PROGRESS TOWARDS COLLABORATIVE NGEM METHODS
A CASE STUDY USING SENSIT FMD

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NGEM: Next Generation Emissions Monitoring
FMD: Fixed Methane Detector

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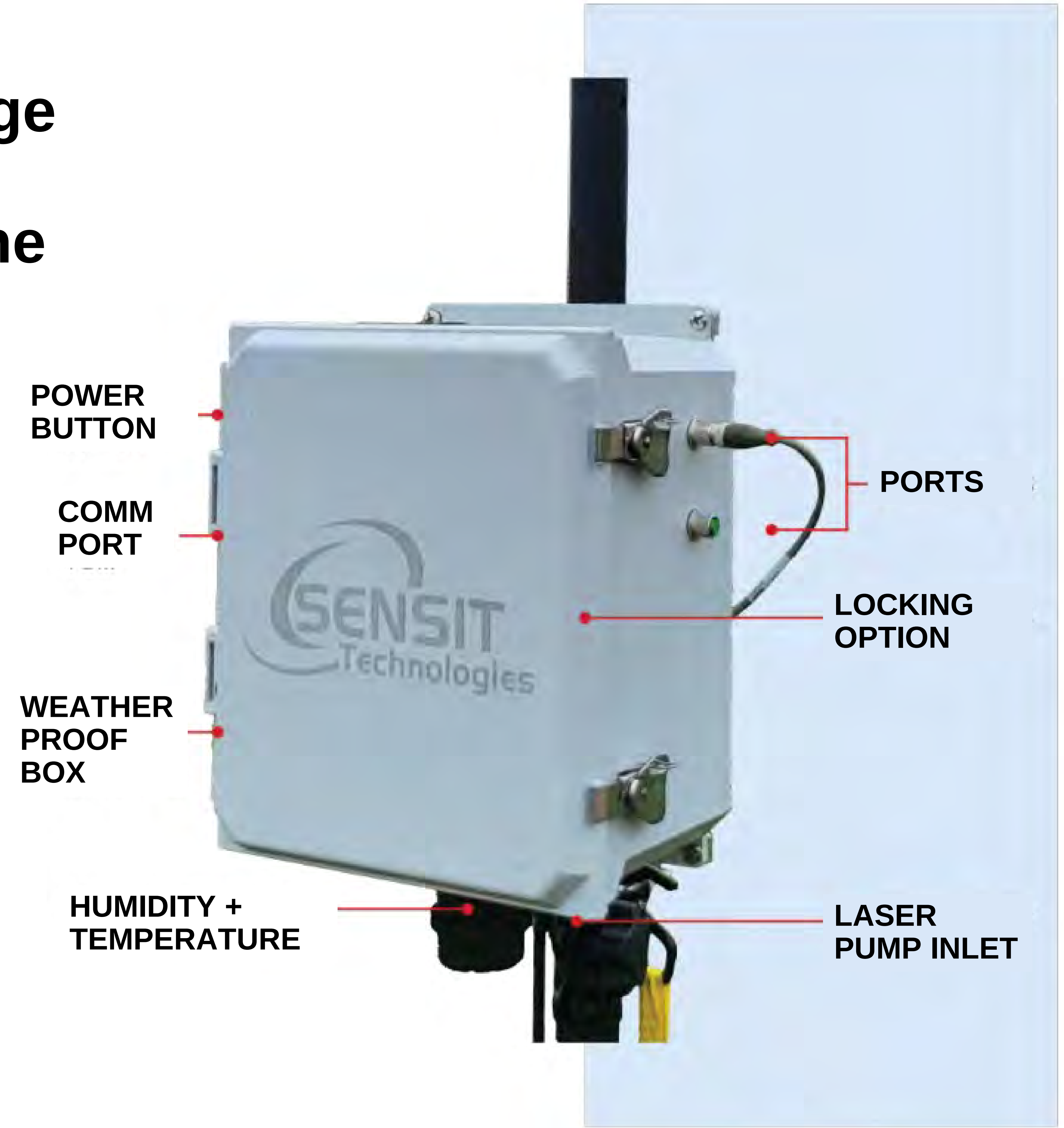
BACKGROUND

