EEMDL Energy Emissions Modeling and Data Lab

**2024 Responsible Gas Symposium**
**Poster Session**

COLORADO SCHOOL OF MINES

# Title: Sampling Frequency Strategies for Methane Emissions from Oil & Gas.


Olga Khaliukova
Will Daniels
Applied Mathematics & Statistics
okhaliukova@mines.edu
wdaniels@mines.edu

Dr Dorit Hammerling
Associate Professor
Applied Mathematics & Statistics
hammerling@mines.edu



## ABSTRACT

Starting in January 2025, the Inflation Reduction Act is set to charge oil and gas operators a methane fee based on annual inventoried site-wide total methane emissions. We study the necessary frequency for measurement campaigns and assess the associated uncertainties in estimating yearly total emissions. We use zero-inflated right-skewed distributions to model emission rate profiles for equipment groups at a ``typical" oil and gas production site. Naturally, we find that an infrequent sampling strategy yields wider emission uncertainty ranges for the yearly average, while weekly sampling, at a minimum, leads to a narrower and symmetric uncertainty distribution. We demonstrate that sites that exhibit greater distribution skewness are more prone to under-reporting emissions unless sampling at least daily. While emissions overestimation at infrequent sampling is improbable, if it occurs, the overestimation could reach thousands of percent depending on the level of skewness of the underlying emissions' distribution. The concept is illustrated using data from an oil and gas production facility equipped with continuous monitoring sensors. In this setting, the continuous monitoring data allows for a detailed description of the underlying emission distribution and provides a real-life comparison to yearly inventory estimates derived from infrequent measurements.


## 1. Motivation

Starting in January 2025, the Inflation Reduction Act is set to charge oil and gas operators a methane fee based on annual inventoried site-wide total methane emissions.

There are limited guidelines for technology choice or sampling frequency.

The sampling frequency is critical and driven by the temporal variability of the methane emissions.

## 3. Methods

### Non-parametric

- To equipment-level data fit a mixed model, Zero-Inflated skewed distribution (e.g., Log-Normal, Gamma, Weibull, Generalized Pareto).

*Example of Zero-Inflated Log-Normal Model:*

$$\text{LogLikelihood}(\log(\mu), \log(\sigma), \text{logit}(p_0), \lambda, \text{data}) = -\sum_{i=1}^{n}\left[\begin{cases}\log\left((1-p_0)\cdot\frac{1}{x_i\sigma\sqrt{2\pi}}\exp\left(-\frac{(\log(x_i)-\log(\mu))^2}{2\log(\sigma)^2}\right)\right), & \text{if } x_i > 0\\ \log(p_0), & \text{otherwise}\end{cases}\right] + \lambda\cdot(\text{logit}(p_0)^2 + \log(\mu)^2 + \log(\sigma)^2)$$

where,

$\log(\mu)$ is the mean parameter of the lognormal distribution in log scale;

$\log(\sigma)$ is the standard deviation parameter of the lognormal distribution in log scale;

$\text{logit}(p_0) = \log\left(\frac{p_0}{1-p_0}\right)$ is the logit transformation of the zero-inflation probability $p_0$;

$\lambda$ is the ridge penalty parameter;

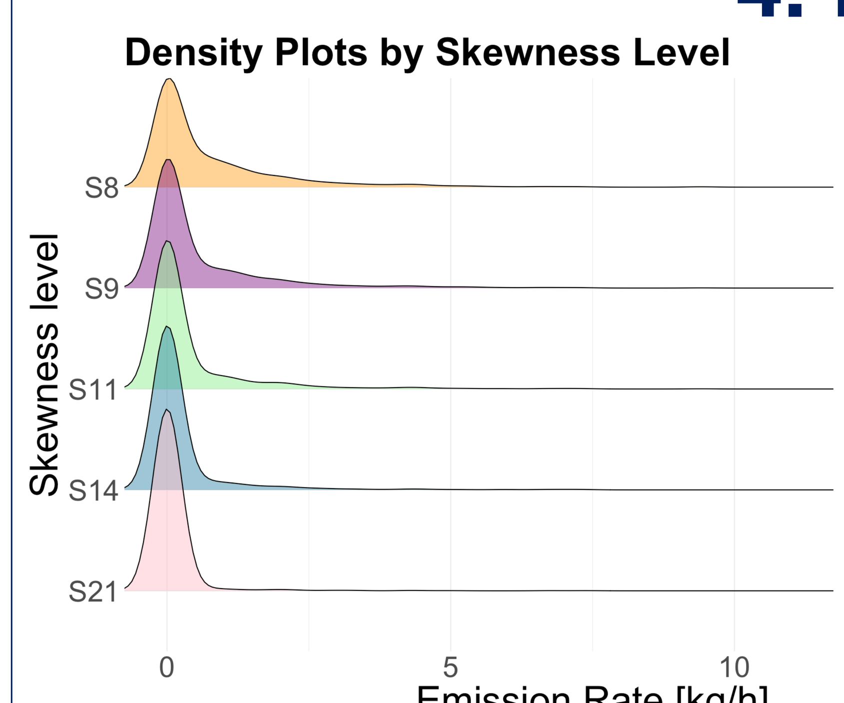
$\text{data} = x_1, x_2, \ldots, x_n$ is the dataset.

