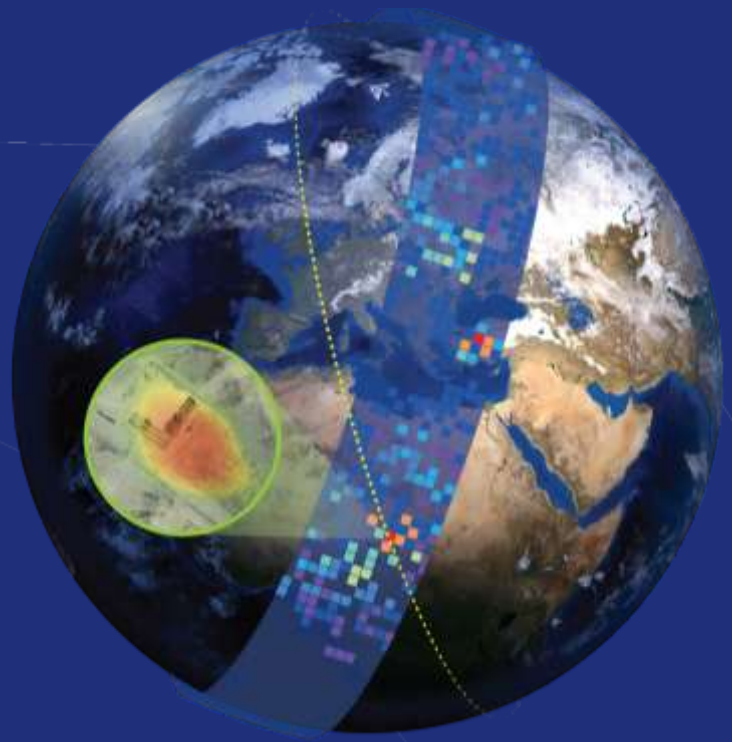


# DETECTION AND QUANTIFICATION OF $CH_4$ AND $CO_2$ EMISSIONS AT THE FACILITY SCALE WITH THE GHGSAT CONSTELLATION

**Jason McKeever,** A. Deslières, M Girard, D Jervis, J-P MacLean, D J Marshall, F Piedboeuf, A Ramier, J. Sampson, M Strupler, E Tarrant and D Young

June 10th, 2025

GHGSAT

# OVERVIEW

- GHGSat Update

- Controlled release validation for methane constellation
  - Detection
  - Quantification
  - New data from Stanford testing

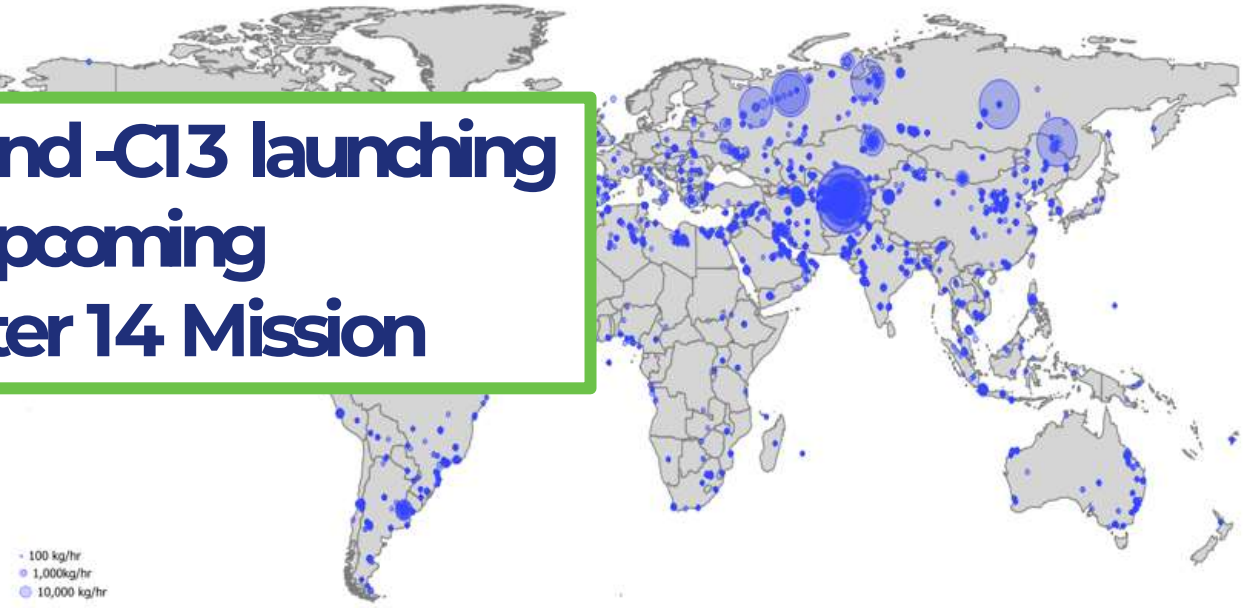
- $CO_2$ satellite – GHGSat-C10 / Vanguard
  - Performance characterization

# GHGSAT

Constellation of **10** small satellites custom-designed for **methane** sensing **+ 1** $CO_2$

- Observe point sou… **targeted mode**
- High spatial resolu…
- **Single-site attribution**
- Very large observation dataset (> 500 observations tasked per day)
- ~Daily revisit possible
- Detection limit ~ **100 kg/h**
- **4 more $CH_4$ satellites launching in 2025, + more in 2026**

