Methane Detection and Emissions Quantification at Undocumented Orphaned Wells

CATALOG Project

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Outline

DOE CATALOG Program Priorities

Gaussian Plume Framework

Field campaigns in Texas and Oklahoma

WP1 Objectives

- Provide DOI with **<u>accurate, cost-effective methane measurement methods that can be used to report well emission reduction values</u>** back to congress as required by the BIL language.

- Most wells are low emitters; large number of emitting wells adds to significant emissions.

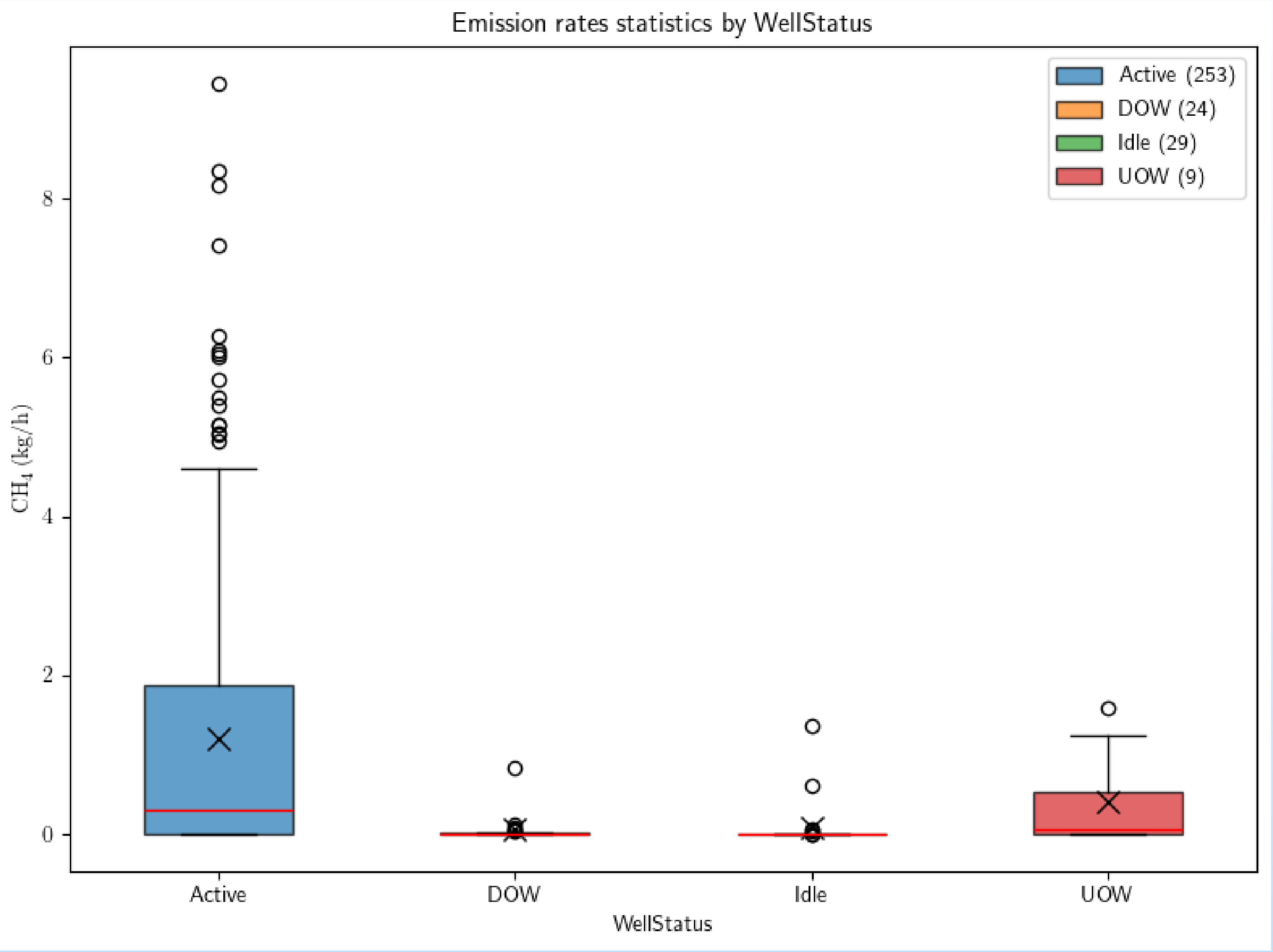
- Flow rate is difficult to measurement to make without complex equipment. Concentration is a much simpler measurement to make.

