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Advancing Development of Emission Detection - FE0031873
2024 NETL Project Review Meeting

April 4th, 2024

Prime: CSU

PI - Daniel Zimmerle

PM – Wendy Hartzell

RS - Ethan Emerson

ADED Subawards:

University of Texas, Austin – David Allen, Arvind Ravikumar

Southern Methodist University – Kathleen Smits

Traditional (prescribed) LDAR program

Survey required every N months:

- Operator + OGI camera
- **Saw** emissions with camera (detection)
- **Identified** a leaking tubing connector at this location (diagnosis)

Dispatch repair team:

1) Within N days
2) Found tag
3) Re-detected the leak
4) Stopped leak by replacing damaged fitting
5) Verified fix

Typically requires a defined detection method

Conceptual ‘Next-generation’ LDAR program

Continuous monitor at site sends alert or dashboard says …

… Using data from the last N minutes …

There is a “high”† probability

of an emissions > 10† SCFH (200 g/h)

in this 2x2x2 m cube

Operator dispatches a response:

1) Arrived N hours after alert*
2) Used OGI to identify leak at this location

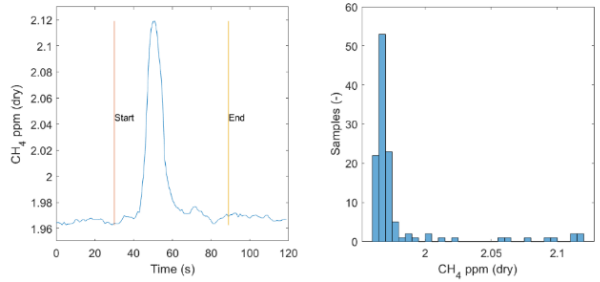
… and possibly others
3) Tagged & dispatched repair as in traditional program

† A solution may have many settings for thresholds, sensitivity, operating times …

* Dispatch urgency often depends on the emission rate estimated by the solution

Think: *Solutions* not *technologies or sensors …*

- Controlled & field testing should:
  - Utilize defined, replicable *single-blind* protocols
  - Test a solution *as it would be deployed*



Sensors

# of sensors / revision / power, etc.

Deployment

Locations / passes / speed / height / # of personnel …

Analytics

Software revision / comms from site & to operator

- Test results should clearly state what/how/how many were deployed … results are only as valid as the test was representative

Quick Overview of System Types

Included in ADED

Separate protocol & testing effort in parallel with ADED

All Solutions
Detect emissions, identify approximate leak locations, possibly quantify

"Continuous" Monitors
Stationary, installed on site, semi-autonomous, no operator

- Facility
- Pipelines (emerging area)
- Regional Sensing (towers, satellites)

Survey Solutions
Mobile, deployed periodically, with operator, detect, quantify, localize

- Component Inspection *Current regulatory approach*
- Facility ← *Wide range of mobility options – foot, robots, drones, aircraft …*
- Remote Sensing *Satellites* ← *Currently not sensitive enough for facility-scale measurement … focused on 'ultra' emitters or regional emission estimates*
- Pipelines (walking or driving)

Screening Solutions
Mobile, deployed periodically, identify possible emissions without localization or quantification

Similar tech subsets as survey solutions

Advancing Development of Emissions Detection (ADED)

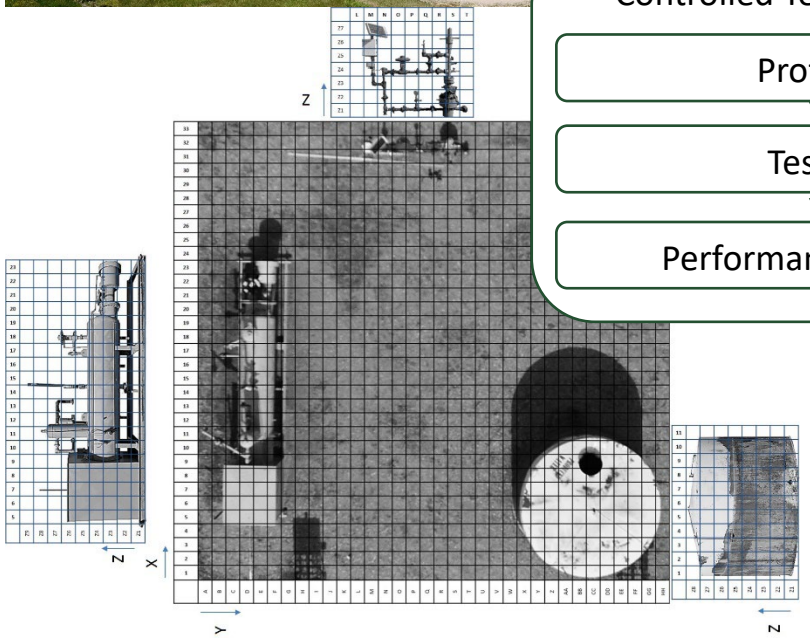
Accelerating natural gas leak detection and quantification solutions through transparent and rigorous scientific validation.

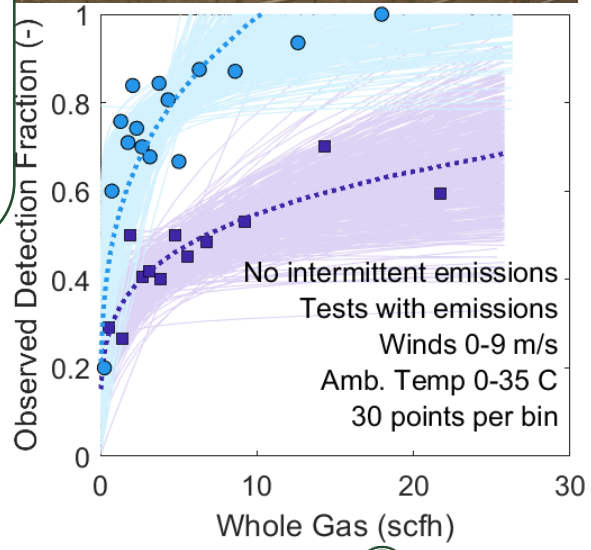
LDAQ Solutions
- Survey Methods
- Continuous Monitoring

Controlled Testing (METEC)
- Protocol
- Testing
- Performance Metrics

Field Testing (Pilot Sites)
- Protocol
- Testing
- Performance Metrics

LDAR Simulation Tool (PTE)
- CAMS MEET
- FEAST





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Objectives

1. Develop and test protocols for controlled testing that reliably assess natural gas leak detection and quantification (LDAQ) solutions under a range of representative field conditions at a controlled test facility;
2. Develop protocols for LDAQ solution field trials and conduct a comprehensive, multi-solution, field trial including a range of facility types;
3. Advance the state of LDAQ solution testing to be scientifically rigorous, affordable, repeatable, and adaptable to field conditions, and make this knowledge generally available to all stakeholders;
4. Propose test standards from the results of Objectives 1-3 that can be adopted and adapted by (a) state and federal regulatory agencies for regulatory approval of LDAQ solutions, and by (b) operators for internal emissions-mitigation efforts.
5. *Develop international consensus for test center qualification to carry out protocol tests.*

