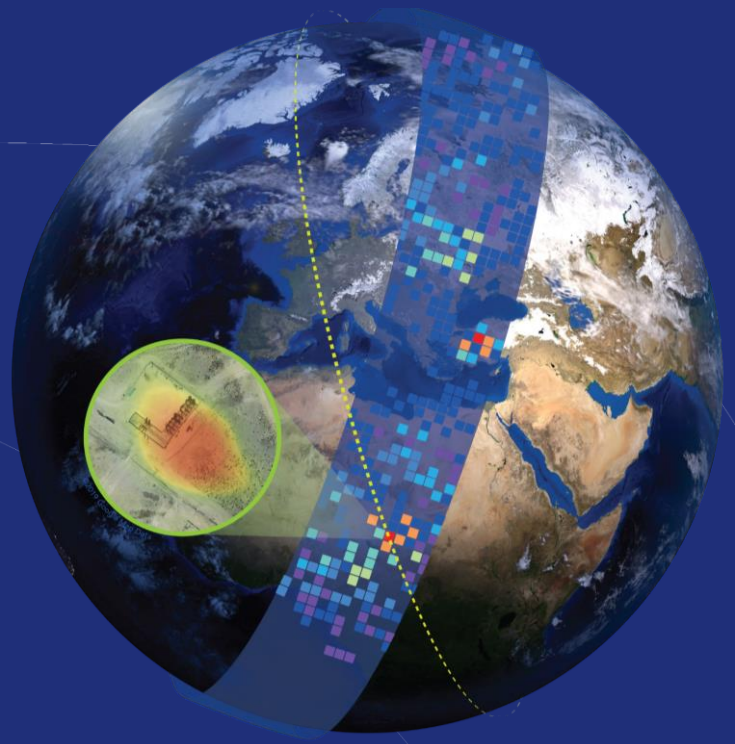


GHGSAT MISSION UPDATE

CEOS AC-VC 20

Jason McKeever

October 17th, 2024

GHGSAT

GHGSAT

Montreal-based (+ Ottawa, Calgary, US, UK)

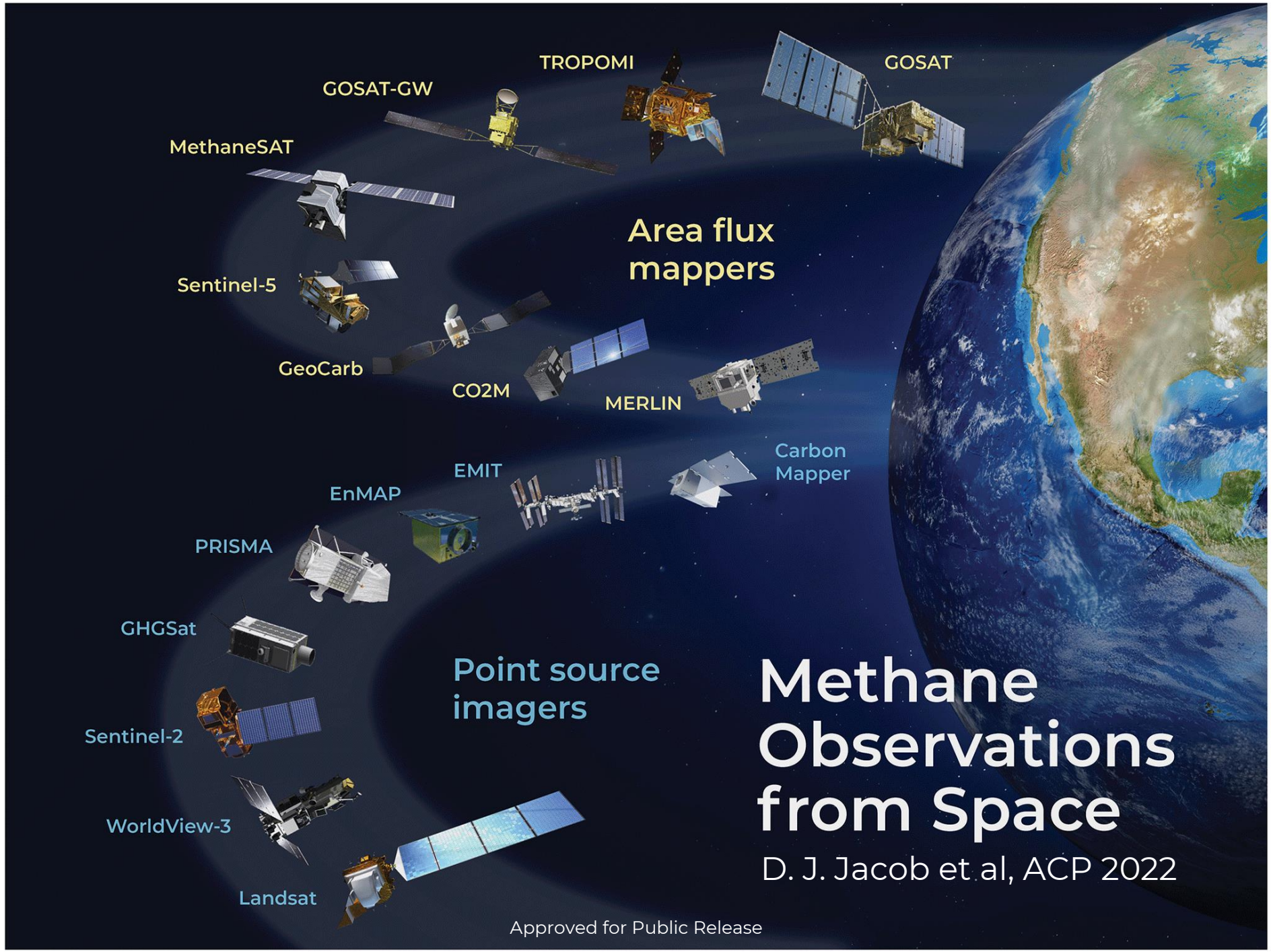
Constellation of small satellites custom-designed for methane sensing