**2024 Methane detections**



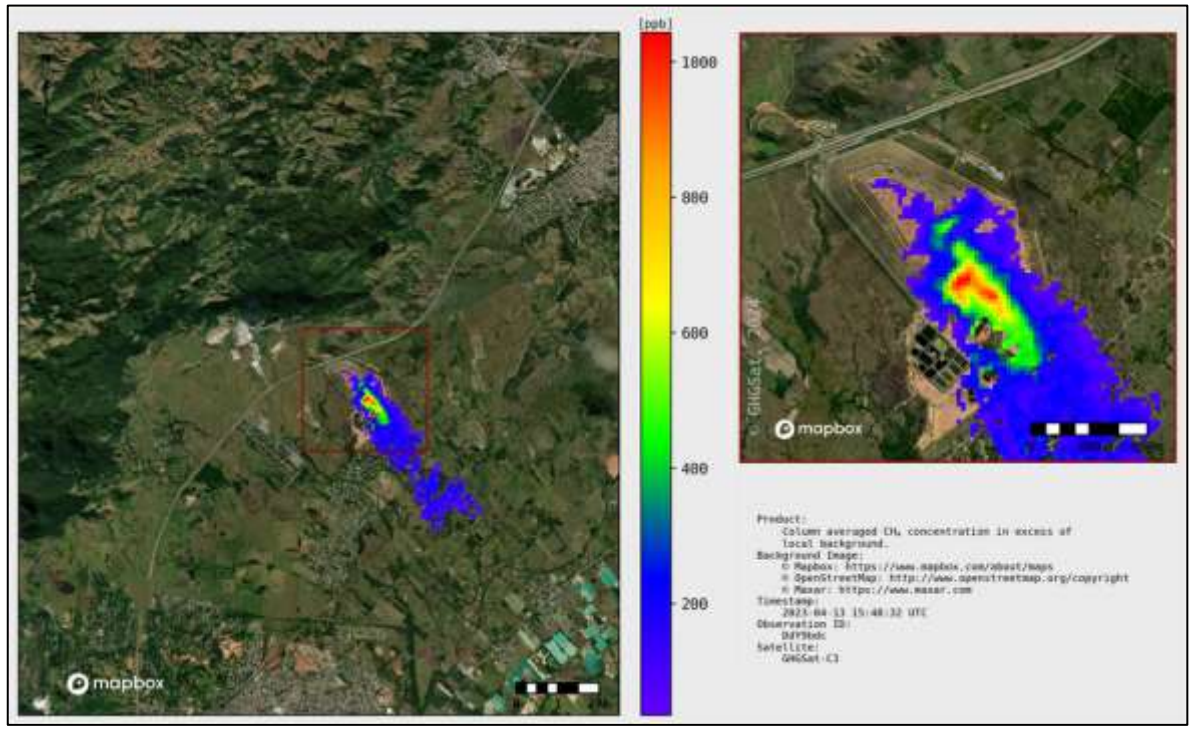

**GHGSat-C12 and -C13 launching on upcoming Transporter 14 Mission**

**> 20,000 detected plumes**

# ESA THIRD PARTY MISSIONS AND NASA CSDA

- GHGSat data is **available** to researchers through the **ESA Third Party Missions** (TPM) program and the U.K. Satellite Applications Catapult

- GHGSat data is also **now available** to researchers funded by the U.S. Government through **NASA Earthdata** portal following successful evaluation
- Evaluation criteria for CSDA assessment:
  - ✓ Utility of the data for advancing Earth system science research (primary criteria)
  - ✓ Quality of the data
  - ✓ Quality of user support services




