

Global monitoring of oil & gas methane emissions

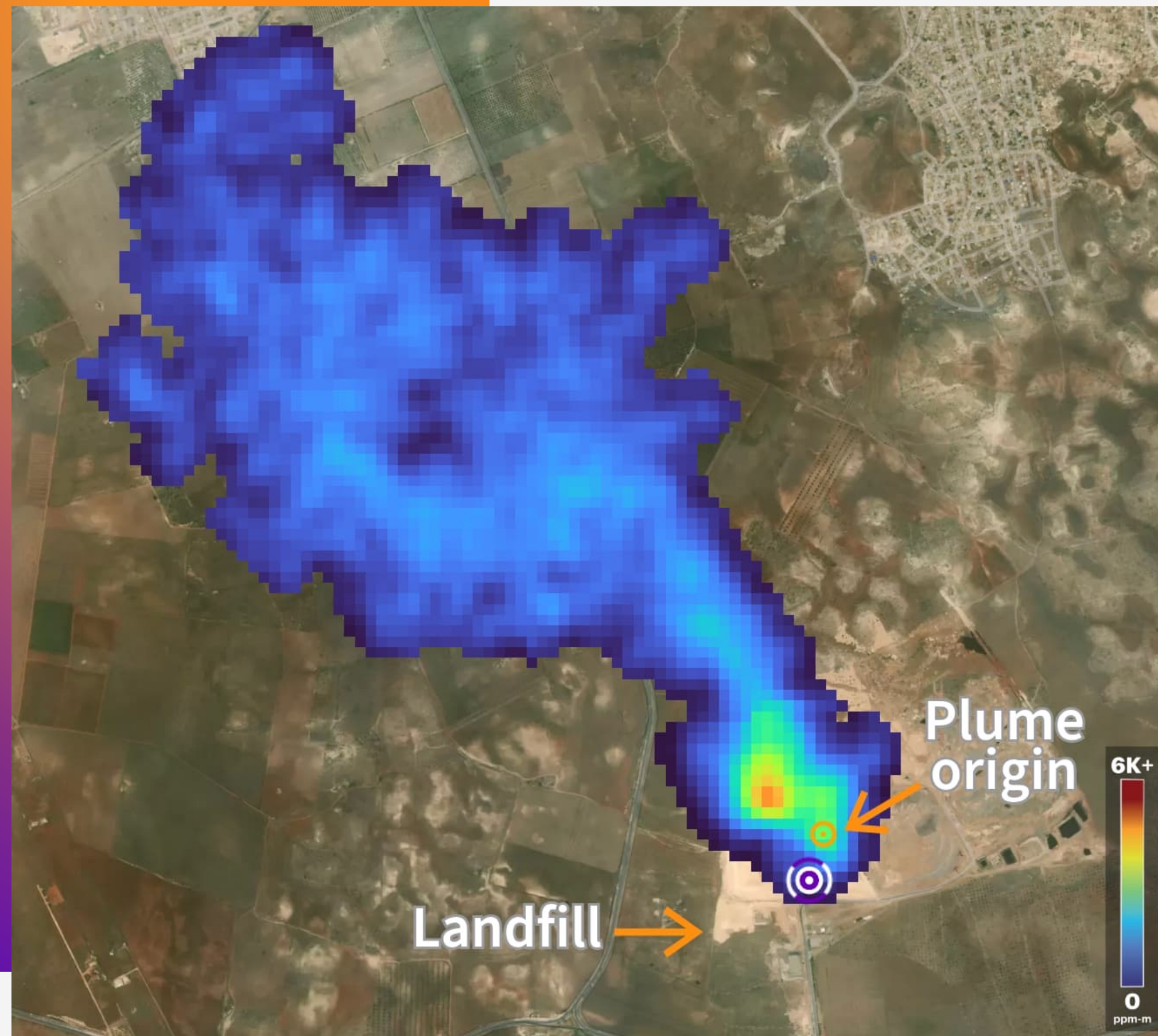


Riley Duren
Founder and CEO
Carbonmapper.org

ABOUT CARBON MAPPER

A non-profit working to to reduce emissions by delivering accessible, actionable methane and carbon dioxide data

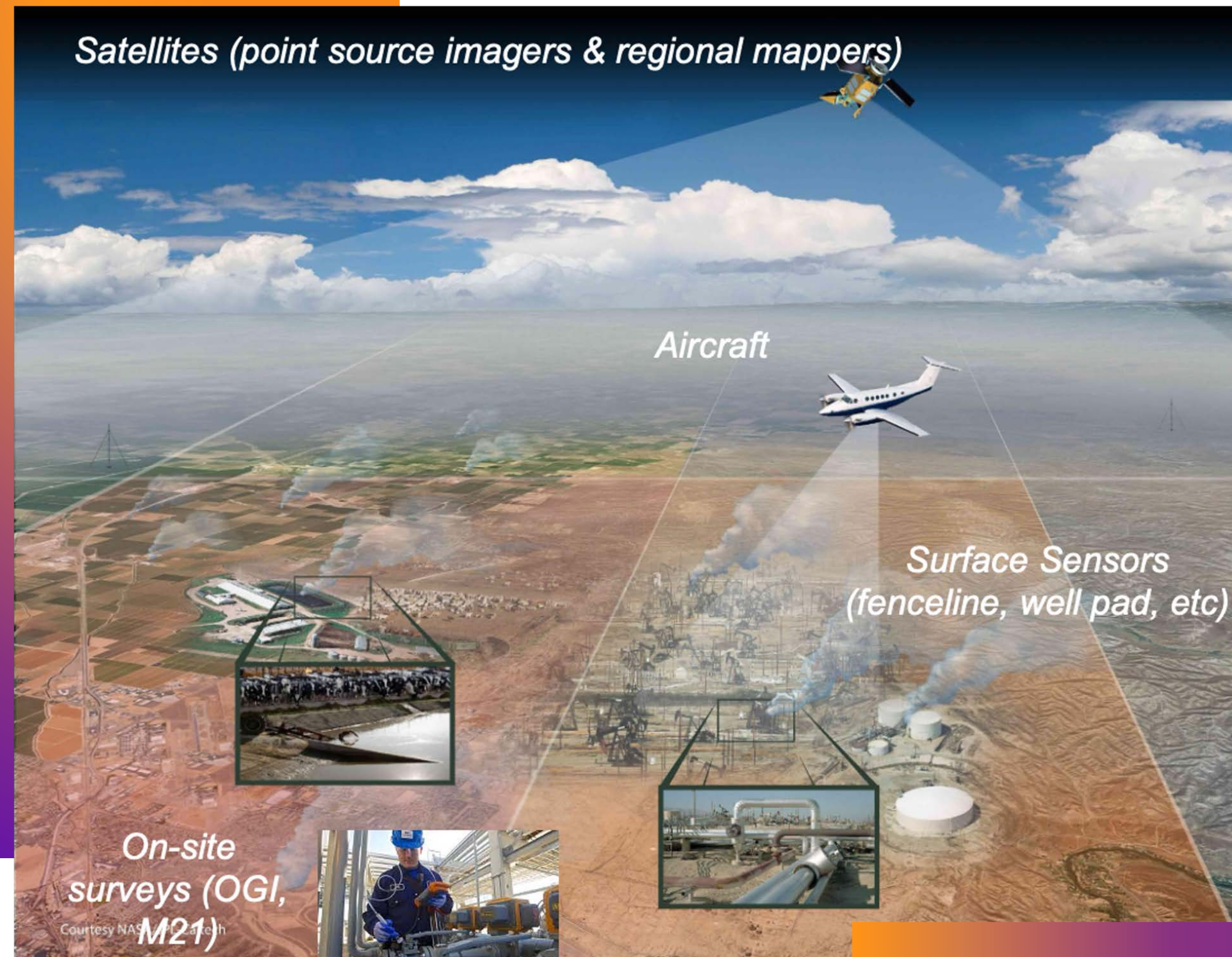
- Leveraging remote sensing technologies, to **detect, pinpoint, and quantify methane and CO2 super-emitters** for effective action
- Launched **first satellite (Tanager-1) in August 2024** - **three more** are being prepared for launch by Planet Labs
- Long-term goal to **monitor 90% of global super-emitters**
- Working with industry, governments and civil society to **translate data into action**
- All methane and CO2 **data publicly available on our portal**



THE EMERGING METHANE MONITORING SYSTEM OF SYSTEMS

Two Main Types of Monitoring

- Direct Mitigation Guidance - use tools that can pinpoint and attribute to specific source for LDAR and process venting reductions
- Aggregate Accounting - use tools that can detect total emissions over large regions and extended supply chains



No single system can measure all methane emissions; need a **portfolio** of methods

