FIRST METHANE SENSING RESULTS FROM GHGSAT'S COMMERCIAL CONSTELLATION

Jason McKeever,

H. Deglint, D. Gains, D. Jervis, J.-P. MacLean, A. Ramier, W. Shaw, M. Strupler, E. Tarrant, D. Varon, D. Young

OUTLINE

- Introduction to GHGSat-C1 ("Iris") and C2 ("Hugo")

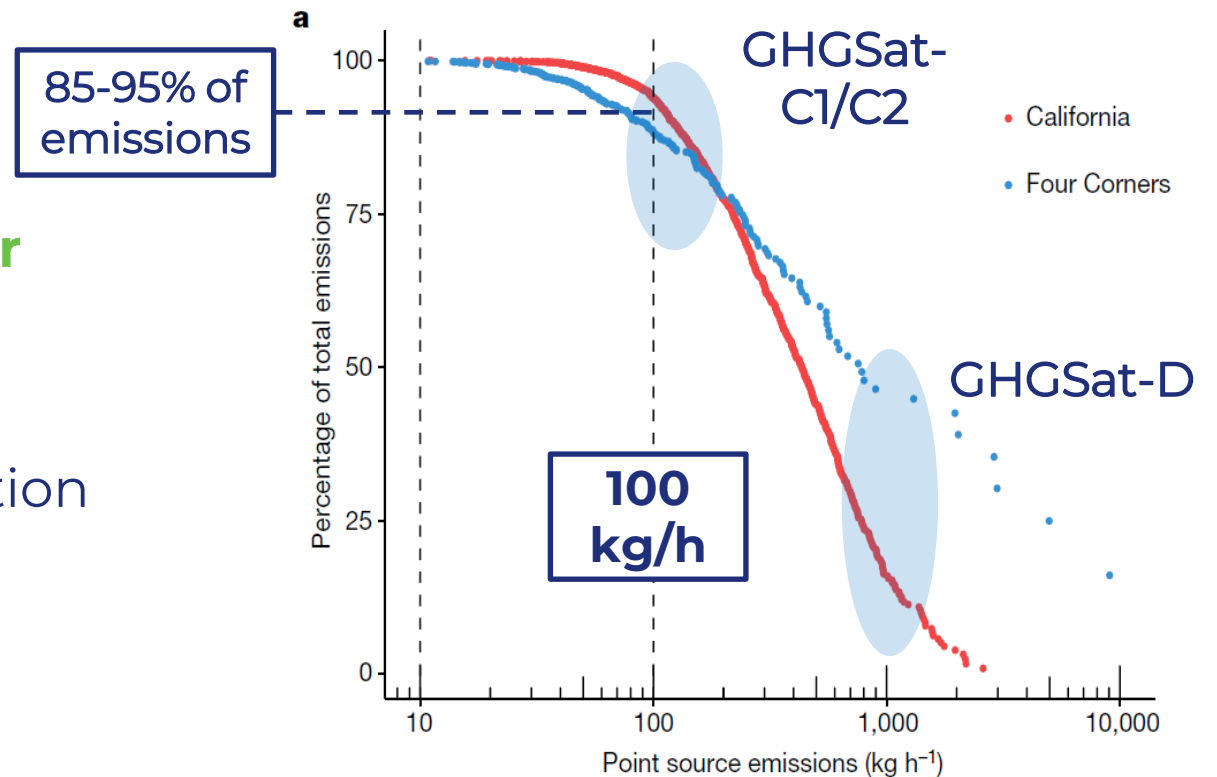- **Methane point source detection**
  - **High spatial resolution (~25 m)**
  - **multisector, worldwide**
  - **~100 kgCH$_4$/hr to >> 10 tonnes/hr**

- Cal/Val:
  - Methane column vs surface elevation
 - Controlled releases

- Performance summary
- Detection statistics

85-95% of emissions

GHGSat-C1/C2

GHGSat-D

100 kg/h

- California
- Four Corners

Percentage of total emissions

Point source emissions (kg h^{-1})

Duren, R. M. *et al.* California's methane super-emitters. *Nature* 575, 180–184 (2019).