- **Fixed Methane Detector (FMD) Tunable Diode Laser Spectroscopy (TDLAS) system tested at U.S. EPA Test Range**
- **Deployed 6 units at Colorado State University (CSU) Methane Emissions Technology Evaluation Center (METEC)**

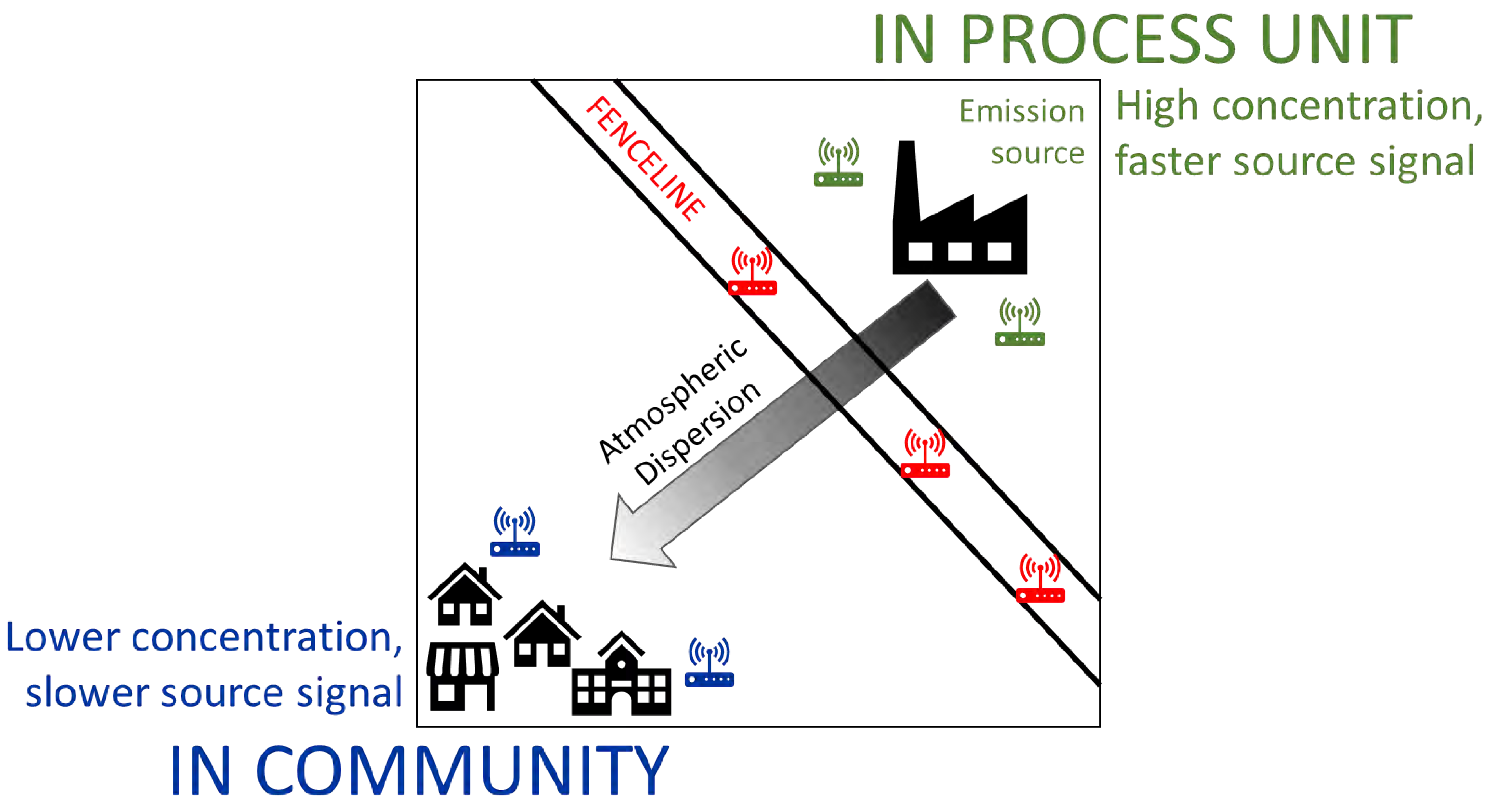
- **Acquired dataset from 6 FMD units along with information regarding calibrated releases**
- **Approached U.S. EPA to help explore METEC data**
  Joint collaborative activity with open-source publishing goals.
  No compensation provided by U.S. EPA ORD
- **Others are welcomed!**