CATEGORIES OF METHANE EMISSIONS

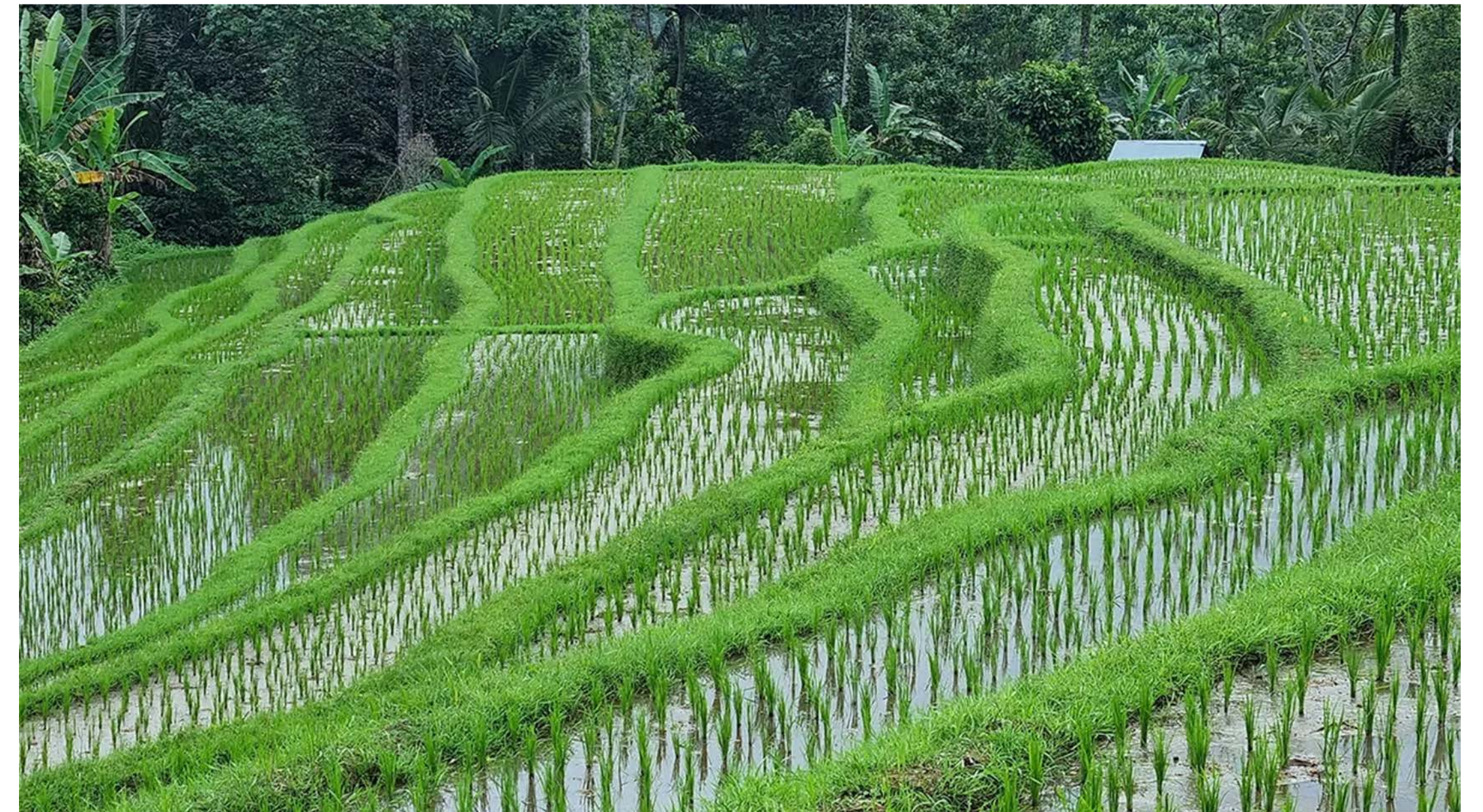
CARBON MAPPER'S FOCUS

Point Source



Emission traced to single origin

Diffuse Source



Emission distributed over an area*

Together point + diffusive sources in a region make up the **total emission flux**

*a large number of dense, small point sources can manifest as a diffuse area source

METHANE SUPER-EMITTER OPPORTUNITY

Methane super-emitters*
can contribute up to

20-60%

of regional emissions

* >30 kgCH₄/hr

**Outsized emission
contributors**

**Super-emitters found in
oil, gas, coal, waste, and
agriculture sectors**

**Addressing super
emitters can also address
public health**

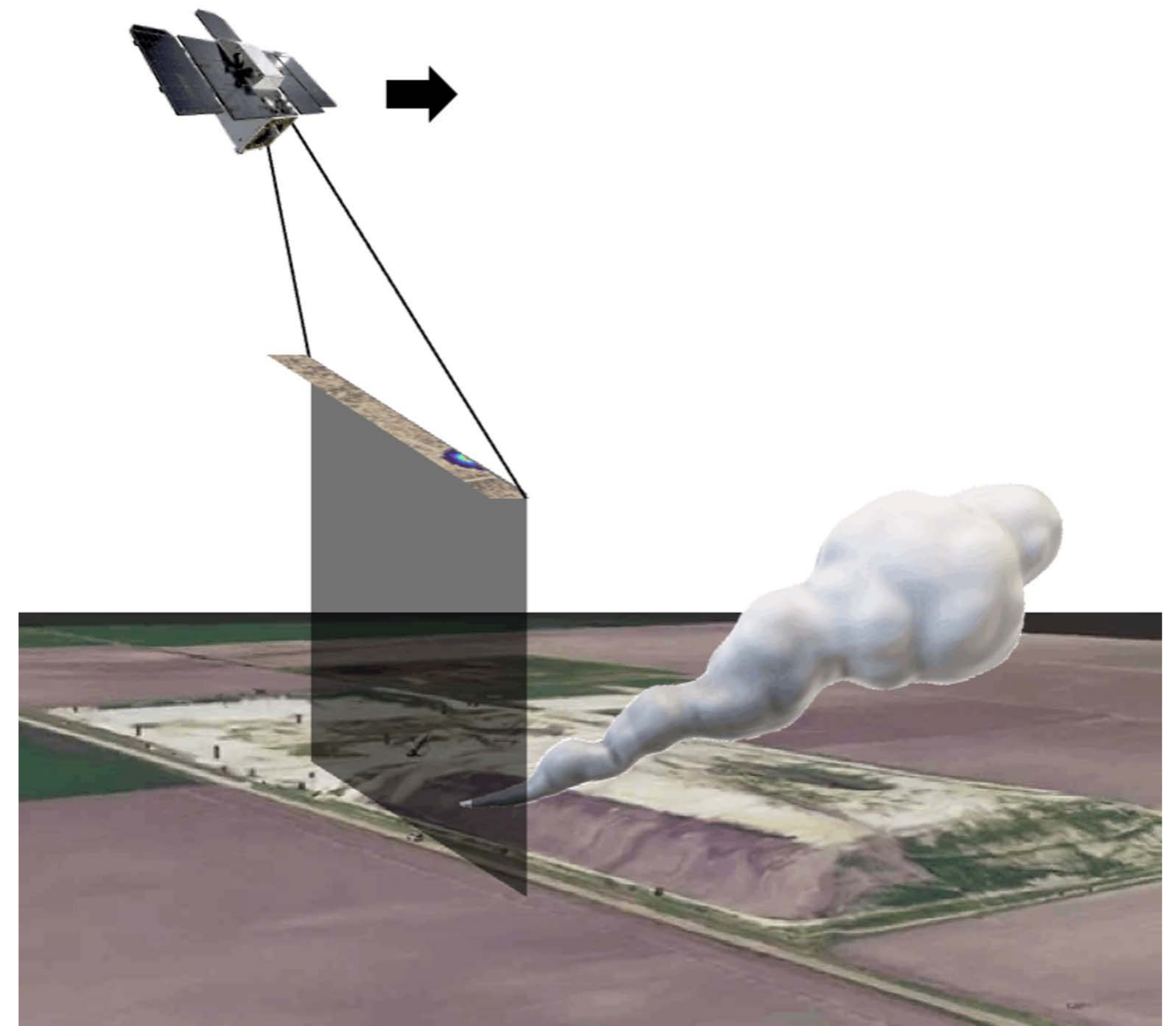
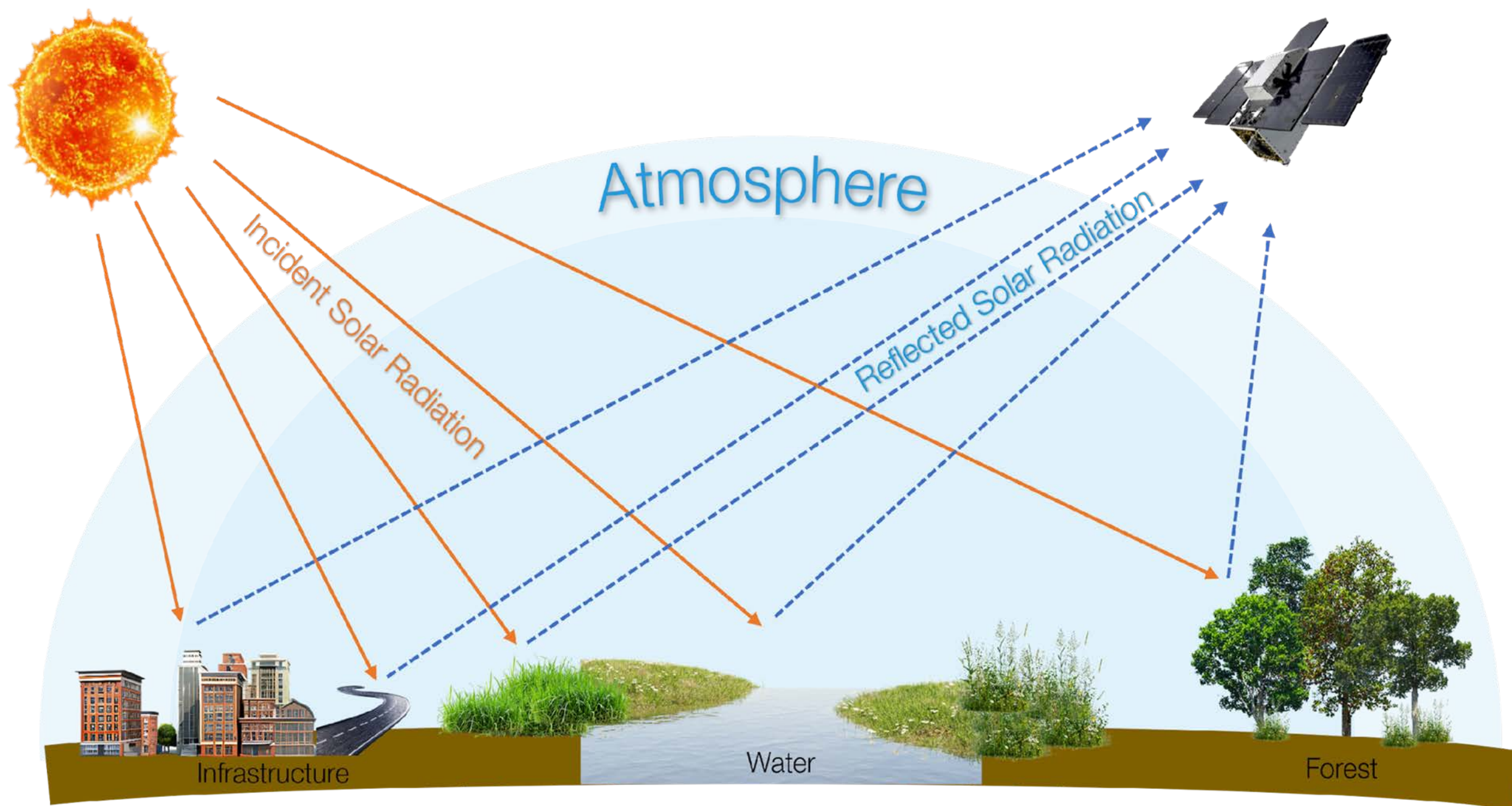
Methane super-emitters detected in Permian, TX