https://www.earthdata.nasa.gov/esds/csda/csda-vendor-ghgsat

TPM NASA CSDA GHGSAT

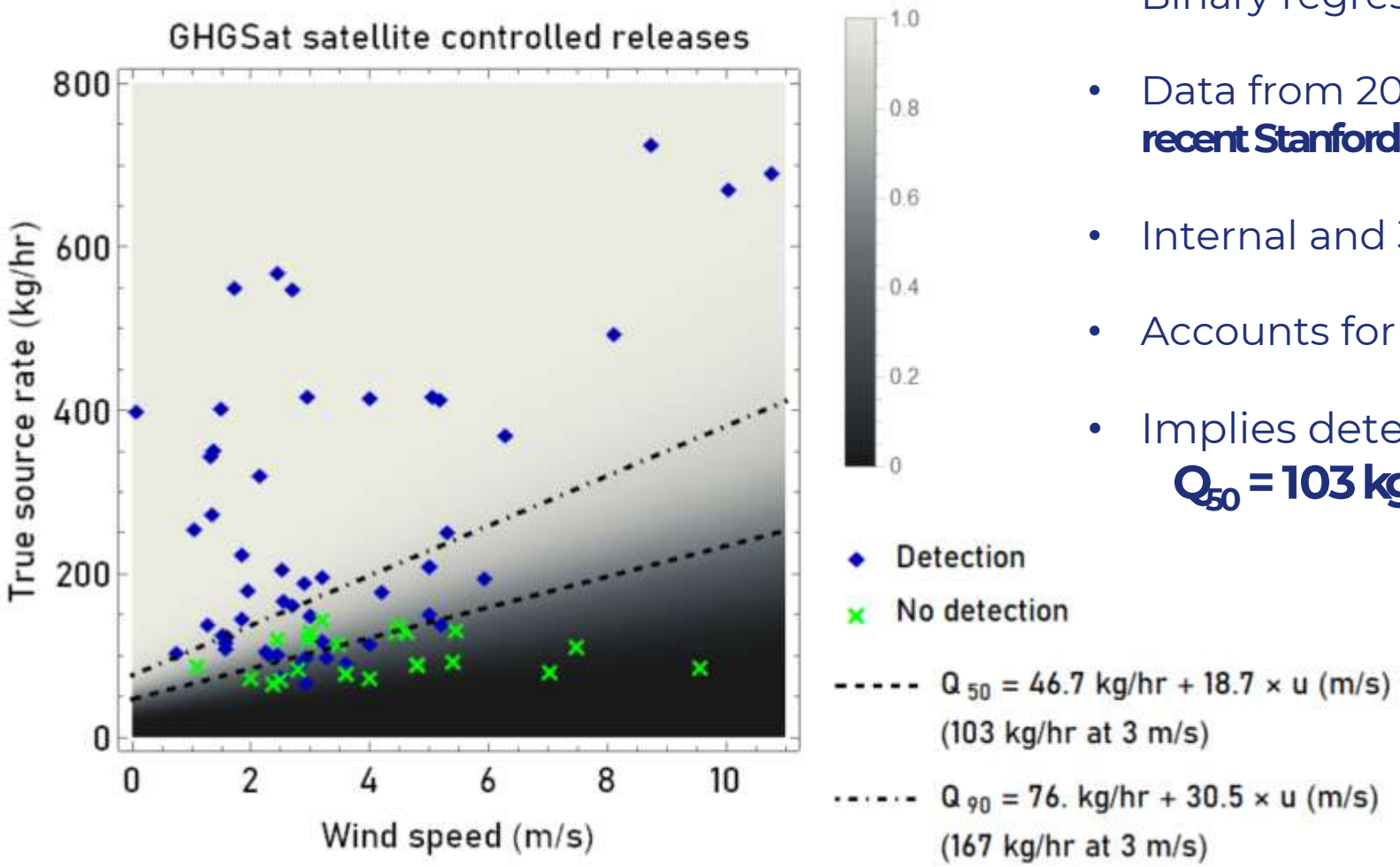
Approved for public release

# PRIMARY VALIDATION METHOD: CONTROLLED RELEASES

## Facility used by GHGSat in Southern Alberta, Canada

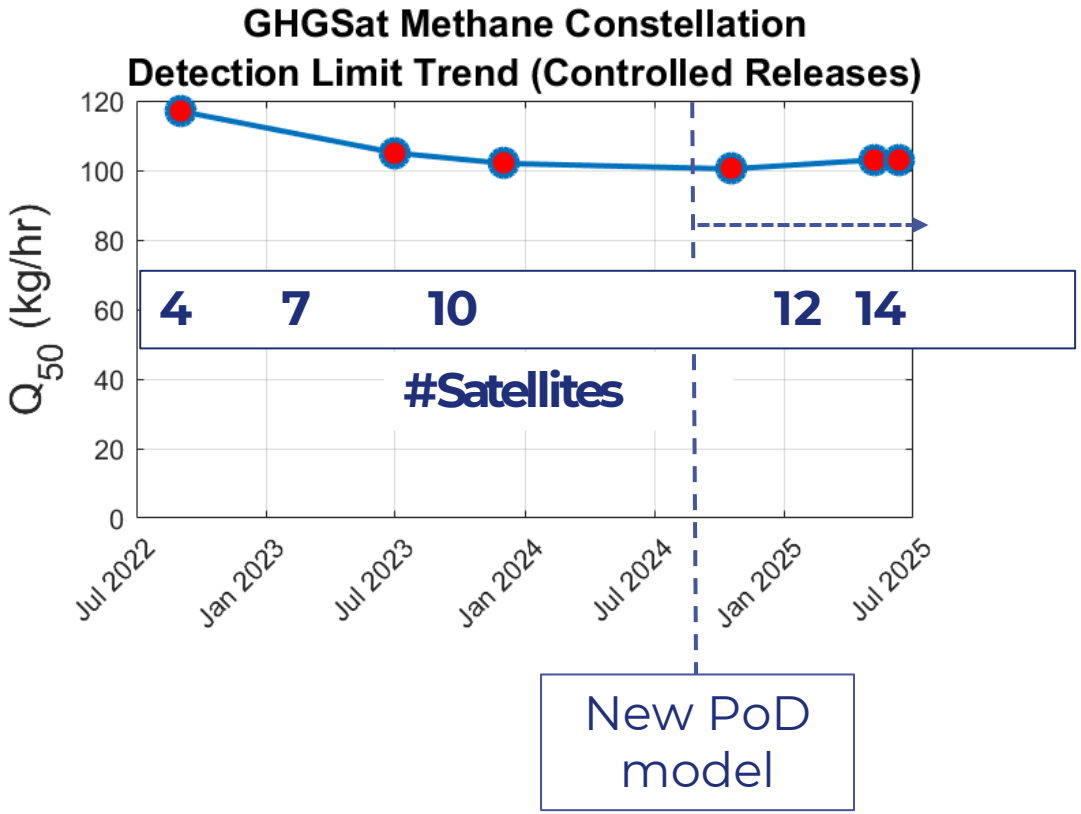
Used to validate both detection limit and quantification accuracy