- Single-site attribution and sensitivity down to ~100 kg/hr

Aircraft instruments for surveys with enhanced sensitivity (~5 kg/hr) and resolution

Also incorporate third-party data (satellite and ground-based) for increased coverage and further insights

Deployment of GHGSat-C7 from Transporter 7, April 15th 2023



POINT SOURCE IMAGERS: AN EMERGING CAPABILITY

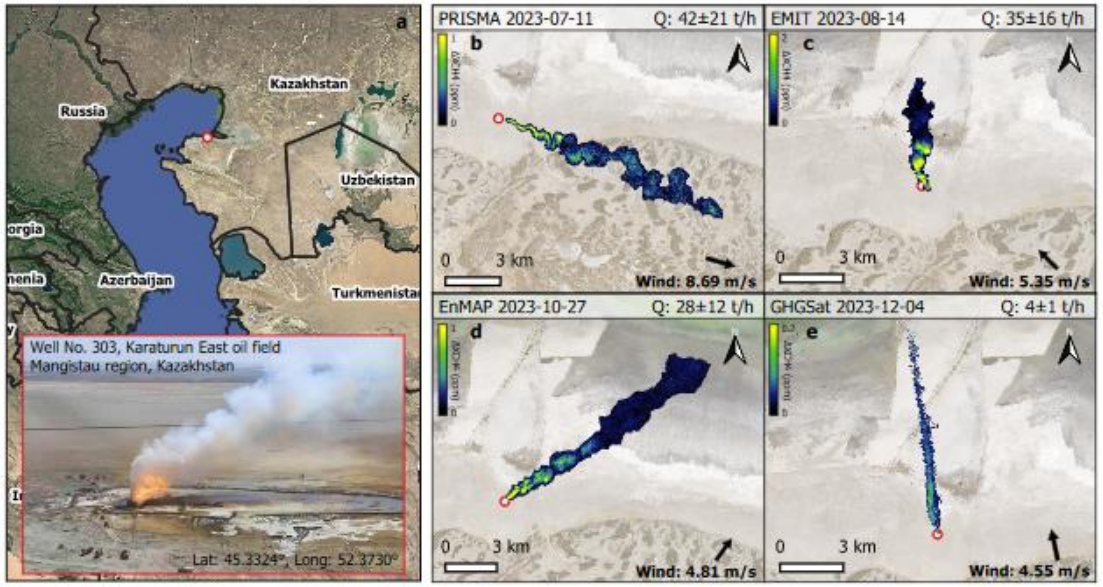
Detect and track superemitters, drive mitigation of emissions

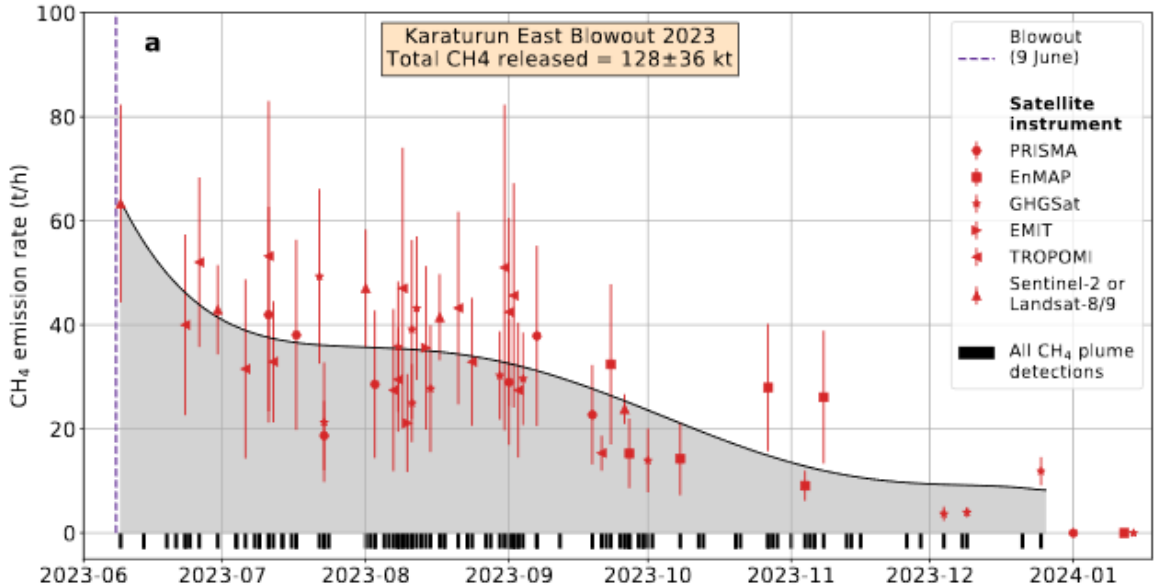
Multi-satellite data depicts record-breaking methane leak from a well blowout

Luis Guanter[1,2*], Javier Roger[1], Shubham Sharma[3], Adriana Valverde[1], Itziar Irakulis-Loitxate[4,1], Javier Gorroño[1], Xin Zhang[3], Berend J. Schuit[3,5], Joannes D. Maasakkers[3], Ilse Aben[3], Alexis Groshenry[6], Antoine Benoit[6], Quentin Peyle[6], Daniel Zavala-Araiza[2]

