Methane measurement at Canadian Landfills

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Funded by Environment and Climate Change Canada (ECCC),
UN Environmental Programme (UNEP) International Methane Emissions Observatory,
and Natural Resources Canada (NRCan)

Environment and Climate Change Canada
Environnement et Changement climatique Canada

UN environment programme | International Methane Emissions Observatory

Natural Resources Canada | Ressources naturelles Canada

Environmental Research & Education Foundation
Lighting the way towards a more circular economy

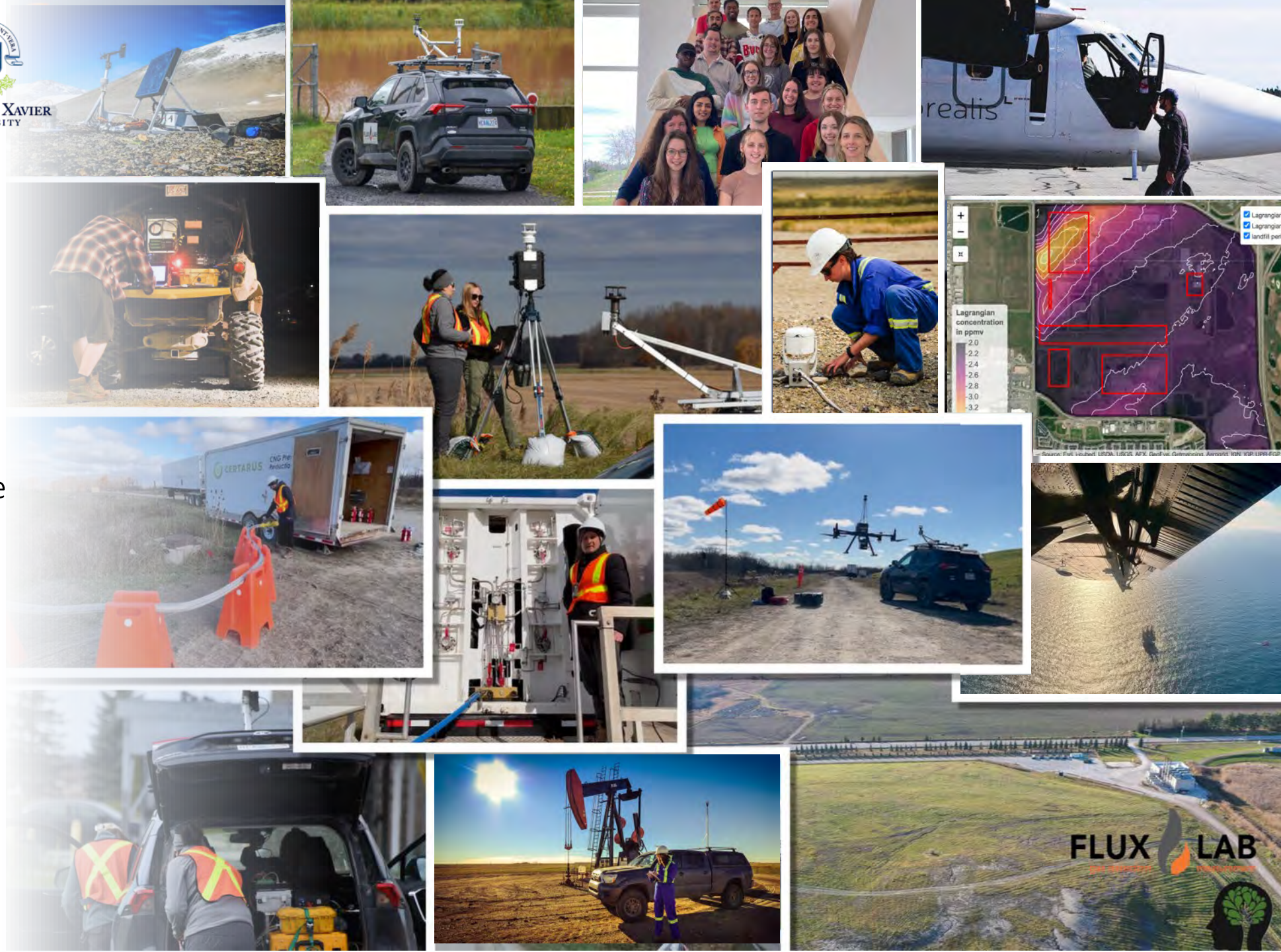
FluxLab

St. Francis Xavier University

- **University-based** team
- St. Francis Xavier University
- Antigonish, Nova Scotia
- 25-35 team members
- Specialize in **detection + measurement** of methane
- Conduct **large** national-scale programs for government and industry
- Contract work for tech companies, and moving tech into the world :

Arolytics

ensense



Why are Measurements Important?

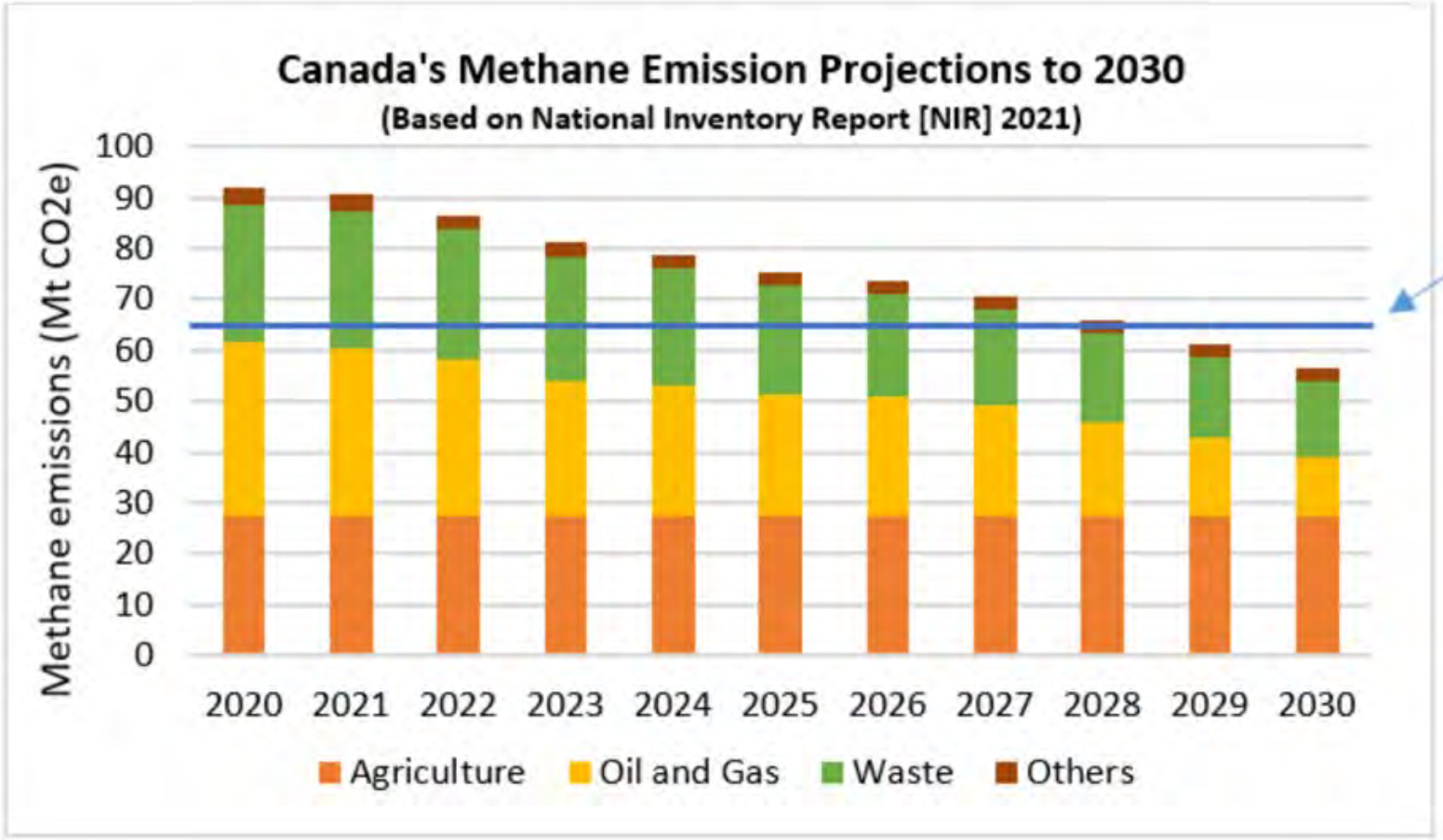
Canada pledged support to global methane initiative, aims to reduce global methane emissions by 30%

Waste sector makes up 23% of Canada's methane emissions as of 2022

Federal government aim to put more accurate regulations into place by 2025

Waste Sector – The Next Frontier

GMP Commitments Aren't Achievable Without the Waste Sector



Canada 50% waste sector reduction planned by ~2030

From now to 2030 – 60:40 O&G vs Waste

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Waste Sector – Playing Catch Up

Substantial time pressure to address key gaps in data and knowledge

Regulations will have ~5 years to achieve the promised 50% reduction – not much!
Waste sector is the biggest source of methane uncertainty in Canada's Inventory. Yikes.

- Starting data: Are reported and modeled values reasonable?
- Do we have an appropriate understanding of sources and variability?
- What types of measurements should the regulator conduct or recommend?