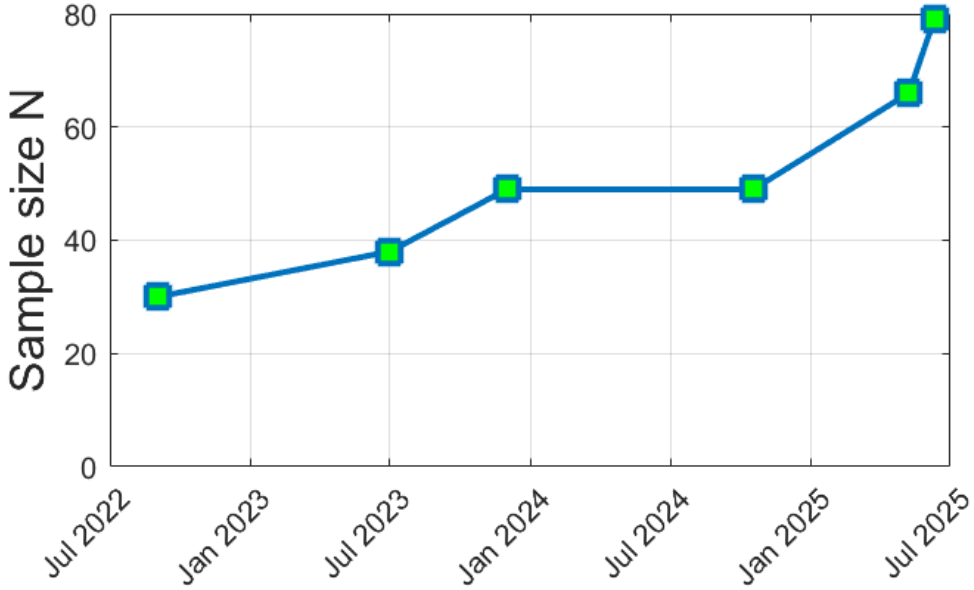
# VALIDATION : DETECTION LIMIT




- Binary regression analysis
- Data from 2021-2025, N=79 points, **including recent Stanford (Phases 0 and 1)**
- Internal and 3rd party releases
- Accounts for wind-speed dependence
- Implies detection limit of
  **$Q_{50}$ = 103 kg/hr (50% PoD, 3 m/s)**