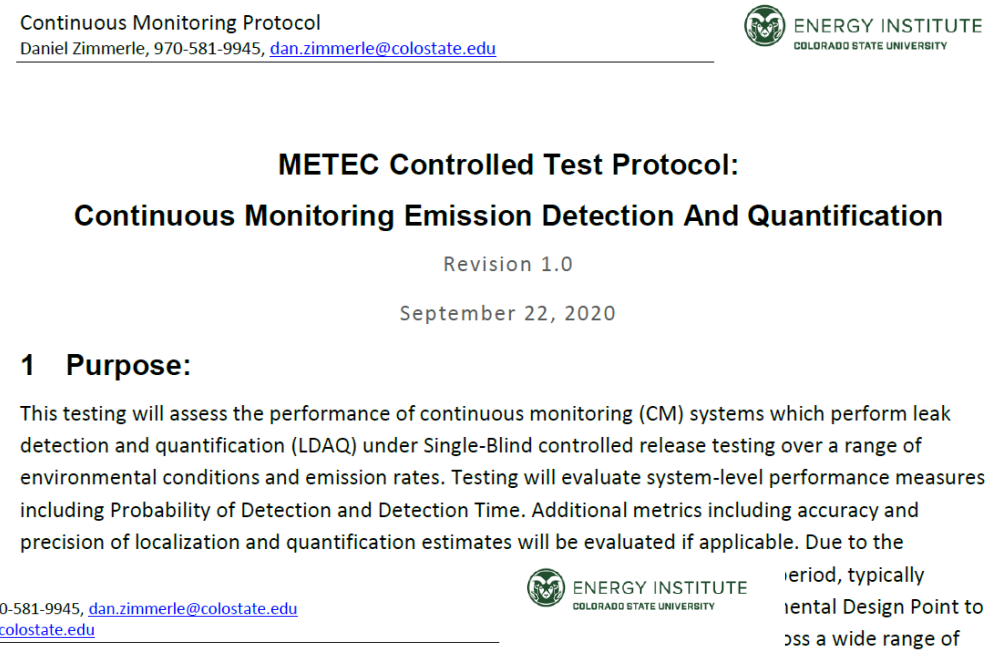
Protocol Objectives

For the two classes (continuous and survey solutions)

- Evaluate *key performance parameters* of leak detection methods required to populate PtE models.
- Test *sensitivity of the solution* as deployed, not *sensitivity of the instrument* alone.
- Develop protocols such that many unique solutions can test under each individual protocol, *enabling comparable results* broadly understood by stakeholder community.
- *Reproducible experimental methodology* allow comparison of newly tested solutions with previously tested solutions

Leak Detection & Quantification Protocols

- Consensus protocols written by CSU and reviewed by a protocol development committee
  - 75+ members
  - 450+ comments across both protocols
  - Implemented and currently being used for testing
- Currently being revised in collaboration with Total Energies, EPA, O&G Operators, and Solution Developers.



Continuous Monitoring Protocol
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METEC Controlled Test Protocol:

Continuous Monitoring Emission Detection And Quantification

Revision 1.0

September 22, 2020

1 Purpose:

This testing will assess the performance of continuous monitoring (CM) systems which perform leak detection and quantification (LDAQ) under Single-Blind controlled release testing over a range of environmental conditions and emission rates. Testing will evaluate system-level performance measures including Probability of Detection and Detection Time. Additional metrics including accuracy and precision of localization and quantification estimates will be evaluated if applicable. Due to the

Survey Protocol
Daniel Zimmerle, 970-581-9945, dan.zimmerle@colostate.edu
Clay Bell, clay.bell@colostate.edu

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METEC Controlled Test Protocol:

Survey Emission Detection And Quantification

Revision 1.0

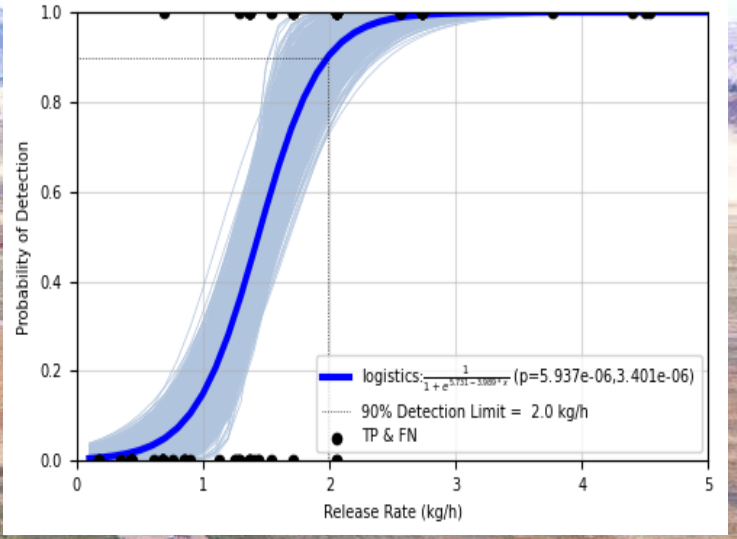
April 26, 2022

1 Purpose:

This testing will assess the performance of survey methods which perform leak detection and quantification (LDAQ) under single-blind controlled release testing over a range of environmental conditions and emission rates. Testing will evaluate system-level performance measures including Probability of Detection and Detection Time. Additional metrics including accuracy and precision of localization and quantification estimates will be evaluated if applicable.

Protocol Testing

Protocol report metric: probability of detection



Next-generation leak detection & quantification solutions deployed at METEC for single-blind protocol testing (survey and continuous monitors)

Continuous Monitor Program

- Conducted annually since 2021
- 12-14 weeks, 500+ emission experiments, 8 kg/hr
- 35+ solutions tested

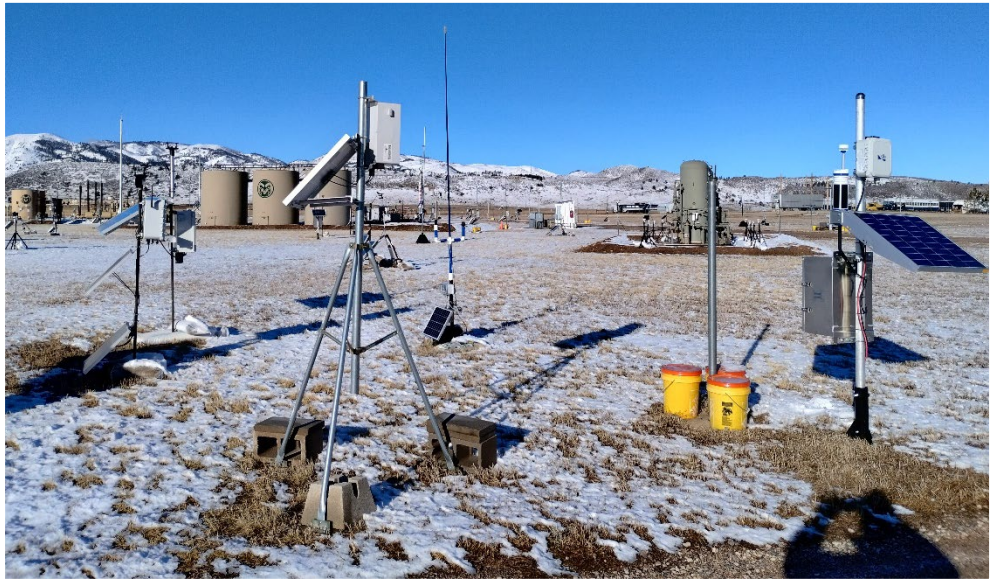
Survey Evaluation

- Conducted on an adhoc basis
- 1 week, 80+ emission points, 0-5 kg/hr
- 10+ solutions tested

Performer reports generated at the end of the program to evaluate solution performance.