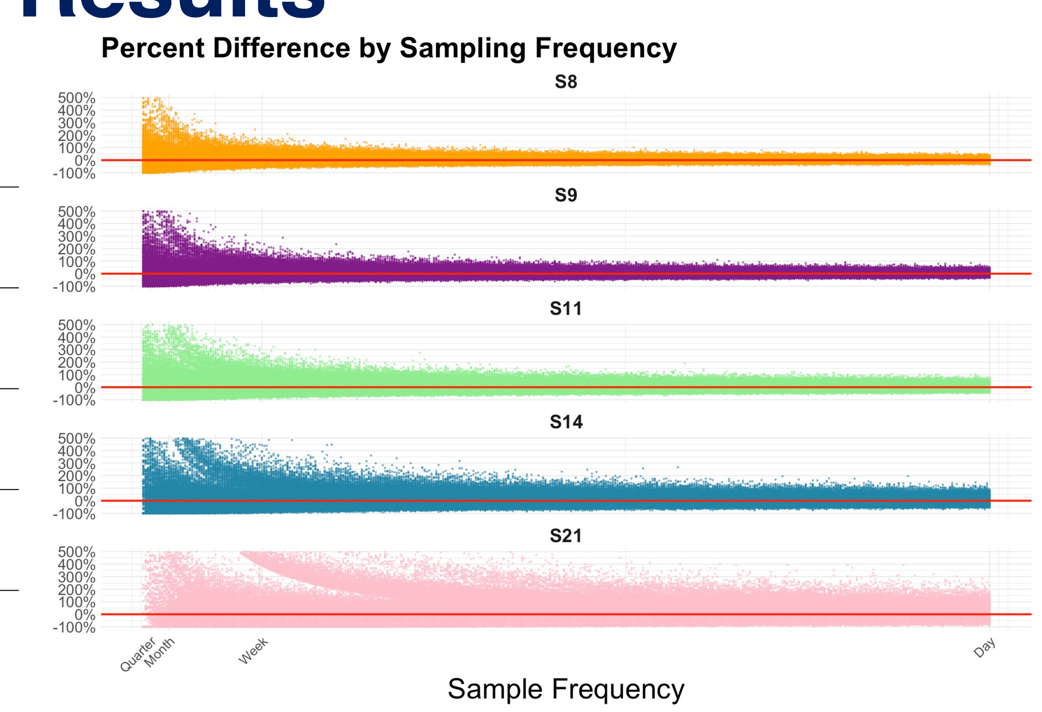
- Evaluate the Bayesian Information Criterion (BIC) and Akaike Information Criterion (AIC). Confirm the best fit using QQ plots.
- Simulate data for each equipment group using MCMC with MLE parameters from selected distributions.
- Compute annual site-wide total methane emissions rates based on various sampling frequency campaigns (e.g., yearly, quarterly, monthly, weekly, daily).

## 2. Objectives

- Find proper distributional fit for methane emissions at equipment level.
- Determine required frequency for measurement campaigns and assess the associated uncertainties in estimating yearly site total emissions.