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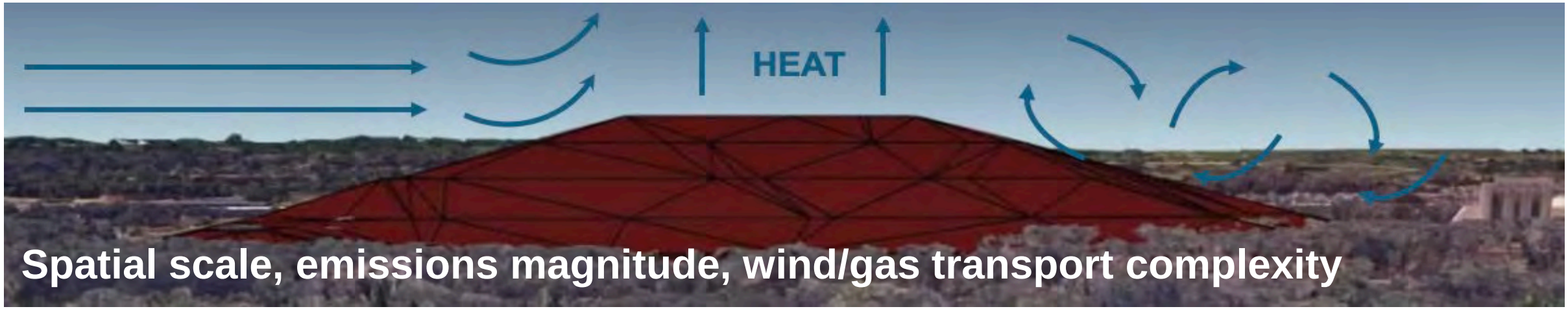
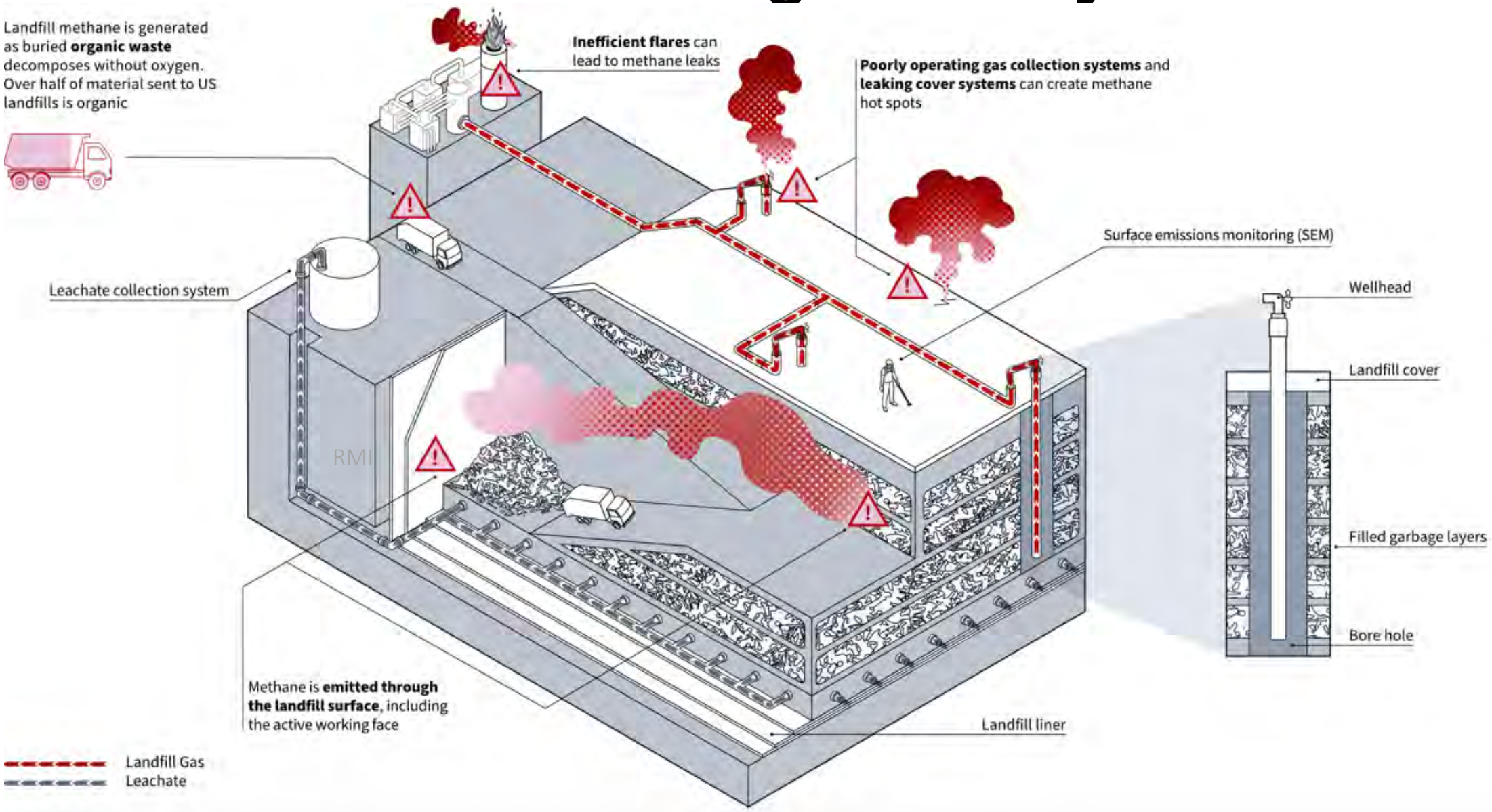
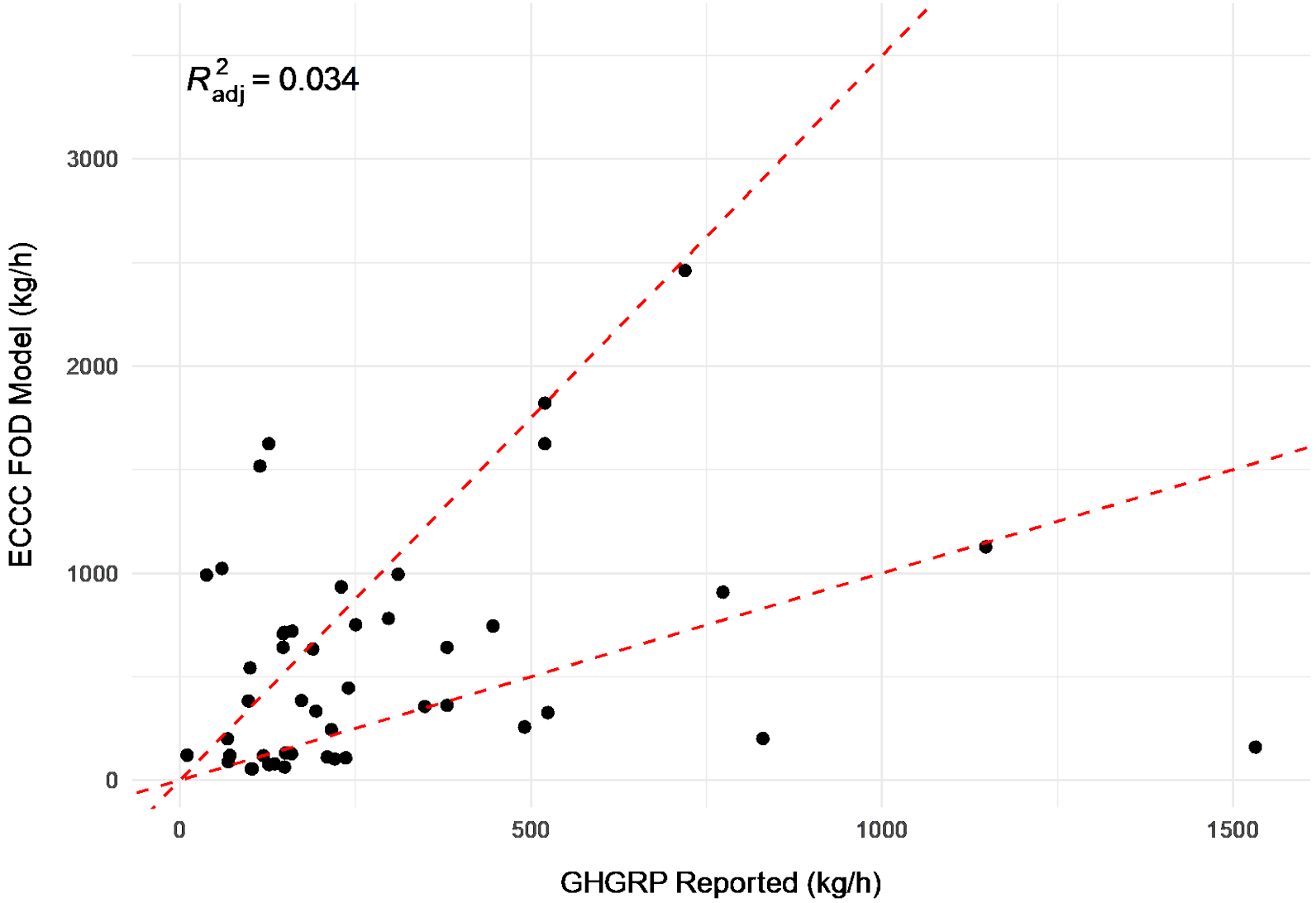
Landfill measurement challenges



Measurement Challenge – Many Sources



Unclear Official Numbers?



- GHGRP = Greenhouse Gas Reporting Program (operator self assessment/reported)
- ECCC = Environment and Climate Change Canada
- FOD = First Order Decay Inventory Model

They don't agree.

Which is right??

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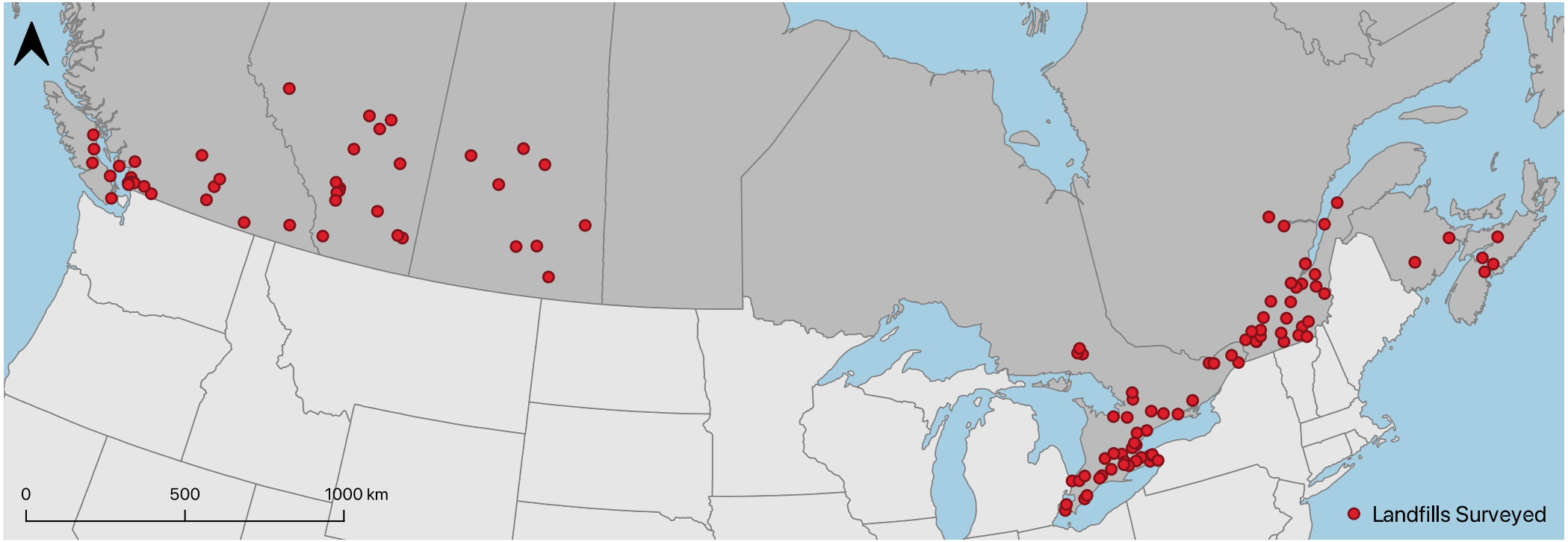
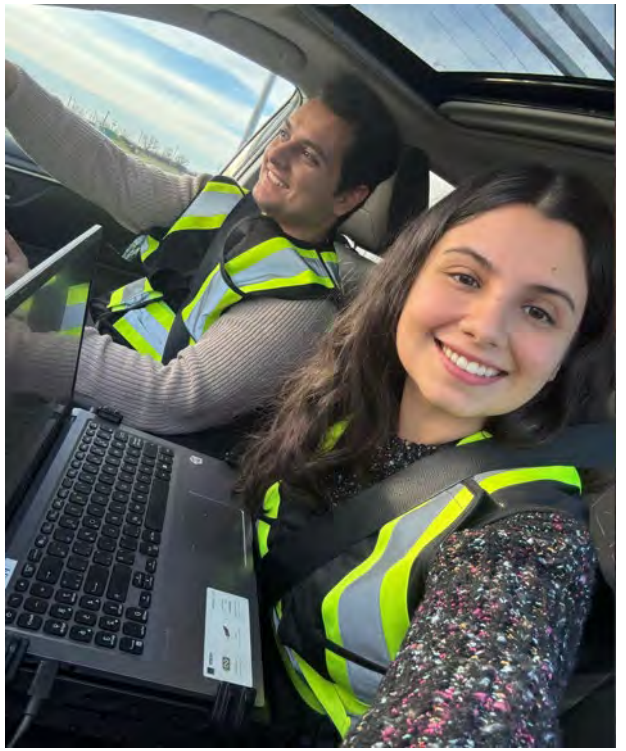
Part 1: 2022 Landfill Survey

- 125 truck snapshot measurements of landfills across Canadian climate zones
  - 10% were visited 2x
- 27 aircraft mass balance snapshot measurements in November 2022
- Not all measurements were successful (78/125 mobile & 13/27 aerial)



CSRS: Albers Equal Area Conic. Provincial boundaries from Statistics Canada. State boundaries from the US Census Bureau.