KEY MESSAGE: Mitigation potential hinges on
COMPLETENESS, ACCESSIBILITY, and RESPONSIVITY

METHANE REMOTE SENSING

Passive remote sensing relies on sunlight, so environmental factors like clouds impact our ability to observe sources

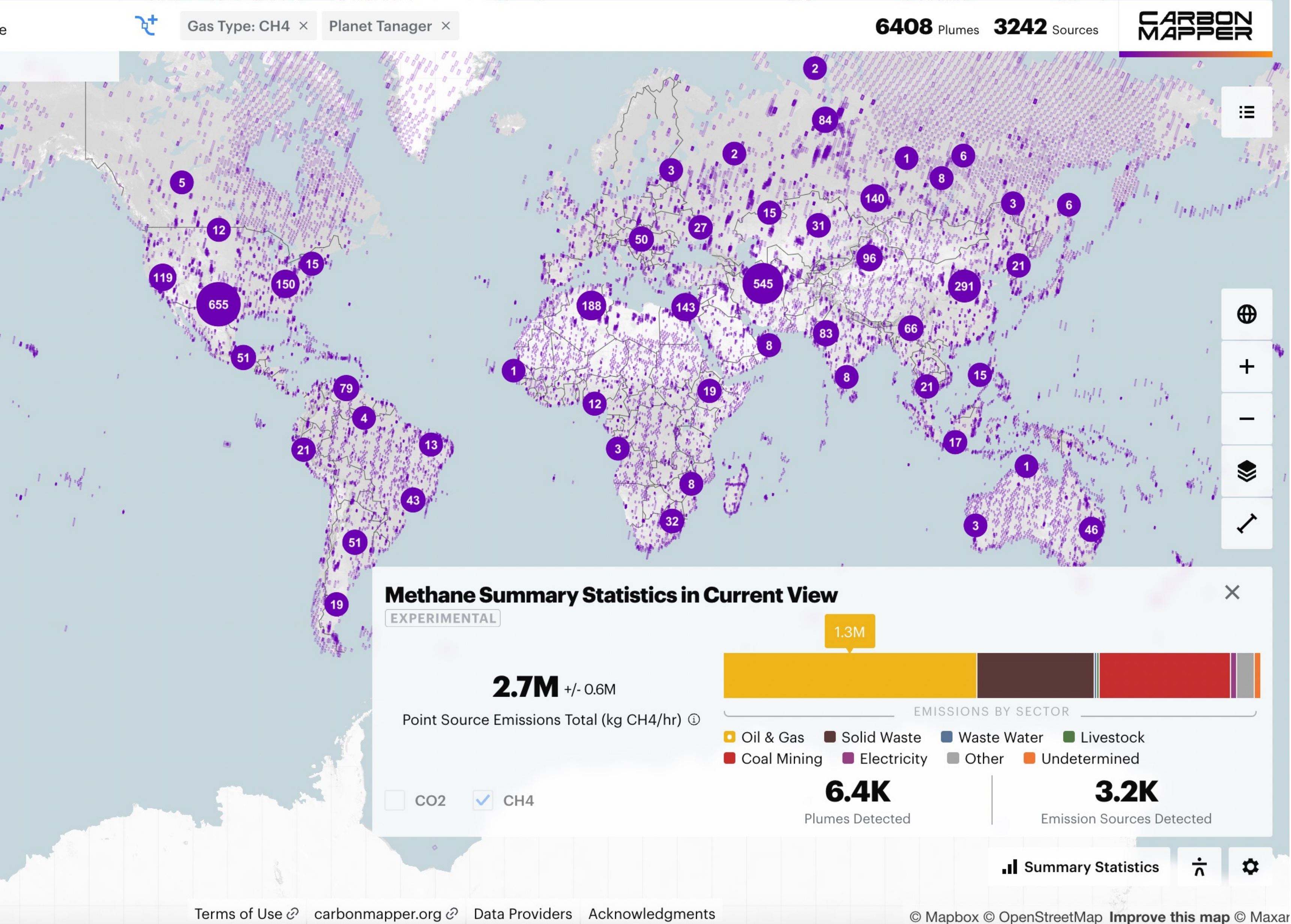
We use imaging spectrometers deployed on aircraft and satellites to detect and quantify CH_4 & CO_2 point sources (as well as flare detection)



KEY MESSAGE: Completeness is a function of detection limit, spatial coverage, and sample frequency