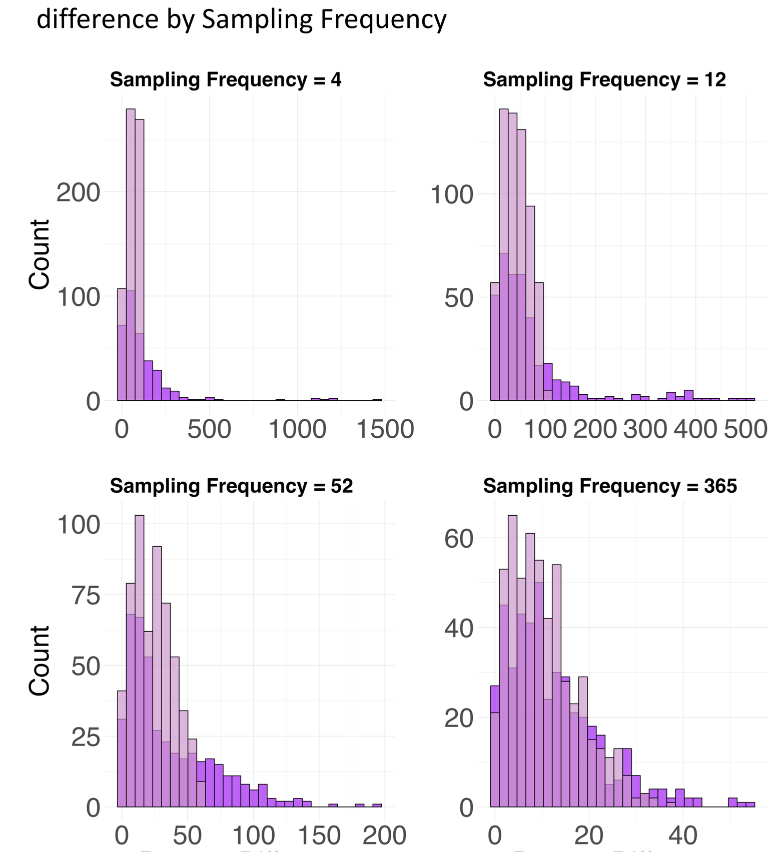
## 4. Results

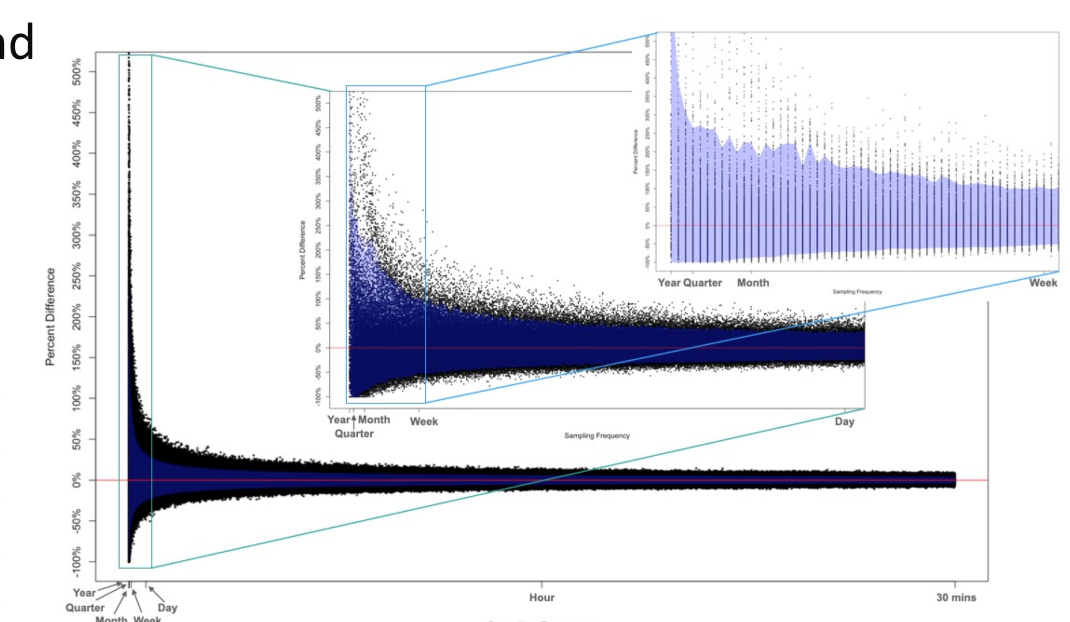



- Zero-inflated Log-Normal distribution 65% of 0 rates, 9.4 skewness, and 283 coefficient of variation.