Measuring by Truck



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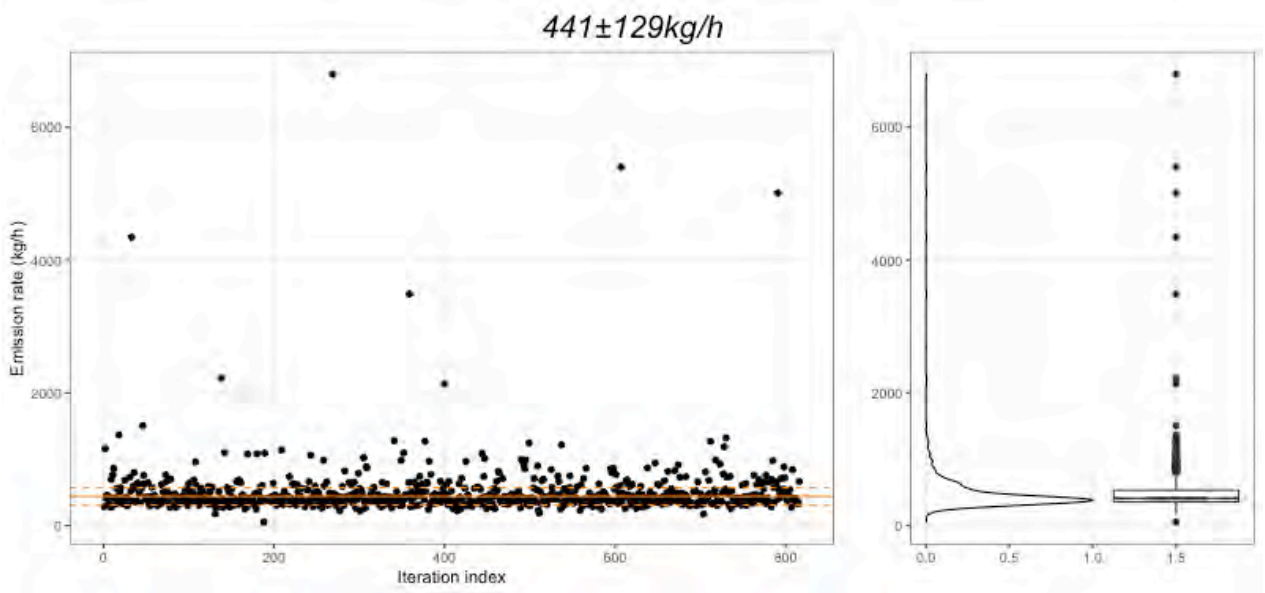
Mobile Data

Offsite downwind transects
Onsite access to many

Measuring by Truck

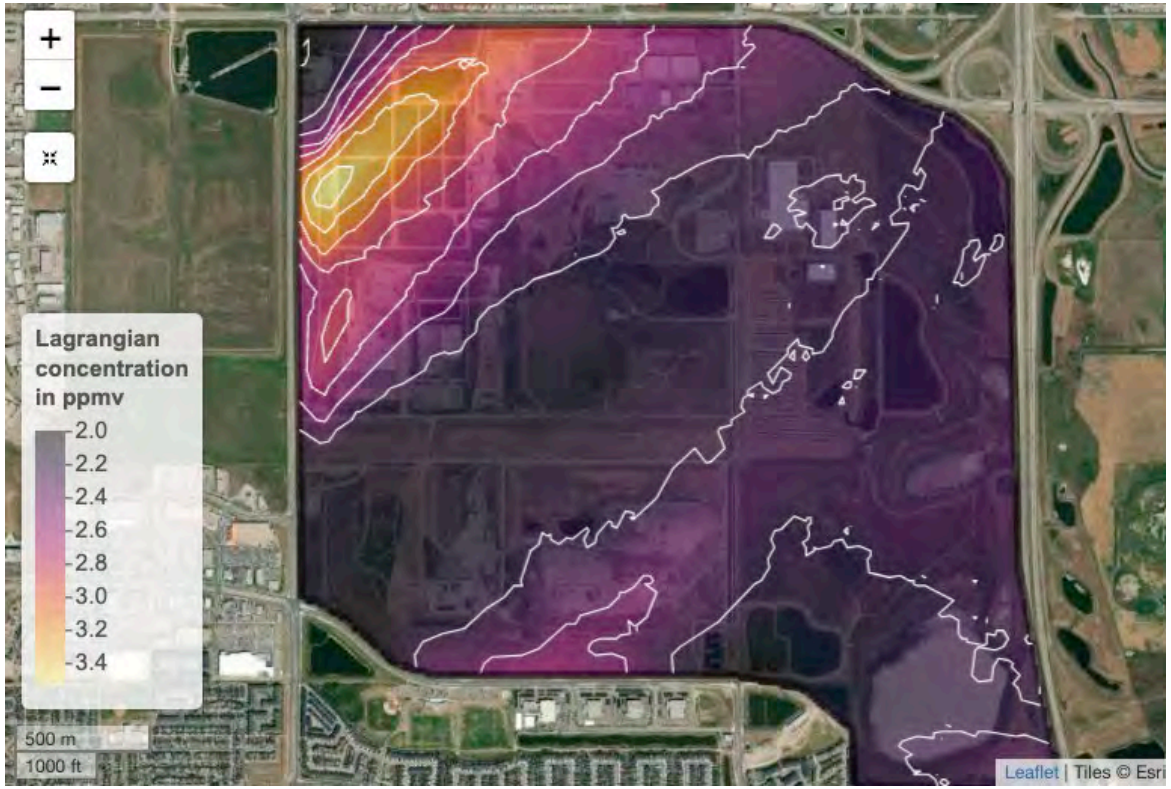
Gaussian Inversion - Rate



- Repeated guesses of emission source combos until match
- Uncertainties: source locations, stability class

Lagrangian – Localization and Rate

- Developed at StFX



Rate Calculation

Obtained methane emissions rates for **86** of the visited landfills

Repeated measurements at 10% of the sites

Gained understanding of major methane sources at landfills

Part 2: Aerial Surveys

Field work: November 2022
Data analysis: Finished (November 2024)

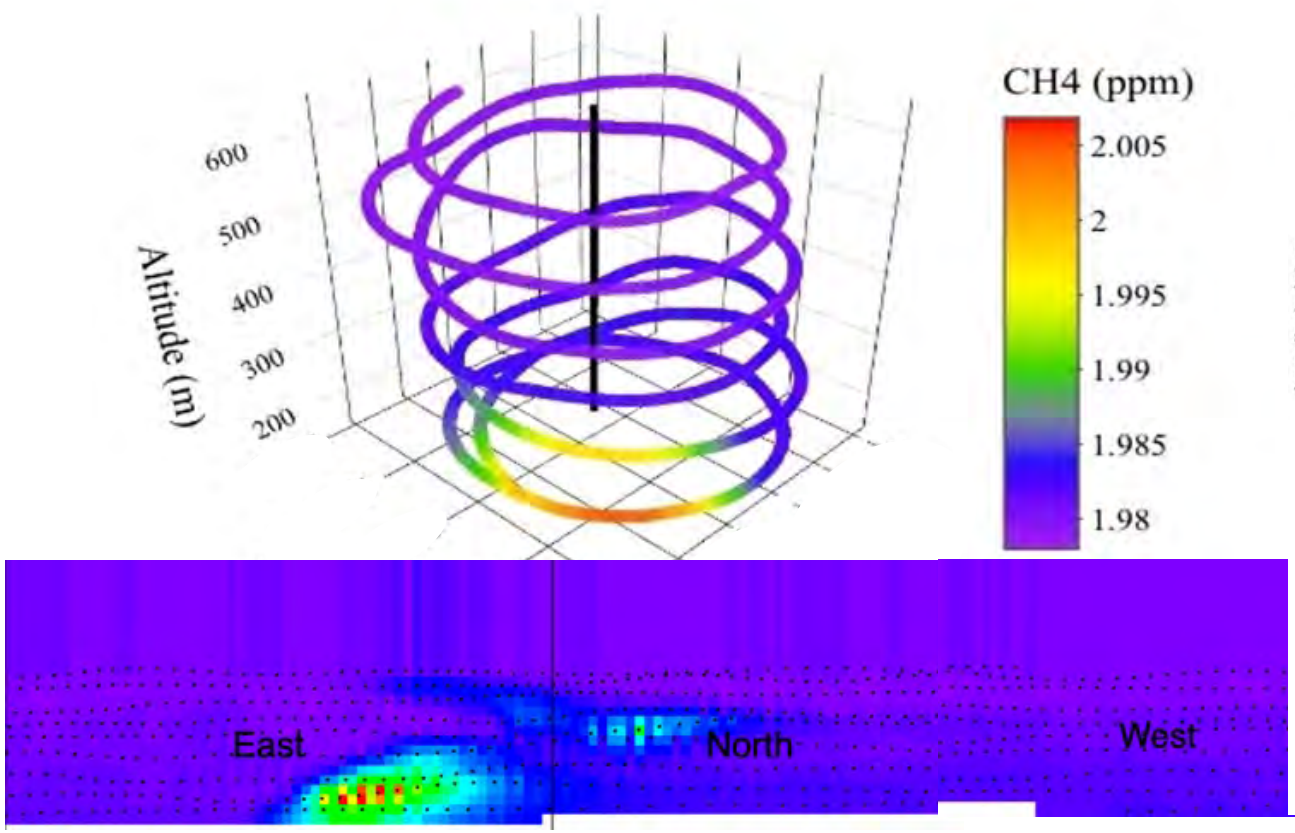
27 landfills surveyed in Ontario and Québec

Top-down Emission Rate Retrieval Algorithm (TERRA) and Gaussian Dispersion Model (GDM)

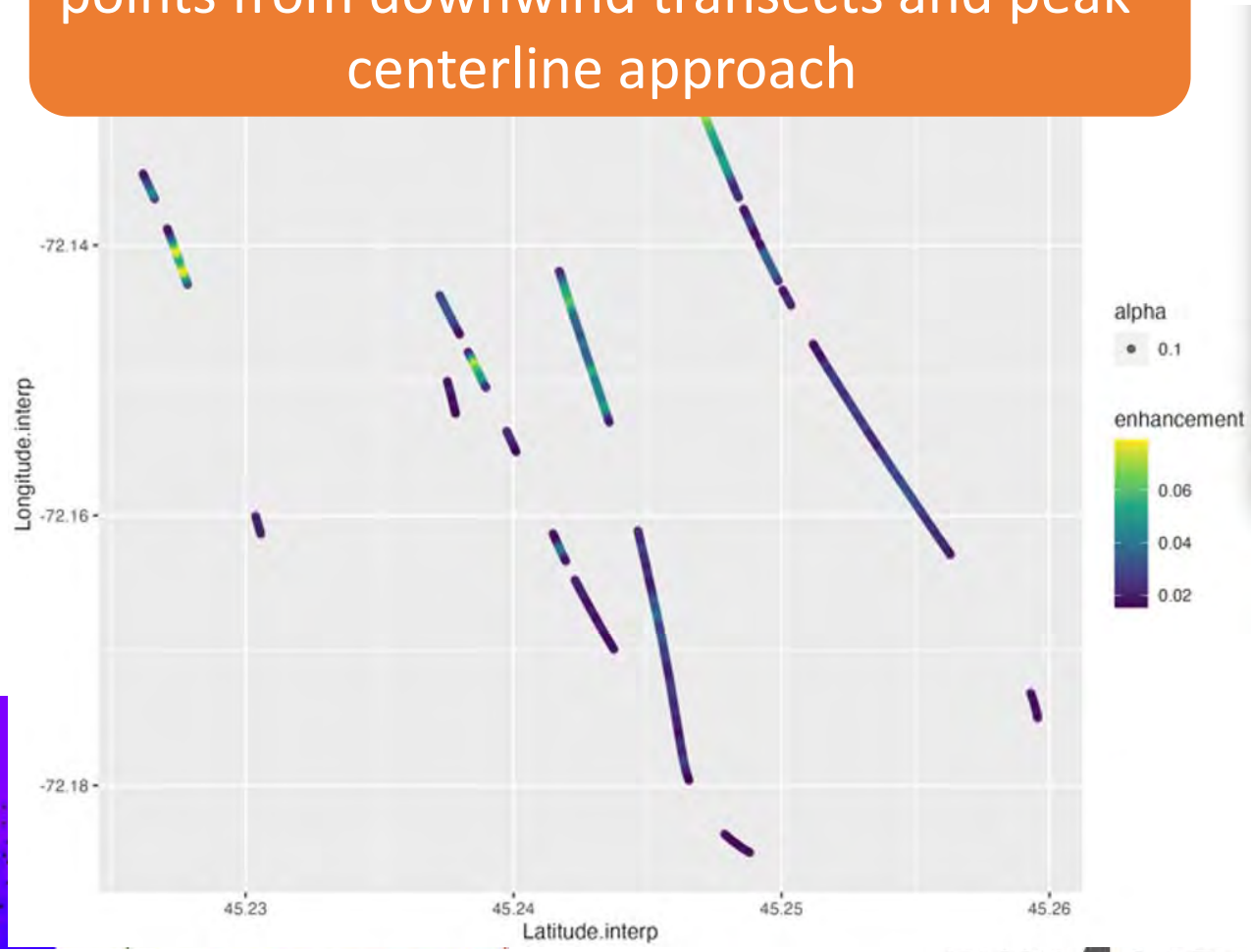
Twin Otter Aircraft Set-up

Rate Calculation

TERRA: Open-top control volume; sensitive to atmospheric conditions and vertical winds