Preprint led by Valencia group, published Feb 13, 2024

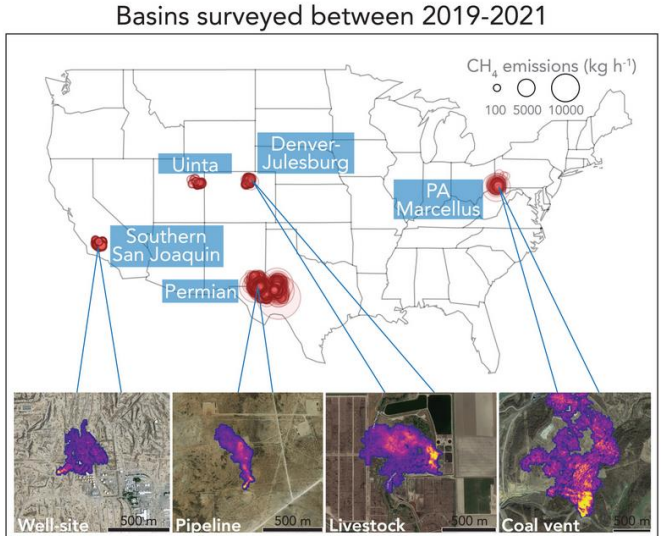
Estimated total emissions 128 ± 36 kt





POINT SOURCE IMAGERS: AN EMERGING CAPABILITY

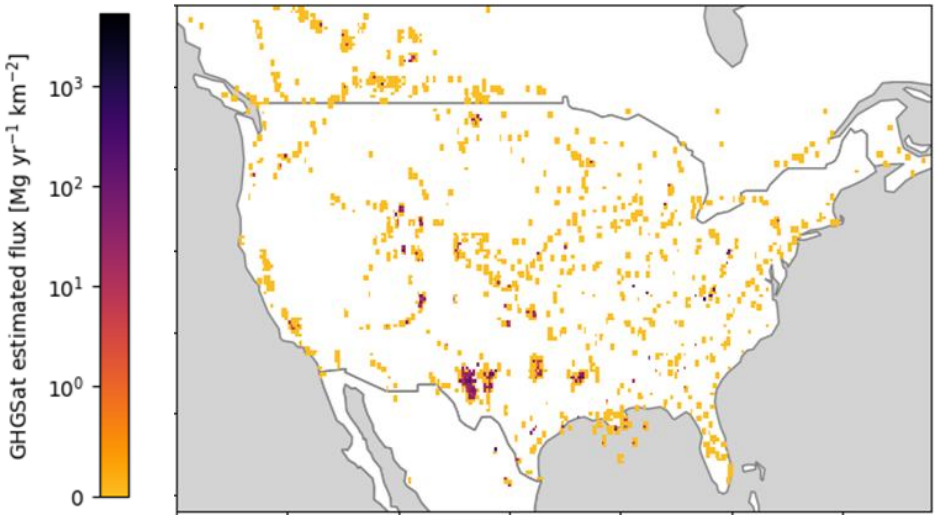
Increasing coverage enables insights through aggregation



[Cusworth et al, PNAS 2023]

- Aircraft surveys of multiple basins in US
- **40% of emissions are from detectable point sources**
- Most of these emissions are above 100 kg/hr

GHGSat US Coverage 2023

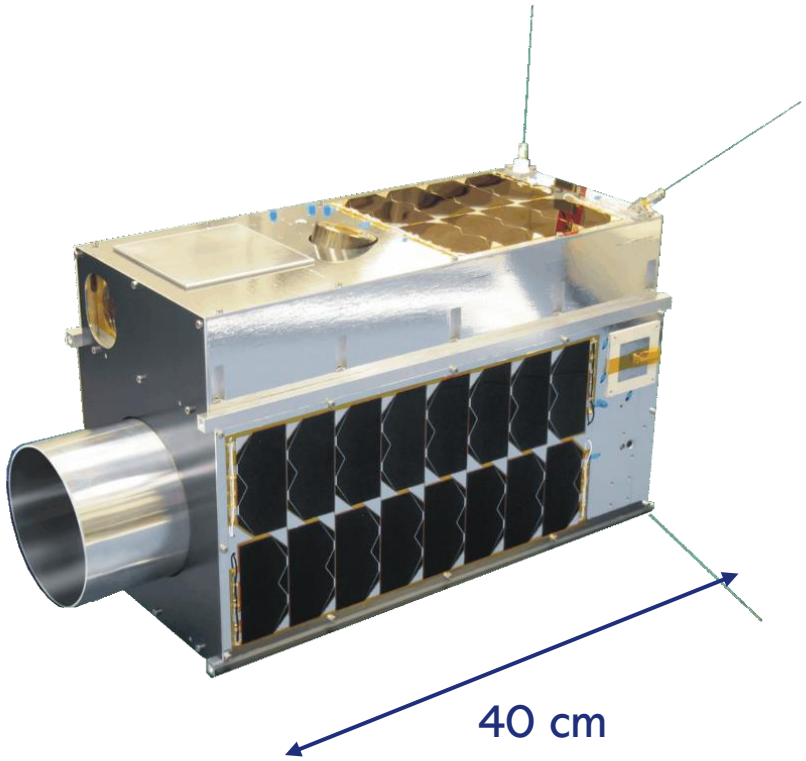


GHGSat – In preparation (D. Jervis *et al*)

- Study methane emissions from **oil-gas** and **coal** sectors worldwide with our constellation (5 to 8 satellites)
- We detected aggregate emissions of
  - **9.4 ± 4.8 Mt/yr** over 12-month period (2023)
- Represents ~**12%** of global total for oil-gas + coal per GFEI
- Coverage: areas observed represent ~**27%** of total GFEI emissions in the sector