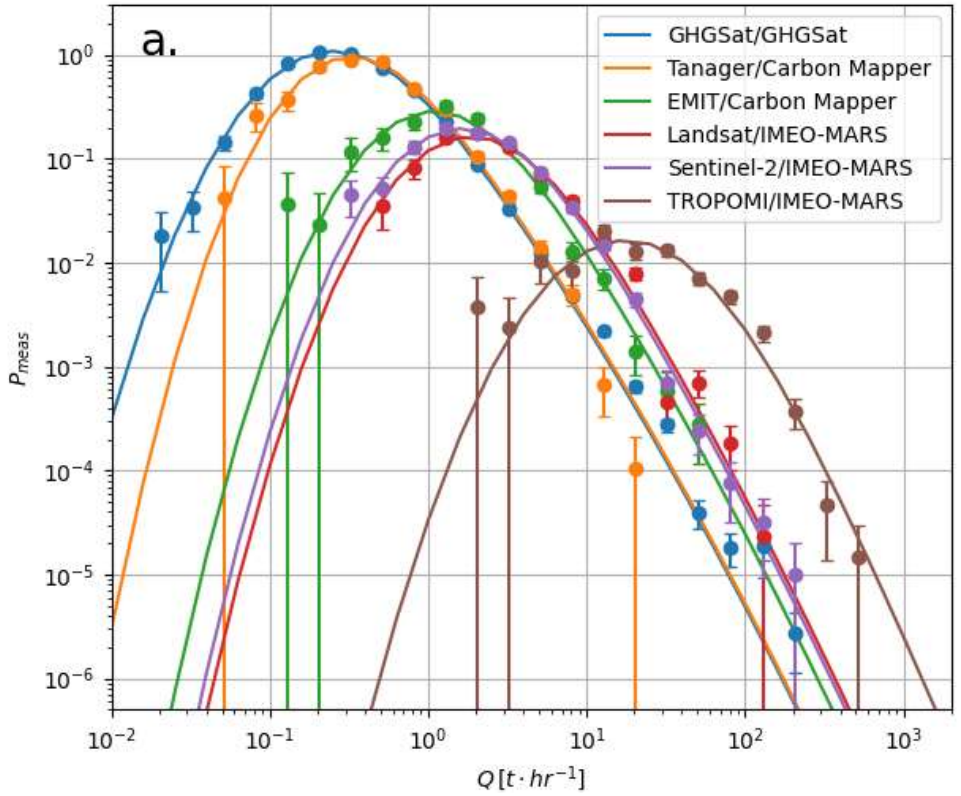
# GHGSAT DETECTION LIMIT – 3 YEAR TREND



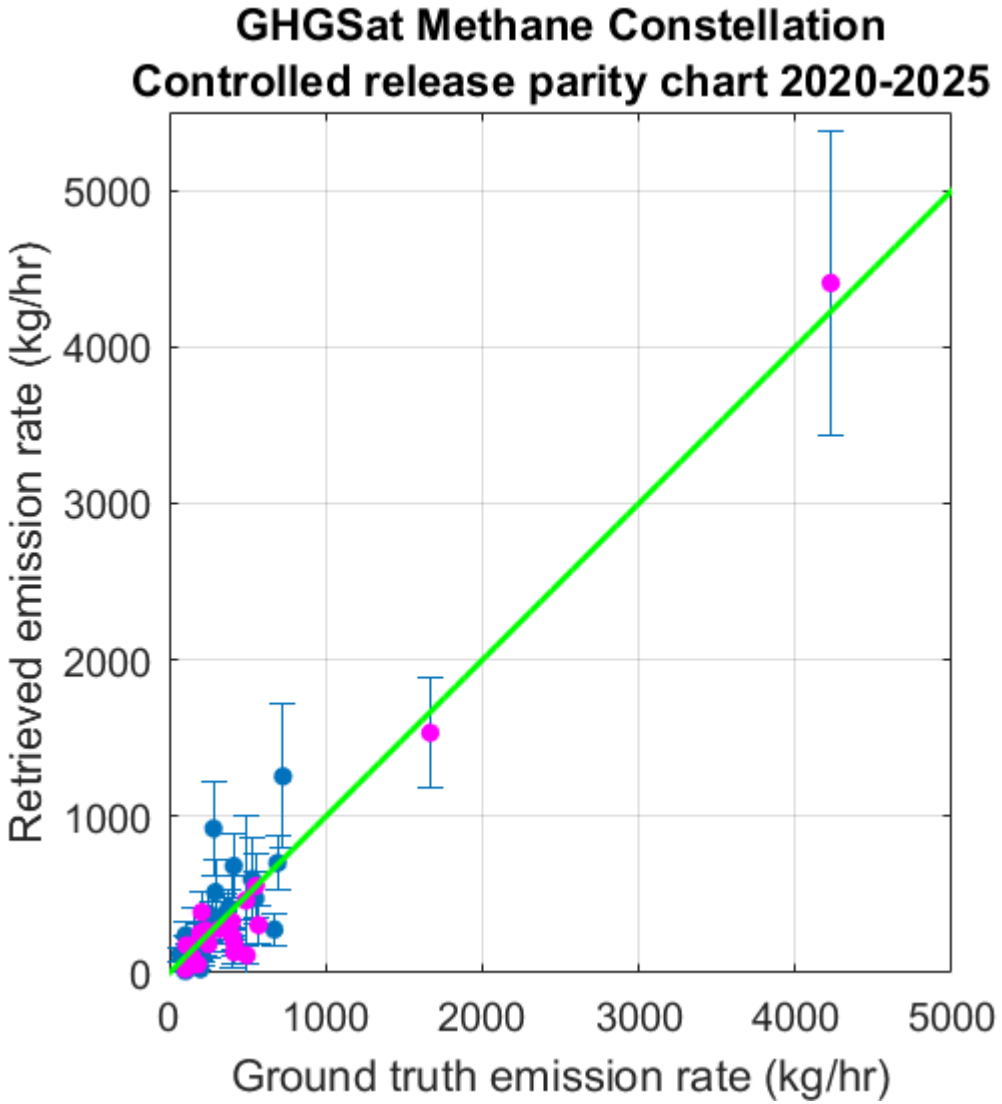

Detection limit as measured by controlled releases robust against new PoD model, new satellites, increasing sample size.

# CONTROLLED RELEASES VS “IN THE WILD”




- Analysis presented by Dylan Jervis yesterday
- Suggests higher detection limits “in the wild” vs. controlled releases
- Applies to our satellites and others
- *Controlled releases don’t tell the whole story but we can push to close the gap – possibly with AI*

