THE GHGSAT CONSTELLATION

Validation and Metrics for Methane Plume Imaging and Quantification

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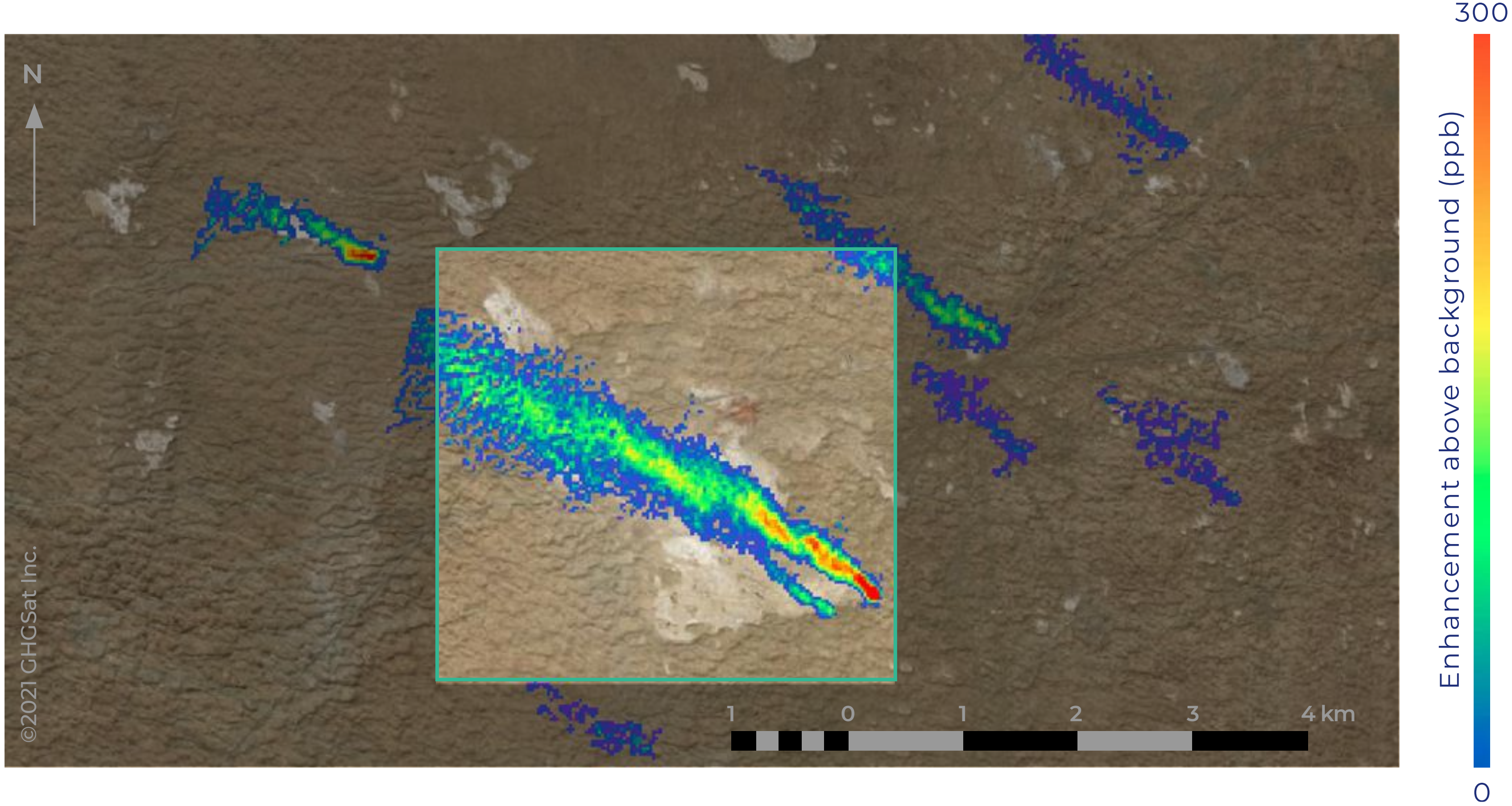
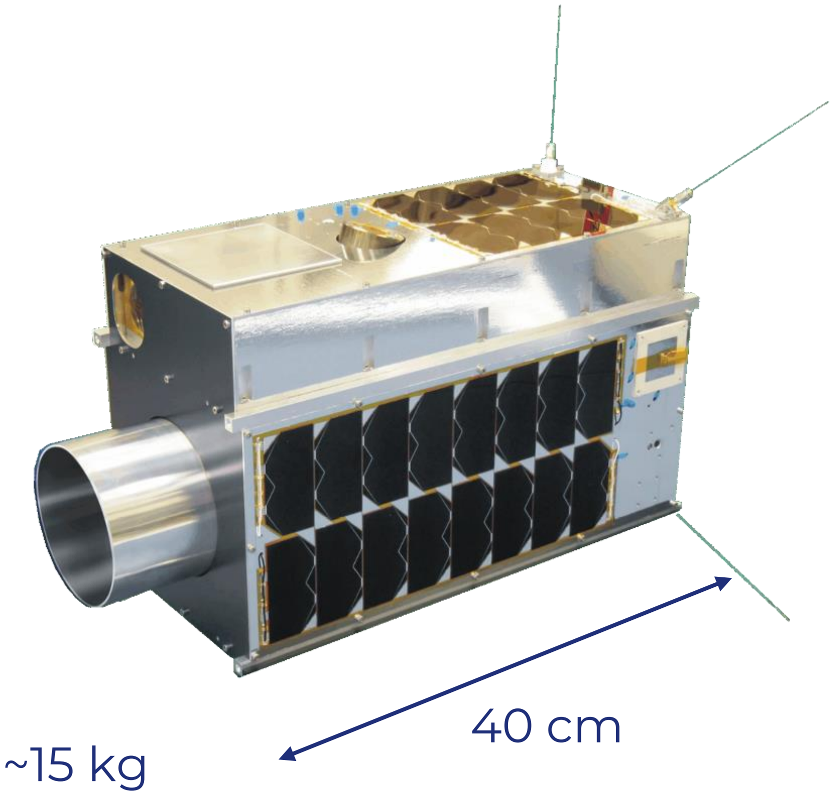
GHGSat satellites detect methane emissions at high resolution (~25m) enabling facility-level attribution