GDM: Uses select points from downwind transects and peak centerline approach



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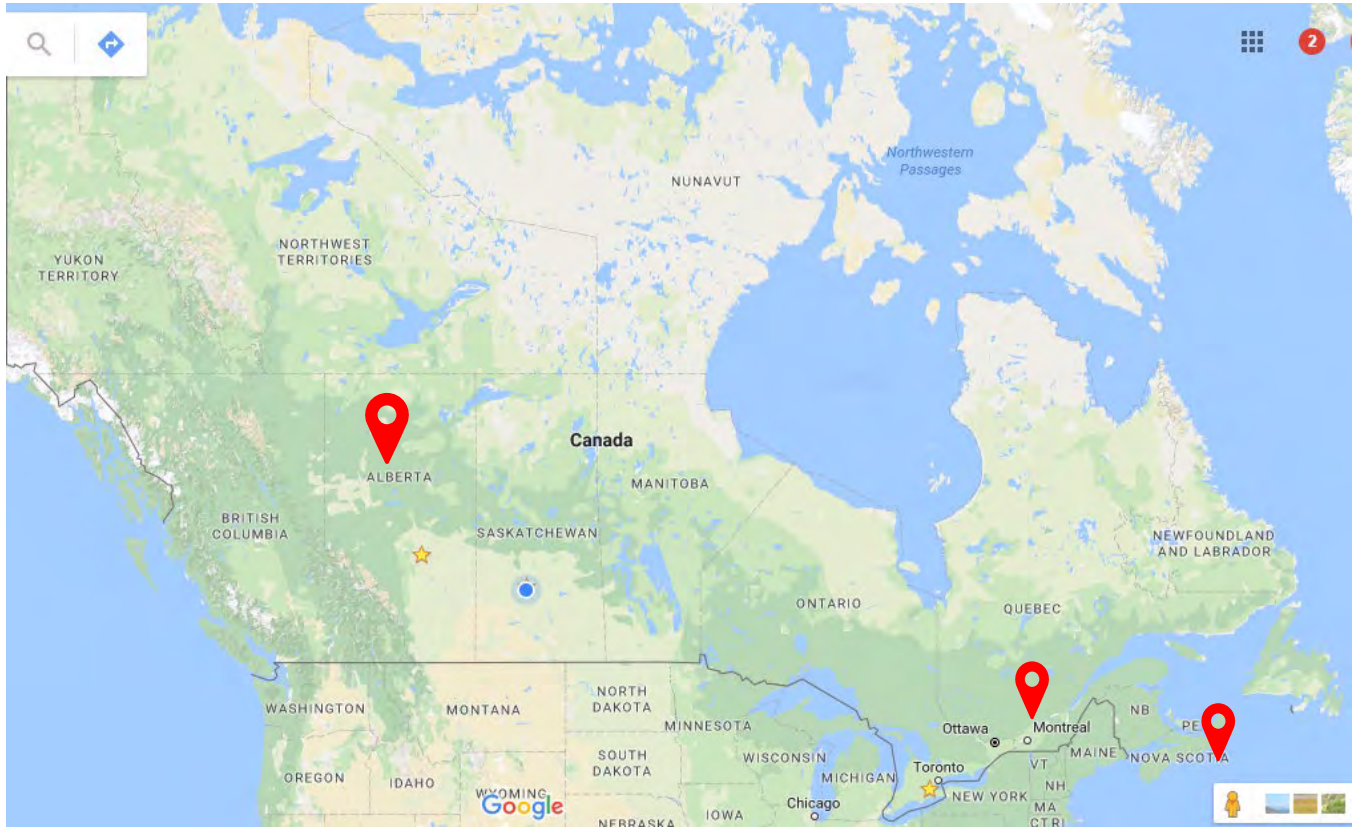
Part 3: Repeating Methane Quantification Survey

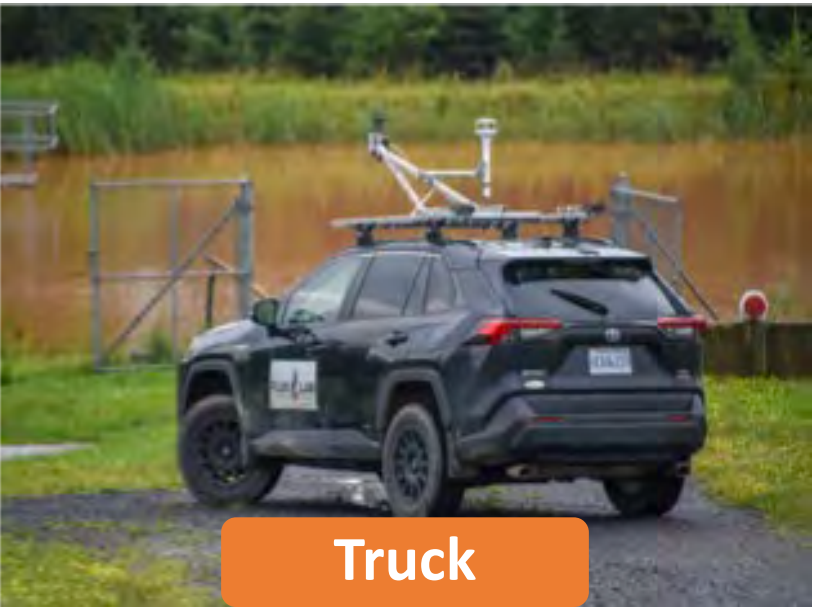
Field work: June 2023 – February 2024
Data analysis: Finished (March 2024)

12 Landfills in 3 different provinces

- ❖ Maritime/ coastal climatic zone
- ❖ Humid/continental climate zone
- ❖ Dry prairie steppe climate



Equipment Set-up



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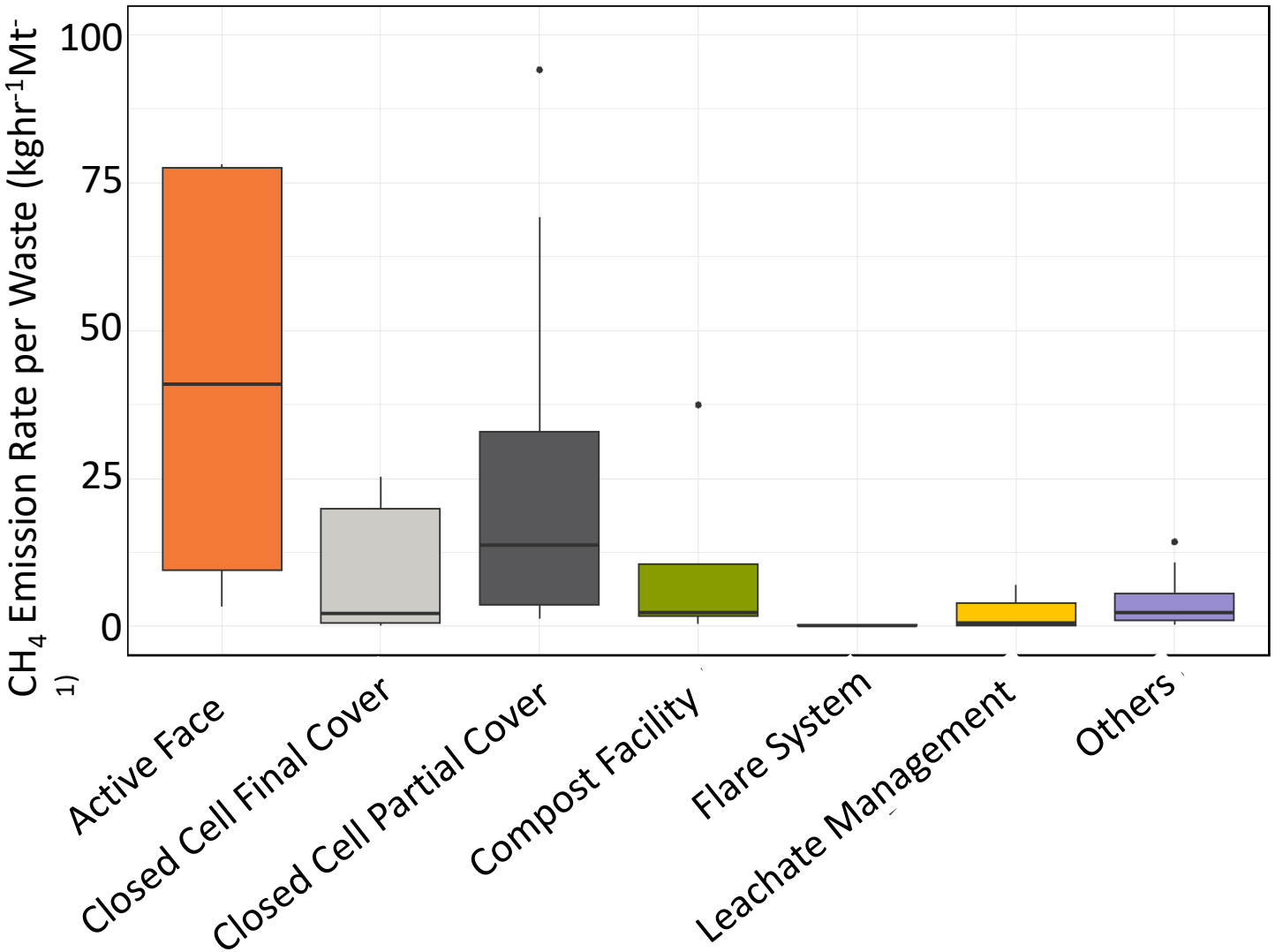
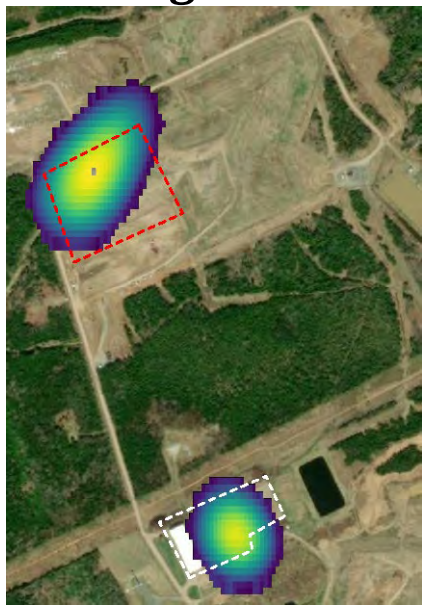
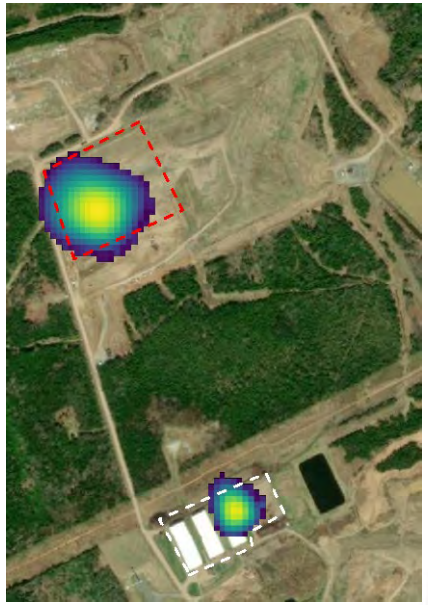
Methane Sources in Landfills



Triangulation



Lagrangian



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SEM – Source Characterization