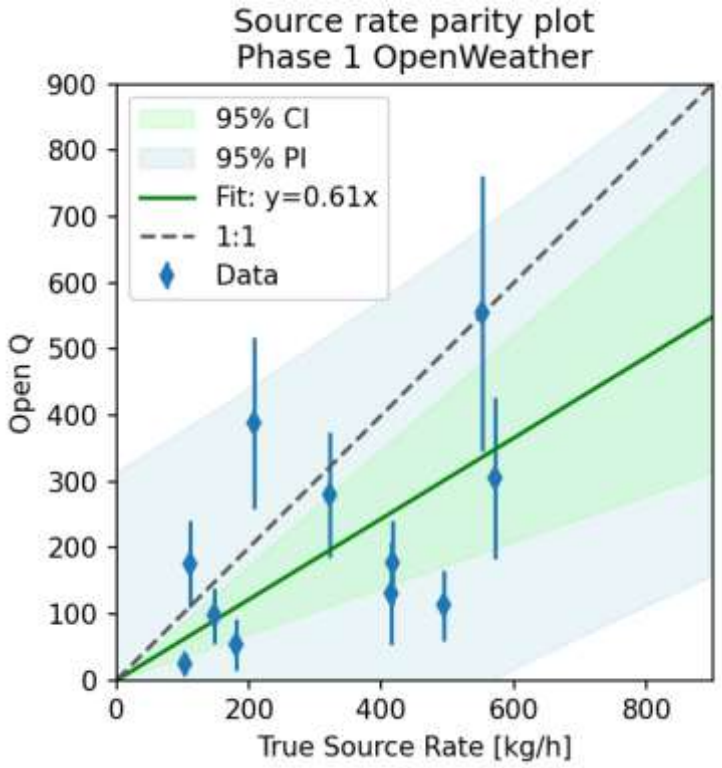
# VALIDATION : QUANTIFICATION ACCURACY

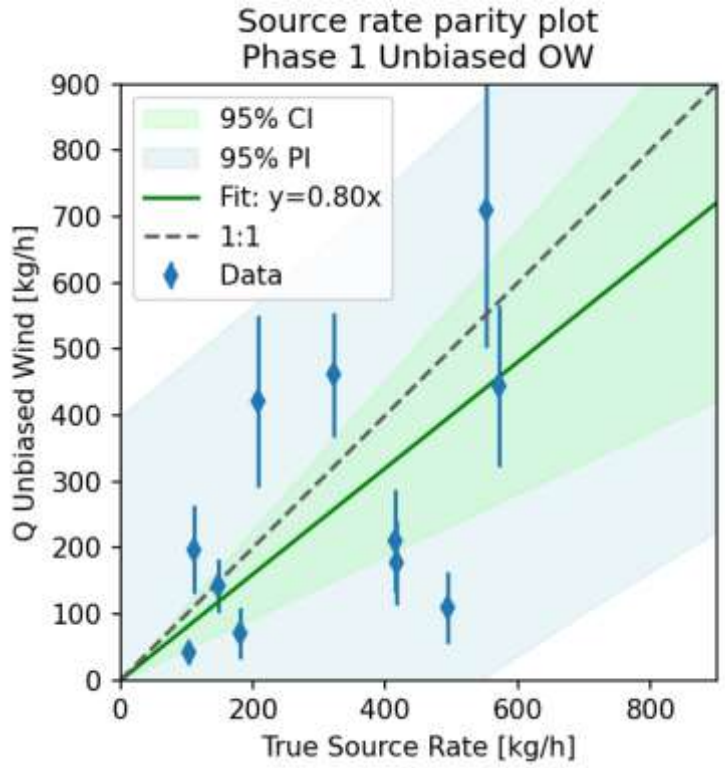



- **N=64 controlled releases (True Positives)**
- **Blue** points: GHGSat facility in Southern Alberta
- Also includes ***single-blind*** releases with customers and collaborators (**magenta points**)
- Participated in 2021, 2022, 2024-5 single-blind studies with group of A. Brandt (Stanford)
  - Sherwin et al, Sci Rep **13**, 3836 (2023)
  - Sherwin et at, AMT **17**, 765 (2024)
  - all points included in plot
- Error typically dominated by wind-related uncertainty (even when using local measured wind)

# QUANTIFICATION ACCURACY – STANFORD PHASE 1 2025

- Public wind data we use in production is biased vs local 10-m wind measurements.
- We have built a bias correction by compiling anemometer data from US airports
- Correction not yet in production for Phase 1 delivery – planning to update for Phase 2.



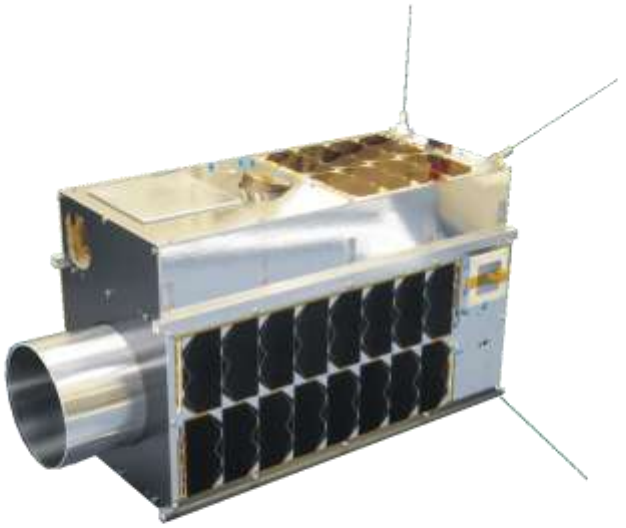

- Reprocess Phase 1 with correction
- Bias reduced significantly (0.61 → 0.80)
- Investigating other possible sources of bias – could lead to retrieval updates.