Histograms of absolute value of average emissions percent difference by Sampling Frequency

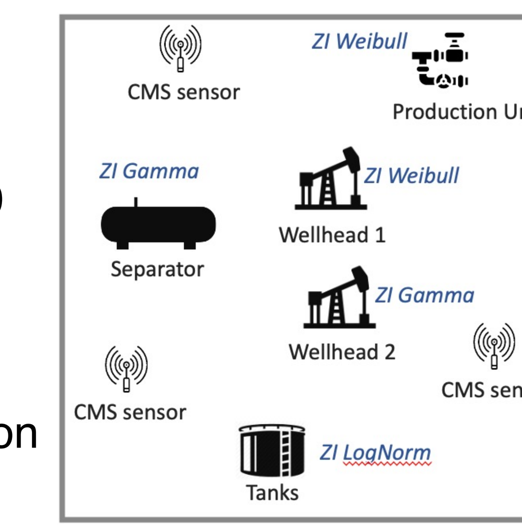


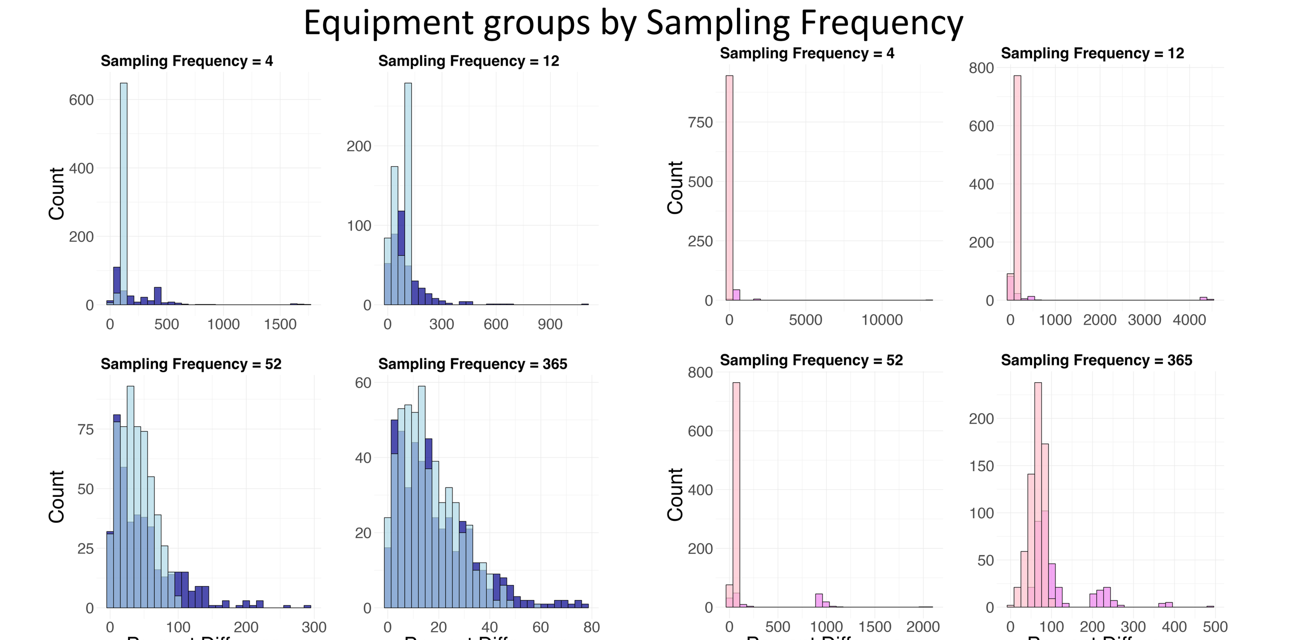
- Quarterly sampling results in overestimations as high as 1500%.
- Weekly sampling average deviates from true annual average by approximately ±100%.
- Daily sampling average results in a more symmetric under- and over-estimations.

## 5. Case Study

- Equipment-level emission rates include between 86% to 98% of 0 kg/h.
- Skewness levels range between 7 to 27
- Kurtosis levels range between 90 to 770
- Coefficients of variance range between 400 to 1870
- Desired sampling frequency highly depends on the skewness of the emission profiles




Histograms of absolute value of average emissions percent difference in two distinct Equipment groups by Sampling Frequency



## 5. Conclusions

- Individual equipment of the same type at a given site might have different emissions profiles.
- Infrequent sampling strategy yields wider emission uncertainty ranges for the yearly average while weekly sampling, at a minimum, leads to a narrower and symmetric uncertainty distribution.
- The equipment that exhibit greater distribution skewness are more prone to under-reporting emissions unless sampling at least daily.
- While overestimation of emissions at infrequent sampling is improbable, if it occurs, the overestimation could reach thousands of percent depending on the level of skewness of the' distribution of the underlying emissions.

Colorado State University

images: Flaticon.com

The University of Texas at Austin
Cockrell School of Engineering