GHGSAT-C1 & C2

- *Launch dates:* Sept 2nd, 2020 (C1), Jan 24th, 2021 (C2)
- 15 kg nanosatellites
- *Sun-synchronous orbit : ~500 km*
- *Payload:*
  - Imaging Fabry-Perot spectrometer
  - Spectral region : 1.6 μm
  - **High spatial resolution (~30 m)**
  - Domain size 15 km x 10 km (typical)
  - Always operate in **target mode**
  - Design improvements over GHGSat-D include:
    - Increased per-pixel signal and decreased straylight
    - Onboard calibration system
    - Optimized spectroscopy
  - Retrievals improvements include:
    - Improved co-registration algorithm
    - Improved instrument model from much more intensive characterization campaign

40 cm

Approved for public release
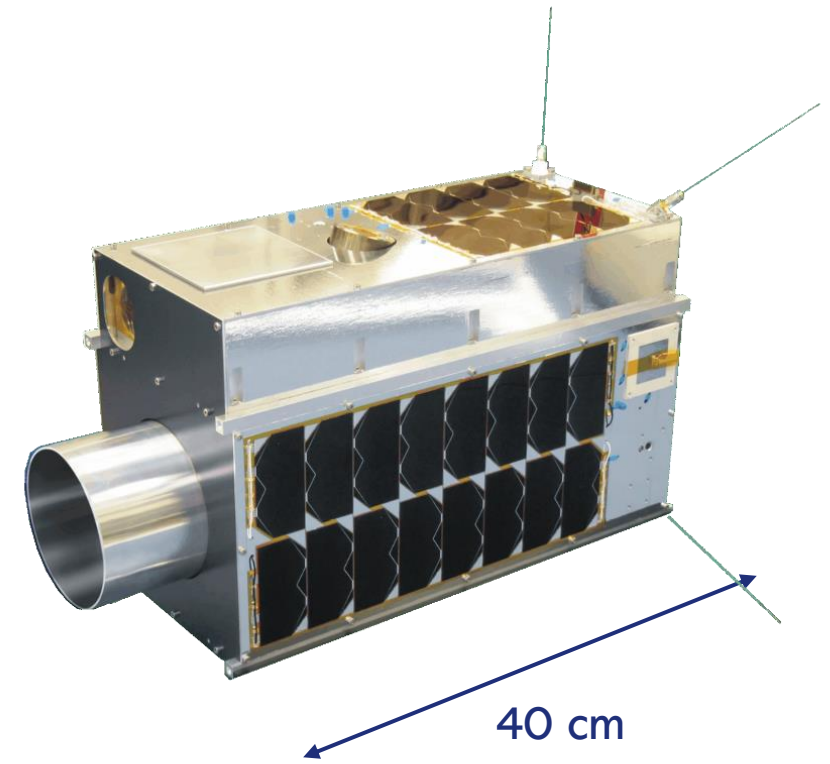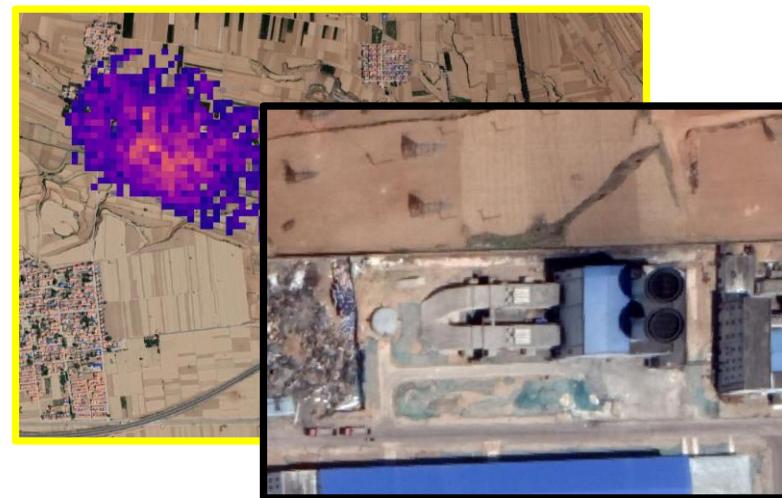
EXAMPLE PLUMES – UNDERGROUND COAL MINING
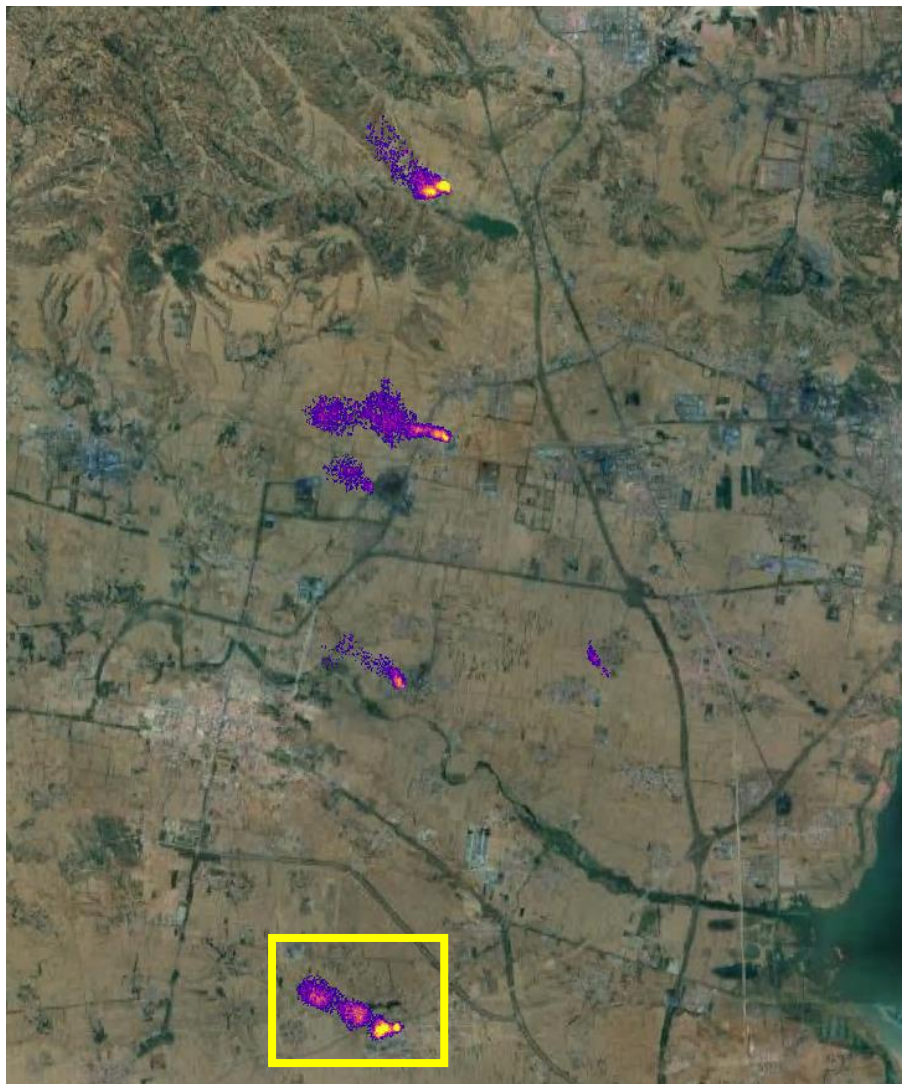
May 2021, Shanxi, China