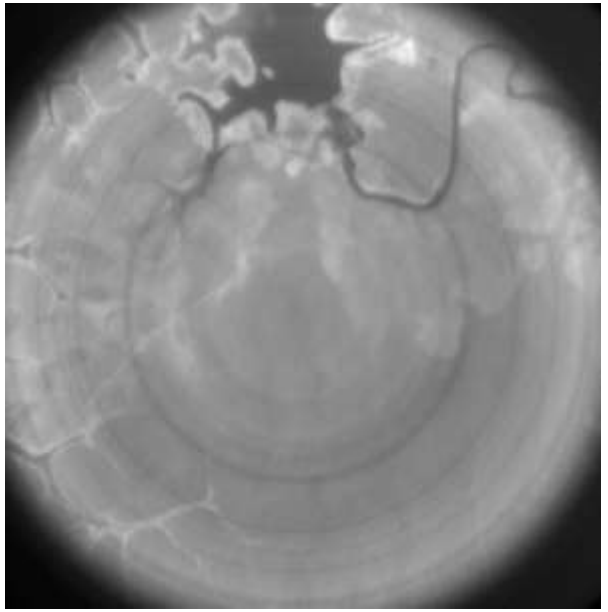
# GHGSAT'S FIRST $CO_2$ SATELLITE

- GHGSat-C10 / Vanguard

- Target performance
  - Detection threshold ~ 1 Mt/yr (~100 t/h)
  - Same Fabry-Perot spectrometer core
  - Same satellite platform
  - Column precision of ~ 1-2 %

- Launched November 2023





# PATH TO FIRST PLUMES

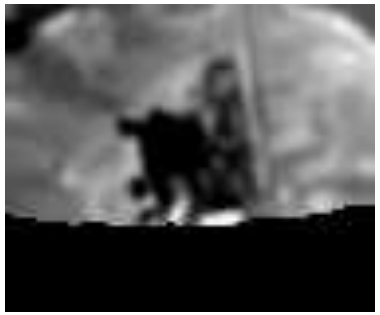
## Power station in Asia

- Satellite pointing issues (fixed)
- Fine tuning retrieval algorithms (in progress)
- $CO_2$ emission split between multiple stacks
- Co-emission of water vapor and aerosols
- High stack (>200m)
  - Plume and plume shadow
  - Parallax error

➥ Higher detection threshold

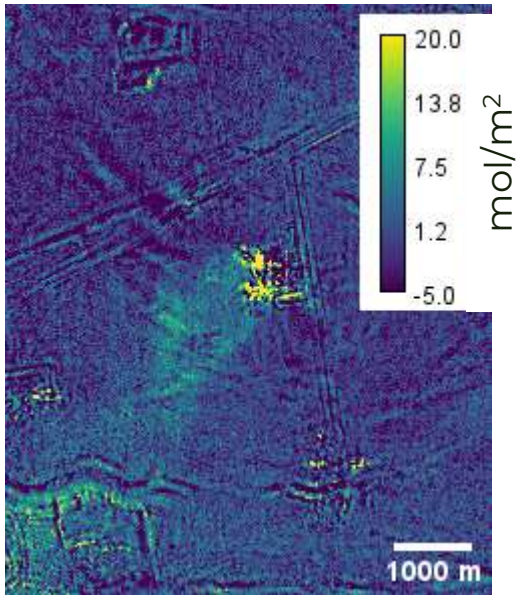
Google maps

VIS cam payload



SWIR-WAFP

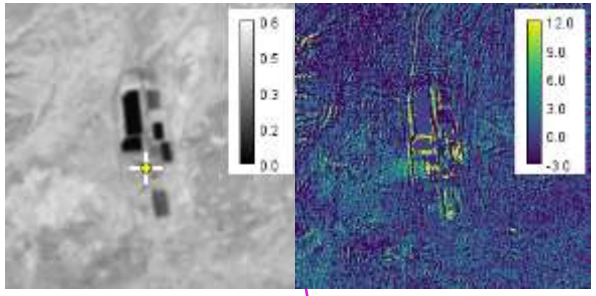

albedo

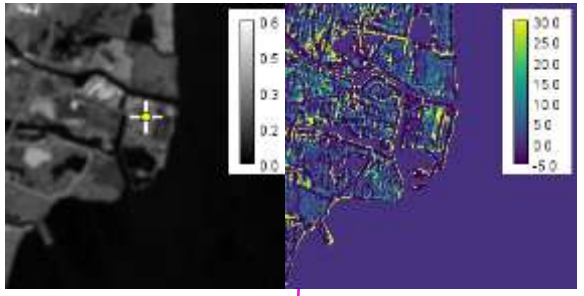



CO2 column enhancement

# DETECTION LIMIT

## Continuous emission monitoring data





- 36 sites in USA
- 230 good observations
- 35 plumes
- Known emission rate at the time of observation from CEMS data

- Probability of detection model derived from Conrad *et al*, RSE 288 (2023) 113499