PROJECT GOALS

- **SENSOR CLASS DEVELOPMENT**
  Understand the core capabilities and limitations of the technology

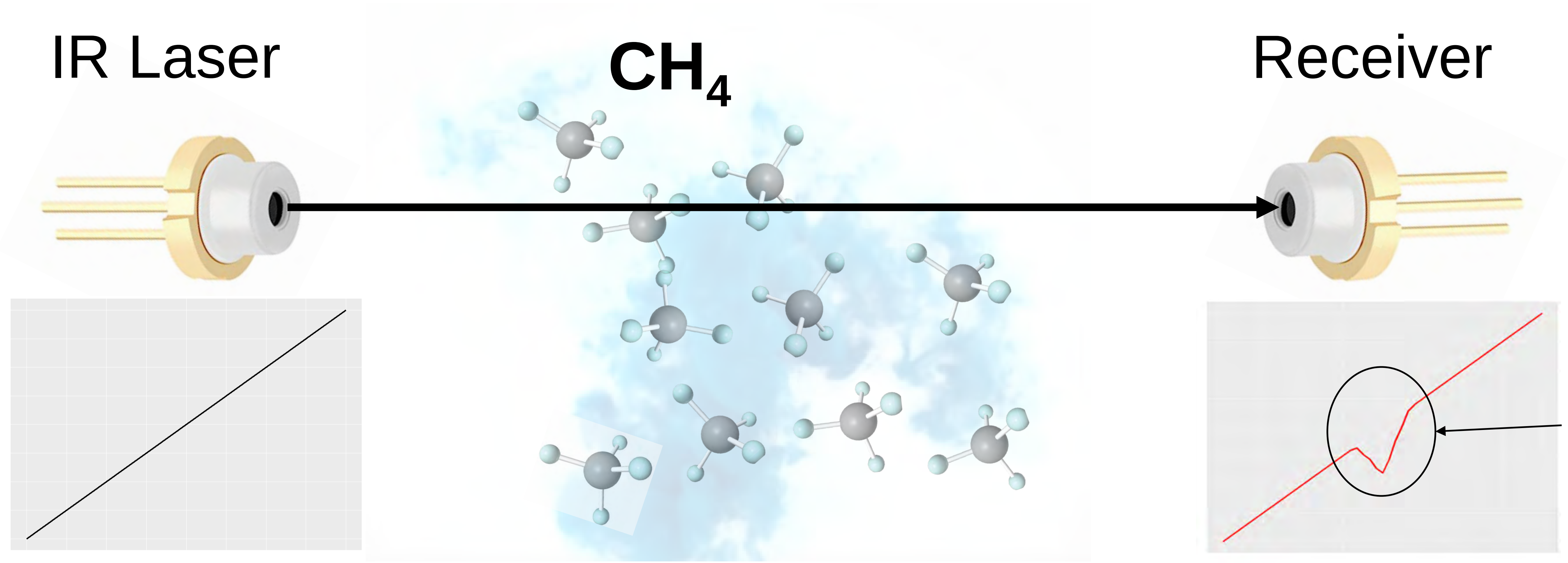
Application	Purpose	Sensor/Instrument Needs
In-Process-Unit	Detect and characterize emissions	• Fast sensor response is important, however concentrations can be very high • Application-specific accuracy/ precision
In-Community	Quantify ambient levels	• Fast sensor response not as important • Precise and accurate measurements required
Fenceline	Detect and characterize emissions	• Between in process unit and in-community • Fast response can be important to capture "dilute plume" – probe overlap



- **OPEN-SOURCE DEVELOPMENT OF METROLOGY AND ALGORITHMS**
  Provide model for data sharing and transparency

U.S. EPA TEST RANGE

TDLAS Operating Principal



Methane Detector Specifications	
Technology	Near Infrared (IR) TDLAS with Multi-Pass Cell
Wavelength	1650 nm
Range	0-100 vol.%
Noise Floor	0.3 Part Per Million (PPM)
T90	10 seconds