Approved for public release

OUR CONSTELLATION OF SATELLITES



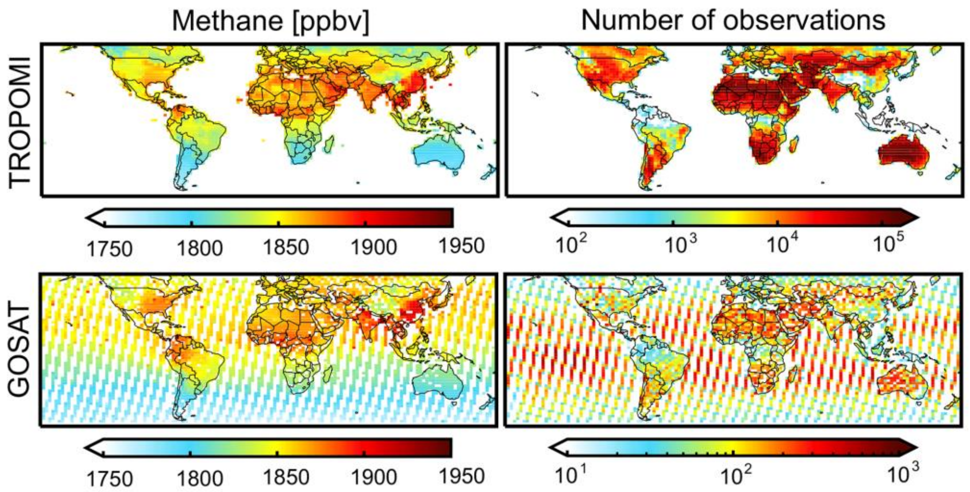
- 12 instruments on orbit
- Orbit: Sun-synchronous polar at ~ 500 km
- Payload: Fabry-Perot spectrometer
- Spectral Region: 1.6 um
- Spatial resolution: 25 m
- Field of View:
    - 40 x 12 km^2
    - 15 x 12 km^2 (isolated targets)
- Column precision: ~2 %
- Detection threshold: ~100 kg/hr