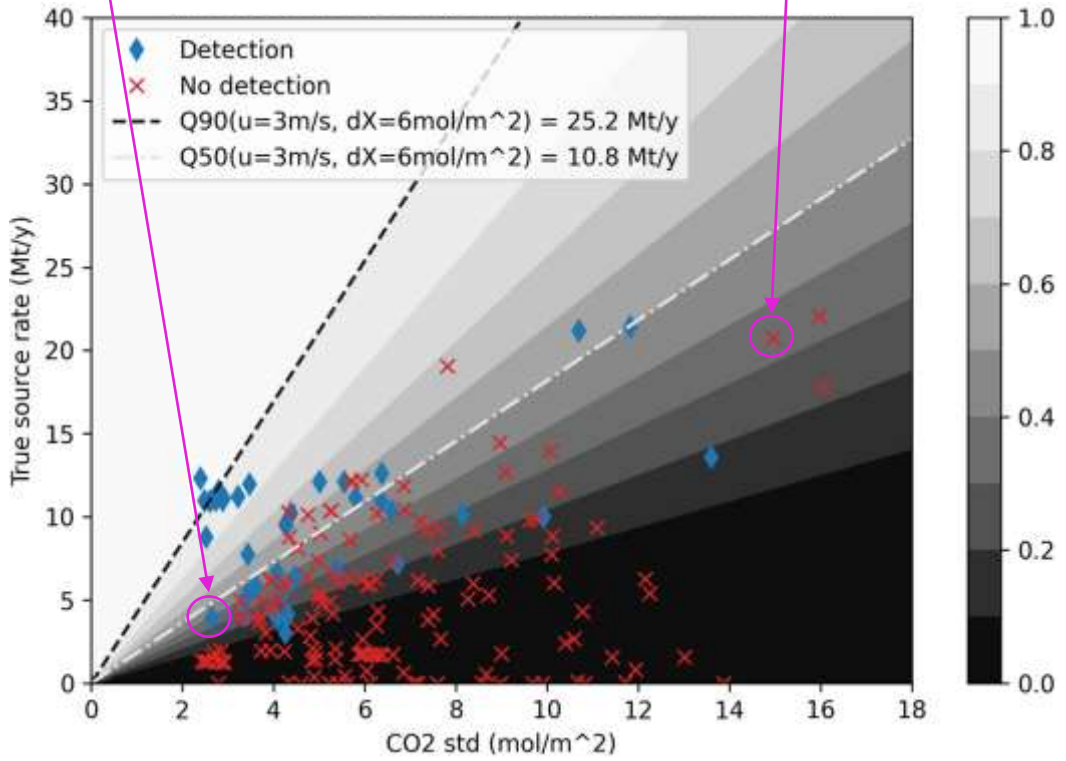
$$\text{PoD} = F(z, \boldsymbol{\theta}) = \Phi\left(\frac{\ln(z) - \mu}{\sigma}\right)$$

$$z = g(\boldsymbol{x}; \boldsymbol{\phi}) = \frac{Q}{3.6\, M\, (u - u_0)\, g\, \delta X}$$

$$\Phi(x) = \frac{1}{2}\left[1 + \text{erf}\left(\frac{x}{\sqrt{2}}\right)\right]$$

$Q$ : Emission rate (kg/h)
3.6 : unit conversion: s to h and g to kg (ks/h)
$M$ : Molar mass (g/mol)
$u$ : Wind speed (m/s)
$u_0$ : Wind speed offset (m/s)
$g$ : Spatial resolution (m)
$z$ : SNR required for detection (unitless)
$\delta X$ : Column precision (mol/m2)

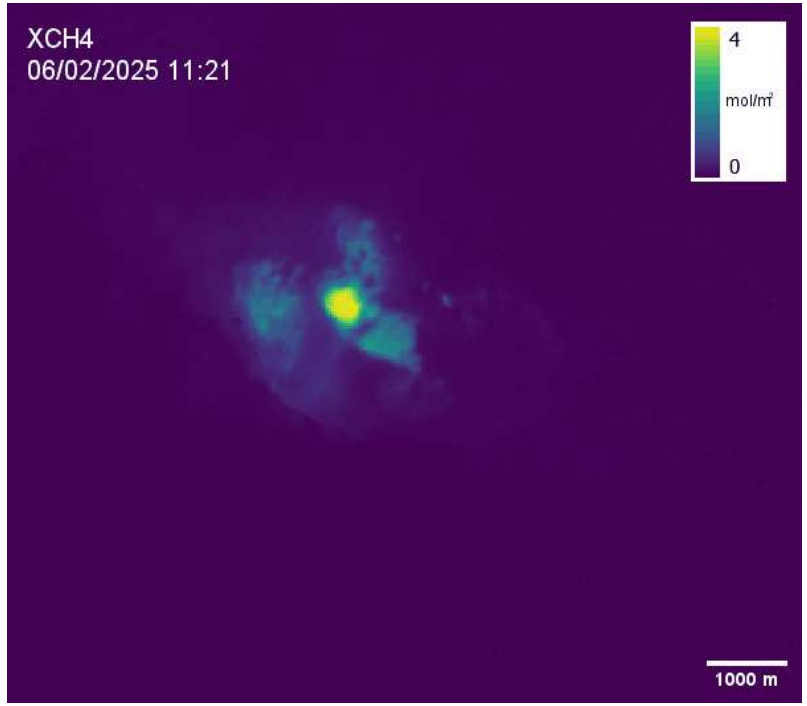
Probability of detection fit



# CO2 OUTLOOK

- Detection limit: 5-15 MT/yr (500 – 1500 t/h) depending on site
- Anticipate 1 Mt/yr target will be achievable in follow-up satellites

## Fentale Volcano (Ethiopia)



# CONCLUSIONS

- **GHGSat constellation expansion** – 11 satellites today and further expansion to follow in 2025 and 2026, along with next-gen technology development

- Controlled release validation
  - DATA.SAT **$Q_{50}$=103 kg/hr** from a sample size of 79 releases
  - Using Stanford data to diagnose and reduce bias

- **CO2 satellite is operational (GHGSat-C10 / Vanguard)**
  - characterized using public emissions data from US facilities

- **GHGSat data is accessible to researchers through NASA CSDA and ESA TPM program**