- **SENSIT FMD TDLAS system co-located with other methane detectors and reference instruments (Picarro and LiCOR)**

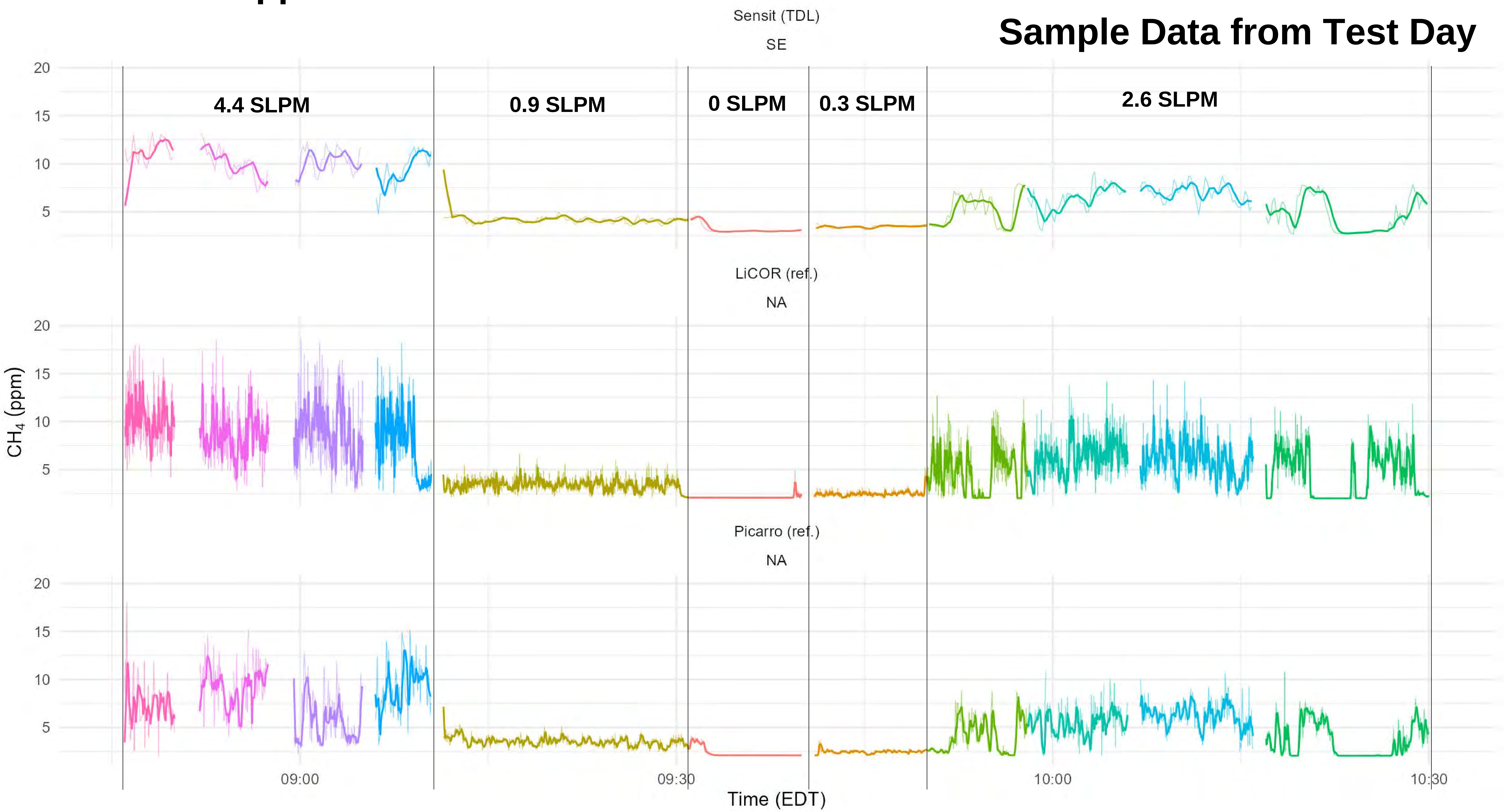
U.S. EPA TEST RANGE

$$Minimum\ Detection\ Limit\ (MDL) = 3 \times \sigma(St.Dev.)$$

Co-located with reference instruments (Picarro and LiCOR)