PERFORMANCE CHARACTERIZATION

1. Column precision (L2)
2. Detection limit (L4)
3. Quantification accuracy (L4)

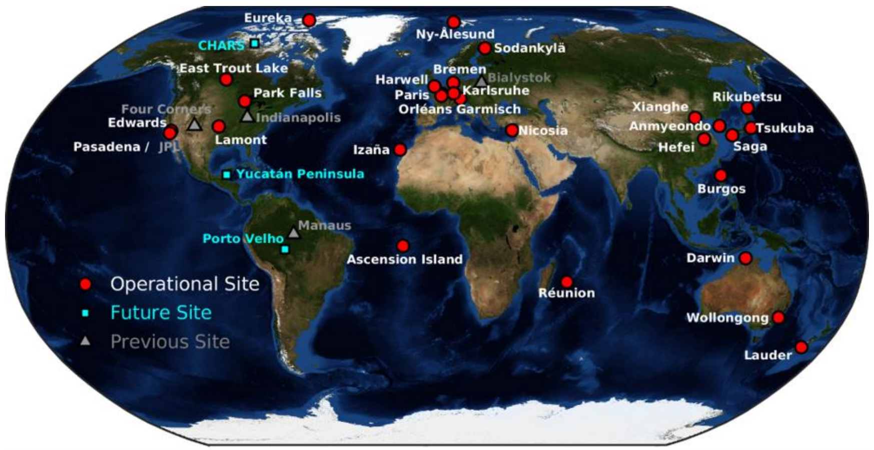
CAL/VAL: DIFFERENT FOR POINT SOURCE IMAGERS

Area flux mappers

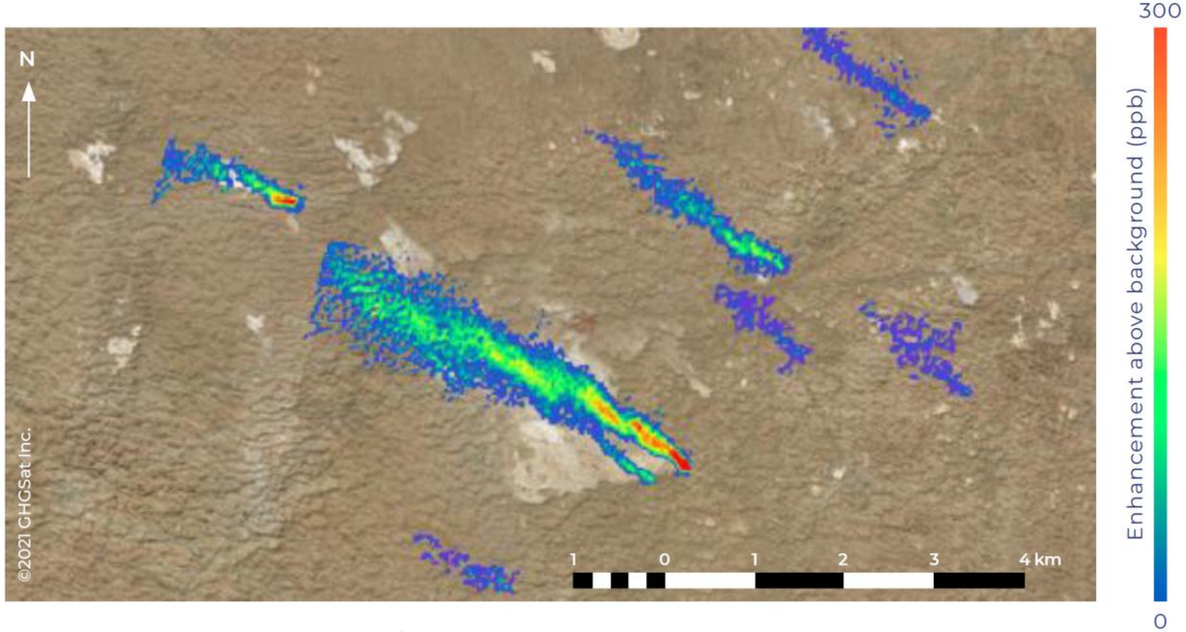


Z. Qu et al, ACP 2021

TCCON Site Map



Point source imagers



No ground truth for the column available at relevant scales (length and time)

Instead:

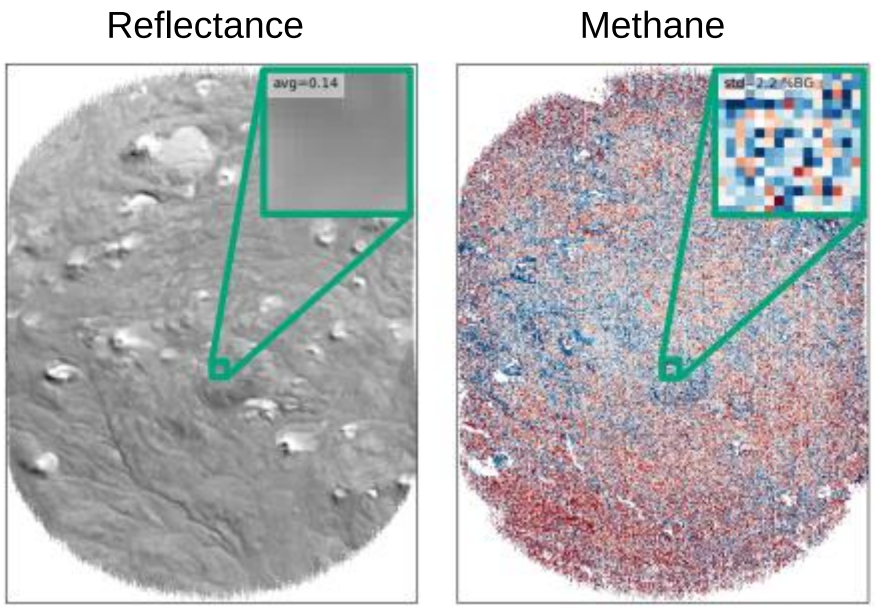
- **L2:** Empirically characterize column precision
- **L4:** Rely on **controlled releases** for detection limit and quantification accuracy

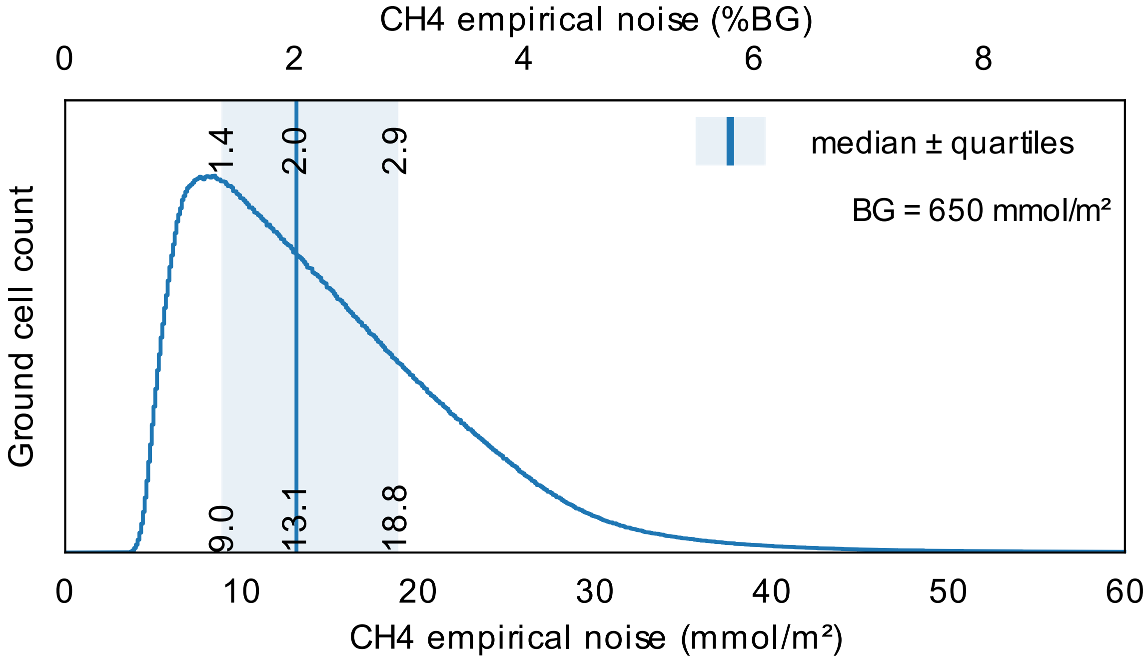
COLUMN PRECISION EMPIRICAL ASSESSMENT

In scenes without plumes, everything is noise → use **spatial statistics** (standard deviation)