- The low level of emissions from individual wells are a challenge for satellites thus require new technologies.

- Understand methane emission distributions + uncertainties from orphan well populations.

- Understand the temporal component of well emissions and the related uncertainty.

Emission Statistics



field campaigns in CA, NM, OK, PA, NM, and TX. N=315 wells

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Plume Model Framework

Methodology is based on Gaussian Plume Model to estimate emission rates from measurements of:

- CH_4 atmospheric concentrations
- 3D wind observations

We assume: y=0 (along the plume centerline) and z=H (source/receptor at same height)

$$C(x,y,z) = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right) \text{ where:}$$

$C(x,y,z)$ is the concentration at the receptor (ppm)

Q is the volumetric emission rate (g/hr)

u is the wind speed component in the direction of advection (m/s)

σ_y is the standard deviation of the horizontal dispersion (m)

σ_z is the standard deviation of the vertical dispersion (m)

H is the height of the emission source (m)

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We can then solve for the estimated flow rate (Q_{est}) as a function of time averaged concentration ($\overline{C}$) and wind speed ($\overline{u}$):

$$Q_{est} = \overline{C} \cdot \overline{u} \cdot K, \quad \text{where } K = \frac{2\pi\sigma_y\sigma_z}{\exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right)}$$

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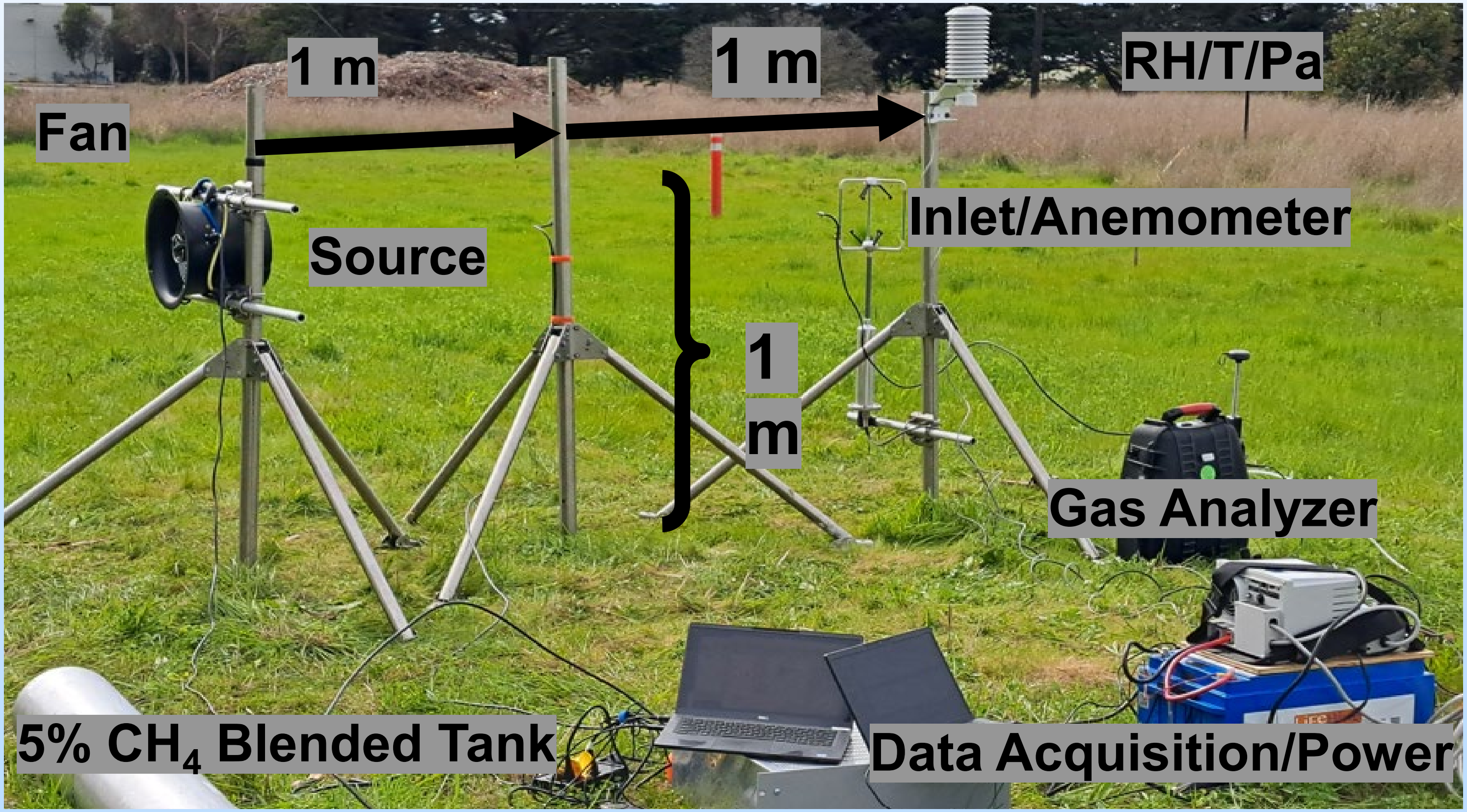
measured ???

