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PROJECTS OVERVIEW

MAIN PROJECTS: IAB (Industry Advisory Board) 2023-24 project & ADED (Advancing Development of Emission Detection)

IAB 2023-24 PROJECT: Overview

The project aims at extending the functionality of the Gaussian Plume (GP) model in quantifying emissions when there are 'small' obstructions between the leak and the sensor/measurement location. Further, the project will integrate aboveground plume width calculation to measurements taken above an area source. For this project, two major experiments were conducted at the Methane Emissions Technology Evaluation Centre (METEC):

1) Aboveground Methane (CH_4) measurements from a belowground leak (an area source of emission)

2) Aboveground CH_4 measurements from an aboveground point source.

Meteorological measurements were taken using an ultra-sonic anemometer. CH_4 measurements were taken using a Micro portable Greenhouse Gas Analyzer (MGGA) at varied heights (0.5, 2,

5, and 7 m) on a portable 8 m tower. A multiplexer was used to cycle through the measurement heights of the tower. These heights were chosen to represent different survey heights.

Experiment 1: Below-ground leak

A controlled below-ground leak (85 % CH_4 and 15 % dry air) was initiated at 0.9 m below the ground. For aboveground CH_4 measurements, the height of the fence obstruction was reduced by 0.3 m each day (from 1.7 m). In this experiment, the major objective is to test the impact of various heights of obstruction on aboveground plume detection. The MGGA was located 7 m from the leak center while the fence obstruction was located 15 m from the leak (Figure 1).