6 plumes detected in one observation

Peak column density ~37% bg

Estimated source rates: 1.2 – 4.5 tCH4/hr

EXAMPLE PLUMES – OIL/GAS PRODUCTION

September 2020, Permian Basin, NM, USA

Peak column density ~12% bg

Estimated source rate: 1.2 ± 0.6 tCH4/hr

EXAMPLE PLUMES – LANDFILL

April 2021, Buenos Aires

Peak column density ~22% bg

Multiple points of origin in active area

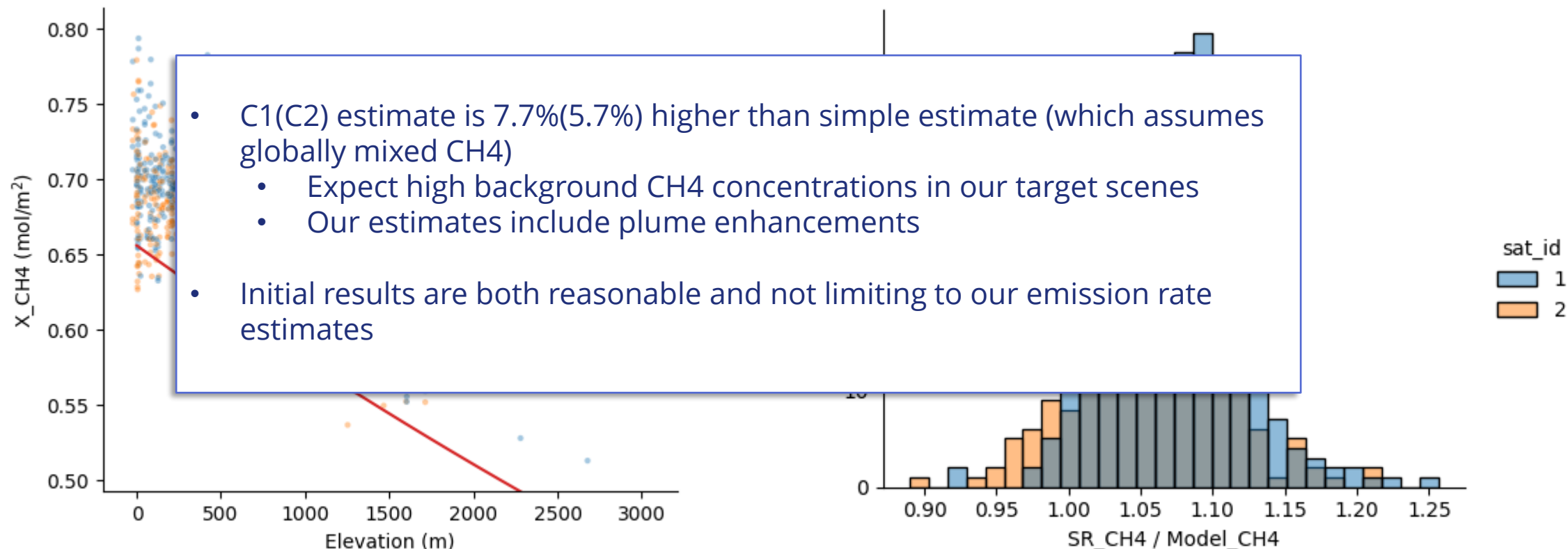**Detectable plume reaches edge of retrieval domain**

Estimated source rate (overall): 15 ± 5 tCH4/hr

CAL/VAL: METHANE COLUMN VS ELEVATION

Scene-wide (15 x 10 km^2) average CH4 column density:

- C1(C2) estimate is 7.7%(5.7%) higher than simple estimate (which assumes globally mixed CH4)
  - Expect high background CH4 concentrations in our target scenes
  - Our estimates include plume enhancements

- Initial results are both reasonable and not limiting to our emission rate estimates

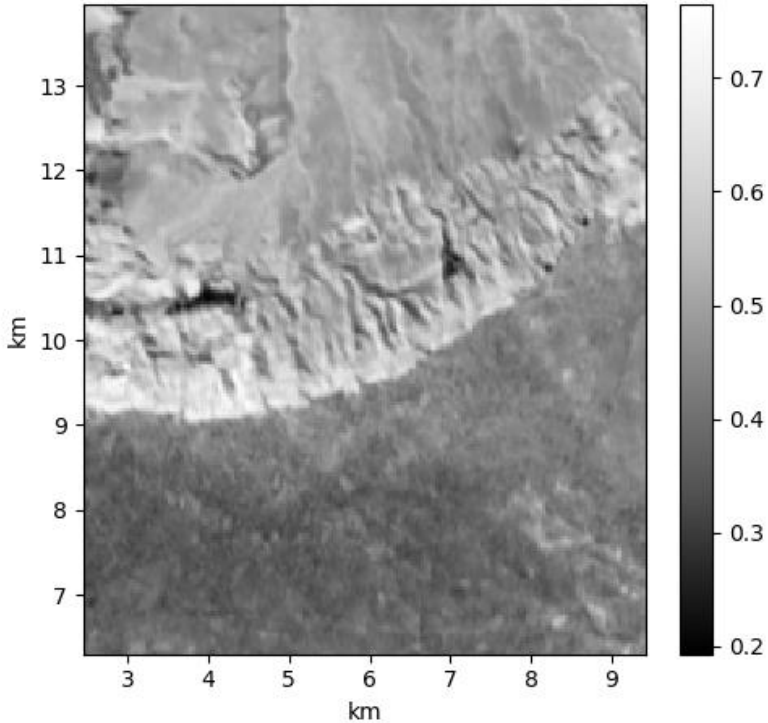Model* @ sea level: 0.66 mol/m^2 = 1890 ppb