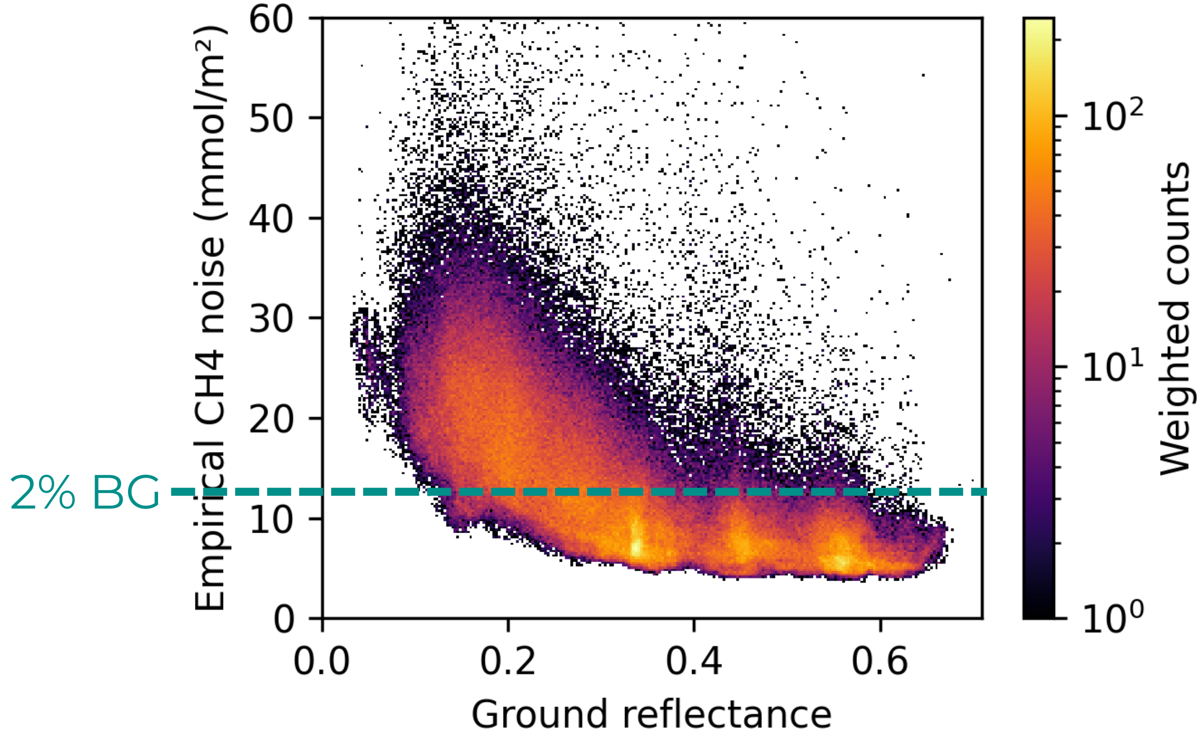
Conditions-dependent: STD within 500m x 500m ROI

Slide window across the retrieval domains of **all observations in 1 year**, excluding flagged pixels.