Calculations are 0.1 Hz Noise Based MDL (Excluding Drift Term). No baseline corrections applied

Sample Data from Test Day



10-s FMD Pre-Test [PPM]

Day	$\bar{x}$	σ	MDL
1	2.96	0.021	0.063
2	3.02	0.030	0.089
3	3.43	0.014	0.044
4	3.14	0.028	0.083
Avg.	3.14	0.234	0.070

10-s Reference Grade [PPM]

Inst.	$\bar{x}$	σ	MDL
Picarro	2.20	0.003	0.010
LiCOR	2.17	0.010	0.030

10-s FMD Between Tests

Day	$\bar{x}$	σ	MDL
1	2.49	0.041	0.122
2	2.97	0.029	0.086
3	3.25	0.081	0.243
4	-	-	-
Avg.	2.90	0.050	0.150

Preliminary data - MDL measurements and calculations are ongoing and contain the noise term only.

CSU METEC DEPLOYMENT

Deployed FMD
Measuring wind speed, wind direction, CH4 concentration

6 FMDS DEPLOYED AT A SIMULATED OIL AND GAS SITE. CONTROLLED EMISSIONS INTRODUCED.

ADVANCED METHANE DETECTION SYSTEM CAPABLE OF IDENTIFYING AND LOCATING INTRODUCED EMISSIONS.

Deployment	Start	2/8/2023	End	4/28/2023
Temperature	Minimum	-25.5°C	Maximum	29°C
Events	Experiments	279	Releases	565
	Avg. Release Size	1566 g/hr	Avg. Duration	3.11 hr


SENSIT Technologies
METEC Visualization
Grid # [default: 15]
Min Red [default: 5PPM]
Max
Generate Wind Rose
Cluster Analysis
Cluster Limit [default is 5PPM]
Choose File
230305 aggregate_data.csv
Detection ID
EmissionID
Leaflet
Methane by Hour [Zoom past 3 hours to enable Map-Update Mode]
LARGE LEAK
MEDIUM LEAK
SMALL LEAK
Values
100 PPM
75 PPM
50 PPM
25 PPM
0 PPM
22:00
23:00
5 Mar
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
6 Mar
FMD1008
FMD1012
FMD1011
FMD1000
FMD1009
FMD1010

SENSIT Technologies
METEC Visualization
Grid # [default: 15]
Min Red [default: 5PPM]
Max
Generate Wind Rose
Cluster Analysis
Cluster Limit [default is 5PPM]
Choose File
230305 aggregate_data.csv
Detection ID
EmissionID
Leaflet
Methane by Hour [Zoom past 3 hours to enable Map-Update Mode]
Reset zoom
SMALL LEAK
6 PPM
4 PPM
2 PPM
0 PPM
-2 PPM
Values
17:15
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15
19:30
19:45
20:00
20:15
20:30
20:45
21:00
21:15
21:30
21:45
22:00
22:15
22:30
22:45
FMD1008
FMD1012
FMD1011
FMD1000
FMD1009
FMD1010


SENSIT Technologies
METEC Visualization
Grid # [default: 15]
1
Max
Remove Wind Rose
Cluster Analysis
Cluster Limit [default is 5PPM]
Choose File
230305 aggregate_data.csv
Detection ID
EmissionID
Leaflet
Methane by Hour [Wind Rose Active - Map Mode Disabled]
6 PPM
4 PPM
2 PPM
0 PPM
-2 PPM
Values
SMALL LEAK
17:15 17:30 17:45 18:00 18:15 18:30 18:45 19:00 19:15 19:30 19:45 20:00 20:15 20:30 20:45 21:00 21:15 21:30 21:45 22:00 22:15 22:30 22:45
FMD1008 FMD1012 FMD1011 FMD1000 FMD1009 FMD1010

METEC RESULTS – Provider P

- **Accomplished via manual visual inspection of the data***

Report

- **Leak Present** — **Report True Positive = 84.2%**
  $P(Emission \mid Report) = 84.2\%$
- **No Leak** — **Report False Positive = 15.8%**
  $P(No\ Emission \mid Report) = 15.8\%$