*US_standard temperature, pressure, and mixing ratio profiles scaled to present day sea-level values
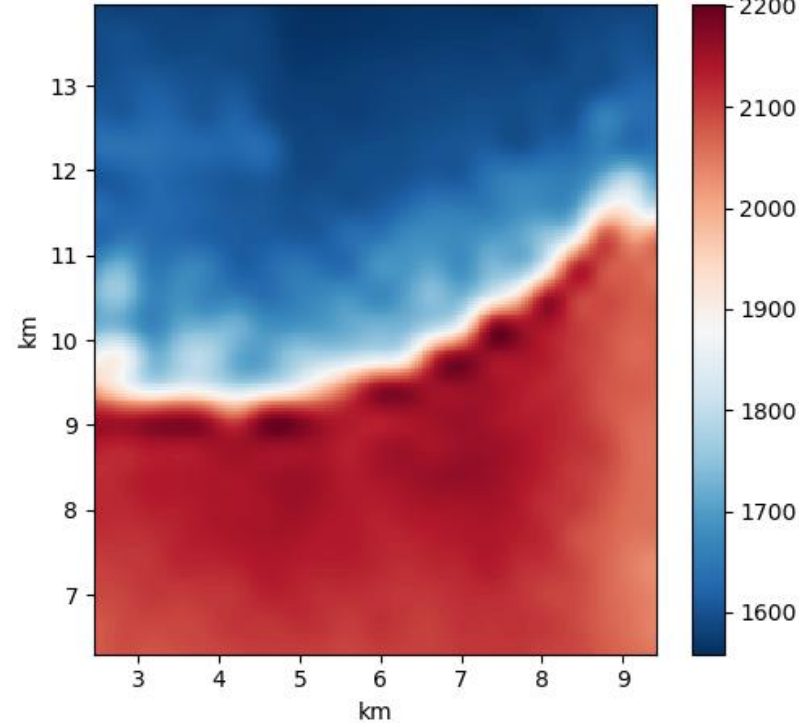