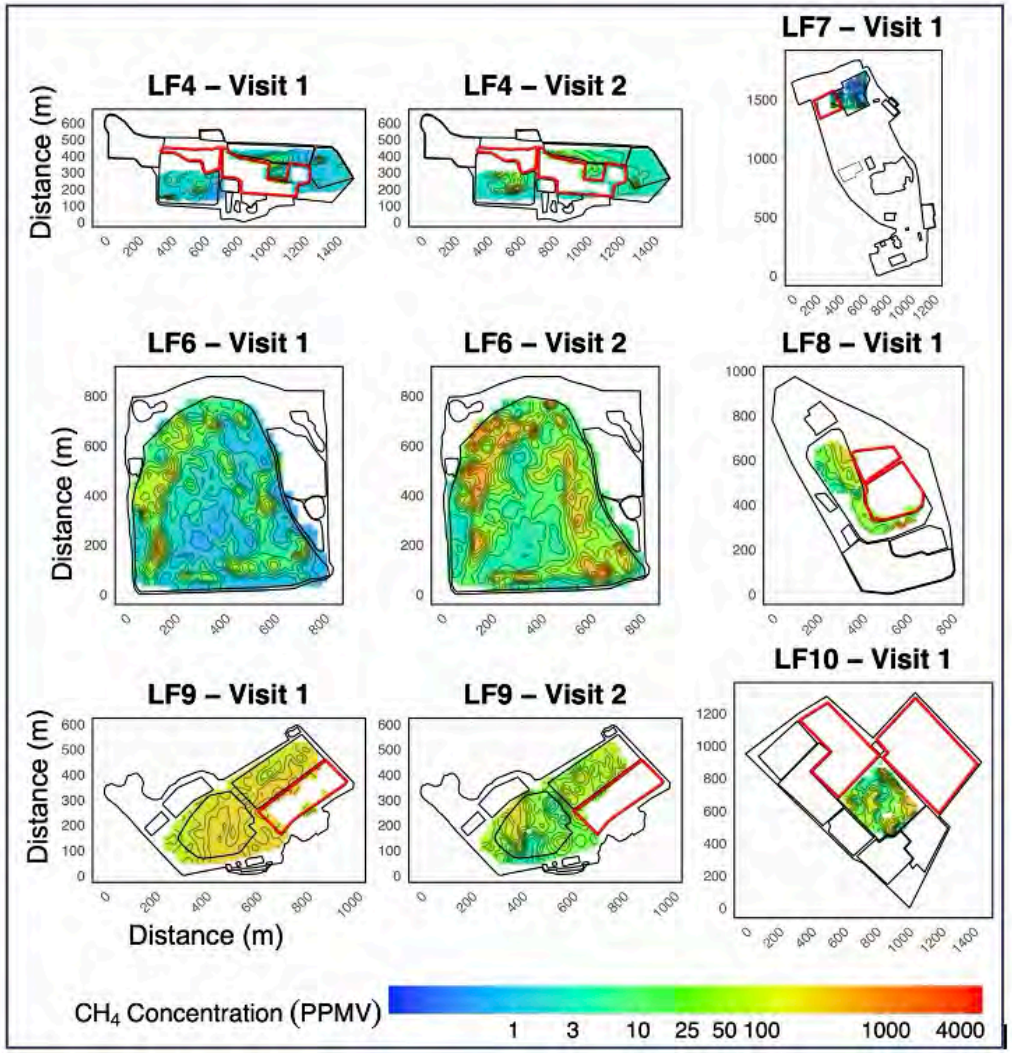
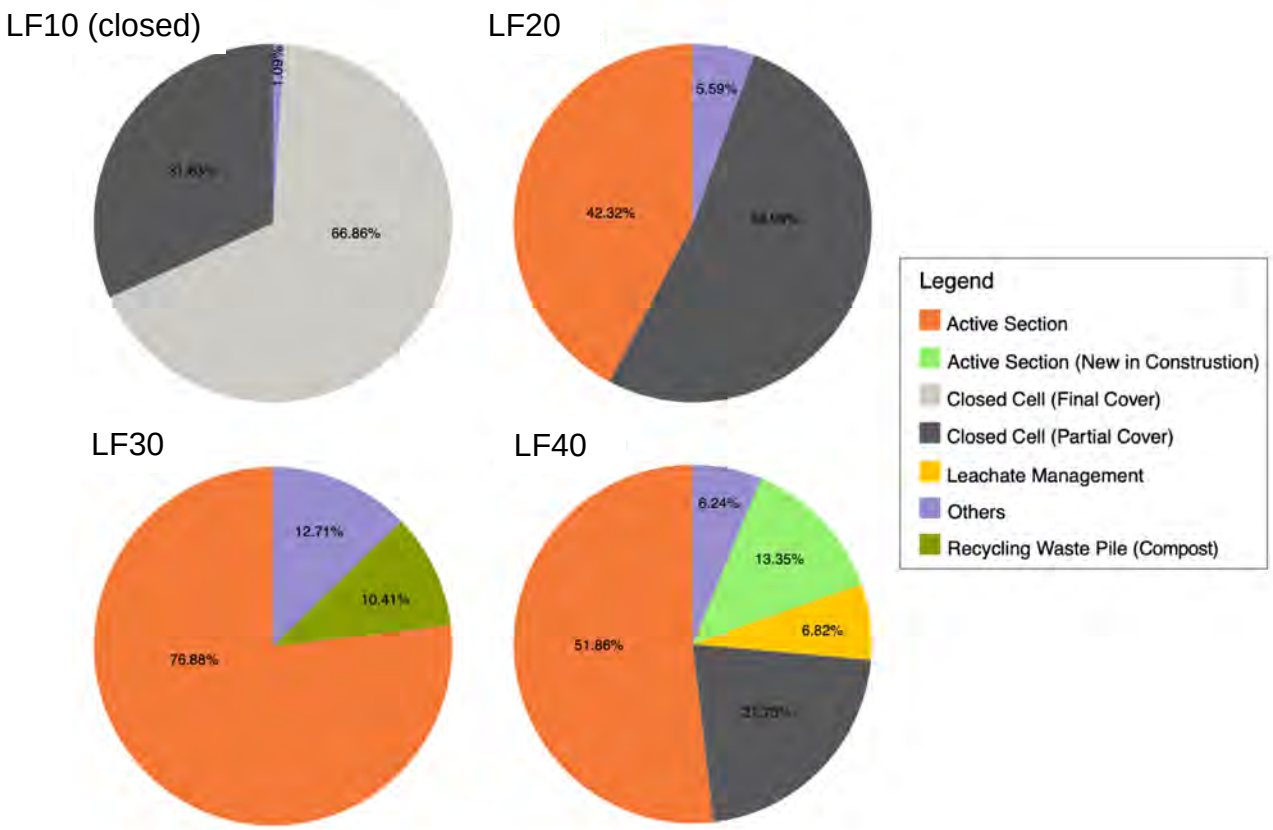


Figure 2. SEM maps of surveyed landfills LF4, LF6, and LF9 from both Visit 1, conducted between August and September 2023, and Visit 2, conducted between October and November 2023, as well as LF7, LF8, and LF10, which were surveyed once. The colors represent different CH_4 concentrations, with red indicating the highest levels and dark blue showing the lowest. The outlined borders mark the landfill perimeter and different component areas. Red borders highlight active face zones, identified through mobile surveys as major contributors to emissions at most sites. These active areas are typically not covered by SEM measurements.



For 40 years we've measured frequency of occurrence of leaks in specific areas, not rates, nor overall emissions. Skeptical of new information and methodologies, comfort in familiar methodologies and patterns.

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Part 4: Controlled Release Experiment

- The Environmental Research and Education Fund (EREF)
- Assessed various methodologies' performance in controlled conditions at a closed landfill
- Methodologies were grouped based on localization, quantification, or both


Pylyp Bunto
Field Engineer

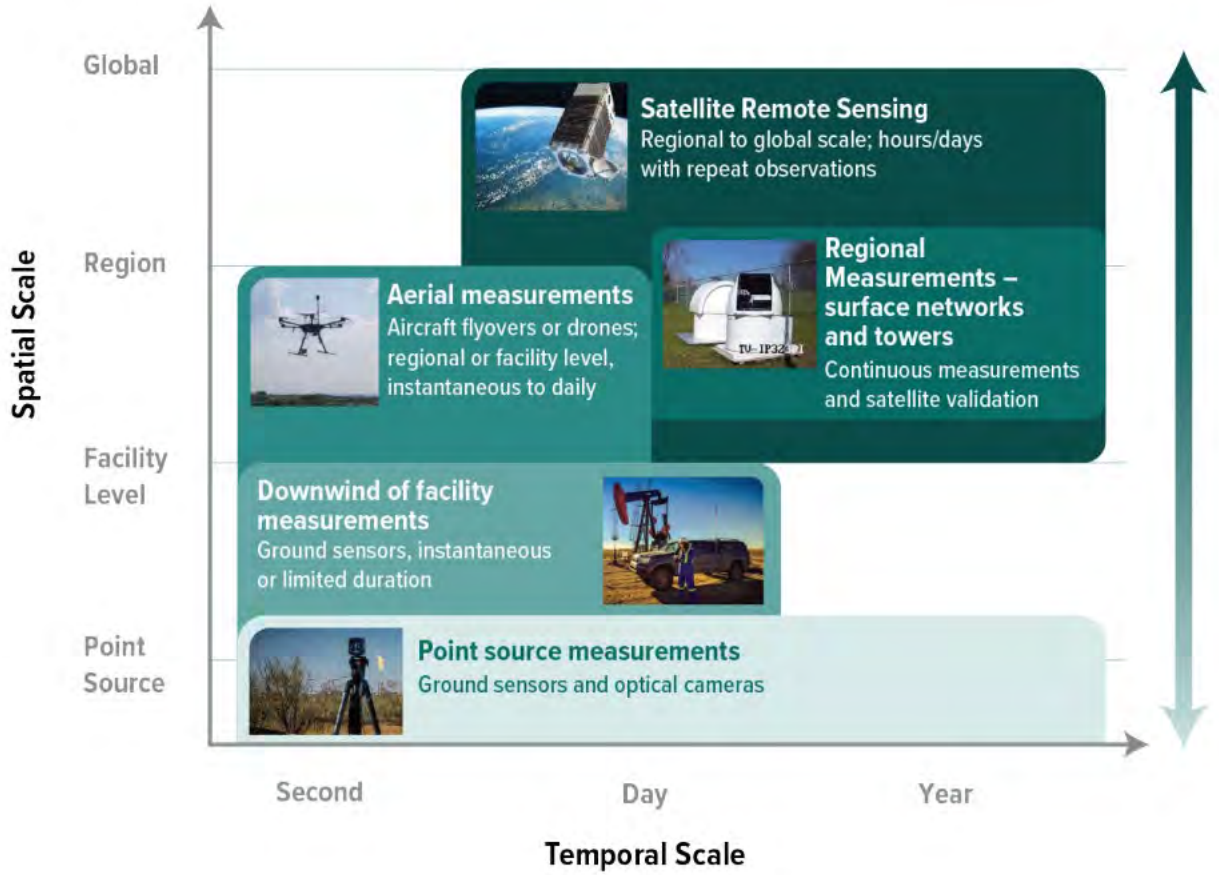
Quantification vs Detection

Quantification: Method of determining rate of emission from a site , usually reported in kg/hr or g/hr .

Detection: Method of determining location of elevated emission concentration , concentration usually reported in ppm or ppm*m.

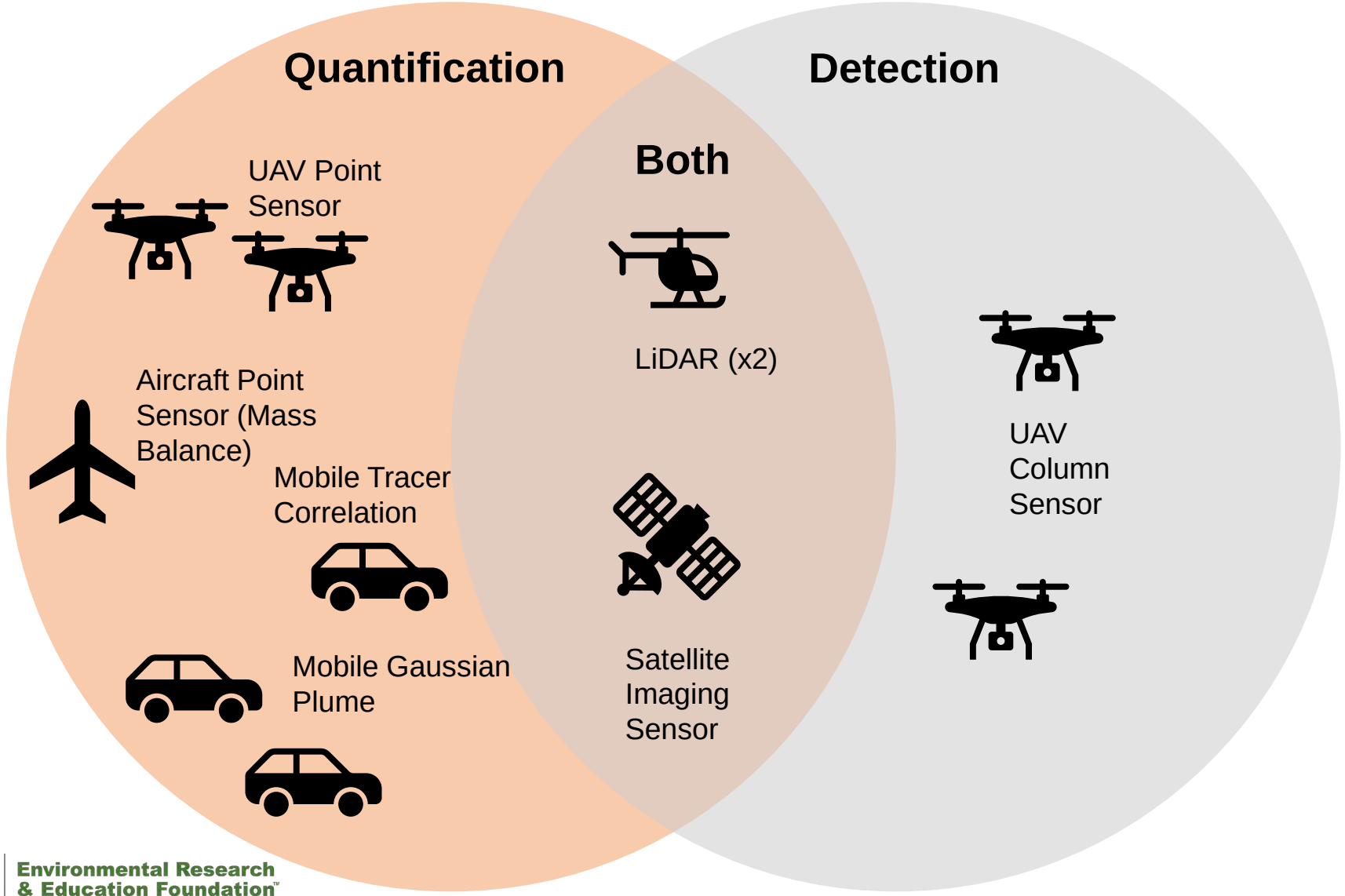
Both methods required for successful methane monitoring and mitigation

How do we determine if technologies are measuring correctly?