GLOBAL MONITORING & TRANSPARENCY

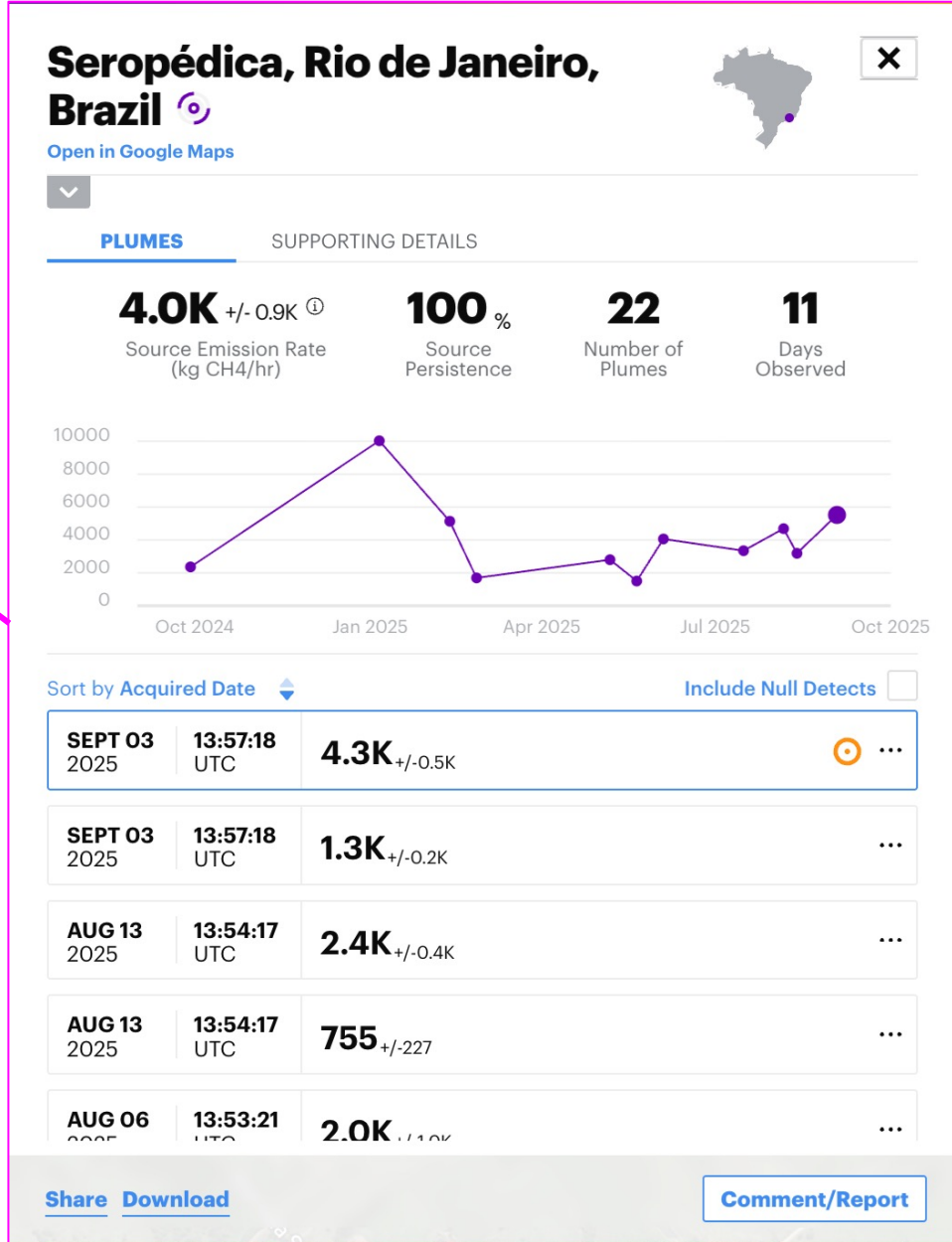
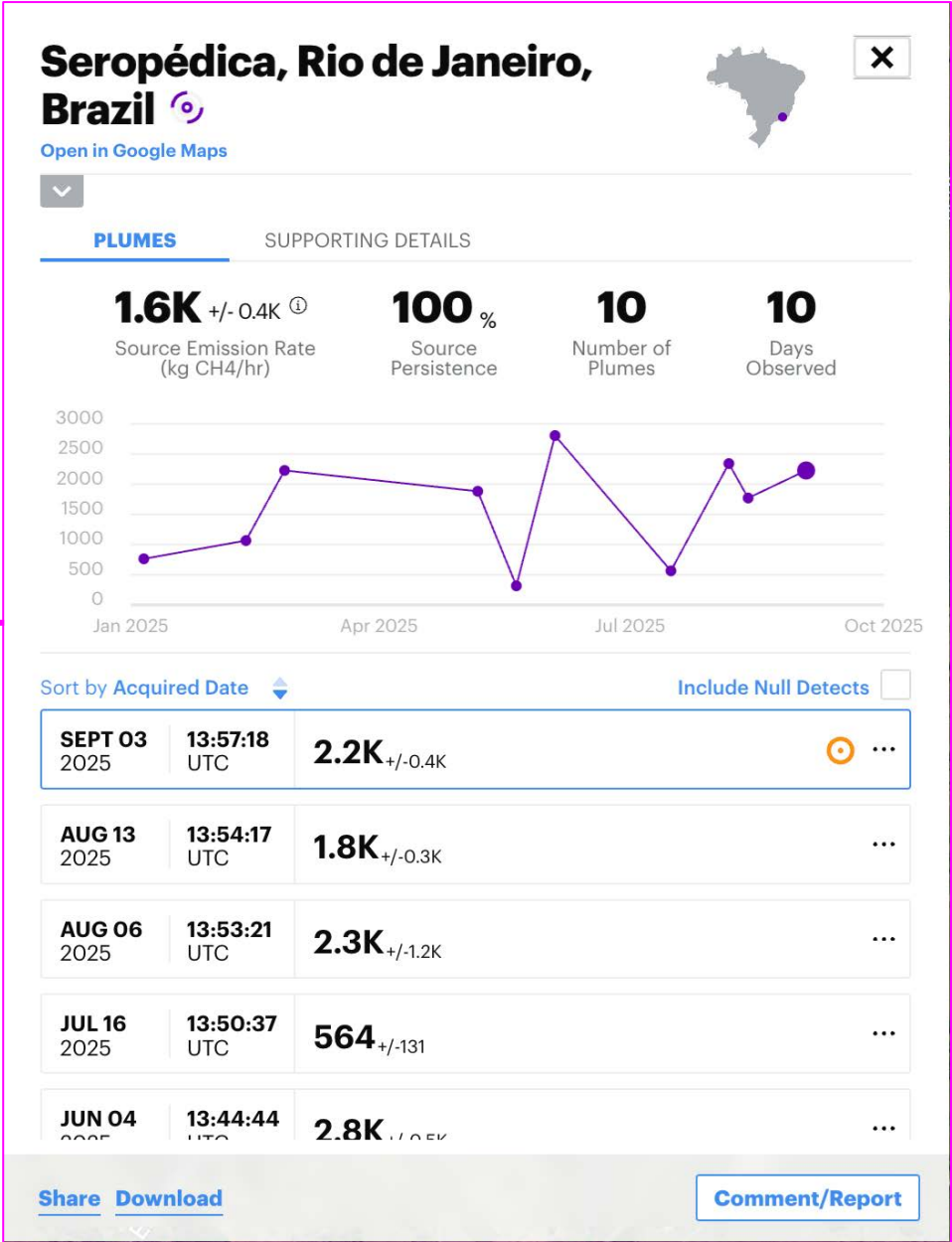
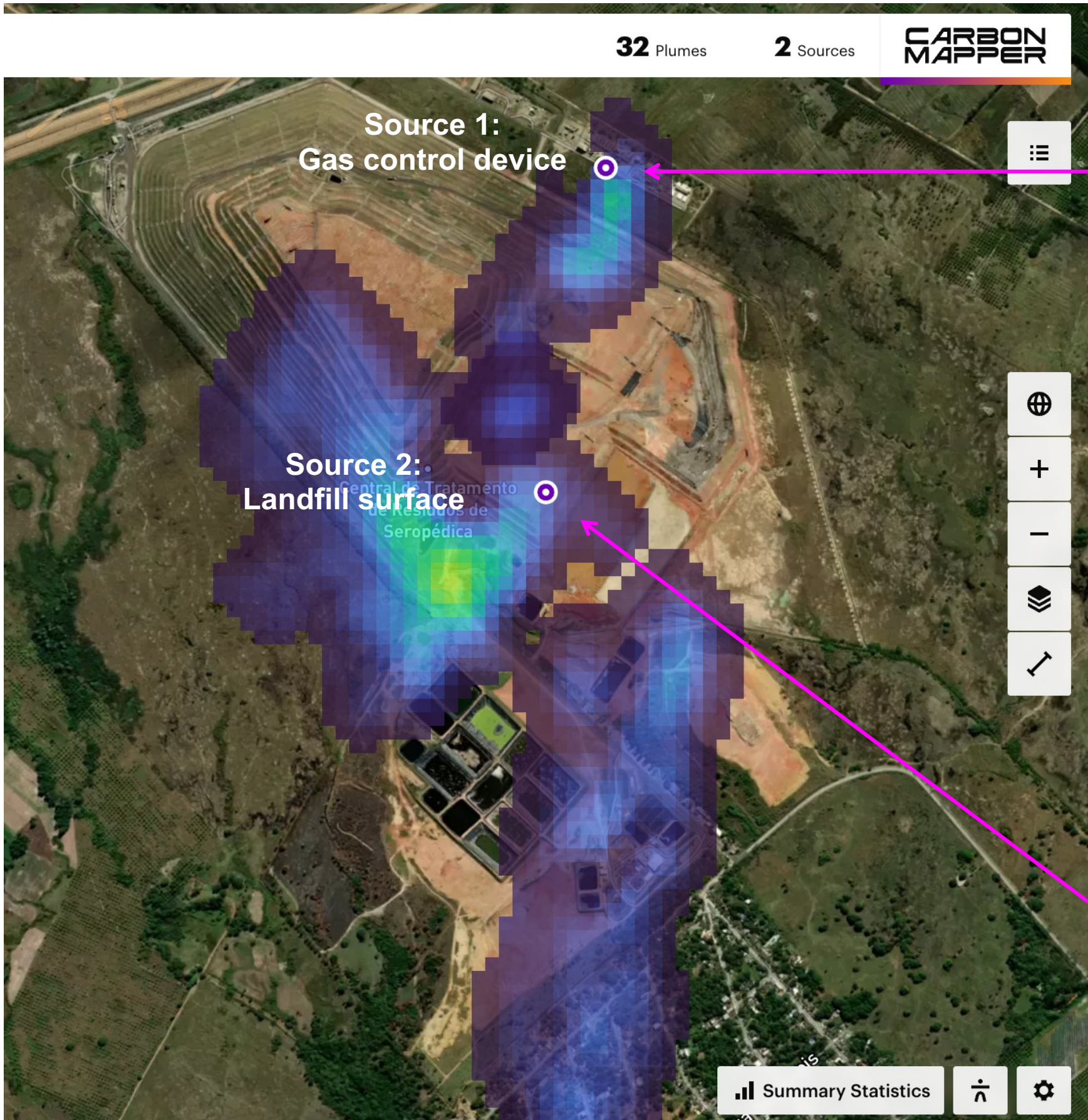
12 months of Tanager-1 observations