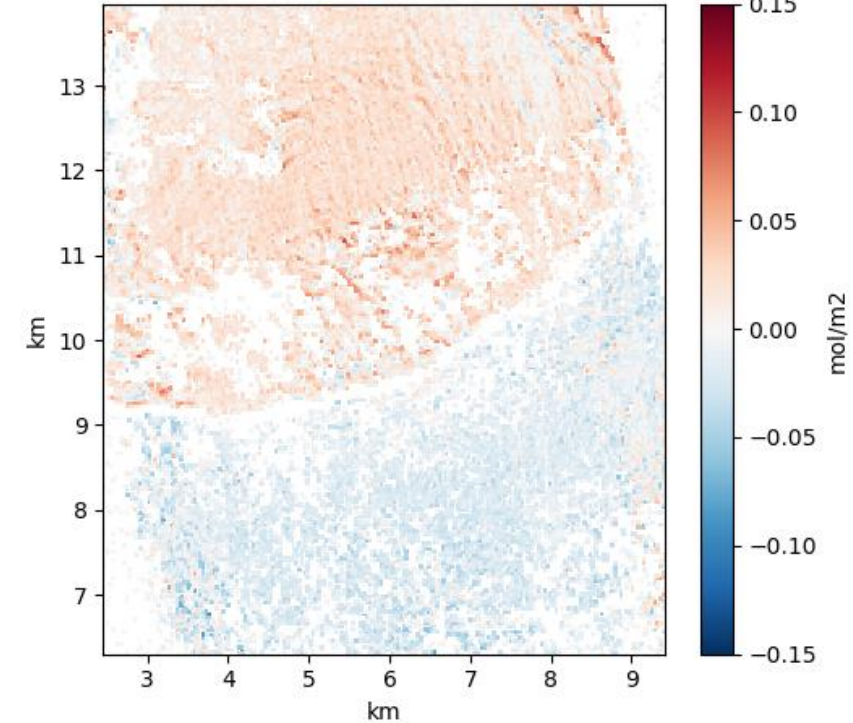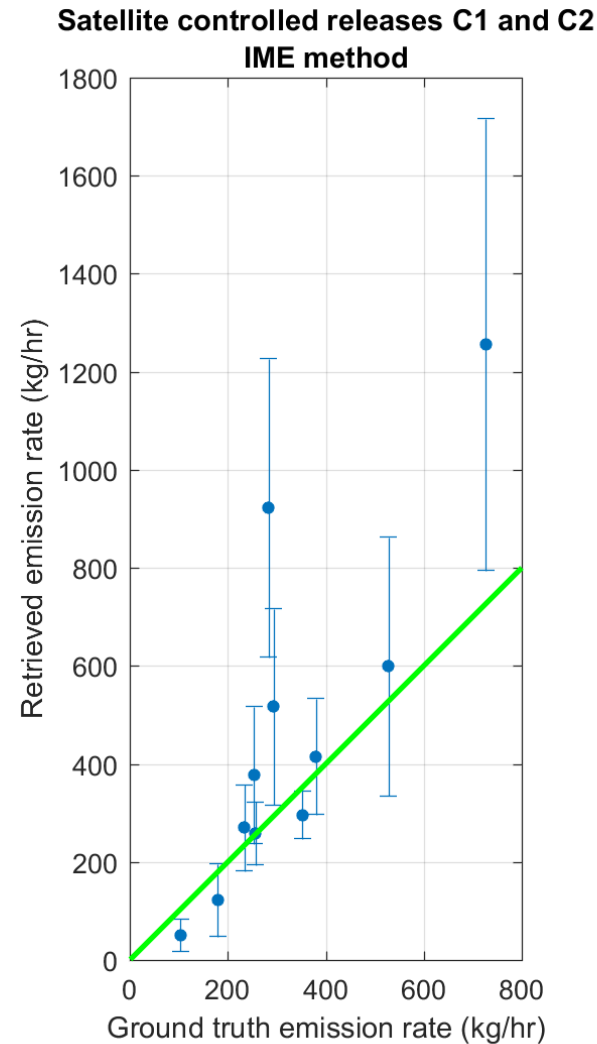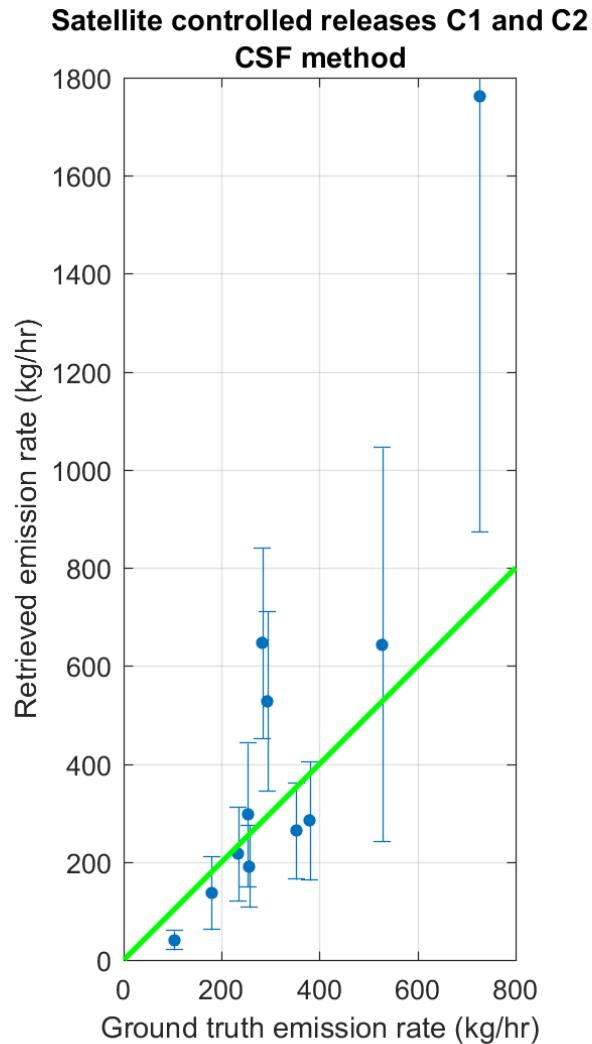# ELEVATION SENSITIVITY WITHIN SCENE   AZ, USA, 2020-09-16