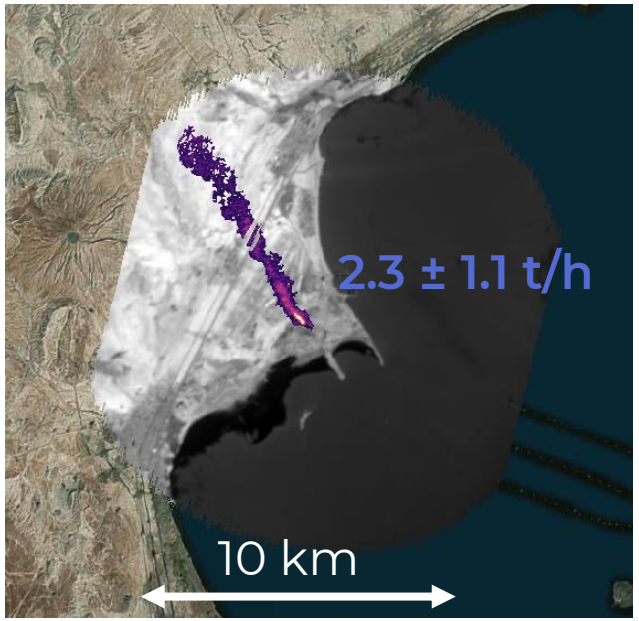
SATELLITE SENSOR DETAILS

- Commercial constellation since 2020 – 10 CH4 satellites today
  - Ongoing expansion includes 4 more in 2025
- 15 kg nanosatellites
- *Sun-synchronous orbit :* ~500 km altitude
- *Payload:*
  - Imaging Fabry-Perot spectrometer
  - Spectral region : 1.6 μm
  - **High spatial resolution (~25 m)**
  - Measurement domain: ~12 km width x 15-35 km length
  - Always operate in **target mode**
  - Onshore and offshore capabilities
- Measurement precision: down to **1%** of background column density
- Emission rate detection threshold: ~**100 kg/hr**
- Number of observations per day (per satellite): up to **60**

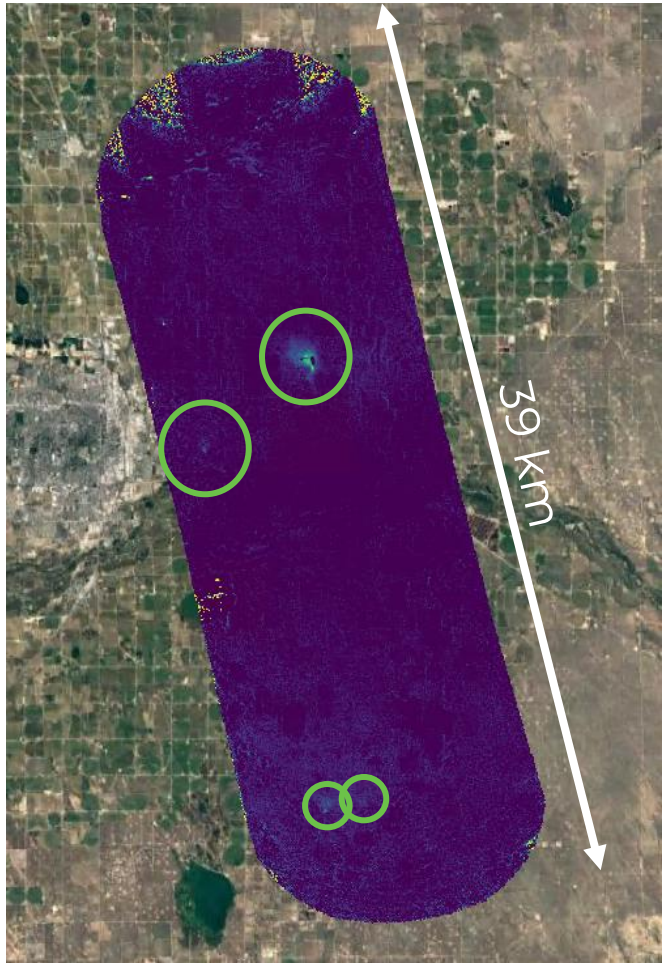


10 CH_4 satellites in orbit → **~Daily revisits**

EXAMPLE DATA



- Standard domain length ~ 15 km
- Used for single-target situations

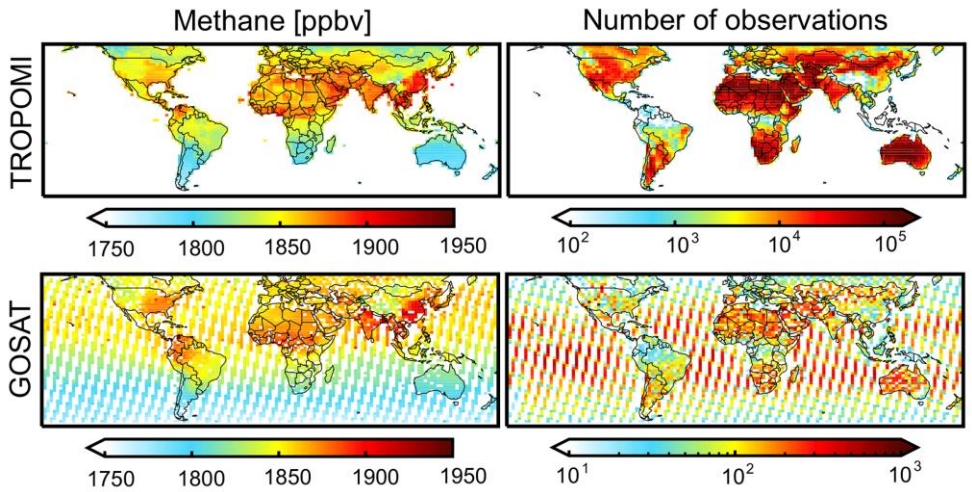


- Extended domain length
- Used for survey-type situations (emitters are distributed)
- Four plumes found
- Retrieved rates from 0.4-2.5 t/h