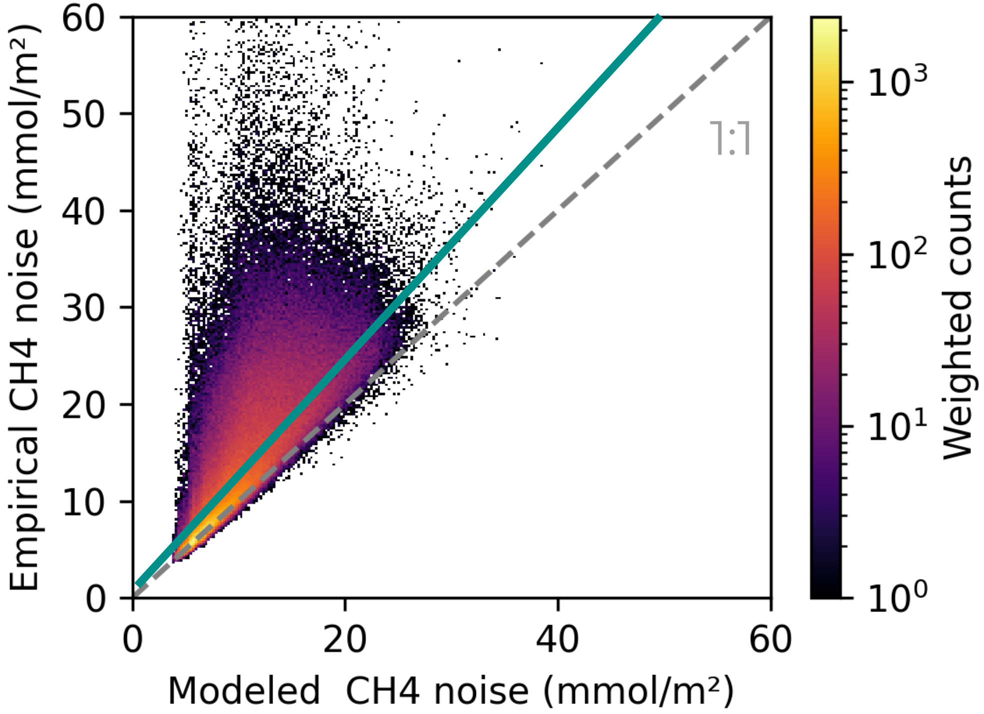




PRECISION DEPENDS ON SIGNAL INTENSITY



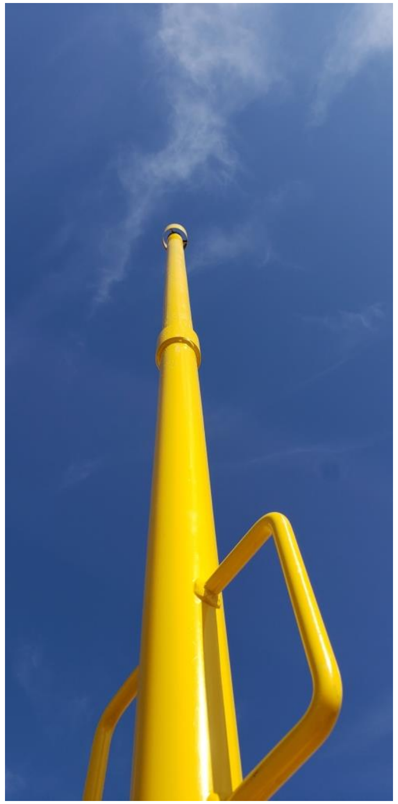
50% of samples within
17% of shot noise limit



Most data is nearly shot noise limited
Main excess noise is found on albedo gradients

PRIMARY VALIDATION METHOD: CONTROLLED RELEASES