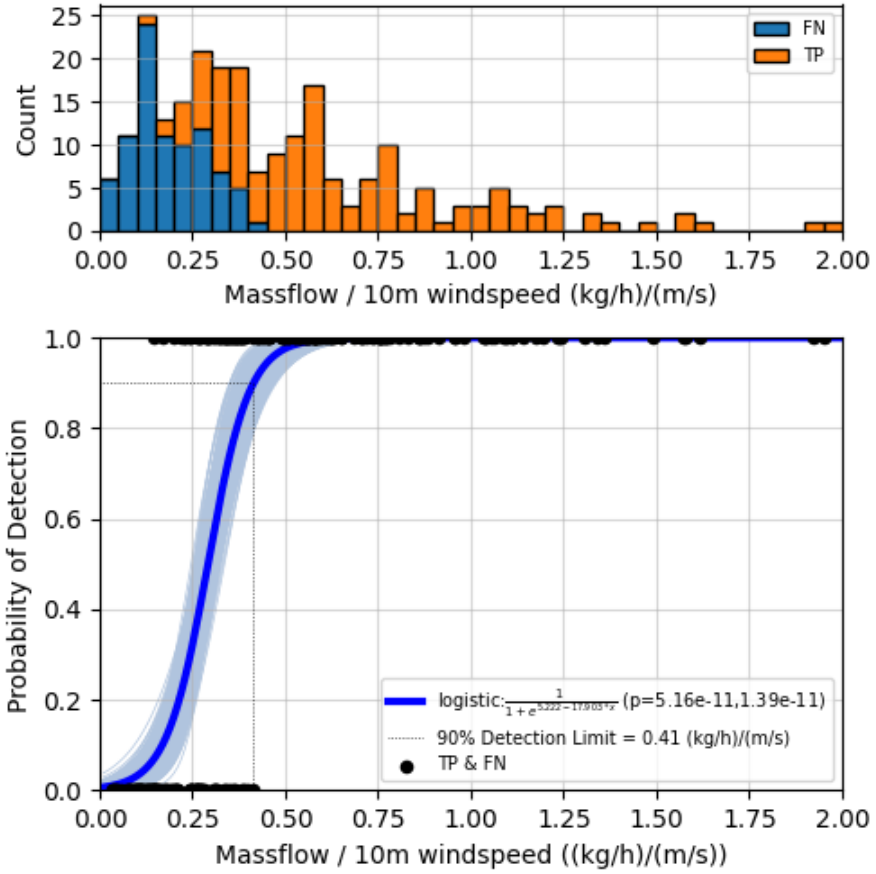
Solution sensors

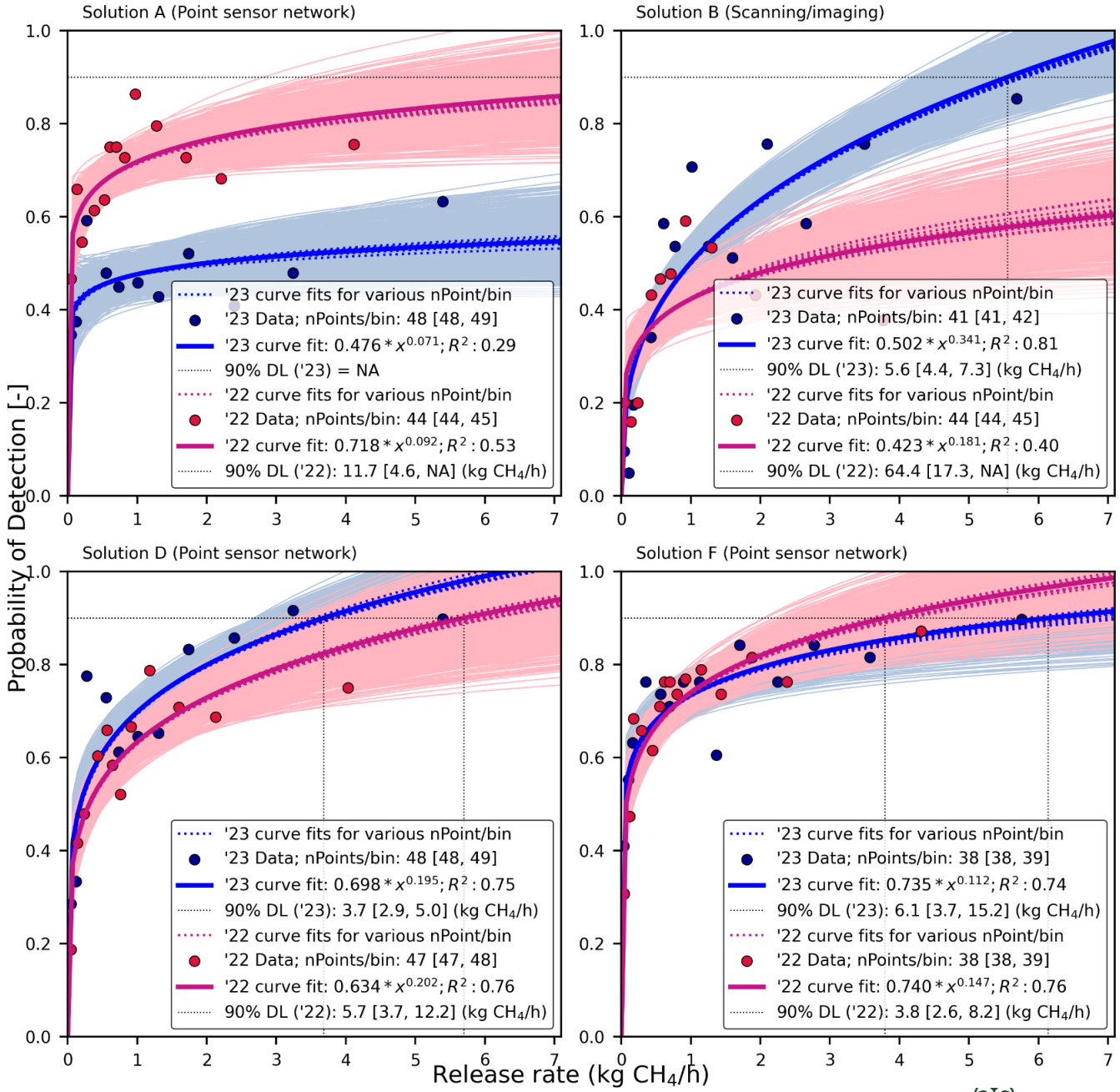
Continuous Monitor Testing 2024