Sourced from: Government of Canada, P. S. and P. C. (n.d.). Information archivée dans le Web. Publications.gc.ca. https://publications.gc.ca/collections/collection_2022/eccc/En4-491-2022-eng.pdf

Participants



R&D

Remote Point Sensor (MOS or TDL or SAS **Quantification**)

Mobile Lagrangian (**Detection**)

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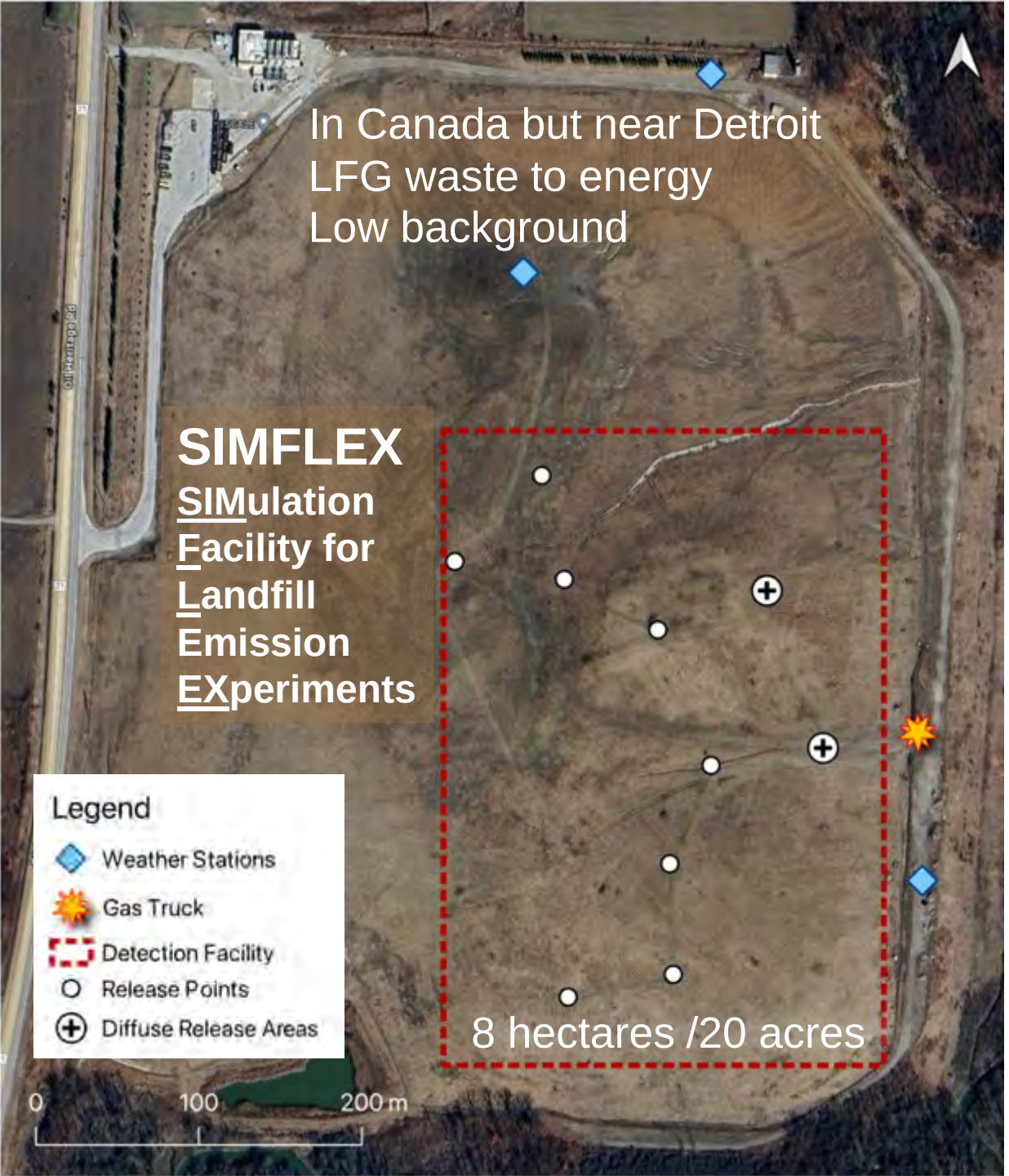

Full-Scale Release Tests

Original (Nov 2023, at left)

- 10 release points over ~20 acres
  - 8 x point, 2 x large area
- To 300 kg/hr total
- One set of experiments Nov 2023

Renewed Install (Nov 2024)

- 11 new release points over ~20 acres
  - 8 x point, 3 x large area
- Buried system
- To >800 kg/hr total
- One set of experiments Nov 2024

for Evaluating and Accelerating Measurement Solutions

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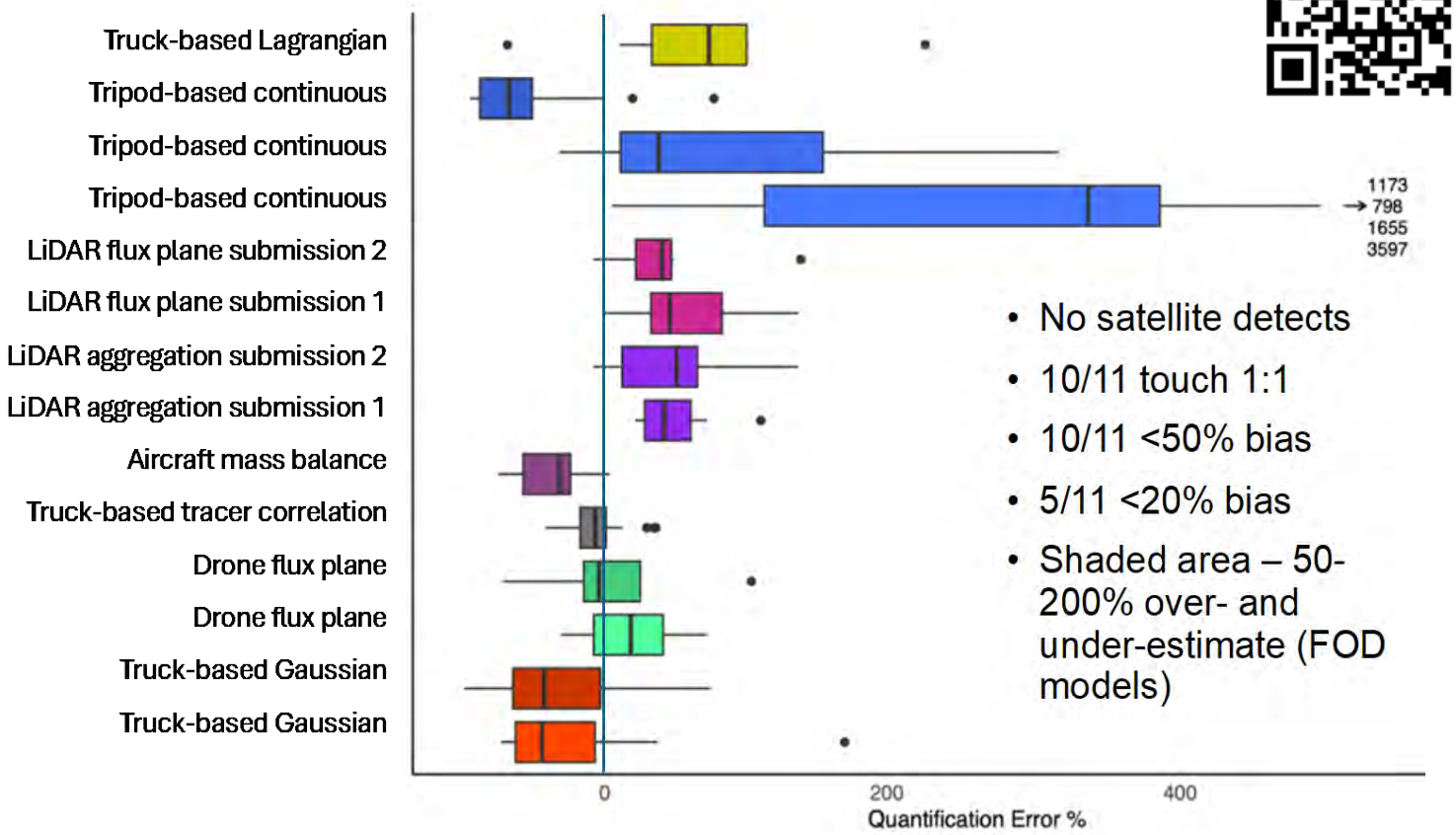
November 2023 - Review

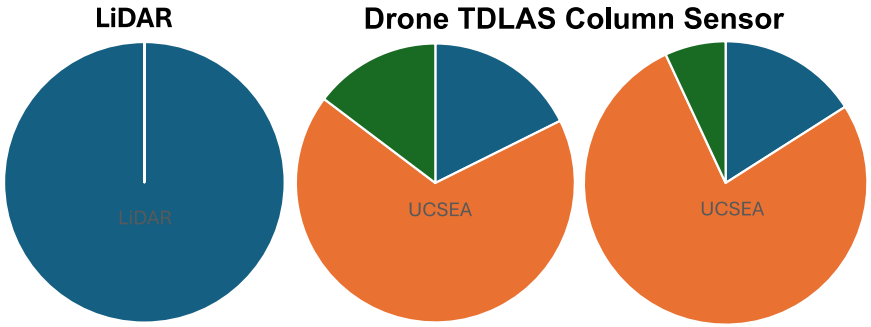
Quantification

Report:



Main learning – Many can perform well compared to models. (Site level inventories are a different challenge!)

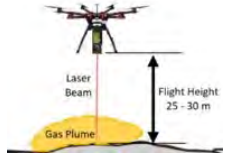
Detection



True positive – Emission successfully detected at the right location

False positive – No emission at the location but an emission detected

False negative – Emission present at the location but wasn't detected



Main learning – Although LiDAR was excellent with 90% POD of 1 kg/hr, UAV column sensors were less sensitive, with higher error rates and 90% POD of 90-100 kg/hr