Current capacity allows up to 60 extended observations (60 × 435 km^2) per day per satellite

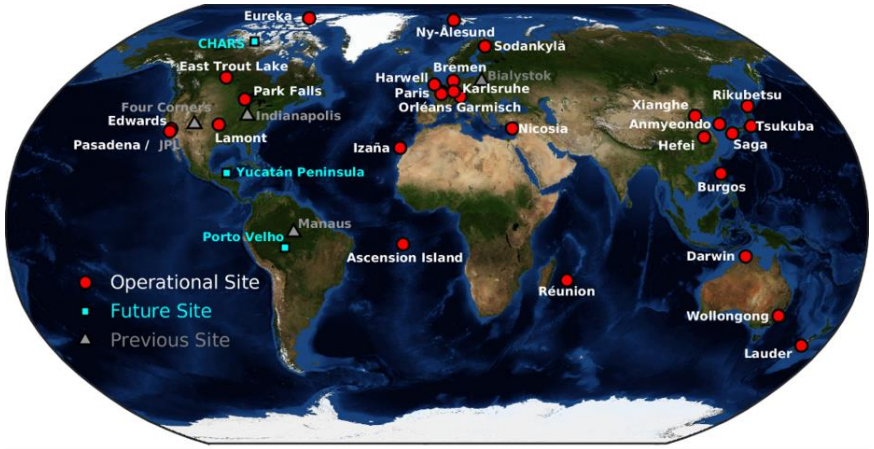
CAL/VAL: DIFFERENT FOR POINT SOURCE IMAGERS

Area flux mappers

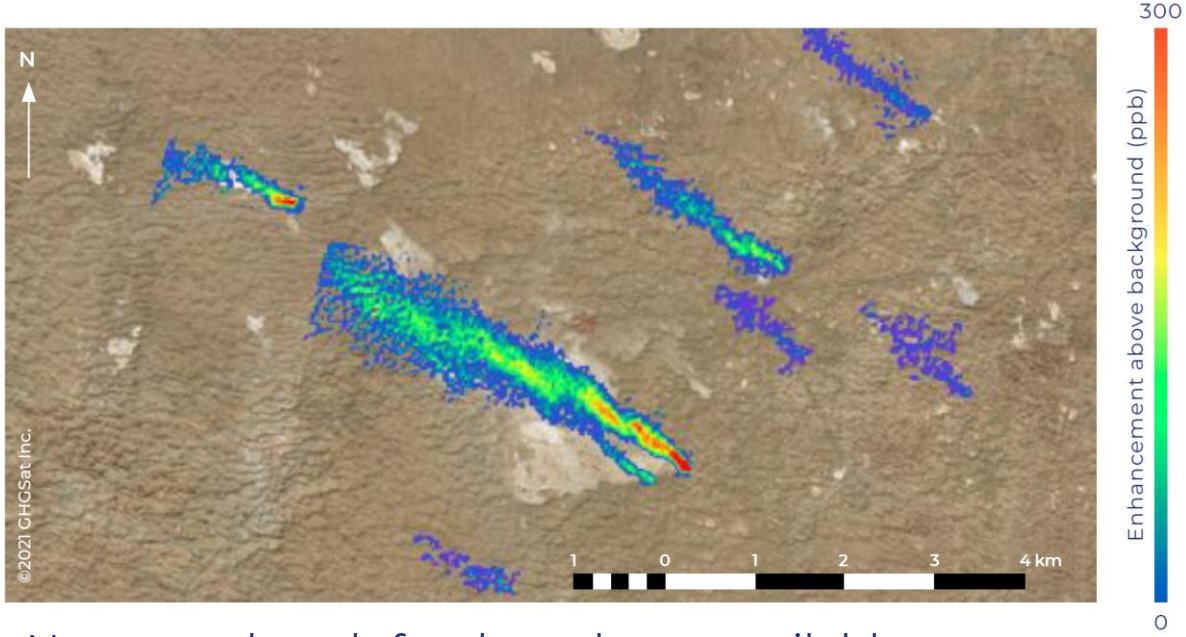


Z. Qu et al, ACP 2021

TCCON Site Map



Point source imagers

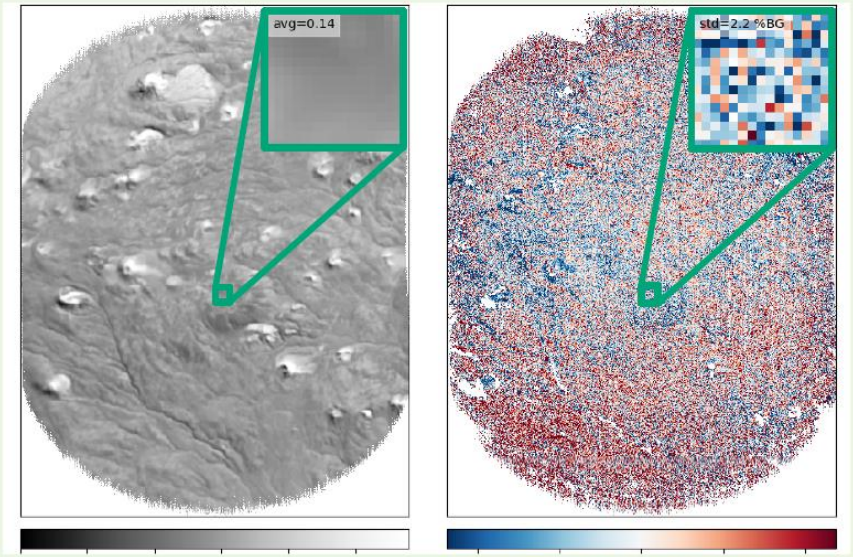


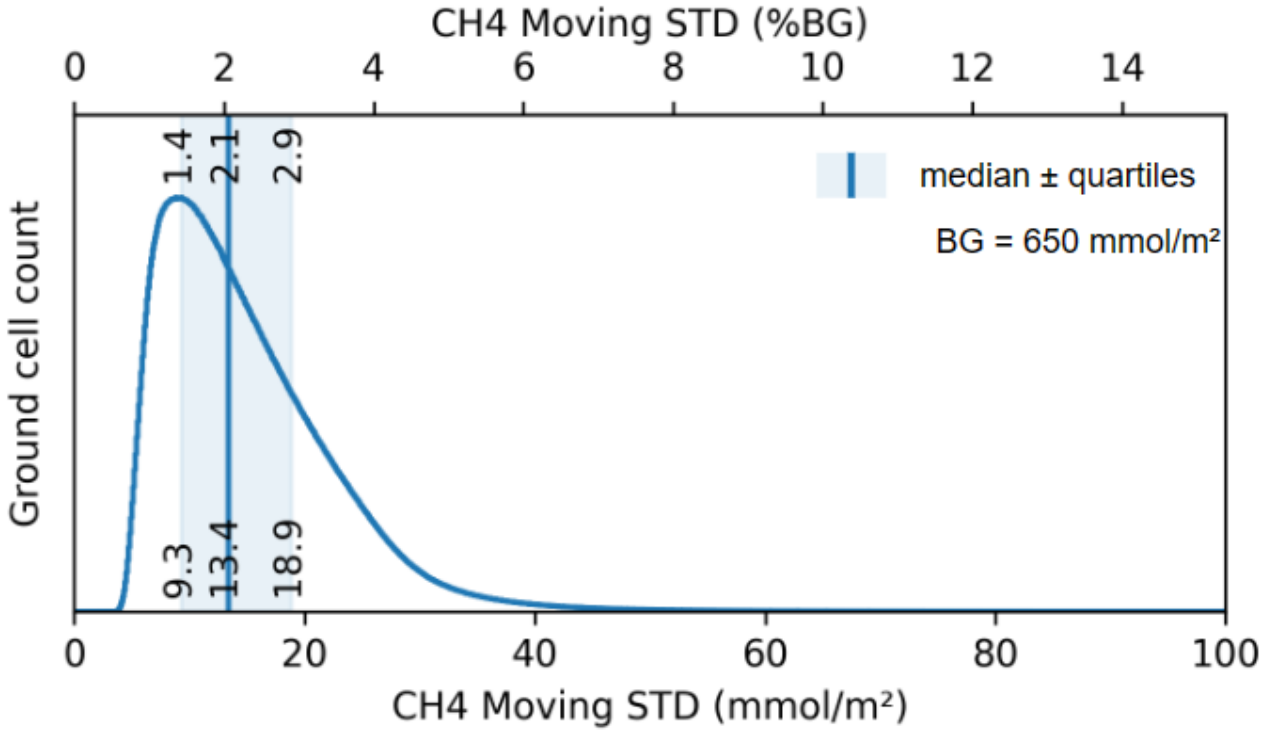
No ground truth for the column available at relevant scales (length and time)
Instead:

1. **Empirically characterize** column retrievals
2. Rely on **controlled releases** for detection limit and quantification accuracy

CAL/VAL: L2 COLUMN PRECISION

Empirical noise analysis





- "Scan" moving 500m x 500m ROI across all retrieval domains
- **Compute spatial standard deviation of retrieved CH4 column in each ROI**

- Nov 2021 – Aug 2023 - ~**19000 observations**
- **All seasons** and **all terrain classes**
- ~ 15% of histogram is below 1%BG (bright, quasi-uniform scenes)