Facility used by GHGSat in Southern Alberta, Canada



Full pipeline validation
(raw data to L4 product)

Used to validate both detection limit and quantification accuracy

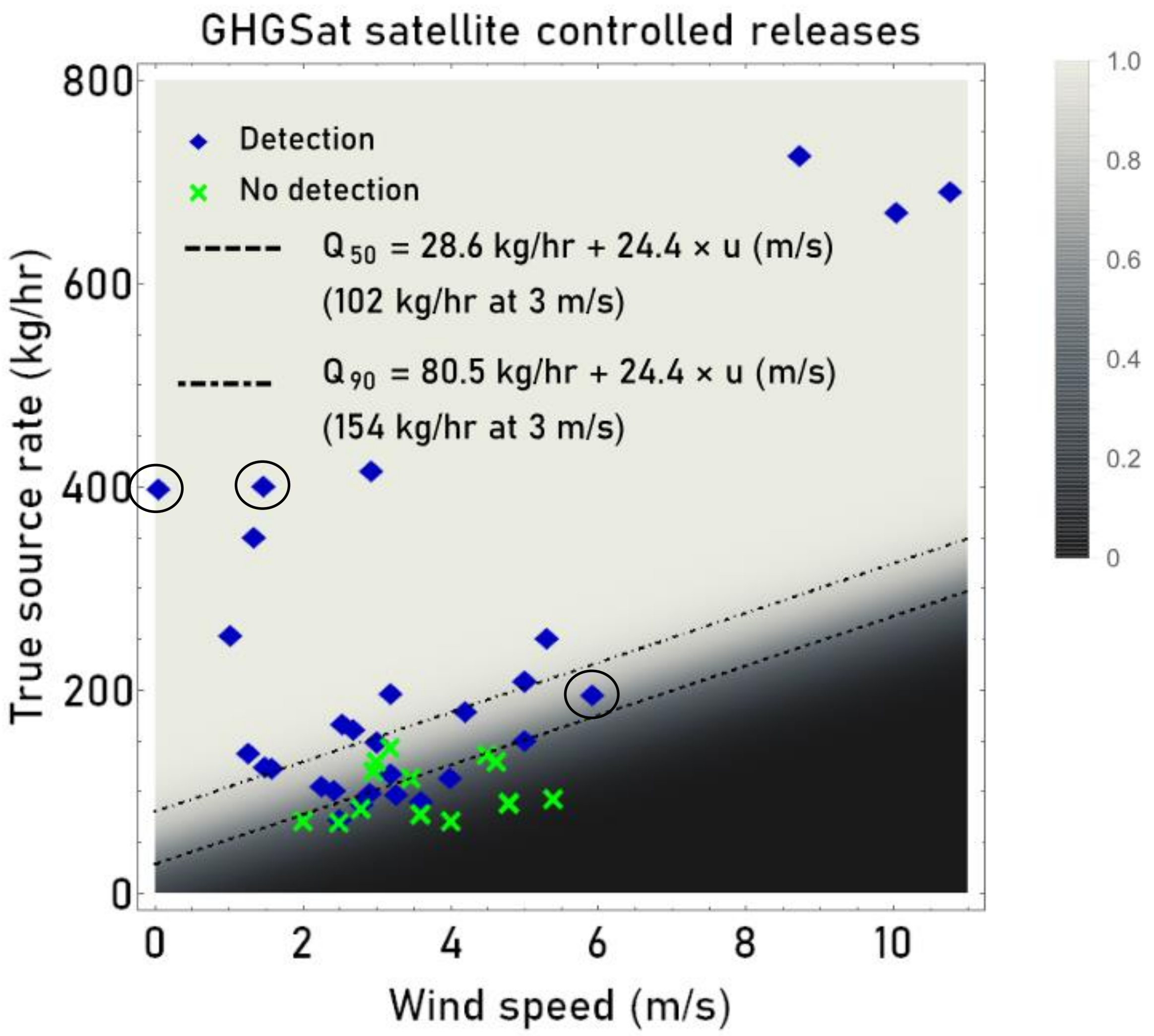
Participated in third-party single-blind study (Sherwin et al.) and self-organized experiments

