine analyses 1 and 2 to conduct a Monte Carlo simulation to demonstrate the use of AMLD for leak detection and quantification in a simulated city with 200 leaks.
- We recommend **5-8 drives** as an attainable surveillance effort that will capture a majority (>90%) of leaks and provide reasonable (-10% to +15%) emissions quantification.
- Adaptive AMLD surveys could increase or decrease survey effort based on the empirical detection probability.

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von Fischer, Joseph C., et al. "Rapid, vehicle-based identification of location and magnitude of urban natural gas pipeline leaks." Environmental Science & Technology 51.7 (2017): 4091-4099.
Weller ZD, Yang DK, von Fischer JC (2019) An open source algorithm to detect natural gas leaks from mobile methane survey data. PLoS ONE 14(2): e0212287. https://doi.org/10.1371/ journal.pone. 0212287