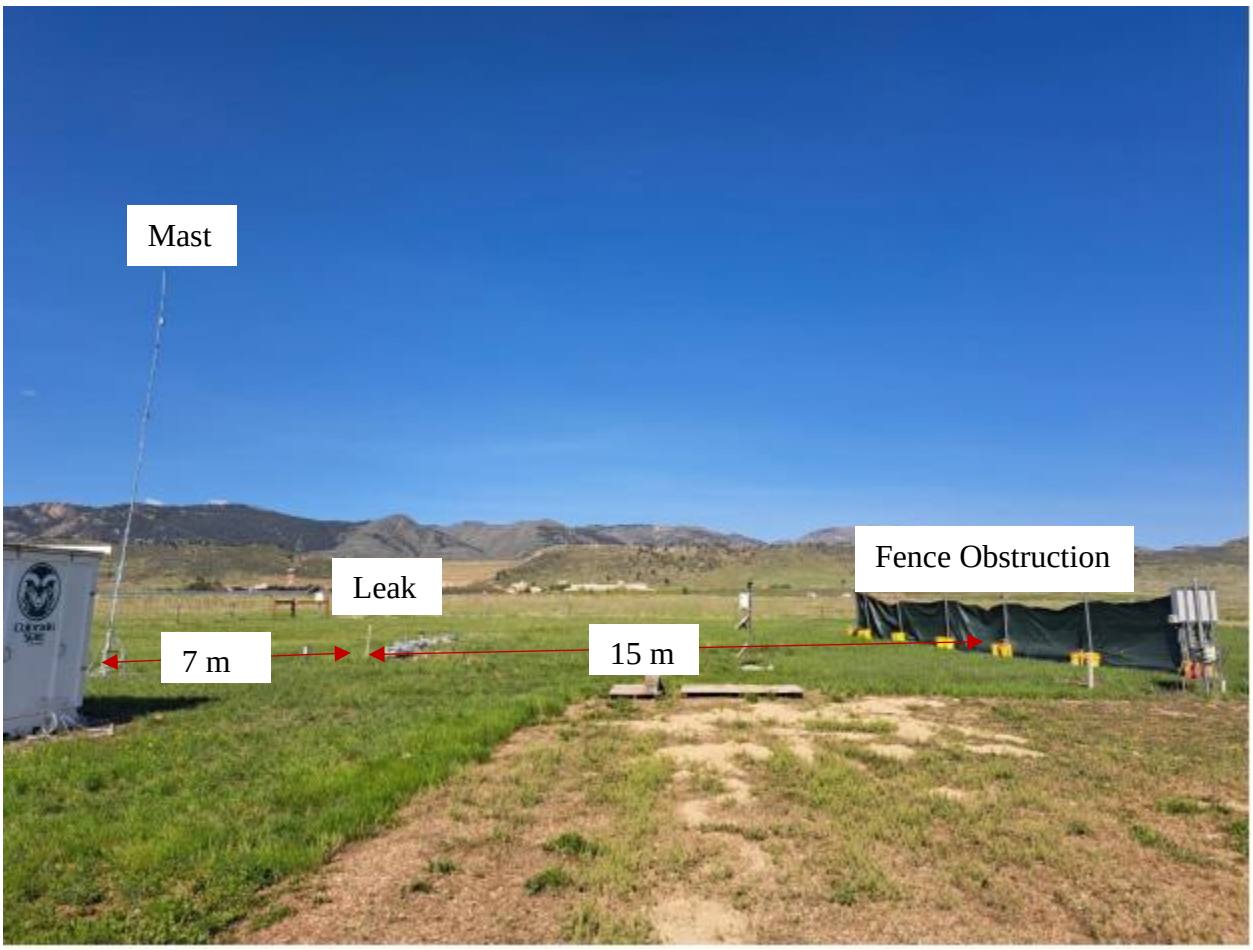

Figure 1 Aboveground set up for Experiment 1 CH_4 measurements conducted at METEC's rural testbed. The CH_4 sampling mast was located 7 m from the leak center, the mast has sampling heights at 0.5, 2, 5, and 7 m. The fence obstruction was located 15 m from the leak center. The obstruction height was set at 1.7, 1.5, 1.1, and 0.8 m to understand the effect of the obstruction on aboveground plume detection.

Experiment 2: Aboveground leak

A controlled aboveground leak (100 % CH_4) was initiated at 0.5 m above ground level. For this experiment, the impact of a fence obstruction, and two setback distances on the GP emission quantification will be tested. In experiment 2, measurements were taken for two fence heights:

1.8 and 0.9 m. Additionally, measurements were taken at 14 m and at 21 m from the leak. Measurements will be compared for when there was a presence/absence of an obstruction.

Research Progress

Preliminary Results: Experiment 1

This section presents only the preliminary results of the project. Four different heights of fence obstructions were used in this experiment: 1.7, 1.5, 1.1, and 0.8 m. Measurements were classified into Pasquill Gifford Stability Classes A, B-C, D, E-F, and G corresponding to extremely unstable, moderately/slightly unstable, neutral, slightly/moderately stable, and extremely stable atmospheric conditions. Preliminary results from the 1.7 m fence obstruction sampled at 0.5 m aboveground level are presented in Figure 2.

0.5 m Sampling height:

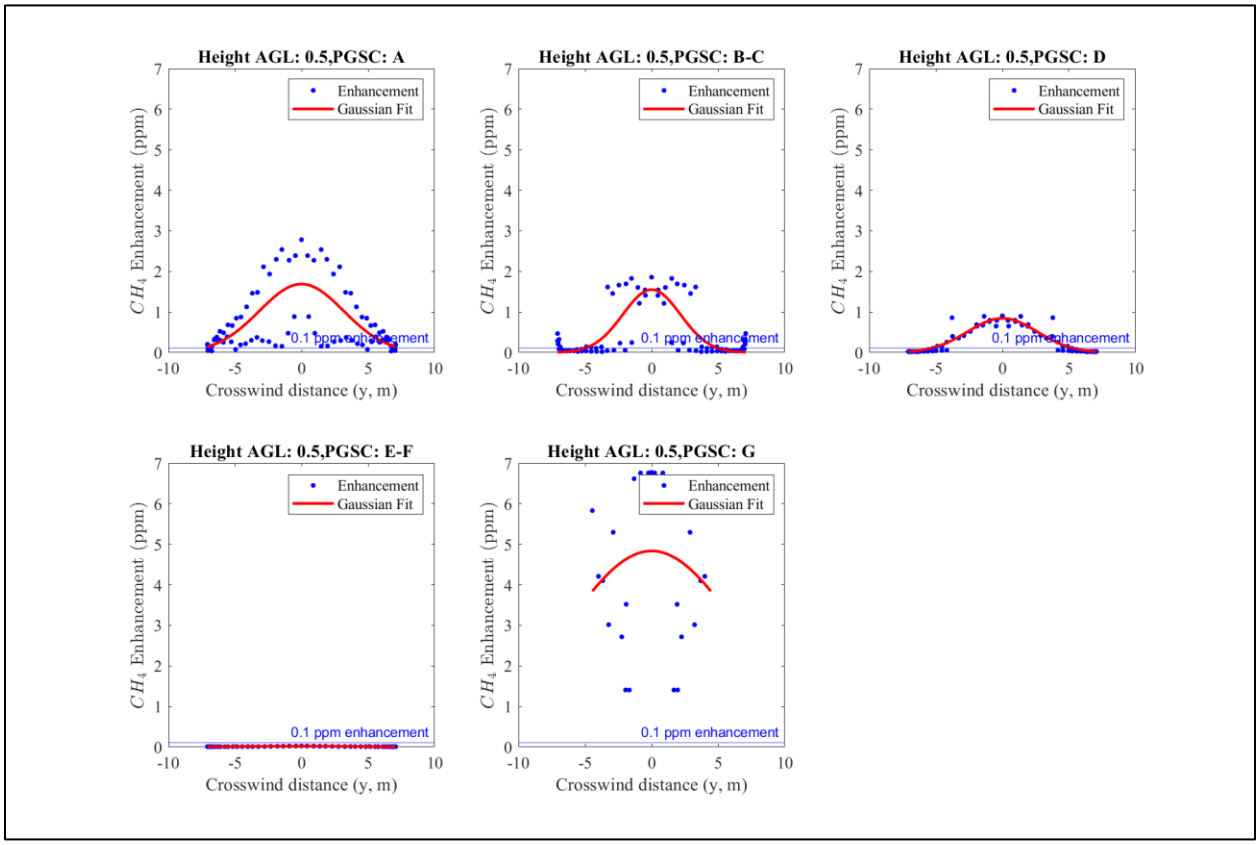

Figure 2 Gaussian fit to CH_4 enhancements above 0.1 ppm for measurements sampled at 0.5 m AGL with a 1.7 m obstruction height. Methane enhancements from PGSC A, and B-C fit to a gaussian model indicating the possibility of detecting an aboveground plume in these stability classes.

Preliminary Results: Experiment 2

Preliminary results show that the GP model over-estimates emissions for measurements taken at 7 m from the leak center when the fence obstruction is 1.8 m high (Figure 3). Measurements were filtered for when the wind was blowing towards the MGGA measurement tower. These

measurements were 1) binned by 4 degrees wind direction, 2) averaged every 15 minutes, and 3) the Obukhov length calculated and used to classify the measurements to different Pasquill Gifford Stability Classes (PGSC). PG stability classes A, D, and E-F correspond to extremely unstable, neutral, and slightly moderately stable atmospheric conditions. Results show that the GP model performs better with PGSC A but over-estimates as the measurement height increases (Figure 3).