FAST (method) to the Rescue

In contrast to previous studies, we investigated the application of “forced advection” by using a fan to reduce variability in U and C associated with wind conditions (fan is isotropic and leads to the creation of a Gaussian distribution within the flow)

FAST: Forced Advection Sampling Technique (Dubey et al., 2024 – in prep)

Dominant wind direction



FAST Method: Control Release

Control Release Settings

- Range: 1 g/hr to 40 g/hr (using 5% CH_4 tank and diluted with UHP N2).
- Target emission rates: 1, 2, 5, 10, 20, 40 g/hr CH_4

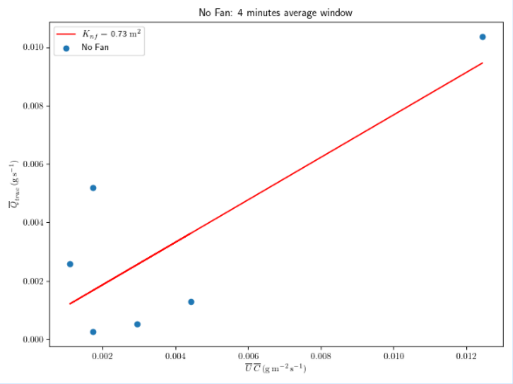
$$K = \frac{Q_{rel}}{C\,.u}$$

Data acquisition - 5 minutes at 3 Fan settings:

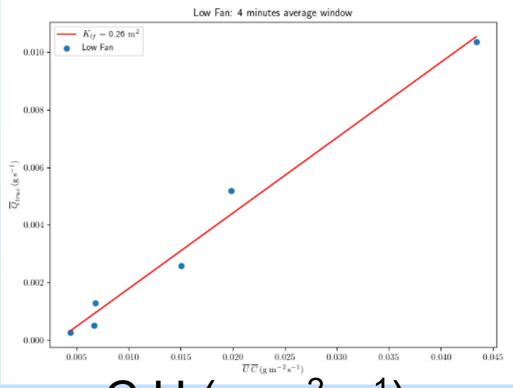
- No Fan
- Low Fan setting (~3 m/s)
- High Fan setting (~5 m/s)

Data filtered to ignore data with negative wind speed (wrong direction), because of strong winds on day of experiment (1-5 m/s with gusts up to 10 m/s)

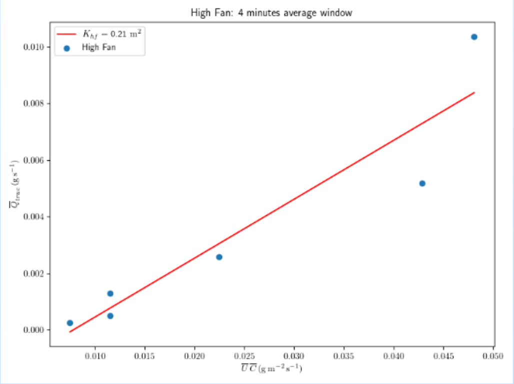
NO FAN



LOW FAN



HIGH FAN



Q $(g\ s^{-1})$

C.U $(g\ m^{-2}\ s^{-1})$

Plotting C * U vs. Q_{true} allows us to estimate values of K. With Fan OFF, data fit is poor ($R^2 < 0.01$) due to variability in wind. With Fan ON, we can fit values of **K ~ 0.26 (Low Fan) and 0.21 (High Fan)**