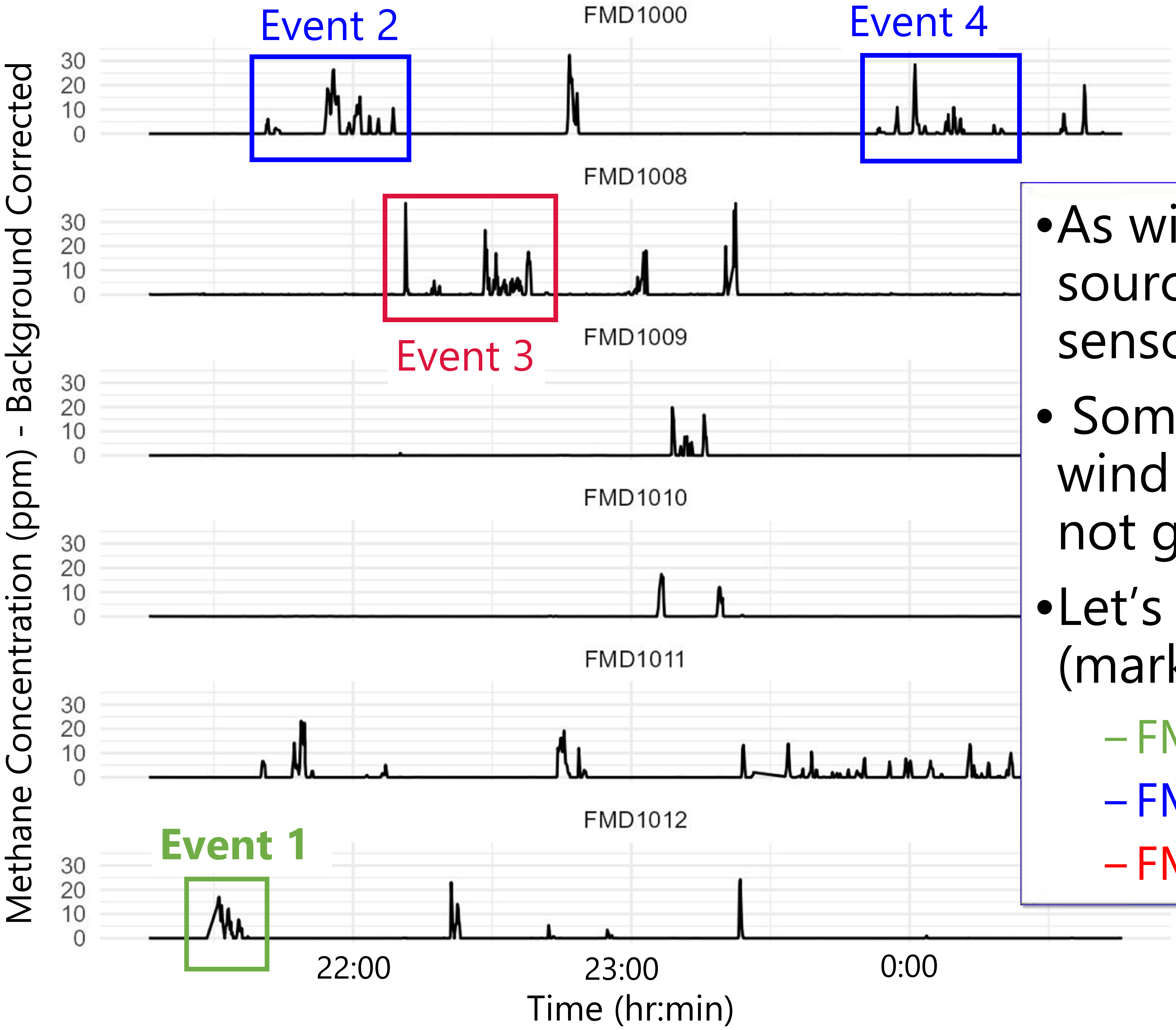
Leaky Asset

- **Reported** — **Asset True Positive = 66.4%**
  $P(Report \mid Emission) = 66.4\%$
  Site True Positive = 88.9%
  $P(Report \mid Site\ Emission) = 88.9\%$
- **No Report** — **Asset False Negative = 33.6%**
  $P(No\ Report \mid Emission) = 33.6\%$
  Site False Negative = 11.1%
  $P(No\ Report \mid Site\ Emission) = 11.1\%$