Elevation change between two areas in scene: 540 m
Expected vertical column density change: 38 mmol/m²
Measured vertical column density change: 40 mmol/m²

CAL/VAL: CONTROLLED RELEASES

**Satellite controlled releases C1 and C2
CSF method**

**Satellite controlled releases C1 and C2
IME method**

- Ongoing series of controlled releases by GHGSat in southern Alberta since C1 launch

- Also includes some single-blind releases with customers

- **Lowest rate detected: 103 kg/hr**

- Source rate retrievals: Similar results from cross-sectional flux (CSF) and integrated mass enhancement (IME) methods

- Error typically dominated by wind-related uncertainty

KEY PERFORMANCE METRICS

Column precision

Standard deviation of retrieved CH_4 values in ROI 1:
Achieved: 0.0058 mol/m² ~ 0.85 % bg
Original target: 1% bg

Typical single-cell SNR: 200
Shot-noise limited SNR: 220

Caveat: Errors higher under certain conditions
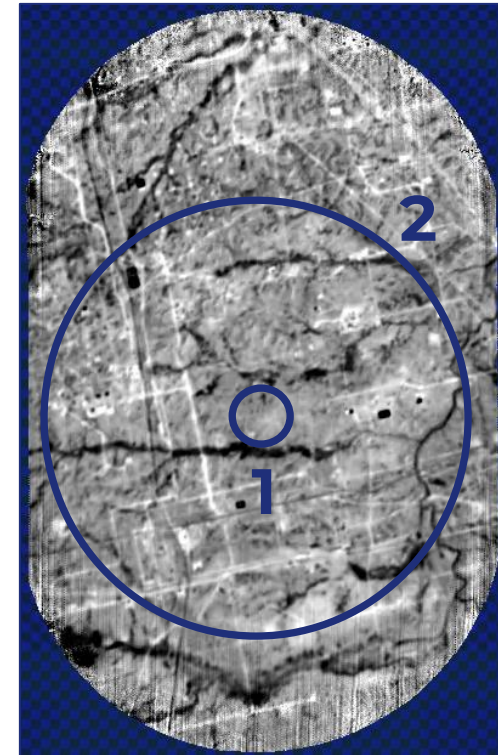(larger ROI2 ~ 1.4 % bg)

Point source detection threshold

Achieved to-date: 103 kg/hr (controlled release)
Original target: 100 kg/hr

Caveat: Small sample, further data and analysis to come

Delaware Basin (TX), April 2021
Retrieved albedo, GHGSat-C2
(No plumes detected)

PLUME DETECTIONS SINCE JANUARY 1, 2021

Measured Emission Rates [tonnes/hr]
- • < 0.5
- • 0.5 - 5
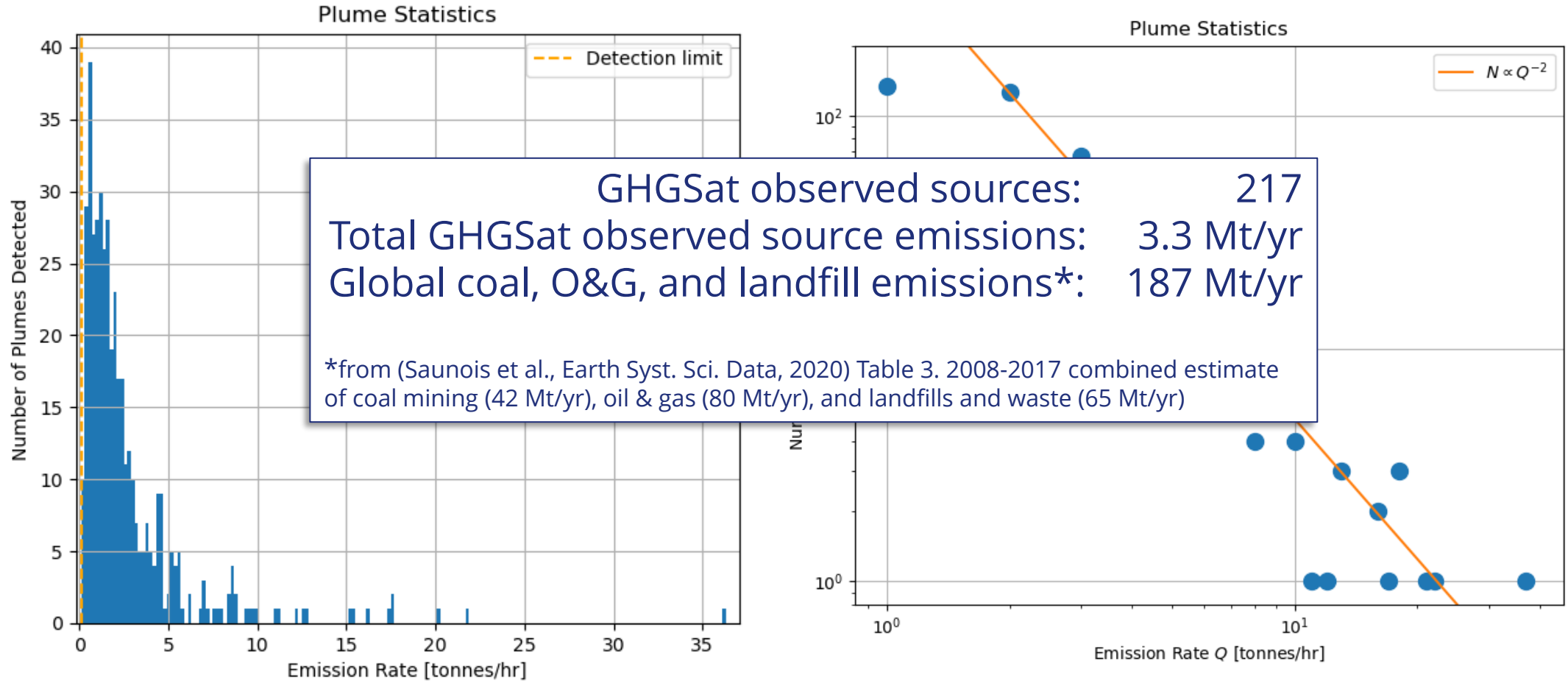- ● 5 - 10
- ● > 10