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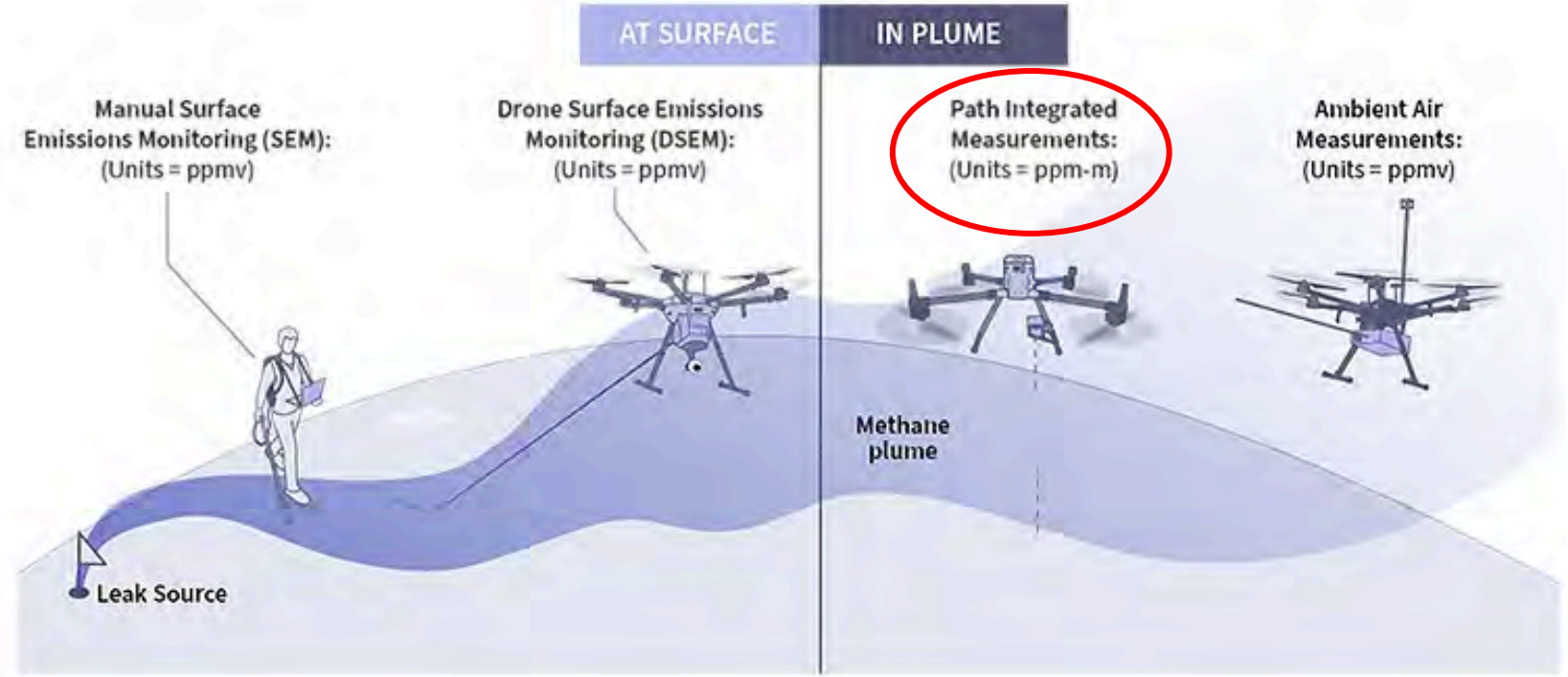
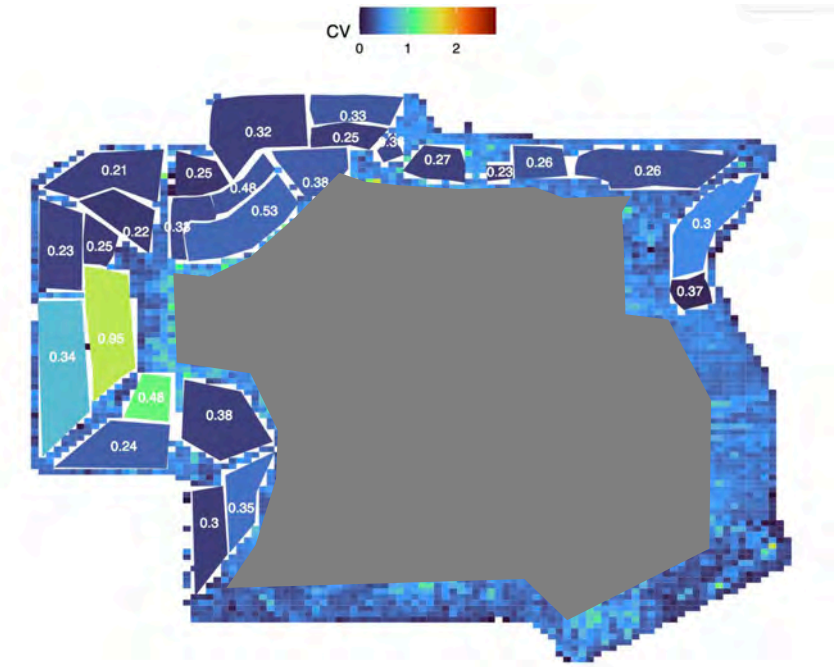
Alternative methods for SEM: Drone

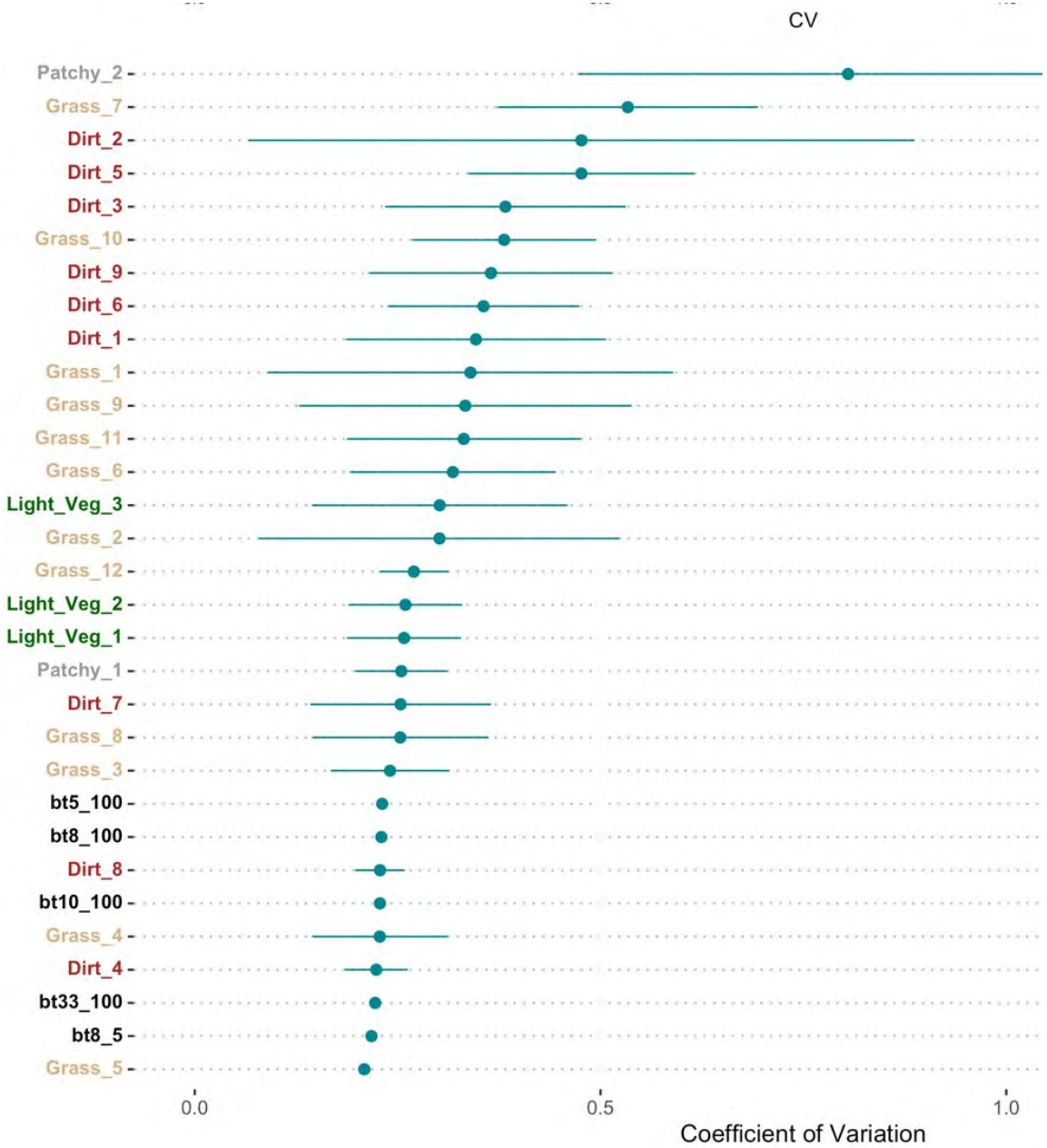
- Involves the bouncing of lasers off the ground and back to a sensor
- Vertically integrated measurement in ppm*m
- Useful in greenhouse gas detection, air quality studies, & vertical profiling
- NO quantification…YET
- Regulatory: leak detection & localization (not approved for USEPA, ppm preferred)



Testing Sensors



Purway outdoors over landfill across 10 days
CV ~0.2-0.5



Extensive landfill - field

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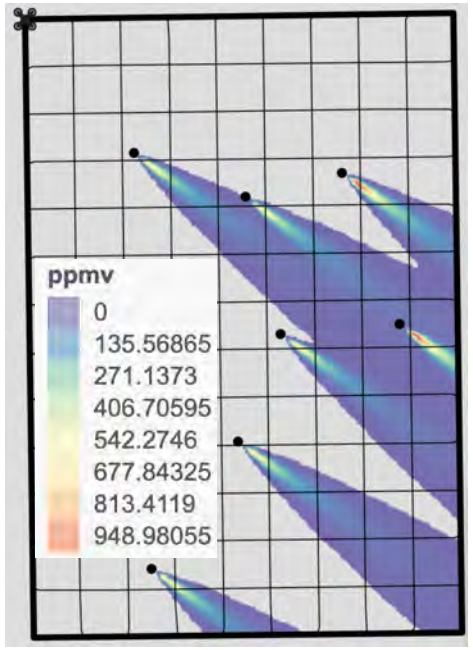
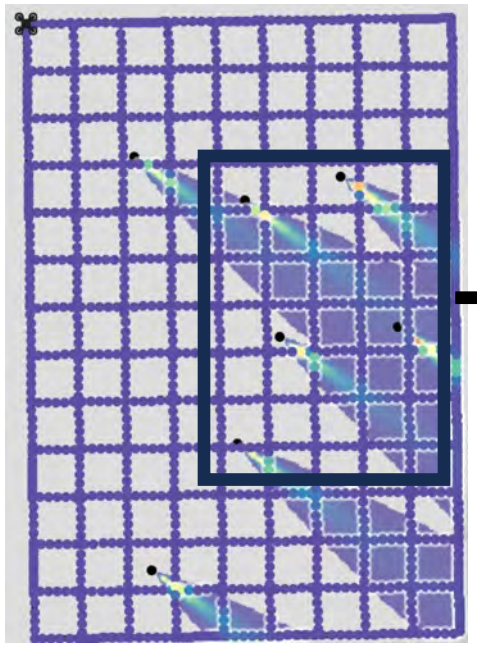
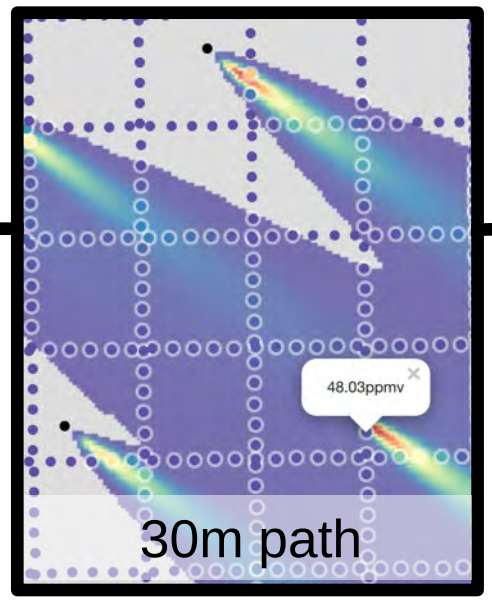
Testing Spacing + Thresholds

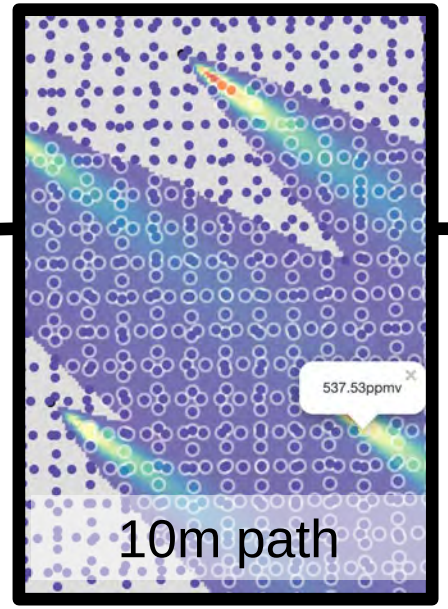
- **UAV SEM and Walking SEM Workpractice, and Data Analysis**
  - Hypothesized that UAV Column Sensor solutions could improve sensitivity if they flew more closely spaced lines, and disregarded formal thresholds.
  - Re-created SIMFLEX using simulations with walking SEM in sequences similar to below

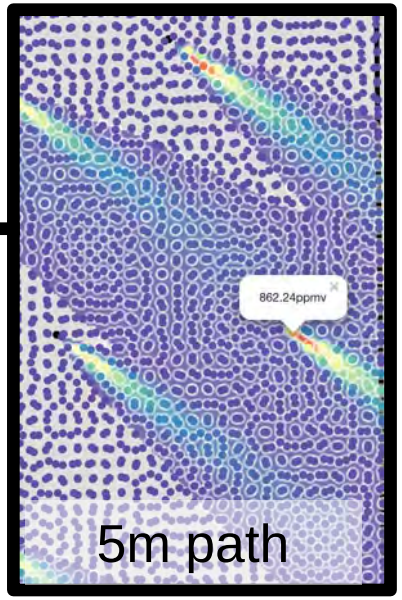




More sensitive







20 acre 2023 CR area, actual rates, ppm <1 m (exp 41)