**Sensit only analysis, no collaboration with EPA ORD at this point.*

Quantification using open-source methods

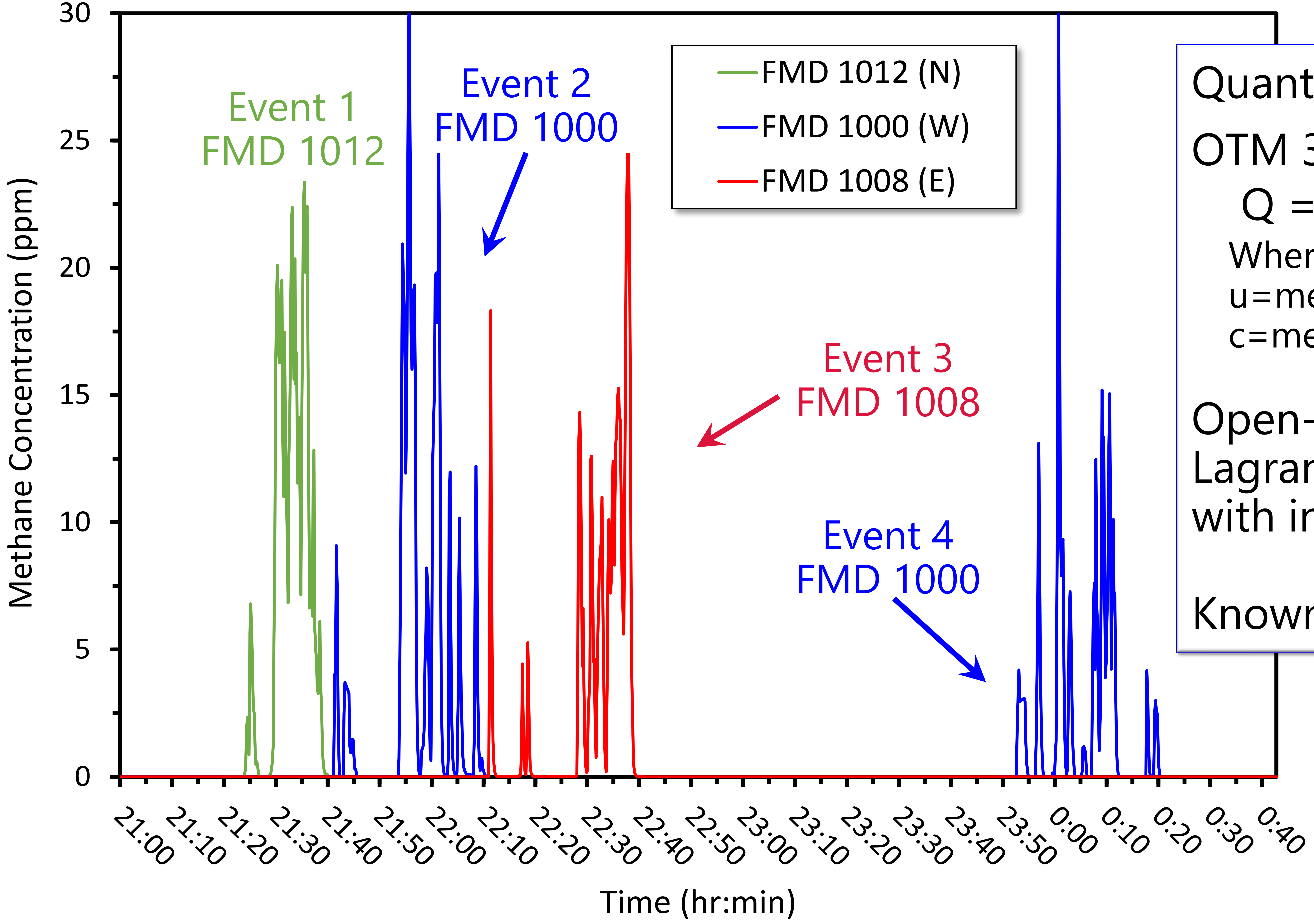
FMD 1100
FMD 1012
SENSIT Technologies
EPA
5.24 kg/hr (4T-1)
FMD 1008
FMD 1000
FMD 1009
FMD 1010
Source at night observed by multiple sensors as wind shifts