PRIMARY VALIDATION METHOD: CONTROLLED RELEASES

Facility used by GHGSat in Southern Alberta, Canada

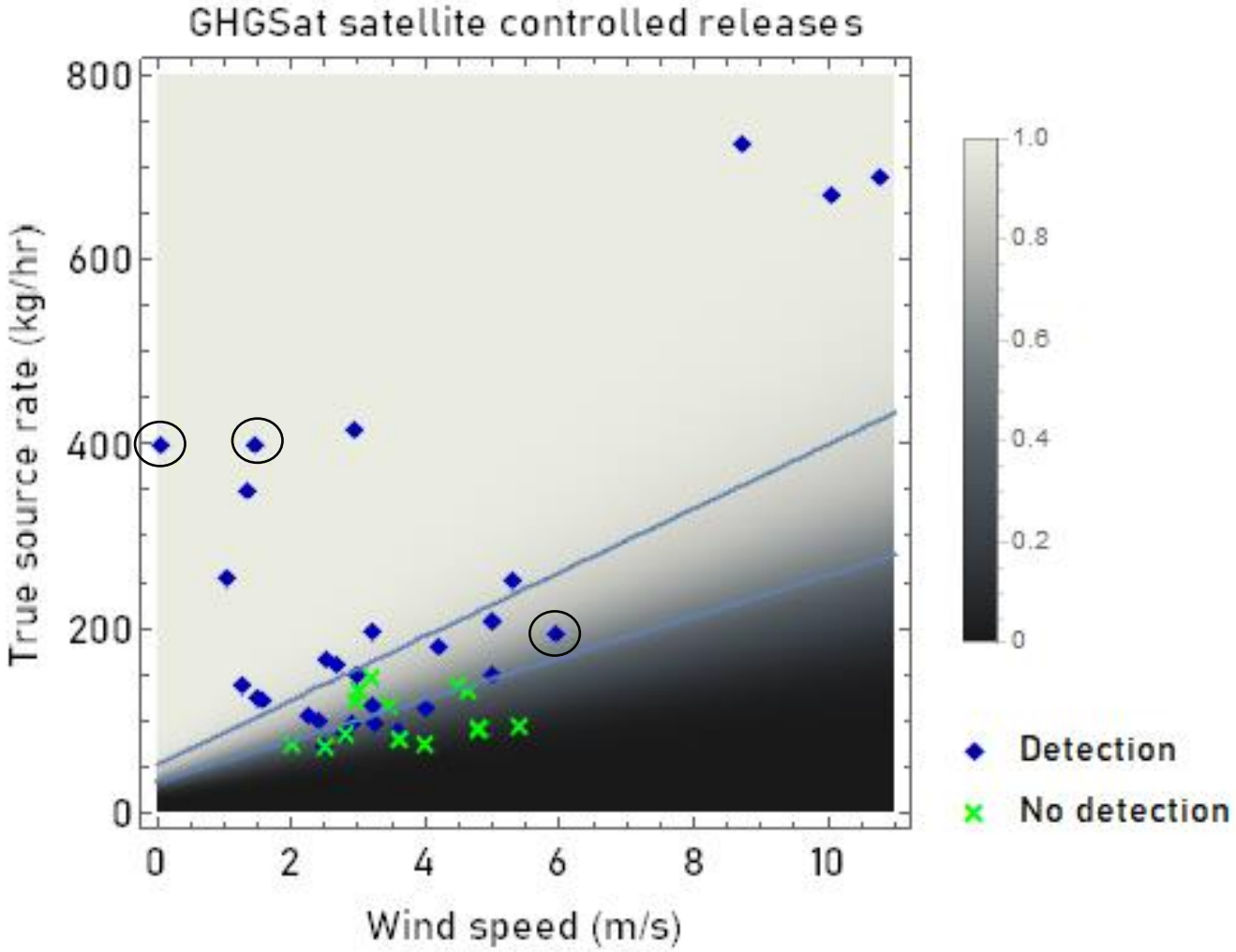
Used to validate both detection limit and quantification accuracy

Both for satellite and aircraft instruments

Most of our effort in 2022-2023 has been toward probing detection limit

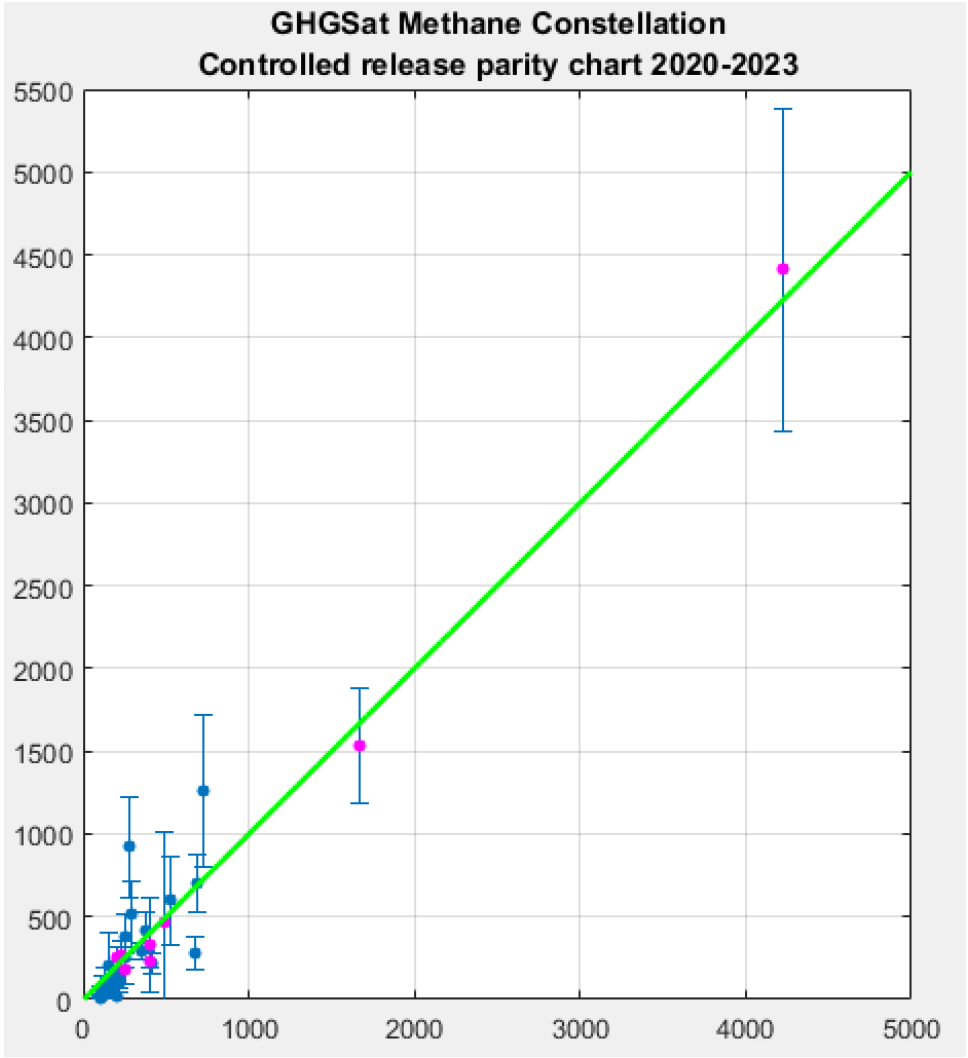
Organized by GHGSat airborne ops team, Calgary