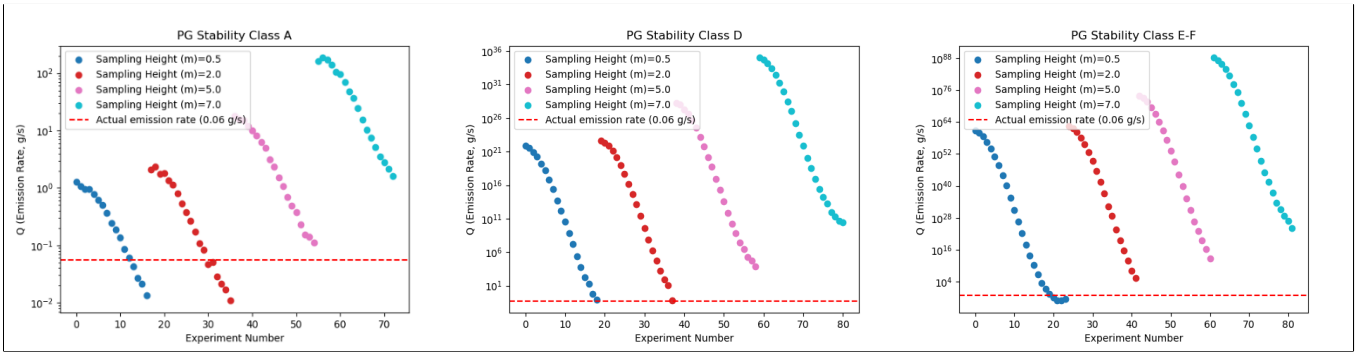

Figure 3 Emission rate as estimated by the Gaussian Plume model for measurements from PG stability classes A, D, and E-F. The measurements were sampled at 0.5, 2, 5 and at 7 m aboveground level 7 m from the fence obstruction and 21 m from the leak. Results show that the GP model overestimates emissions but works better when the atmosphere is extremely unstable (PGSC A).

Research plan

1. Plume width calculation (Experiment 1).
2. Emission quantification using the GP model for 21 m setback distance and 0.9 m fence obstruction in different stability classes (Experiment 2).
3. Complete draft of the IAB project paper and send it out for peer review.

PUBLICATIONS

Cheptonui, F., Riddick, S. N., Hodshire, A. L., Mbua, M., Smits, K. M., & Zimmerle, D. J. (2023). Estimating the Below-Ground Leak Rate of a Natural Gas Pipeline Using Above-Ground Downwind Measurements: The ESCAPE^{-1} Model. *Sensors*, *23*(20), 8417. https://doi.org/10.3390/s23208417

Mbua, M., Riddick, S. N., Tian, S., Cheptonui, F., Houlihan, C., Smits, K. M., & Zimmerle, D. J. (2023). Using controlled subsurface releases to investigate the effect of leak variation on above-ground natural gas detection. *Gas Science and Engineering*, *120*, 205153. https://doi.org/10.1016/j.jgsce.2023.205153

Riddick, S., Mbua, M., Santos, A., Emmerson, E. W., Cheptonui, F., Houlihan, C., ... & Zimmerle, D. J. Methane Emissions from Abandoned Oil and Gas Wells in Colorado. *Available at SSRN 4639539*.

Riddick, Stuart N., Ancona Riley, Cheptonui Fancy, Clay S. Bell, Aidan Duggan, Kristine E. Bennett, and Daniel J. Zimmerle. "A cautionary report of calculating methane emissions using low-cost fence-line sensors." Elementa 10, no. 1 (2022).

Riddick, Stuart N., Fancy Cheptonui, Kexin Yuan, Mercy Mbua, Rachel Day, Timothy L. Vaughn, Aidan Duggan, Kristine E. Bennett, and Daniel J. Zimmerle. "Estimating regional methane emission factors from energy and agricultural sector sources using a portable measurement system: Case study of the Denver–Julesburg Basin." *Sensors* 22, no. 19 (2022): 7410.

Jayarathne, N. J., Kathleen M. Smits, Stuart N. Riddick, Daniel J. Zimmerle, Younki Cho, Michelle Schwartz, Fancy Cheptonui, Kevan Cameron, and Peter Ronney. "Understanding mid-to large underground leaks from buried pipelines as affected by soil and atmospheric conditions–Field scale experimental study." In *Proceedings from the pipeline research council international (PRCI) REX2022 Meeting. Orlando, FL. doi: https://doi. org/10.18738*, vol. 8. 2022.