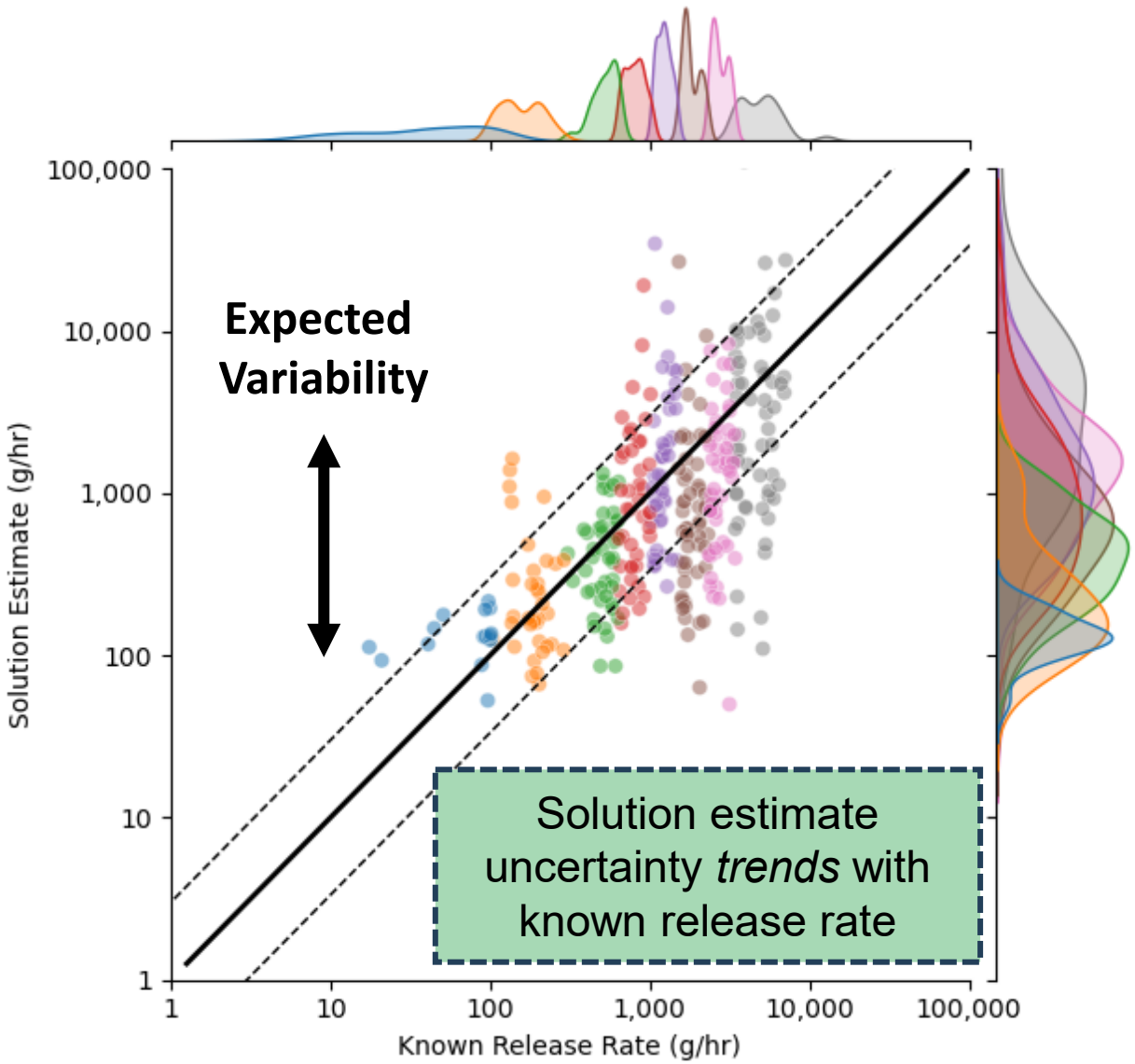
Detection

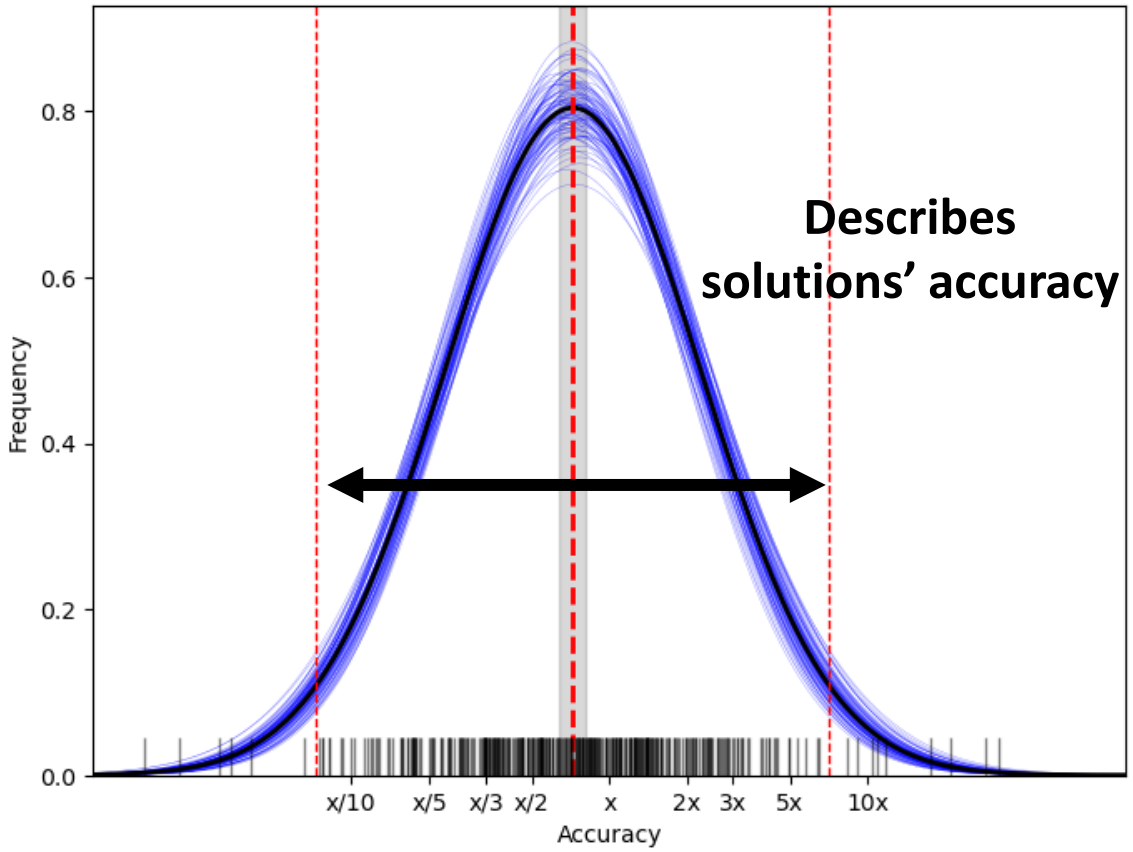
- Will solution reliably detection an emission?