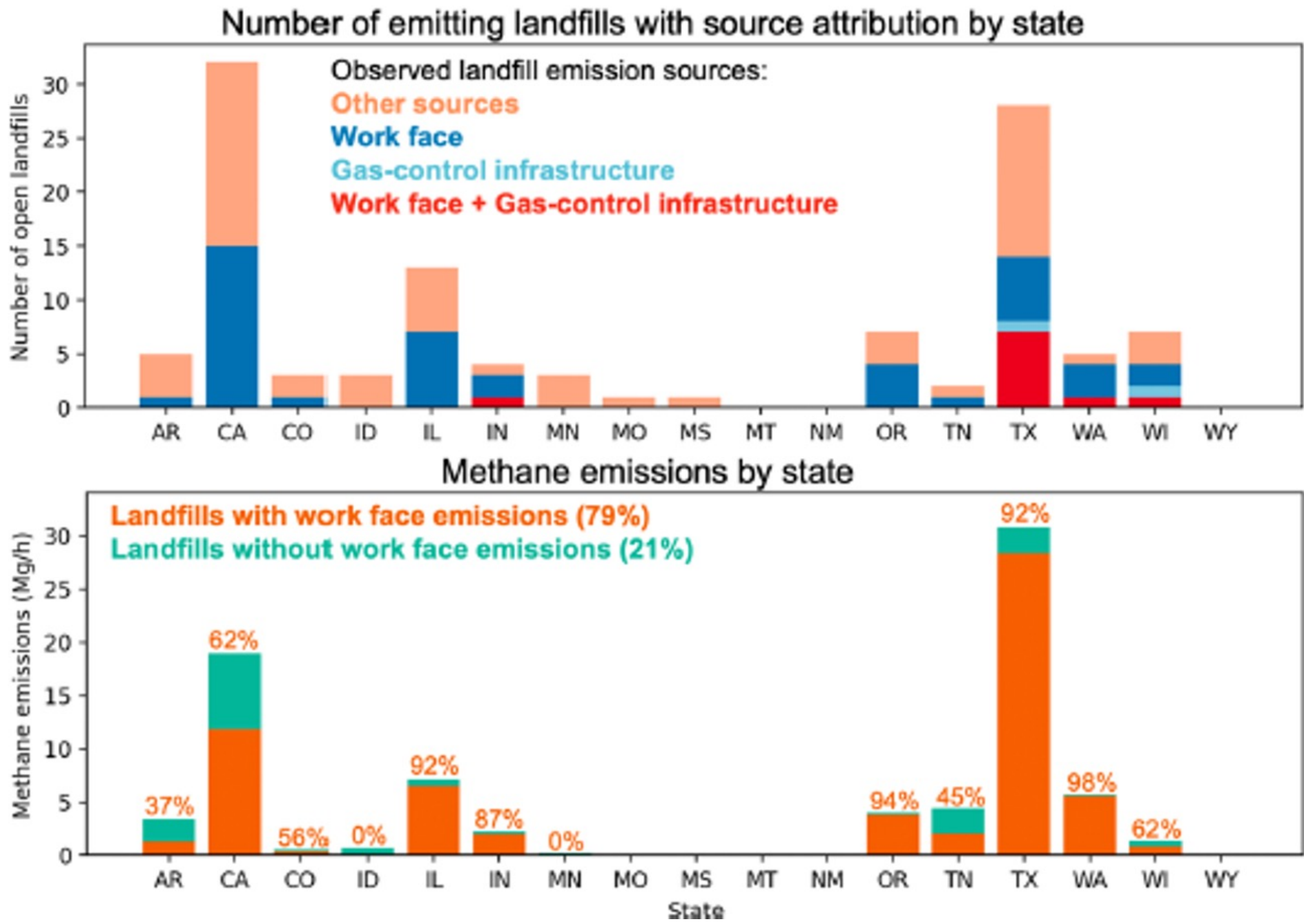
- 30 meter resolution
- 300,000 km2/day/satellite
- 100 kgCH4/hr 90% detection limit
- Ultimate sub-daily frequency
- **All CH4 and CO2 data is public**

data.carbonmapper.org
api.carbonmapper.org

GRANULAR FACILITY-LEVEL INSIGHTS



•Satellites can guide facility level mitigation action and resource prioritization and provide globally consistent data

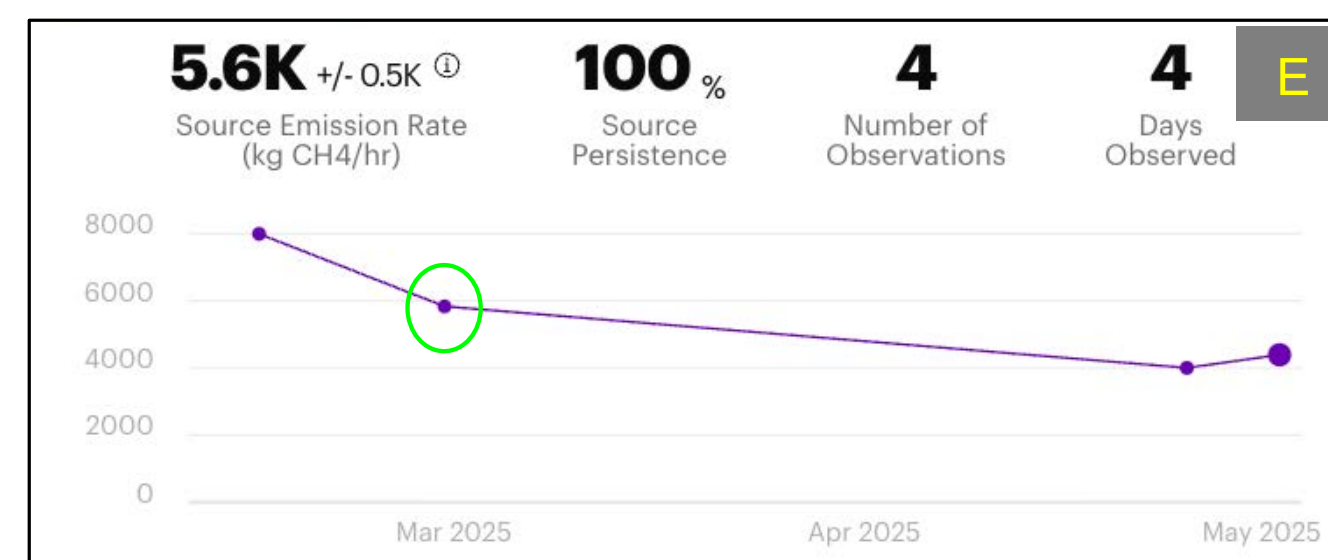
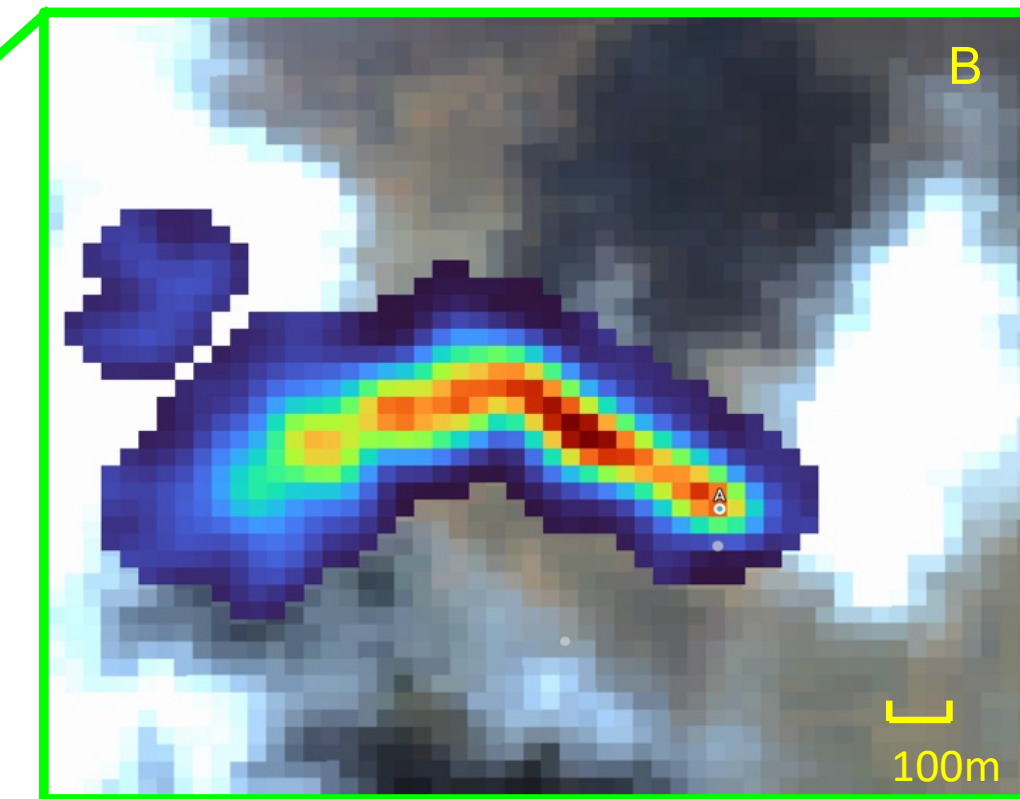