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Planned Q	Actual Qrel	Xplorobot†
1	0.93	1.66
2	1.86	1.76
5	4.66	2.4
10	9.33	6.2
20	18.67	27.1
40	36.96	37.2

All Q estimates are reported in g/hr
† https://www.xplorobot.com/

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Field Campaigns: Sensors Tested

- ✓ OGI camera (FLIR, cost: $80k)
- ✓ In situ High Flow sensor (Heath-SEMTECH, HI-FLOW-II, cost: ~$50K)
- ✓ In situ CH_4 sensors Conc. (Picarro, model: G4302, cost: ~$45K) + In situ wind sensor (Gill, model: R3-50; cost: ~$10k)

- ✓ LIDAR (Xplorobot, cost: ~$150 scanned well)
- ✓ Gas rover (Bascom-Turner, cost: ~$4.5k)

FAST Method: Reality check #1 (Texas)

<u>Charge</u>: Quantify methane emissions at 11 Documented Orphaned Wells (DOW) before Plugging and Abandonment (P&A)

<u>Location</u>: US Forest Service (Angelina and Sabine Districts)

<u>Timeline</u>: Feb 5-7, 2024

<u>Approach</u>: FLIR / SEMTECH / FAST / XploRobot / EPA (2-point)

FAST Method: Reality check #1 (Texas)

Well ID	FLIR	SEMTECH	FAST *	Xplorobot	EPA+
Arco Fee #2	Not Detected	0.1±0.0	N/A	N/A	N/A
Long Bell #1ST	Not Detected	6.2±5.5	N/A	35	60.2±29.8
Long Bell #2ST	Plume in water	3.0±2.1	N/A	16	N/A
Long Bell #3ST	Not Detected	0	N/A	N/A	N/A
Rayburn #2	Not Detected	0	N/A	0	N/A
Rayburn #6	Not Detected	0.3±0.1	N/A	N/A	N/A
Rayburn #7	Not Detected	2.9±0.0	4.9±2.7	3.0	0.5±0.3
Rayburn #8	Not Detected	0	N/A	N/A	N/A
Rayburn #11	Not Detected	1.0±0.1	N/A	3	N/A
USA 482 #1	Not Detected	0.1±0.0	N/A	0	N/A
Anonymous Well	Not Detected	6.1±0.7	0.9±1.1	3.3	6.3±7.8

*Setup similar to control release, with sensor geometry adjusted for vegetation.
+Methodology used by Riddick et al, 2024
All Q estimates are reported in g/hr

FAST Method: Reality check #2 (Oklahoma)

Charge: Quantify methane emissions at Documented and Undocumented Orphaned Wells (DOW and UOW)

Location: Osage County

Timeline: March 11-15, 2024

Approach: FLIR / SEMTECH / FAST / XploRobot

All Q estimates are reported in g/hr

Well ID	FLIR	SEMTECH	FAST	Xplorobot
NRU-CHUCK 2A	Detected	215.5±19.6	290	280
NRU-1-11	Not Detected	2.0±0.4	N/A	2.0
LUCY-2A	Detected	1250±197	Saturated	1450
HUMPHREY-5	Not Detected	2.0±0.1	7.8	N/A
HOOPER 41	Not detected	70.1	71.5	N/A

Next Steps

- Forced advection (Fan) enhances results compared to ambient wind conditions (No Fan)
- Uncertainties in emissions, though sizable compared to SEMTECH, remain reasonable for quick screening
- Further analysis required on wind direction filtering and optimal averaging windows to improve existing results
- Additional experiments needed to determine wind speed and geometry effects on K values
- Future work includes validating method with low-cost sensors, in order to bring down cost and establish standard emission quantification protocol
- Expand the scope of field campaigns to thoroughly validate the method across a spectrum of real-world scenarios