VALIDATION AND PERFORMANCE METRICS : DETECTION LIMIT



- Binary regression analysis
- Data from 2021-2023, including C6-C8
- Internal and independently organized releases
- Average albedo very close to global average from our standard operations
- Fit model for probability of detection:
  - Lognormal CDF
  - Simple predictor function
  - Conrad *et al*, RSE 288 (2023) 113499
- Accounts for wind-speed dependence
- **Implies detection limit of**
  100.4 kg/hr (50% PoD, 3 m/s)
  155.6 kg/hr (90% PoD, 3 m/s)

CONSTELLATION PERFORMANCE: QUANTIFICATION ACCURACY



- Ongoing series of **controlled releases** 2020-2023
- GHGSat facility in Southern Alberta
- Also includes some ***single-blind*** releases with customers and collaborators (**magenta points**)
- Participated in 2021 and 2022 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)

OTHER CAL/VAL ACTIVITIES AND COLLABORATIONS

- **NIST** Facility-scale intercomparison efforts - ongoing
- **UNEP-IMEO** Workshop (June 2023)
- **NPL** UK Workshop February 2024
- ESA-funded **MEDUSA** project led by SRON
- Stanford controlled release studies (**single-blind**)
  - Satellite and aircraft (two published studies for each)
  - Releases underway in 2024 – cooperative phase for now
- **Landfill** releases with David Risk group

- Coincident measurements with **EMIT** (part of CSDA evaluation)

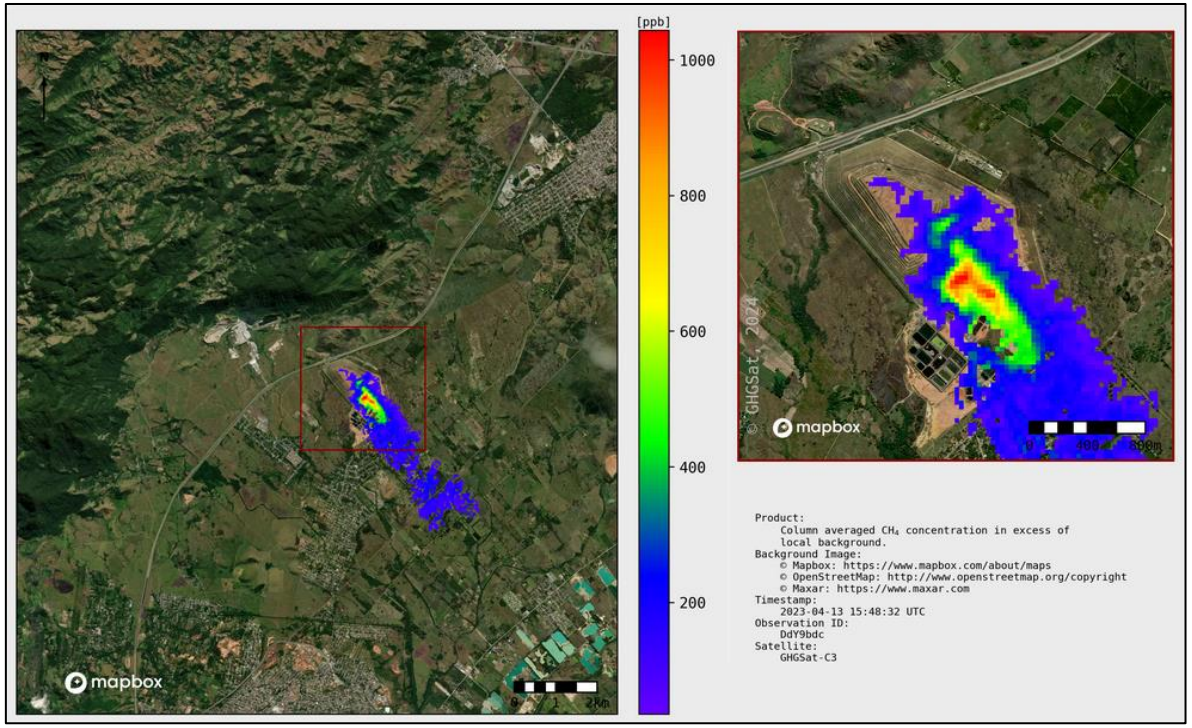
- Interested in **common controlled release facilities**
  - Diverse locations, different terrain classes
  - Have discussed with Stanford, CSU, IMEO
  - Off-shore of particular interest

NASA COMMERCIAL SMALLSAT DATA ACQUISITION

GHGSat data is now available through the NASA Earthdata portal

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

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



PI	Institution	Project Description
Clayton Elder	NASA JPL	Evaluating GHGSat methane datasets with respect to EMIT methane plume data
Ben Poulter	NASA Goddard	Evaluating GHGSat for monitoring natural ecosystem methane fluxes
Max Krause	EPA	Evaluating uncertainty of remote sensing landfill methane emission assessments
Davida Streett	NOAA	Evaluating GHGSat data offshore in the Gulf of Mexico
John Worden	NASA JPL	Evaluating GHGSat plume data for updating CH4 emission inventories and trends
Nicolay Balashov	NASA Goddard	Evaluation of GHGSat point source quantification in an urban environment
Danielle Wood	MIT	Assessing accuracy of greenhouse gas emission inventories in a multi-municipality metropolitan area

CONCLUSIONS AND OUTLOOK

- GHGSat methane constellation is expanding – 10 satellites today and further expansion to follow, along with next-gen technology development
- Empirical analysis shows measured noise magnitudes at the column density level (L2)
- Detection limit and quantification accuracy (L4) validated through controlled releases
- Increasing capacity enabling deeper insights through aggregation
- GHGSat data is accessible to researchers through NASA CSDA and ESA TPM program

THANK YOU