data.carbonmapper.org

Scarpelli et al 2025,
<https://doi.org/10.1021/acs.est.4c07572>

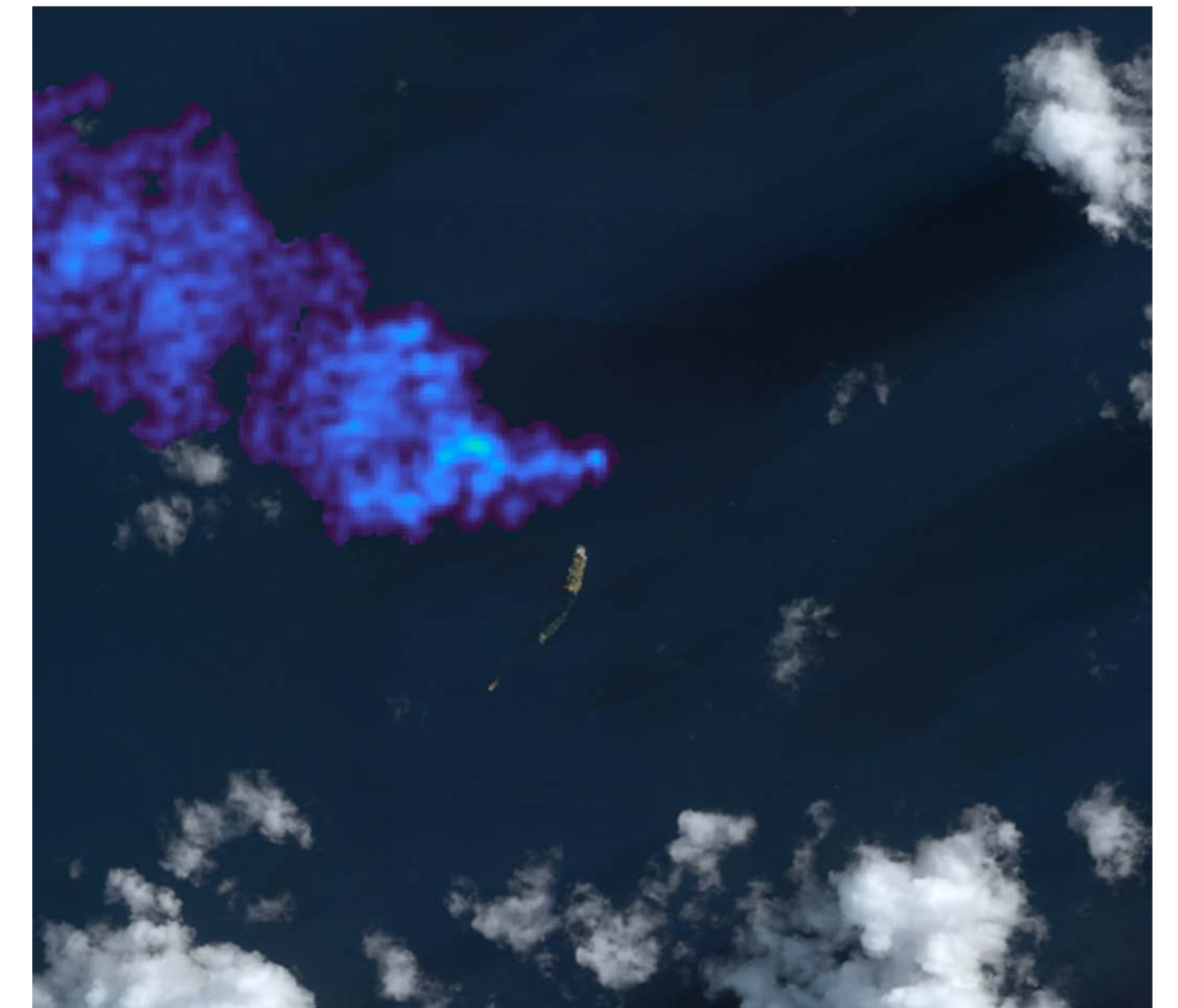
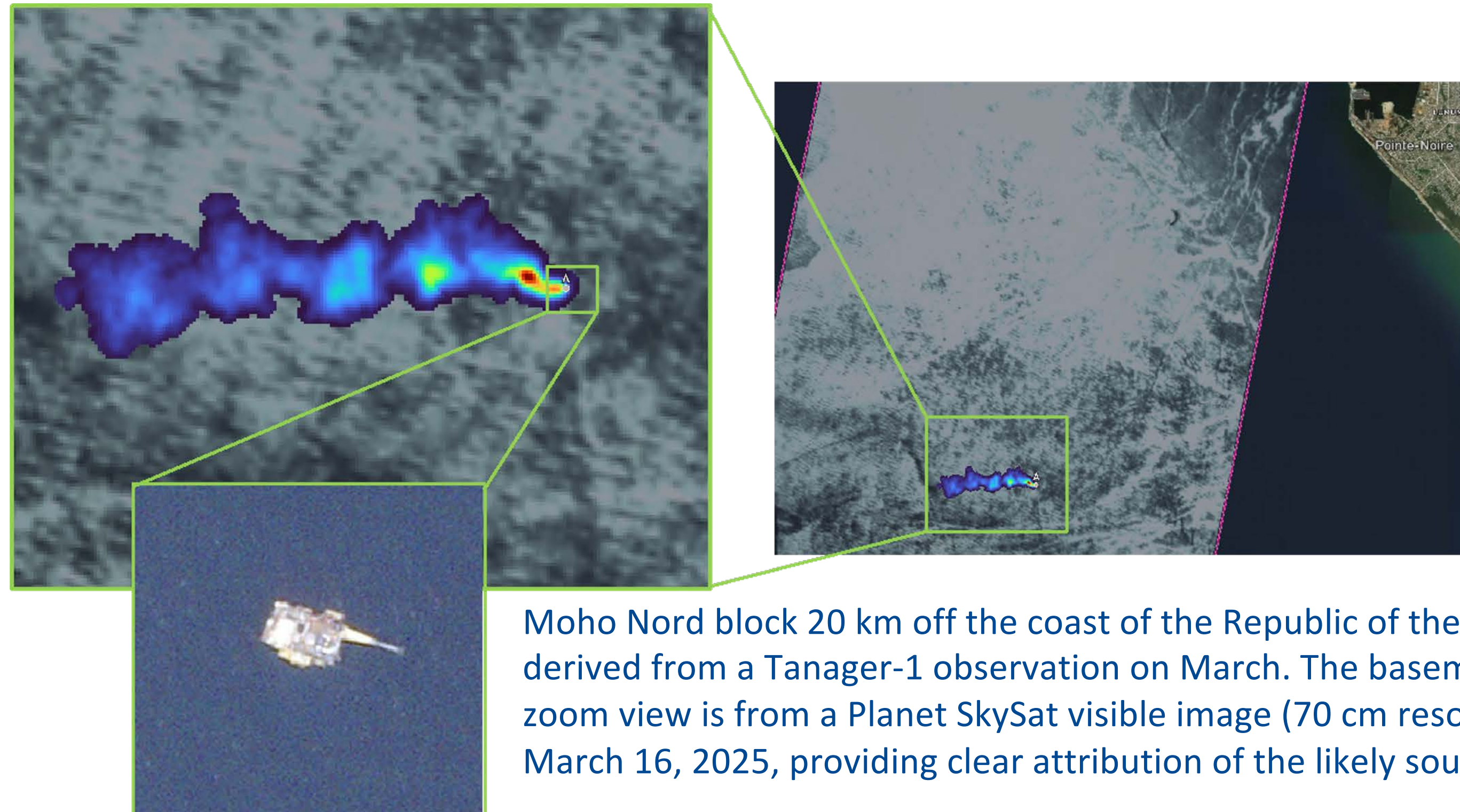
LOOKING THROUGH GAPS IN CLOUDS