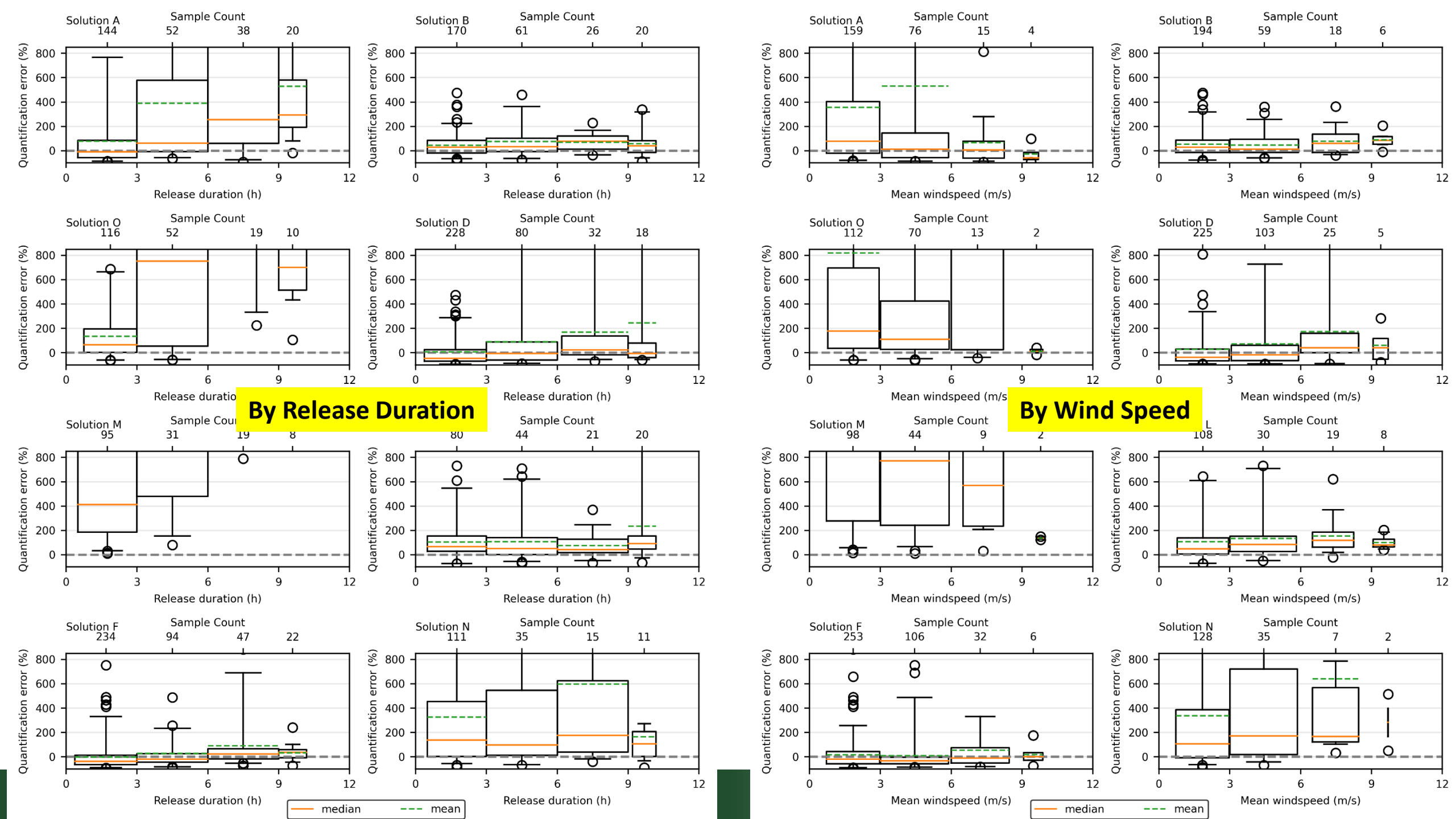
Quantification





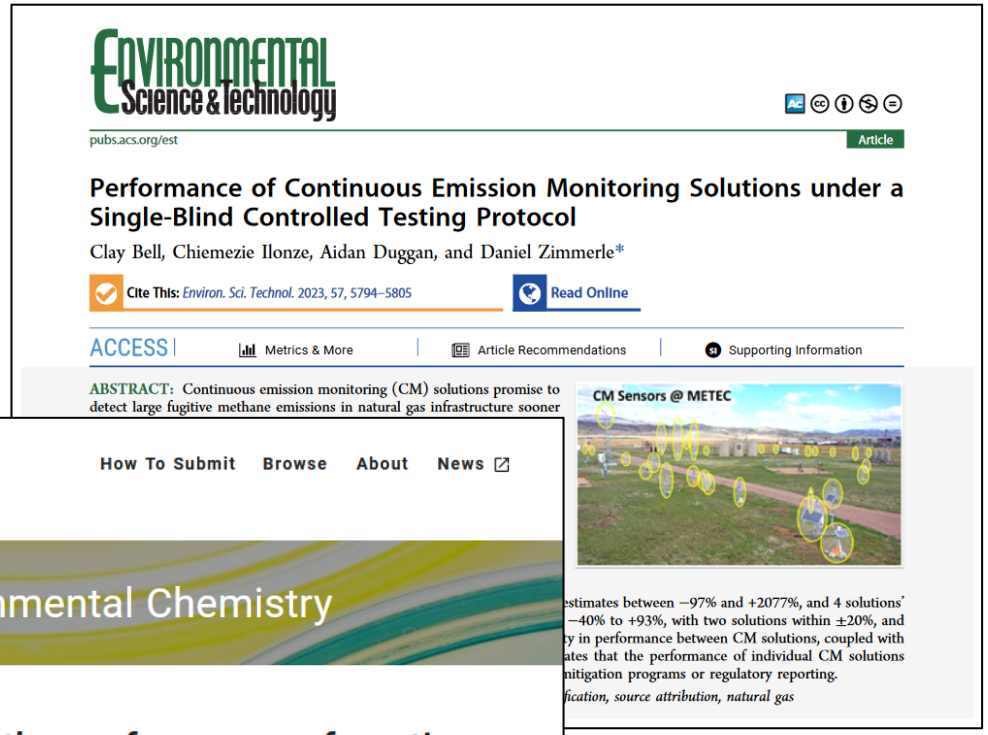
$$Accuracy = Log_{10}\left(\frac{Estimate}{Actual}\right)$$

Evaluate the aggregate accuracy of the solutions' performance.