Data from 2021-2023, including C6-C8. More releases planned with C9-C11

Average albedo very close to global average from our standard operations

Work by H. Deglint and GHGSat AV-Ops team

VALIDATION AND PERFORMANCE METRICS : DETECTION LIMIT

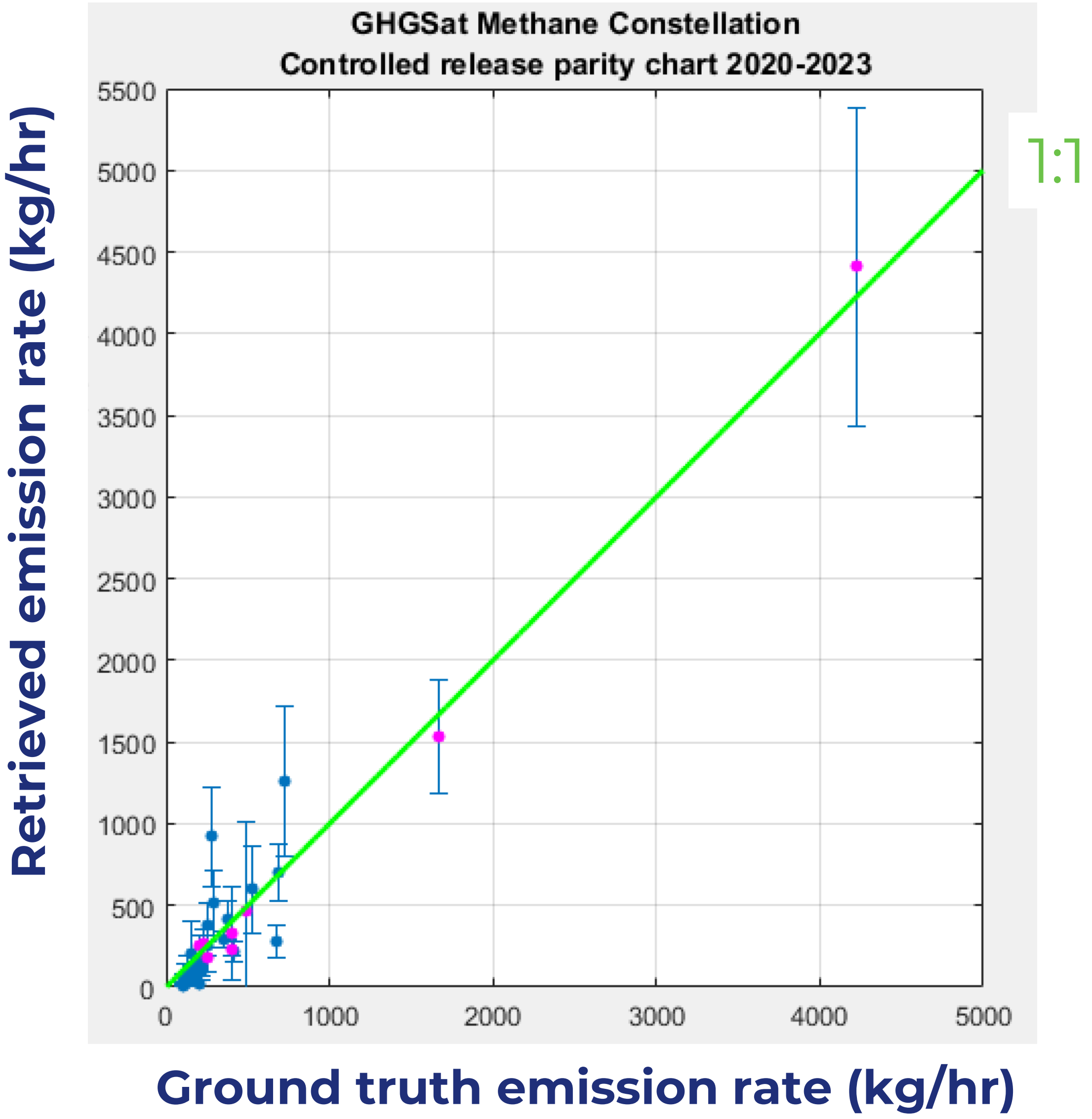


- Binary regression analysis (no binning required)
- Probability of detection (PoD) model:

$$p = \frac{1}{2}\left(1 + \mathrm{erf}\left(\frac{\beta_0 + \beta_1 Q + \beta_2 U}{\sqrt{2}}\right)\right)$$

- Accounts for wind-speed dependence
- **Implies detection limit of 102 kg/hr (50% PoD, 3 m/s)**

CONSTELLATION PERFORMANCE: QUANTIFICATION ACCURACY



- GHGSat facility in Southern Alberta + ***single-blind*** releases with customers and collaborators (**magenta points**)
- No noticeable bias
- Error typically dominated by wind-related uncertainty (even when using local measured wind)

SUMMARY: SOURCES OF NOISE AND ERROR

Column density measurement:

- Fundamental limit set by available light signal
- Systematic errors due to albedo edges (produce spatially correlated errors)

Plume detection:

- Emission rate
- Wind speed
- Column precision

Individual source rate error:

- Wind speed error dominates

PEER-REVIEWED PUBLICATIONS (SELECTED)

1. Varon, Daniel J., et al. "Quantifying methane point sources from fine-scale satellite observations of atmospheric methane plumes." *Atmospheric Measurement Techniques* 11.10 (2018): 5673-5686.
2. Varon, D. J., et al. "Satellite discovery of anomalously large methane point sources from oil/gas production." *Geophysical Research Letters* 46.22 (2019): 13507-13516.
3. Varon, Daniel J., et al. "Quantifying time-averaged methane emissions from individual coal mine vents with GHGSat-D satellite observations." *Environmental Science & Technology* 54.16 (2020): 10246-10253
4. Cusworth, Daniel H., et al. "Multisatellite Imaging of a Gas Well Blowout Enables Quantification of Total Methane Emissions." *Geophysical Research Letters* 48.2 (2021): e2020GL090864.
5. Jervis, Dylan, et al. "The GHGSat-D imaging spectrometer." *Atmospheric Measurement Techniques* (2021): 1-23.
6. Varon, Daniel J., et al. "High-frequency monitoring of anomalous methane point sources with multispectral Sentinel-2 satellite observations." *Atmospheric Measurement Techniques* (2021): 1-21.
7. Maasakkers, J. D., et al. "Using satellites to uncover large methane emissions from landfills." *Science Advances* **8**, eabn9683 (2022).

Validation White Paper **(McKeever and Jervis, 2022)**
https://go.ghgsat.com/validation-and-metrics-for-emissions-detection-by-satellite

THANK YOU