Leaking oil well in Venezuela

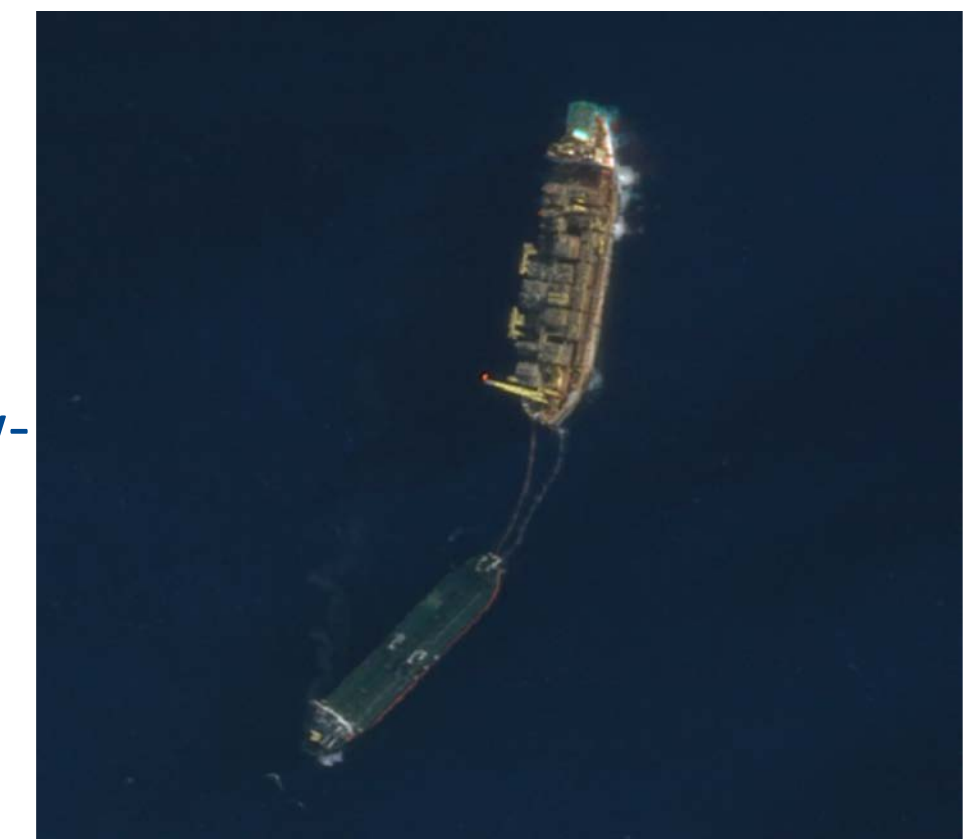


Duren *et al.*, in review

IMAGING OFFSHORE METHANE EMISSIONS

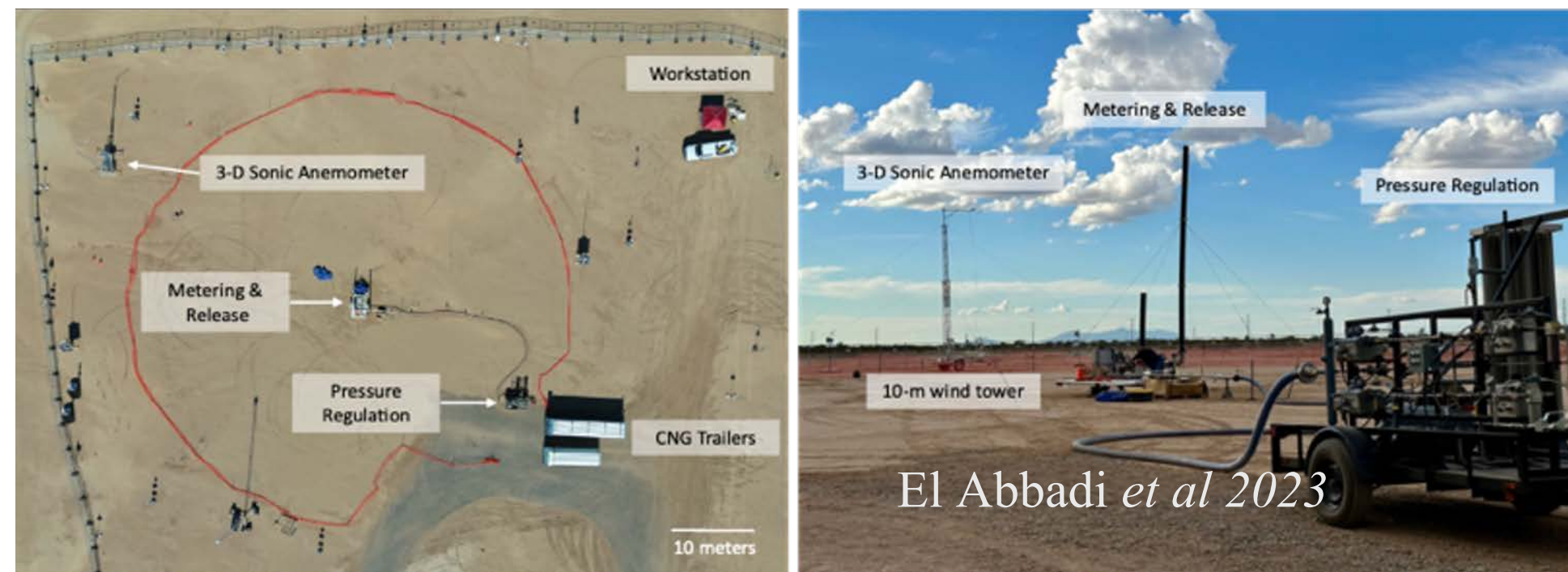


Similar example in Brazilian waters showing drilling ships and tankers revealed by follow-up SkySat tasking

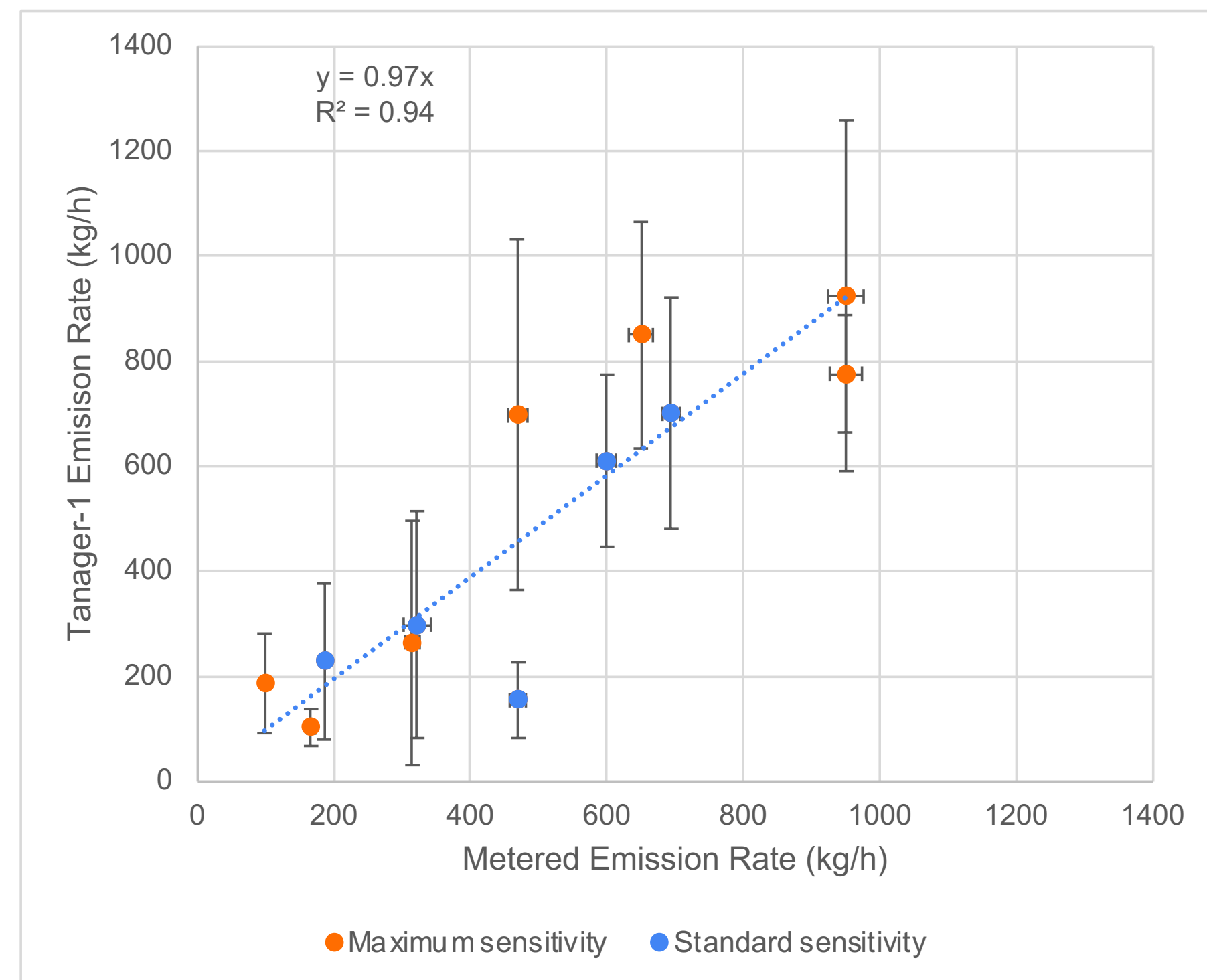
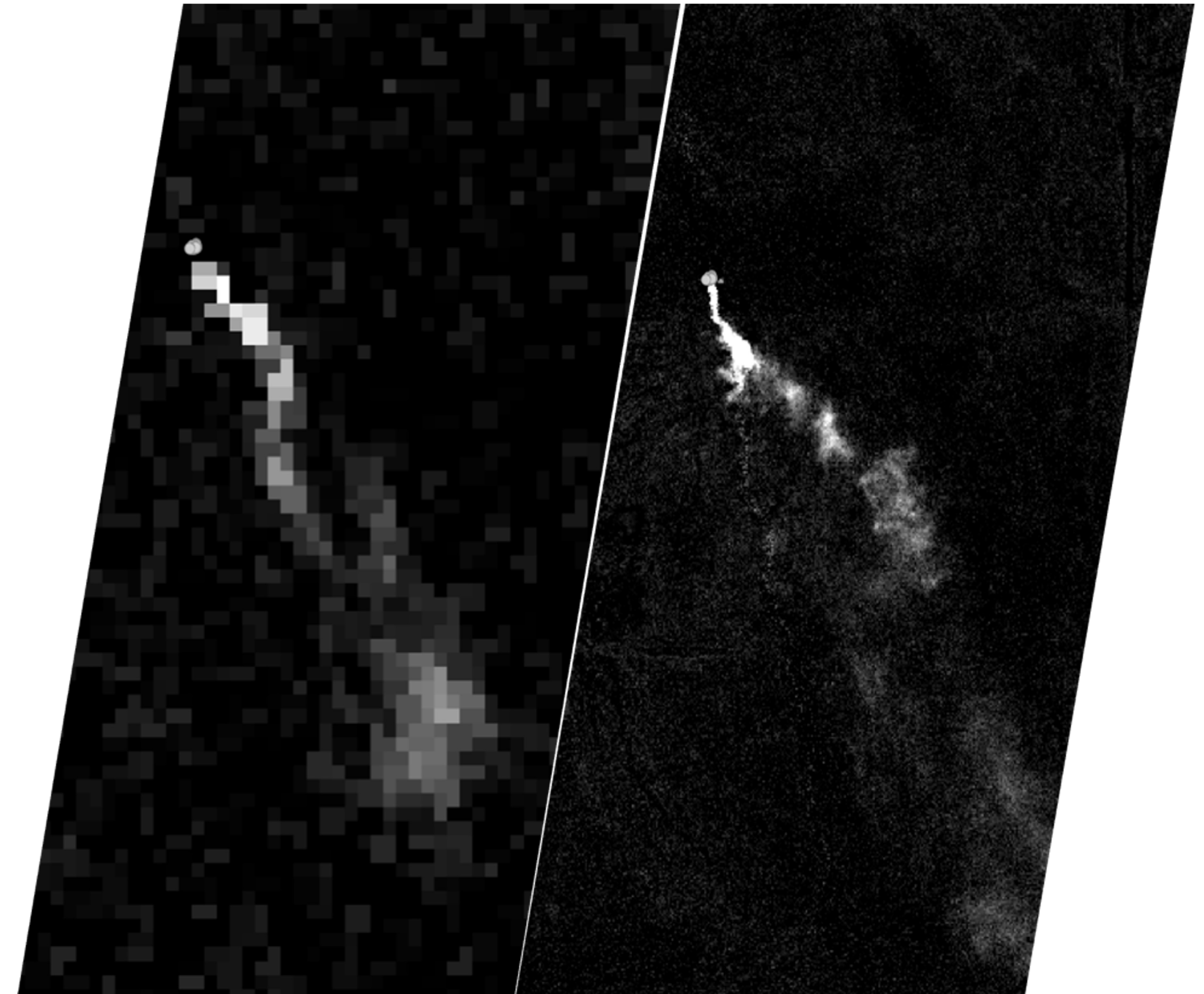