Solution A
Sample Count
144 52 38 20
Solution B
170 61 26 20
Solution O
116 52 19 10
Solution D
228 80 32 18
Solution M
95 31 19 8
80 44 21 20
Solution F
234 94 47 22
Solution N
111 35 15 11
Quantification error (%)
Release duration (h)
By Release Duration
Solution A
159 76 15 4
Solution B
194 59 18 6
Solution O
112 70 13 2
Solution D
225 103 25 5
Solution M
98 44 9 2
108 30 19 8
Solution F
253 106 32 6
Solution N
128 35 7 2
Mean windspeed (m/s)
By Wind Speed
median
mean

Objective 1 & 3: Controlled Testing

1. Initial Protocol Development: 2020-2021
2. Controlled testing at METEC: 2021 to present
    1. 35+ continuous solutions tested (some duplicates)
    2. 10 survey solutions tested
3. Analysis: 2021 to present
    1. One publication, one in preprint
    2. Survey manuscript in draft
4. Protocol Revision: present



Environmental Science & Technology

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Article

Performance of Continuous Emission Monitoring Solutions under a Single-Blind Controlled Testing Protocol

Clay Bell, Chiemezie Ilonze, Aidan Duggan, and Daniel Zimmerle*

Cite This: *Environ. Sci. Technol.* 2023, 57, 5794−5805 | Read Online

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ABSTRACT: Continuous emission monitoring (CM) solutions promise to detect large fugitive methane emissions in natural gas infrastructure sooner

CM Sensors @ METEC

estimates between −97% and +2077%, and 4 solutions' −40% to +93%, with two solutions within ±20%, and y in performance between CM solutions, coupled with ates that the performance of individual CM solutions nitigation programs or regulatory reporting.

fication, source attribution, natural gas

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Earth, Space, and Environmental Chemistry

Assessing the progress of the performance of continuous monitoring solutions under single-blind controlled testing protocol

08 February 2024, Version 2

Working Paper

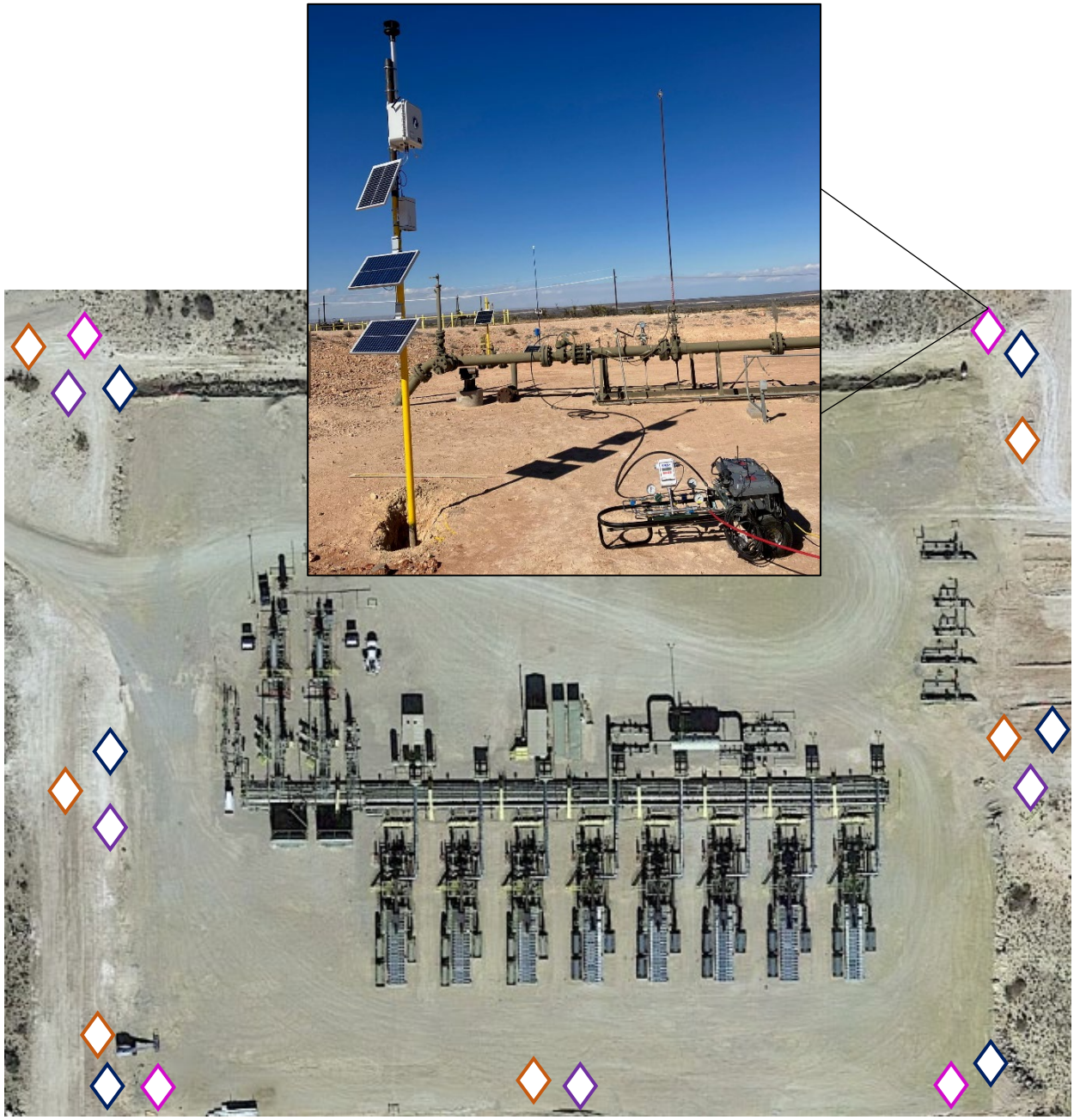
Chiemezie Ilonze, Ethan Emerson, Aidan Duggan, Daniel Zimmerle