© Mapbox © OpenStreetMap

©2021 GHGSat Inc.

PLUME DETECTION STATISTICS 2021

Observations January 1 - June 1, 2021

GHGSat observed sources: 217
Total GHGSat observed source emissions: 3.3 Mt/yr
Global coal, O&G, and landfill emissions*: 187 Mt/yr

*from (Saunois et al., Earth Syst. Sci. Data, 2020) Table 3. 2008-2017 combined estimate of coal mining (42 Mt/yr), oil & gas (80 Mt/yr), and landfills and waste (65 Mt/yr)

CONCLUSION AND OUTLOOK

GHGSat's constellation is operational **now**, detecting large methane emitters (>100 kg/hr) worldwide

Potential for **meaningful, immediate impact** (emissions reduction)

Rates from plumes seen in 2021 alone (5 months) add up to 3.3 MtCH4/yr = 3.3 Tg/yr

| 2016 | 2020 | **2021** | 2022-23 |

Approved for public release
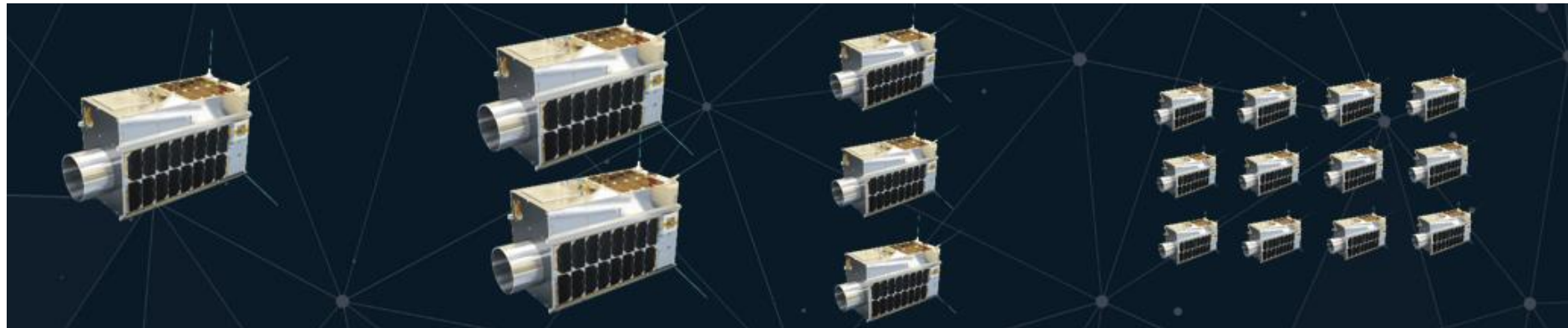
PEER-REVIEWED PUBLICATIONS

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.

THANK YOU