Tighter = higher likelihood to find high concentrations

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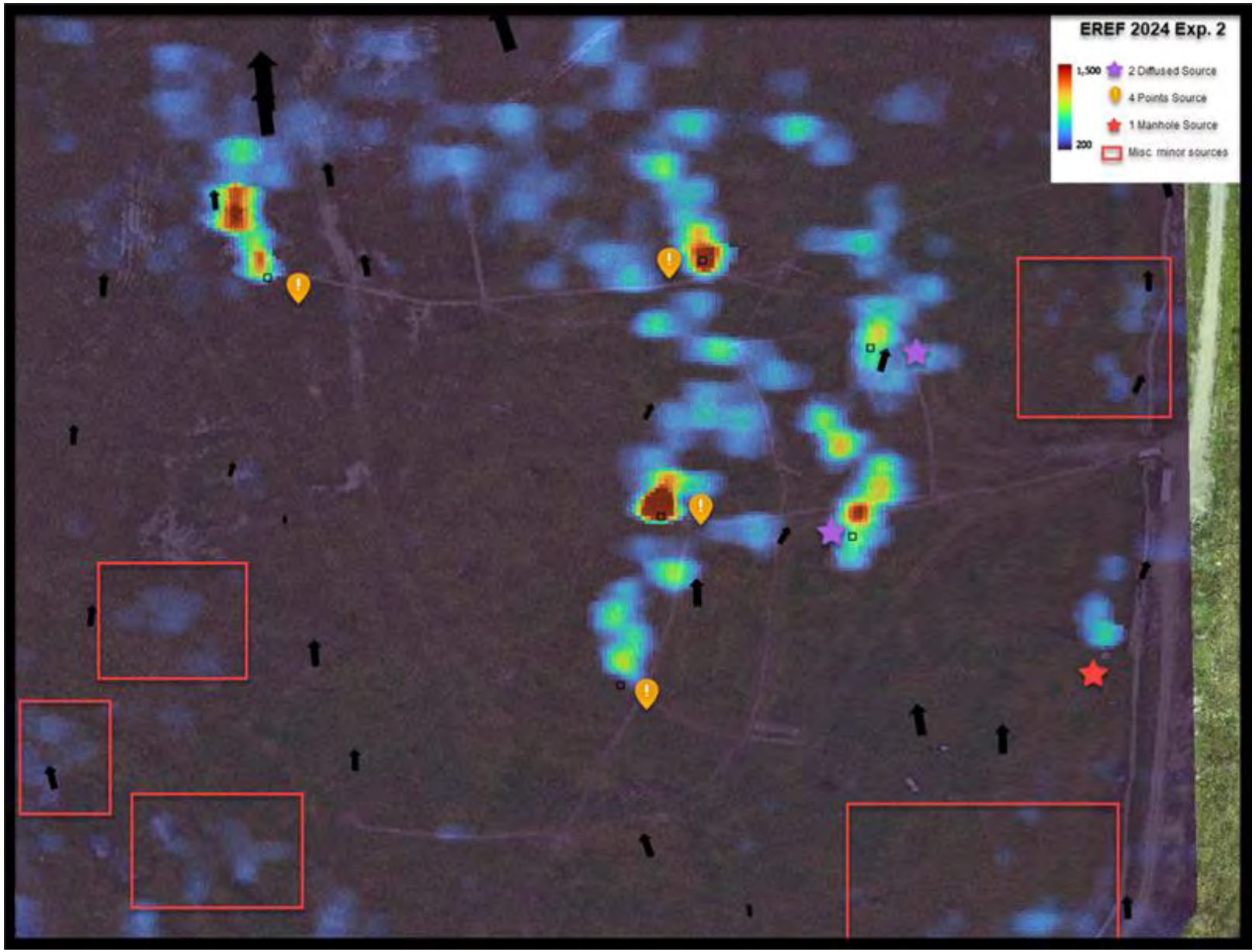
November 2024 Back to SIMFLEX



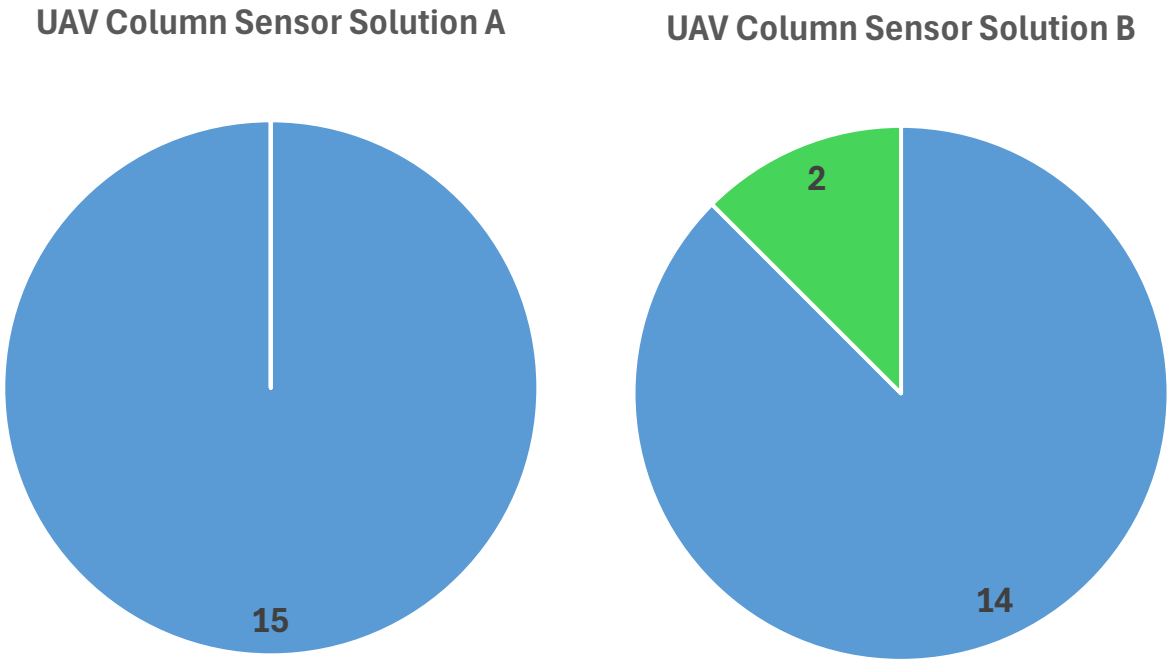
After recommendations

- Tighter (7.5m max)
- Higher (30m vs 20m)
- Faster (almost 50 km/h)
  - 10Hz sampling
  - 3x faster survey time
  - Line-to-line consistency
- Gimbal on Purway
- Mapping super-ambient against local background
- Nested follow up
- Wind-based interpretation

- Early text. Now seeing plumes.
- Looks promising.

November 2024 Column Sensor CR Results

Column Sensor SEM



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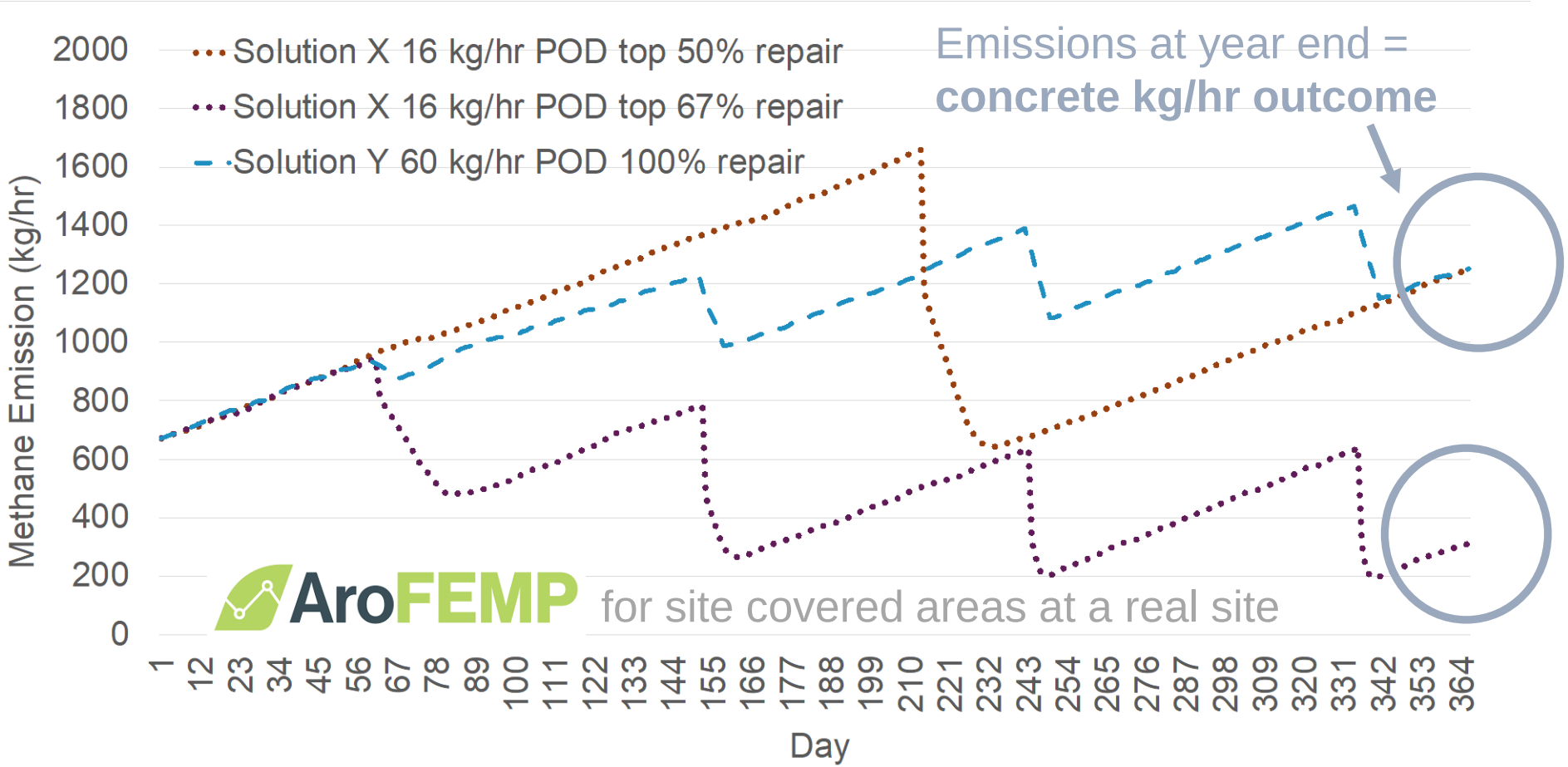
Very different results from 2023

- Not totally clear yet on workpractice used by each participant
- Definitely tighter spacing
  - A - 7.5m @ 30m agl, Purway
  - B – 15m @ 10m agl, Pergam
- 90% Probability of Detection Rate
  - **Solution A – 5.7 kg/hr**
  - **Solution B – 5.7 kg/hr**
  - Much better than 90-100 kg/hr 2023
- **Significantly out-performed walking EPA Method 21 SEM**

Thinking by Program, Not by Tech Solutions

- **Column sensor standard method now looks likely – how to use when it's more sensitive?**
- **Use 90% POD in Program "Effectiveness Modeling (EM)"**
- Simulates emission **outcomes** for a **program of action at a site** – measurement POD + frequency + source likelihood and distribution + repair threshold (Examples - FEAST, AroFEMP, LDARSIM)



More sensitive measurement solutions *can* be deployed less often for emissions management, OR *can* be deployed at same frequency but with less repair follow up

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Next steps

- **Report to come from these results**
- **Maintain focus on dispersed sources**
- **Spring 2025 experimental priorities**
  - More SEM vs UAVCS vs OTM51
  - Satellite
  - Aircraft imagers and mass balance
  - Drone flux plane
  - CEMs
  - Mobile truck
  - Wind studies
  - May and June…with more upgrades coming… sources, rates

- **Standard Methods and Simulations**
- **Adjunct site under development**
  - More convenient for exploring aerial and satellite MDLs on dispersed sources

FluxLab’s Future Directions for Landfill Management Enhancement

1. **Enhance Data Collection**

   - **Objective**: expand knowledge of design and operational practices at each landfill.
   - **Advantage**: enables practical, economic strategies for operators to meet regulatory standards and reduce costs.

2. **Assess Environmental Influences**

   - **Study Area:** explore how environmental factors affect emissions.
   - **Advantage:** identify variable impacts to refine emission estimates.

3. **Refine Methodologies**

   - **Focus**: improve the accuracy of measurement techniques.
   - **Advantage**: ensure reliable and precise emission data, supporting operators in obtaining carbon credits and improving regulatory compliance.

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Thank You!

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