Show author details

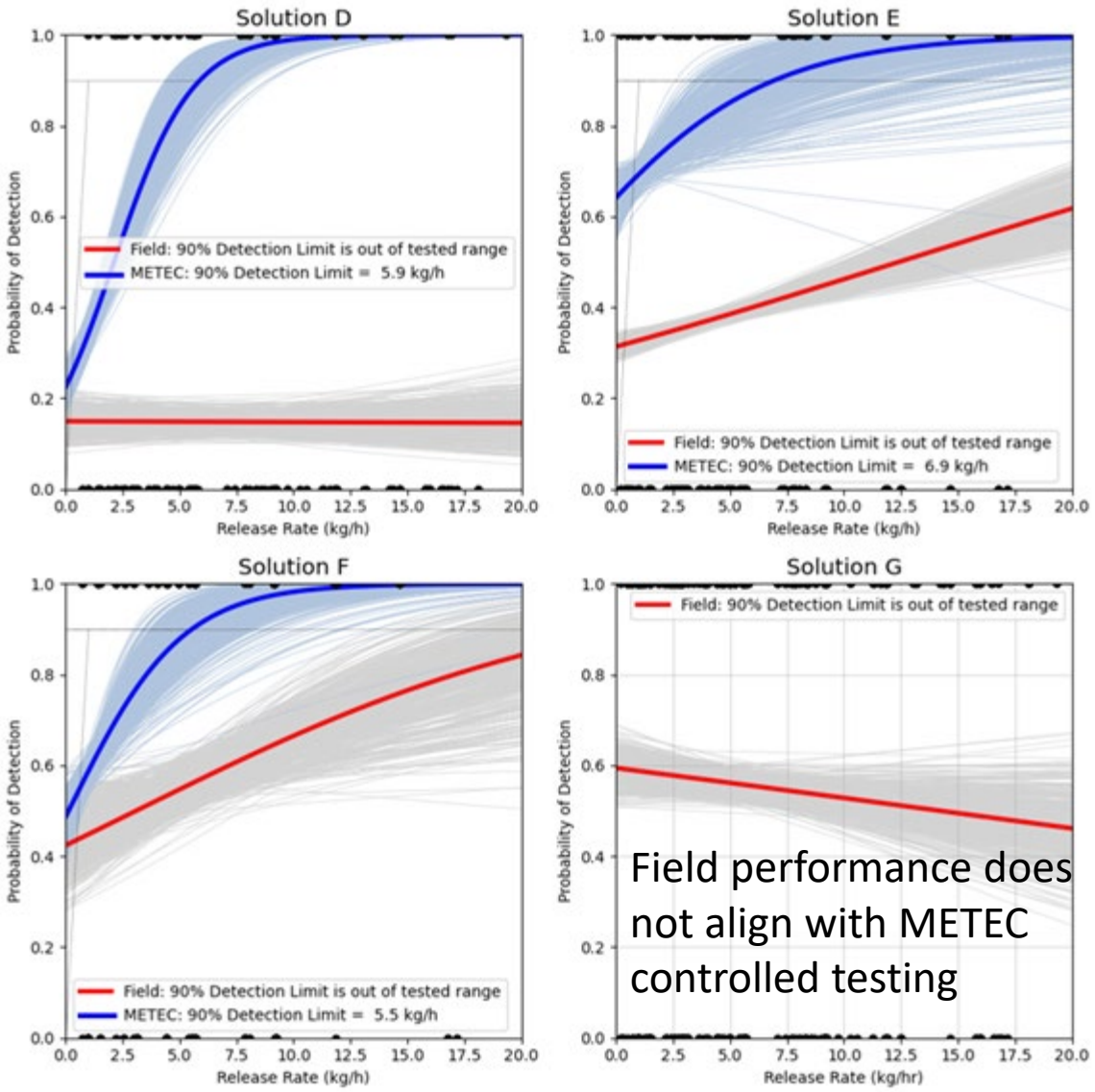
This content is a preprint and has not undergone peer review at the time of posting.

Objective 3: Field Trials

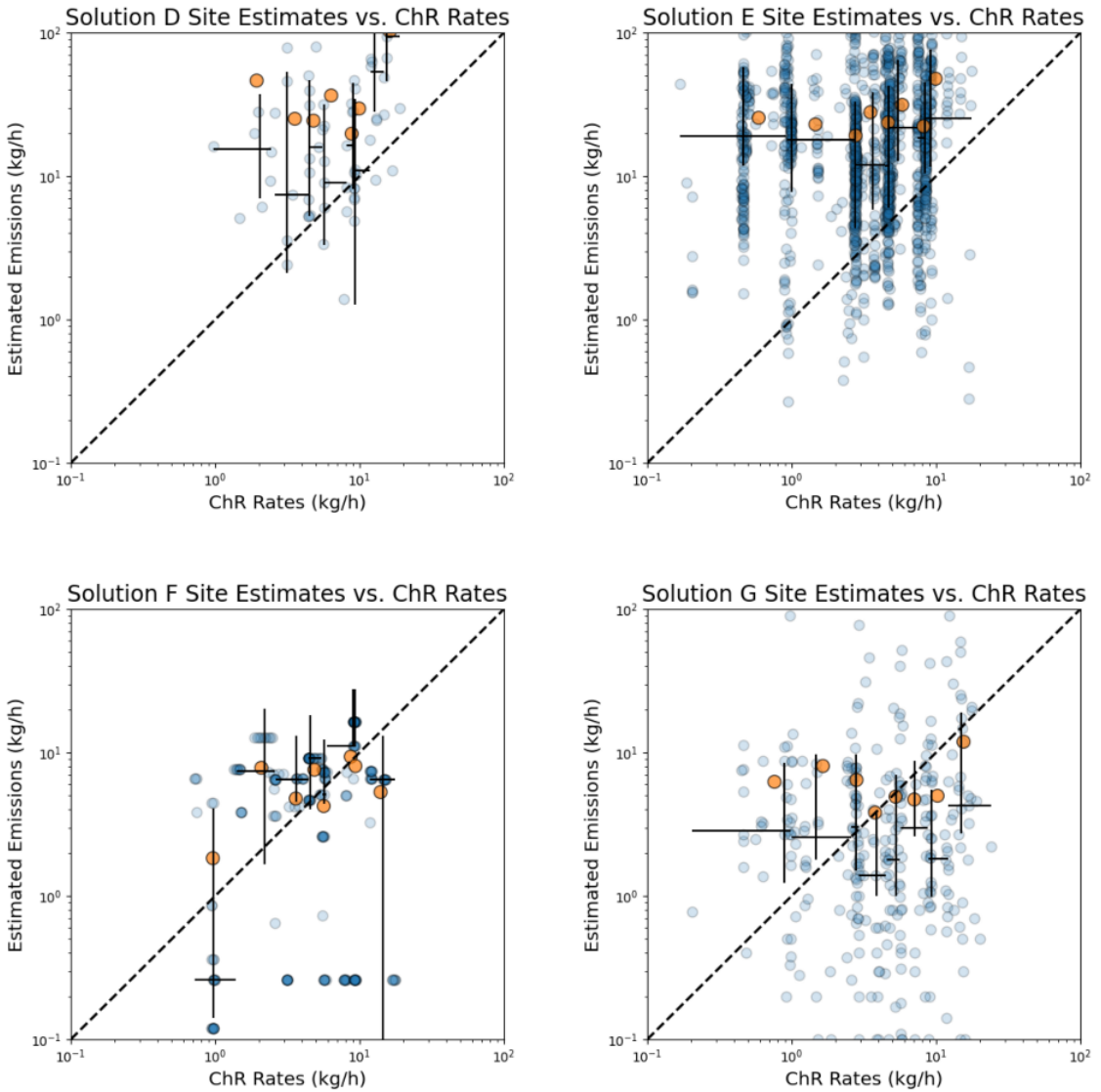
- Onsite field testing on operational sites with solutions deployed by operators and sensor companies
  - Challenge testing using a portable release rig from representative locations and rates around the facility
  - 11 total sites, 7 production and 4 midstream facilities
  - Upper Green, Marecellus, and Permian Basins