- As wind direction changes, the source is observed by different sensor nodes
- Some detections at very low wind speed are off-axis and are not good for quantification
- Let's look at 4 sub-events (marked by colored squares)
  - FM1012 (North) – Event 1
  - FM1000 (West) – Events 2 and 4
  - FM 1008 (East) – Event 3


FMD 1100
FMD 1012
SENSIT Technologies
EPA
FMD 1008
Changing Winds
FMD 1000
5.24 kg/hr (4T-1)
FMD 1009
FMD 1010

Measured Concentrations for quantification trials



Quantification by:

OTM 33A[1] simple emission estimate

$$Q = 2\pi * u * c * \sigma_y \sigma_z$$

Where:

u=mean wind speed (max bin)

c=mean max bin concentration (kg/m^3)

Open-source WindTrax™ backwards Lagrangian stochastic (bLs) model with inputs from OTM 33A binning.

Known source location (4T-1)

[1]https://www.epa.gov/emc/emc-other-test-methods – draft, results, nonstandard wind data, night observations (10°max bin mean for a1 and wind speed)

[2]http://www.thunderbeachscientific.com/ - inputs for bLs determined by OTM 33A max fit. Used Pasquil-Giiford (PG) Class D OTM33A PGI index 6


SENSIT Technologies
EPA
FMD 1012
Obstruction lowers measured concentration
FMD 1008
FMD 1000
Event 1
5.24 kg/hr
Event 1
OTM33A = 1.81 kg/hr (-65.5% error)
[1.03 kg/hr to 2.87 kg/hr]
WindTrax = 1.84 kg/hr (-65.1% error)
[0.83 kg/hr to 2.85 kg/hr]
FMD 1009
FMD 1010
Preliminary uncertainty estimates
OTM 33A at PGI 6 and 68 m [±2 m, ± 1 PGI class]
WindTrax at PG Class D [±2 m, ±5 deg, ±1 PG class]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EPA
Poor coupling for Event 4, need to develop QA flag. More measurements of the source over time will help
FMD 1012
FMD 1008
Event 2 and Event 4
5.24 kg/hr
FMD 1000
Event 2
OTM33A = 6.37 kg/hr, 21.6% error
[3.70 kg/hr to 9.99 kg/hr]
WindTrax = 5.55 kg/hr, 6.1% error
[2.34 kg/hr to 8.77 kg/hr]
FMD 1009
Event 4
OTM33A = 2.18 kg/hr, -58.4% error
[1.27 kg/hr to 3.42 kg/hr]
WindTrax = 1.82 kg/hr, 65.3% error
[0.80 kg/hr to 2.84 kg/hr]
1010
Preliminary uncertainty estimates
OTM 33A at PGI 6 and 68 m [±2 m, ± 1 PGI class]
WindTrax at PG Class D [±2 m, ±5 deg, ±1 PG class]

SENSIT Technologies
EPA
FMD 1100
FMD 1012
FMD 1008
Event 3
5.24 kg/hr
FMD 1000
Event 3
OTM33A = 5.41 kg/hr, 3.6% error
[3.15 kg/hr to 8.42 kg/hr]
WindTrax = 4.31 kg/hr, -17.8% error
[1.76 kg/hr to 6.86 kg/hr]
FMD 1009
FMD 1010
Preliminary uncertainty estimates
OTM 33A at PGI 6 and 68 m [±2 m, ± 1 PGI class]
WindTrax at PG Class D [±2 m, ±5 deg, ±1 PG class]

CONCLUSIONS

- Open collaboration leads to better understanding of the data and greater transparency
- SENSIT FMD is for capturing plume-probe overlap within process units and at the fence line.
- Deployment at METEC was able to identify and localize leaks.
- Freeware modeling packages capable of providing approximate estimates of leak rates.
- Be careful of model assumptions – know when they aren't applicable
- Work on this data set continues!

www.gasleaksensors.com

Protecting life, property, and the environment from hazardous gases