Field Performance



Field performance does not align with METEC controlled testing



Quantification signal response to challenge releases is limited

Not all gloom

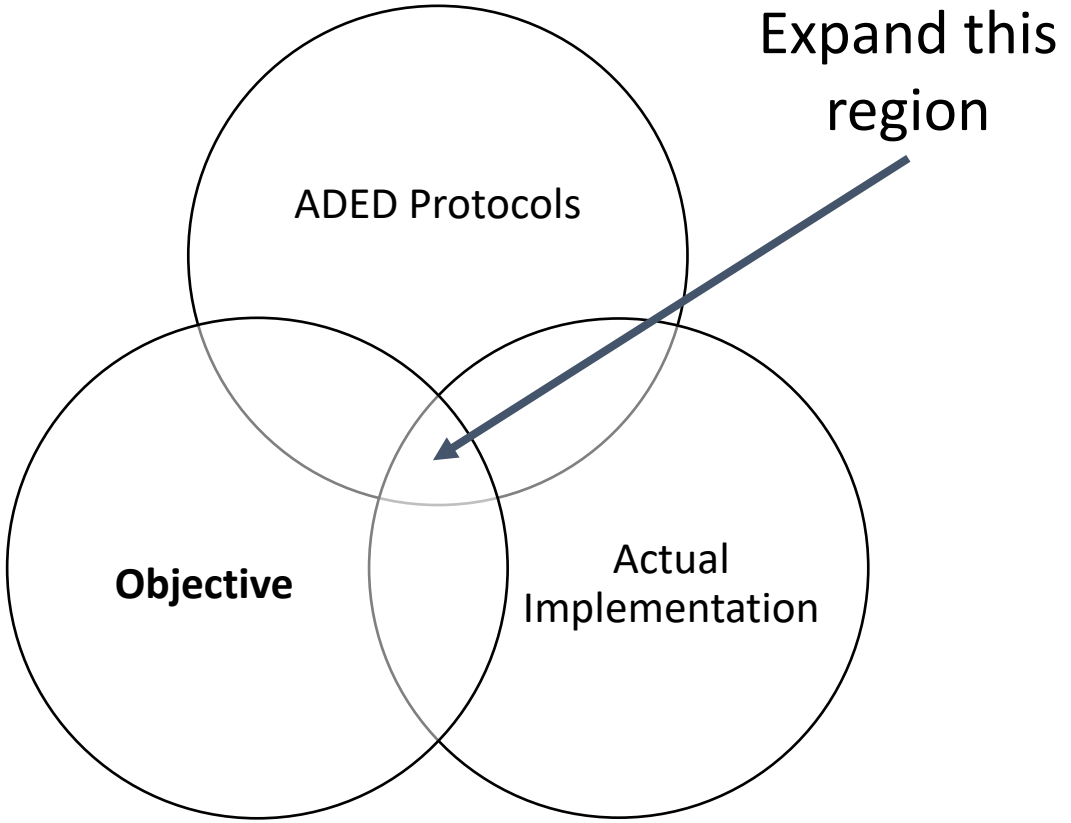
- Testing probability of detection:
  - Simple classification approach
  - χ^2 test
  - Yes → **a statistical relationship *cannot be ruled out***
  - No → results are indistinguishable from random
- Results show there ***might*** be some signal, some of the time
- Points to need for improved algorithms (and/or sensors)

Possibly Observed Detection

	Facility Type	*D*	*E*	*F*	*G*
Facility 1	Production	No	No	Yes	No
Facility 2	Production				Yes
Facility 3	Production				No
Facility 4	Production				No
Facility 5	Production				Yes
Facility 6	Compressor		Yes		Yes
Facility 7	Gas plant		Yes		
Facility 8	Compressor		Yes		No
Facility 9	Compressor	No			No
Facility 10	Production	Yes			No
Facility 11	Production	No			No

Protocol Revision

- Field performance does not align with METEC controlled testing
  - “Detection” in field conditions is vastly simplified from controlled testing
- Why?
  - Methods struggled with complexity at METEC – intentionally simplified testing – field conditions are (intentionally) more complex
  - Field facilities are larger than METEC
- Complexity is borne out in field … controlled testing needs to ‘step up’



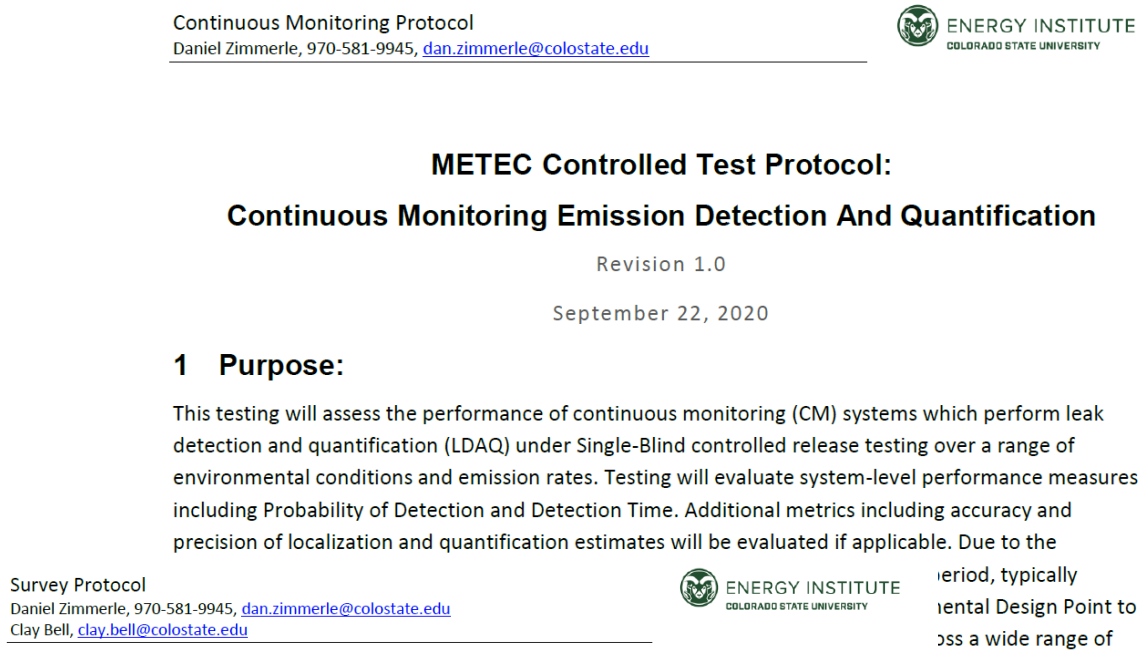
Primary driver of the test program and leak detection and quantification solutions Objectives are driven by Operators and Regulators

Protocol Revision

Currently being revised in collaboration with Total Energies and EPA

Strong Stakeholder Engagement

- 75+ members
- Operators
- Solution Developers
- Academic Organizations
- NGOs



Continuous Monitoring Protocol
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Objective 5: ADED International

Controlled Test Protocols

Do test centers show the same performance when evaluating different protocols?

Controlled Testing **METEC**

Controlled Testing **TADI**

Controlled Testing **Others**

TotalEnergies

Objectives:

- Establish internationally recognized test protocols
- Establish a program to ‘test the test center’

Thank You

Contact

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