MEASUREMENT METHODS VALIDATED BY INDEPENDENT TESTING

Controlled Release Test Site in Arizona



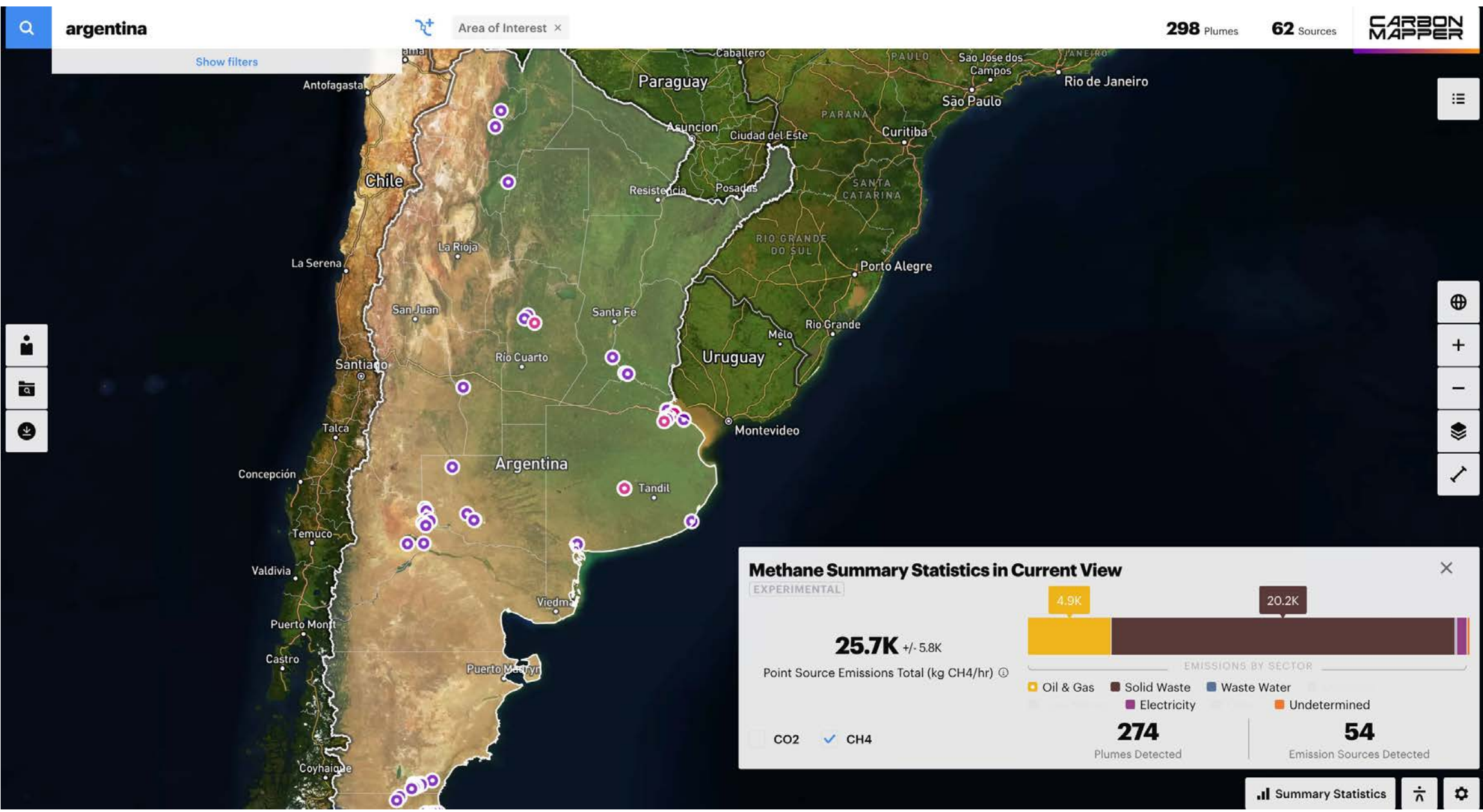
Simultaneous measurements of controlled release test by satellite and aircraft



Duren *et al* in review

All of our methane data and methods are PUBLIC

SUPER-EMITTER STATISTICS BY JURISDICTION



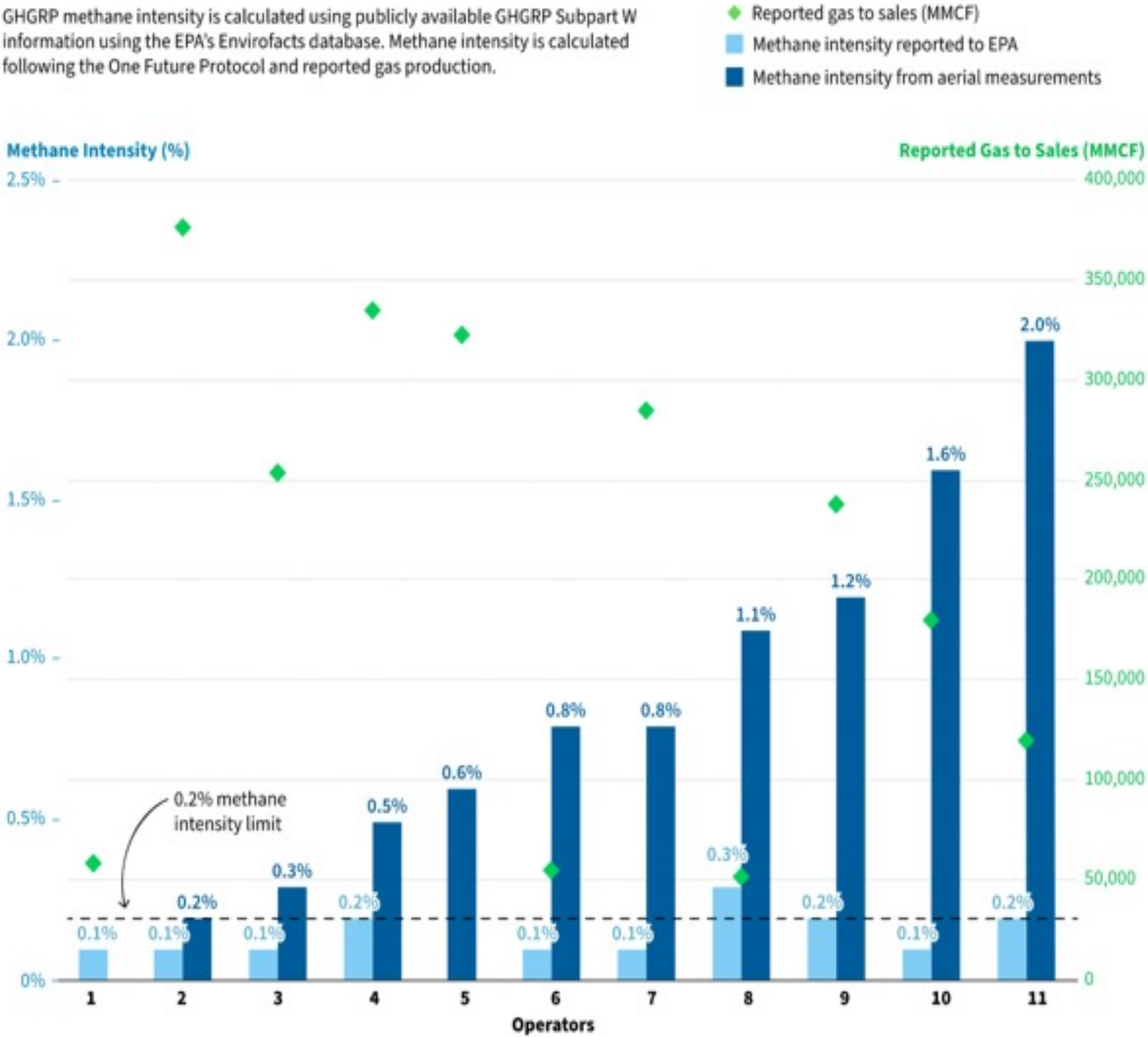
INTENSITY METRICS → DIFFERENTIATED SUPPLY CHAINS

EDF & Carbon Mapper collaboration to quantify Permian super-emitter intensities

Exhibit 1: Super-emitter observations vs. reported emissions.

Super-emitter observations vs. reported emissions - 2020 Permian facility methane intensities and reported gas to sales

GHGRP methane intensity is calculated using publicly available GHGRP Subpart W information using the EPA's Envirofacts database. Methane intensity is calculated following the One Future Protocol and reported gas production.



METHANE INTENSITY OF MAJOR PRODUCERS IN THE STUDY REGIONS

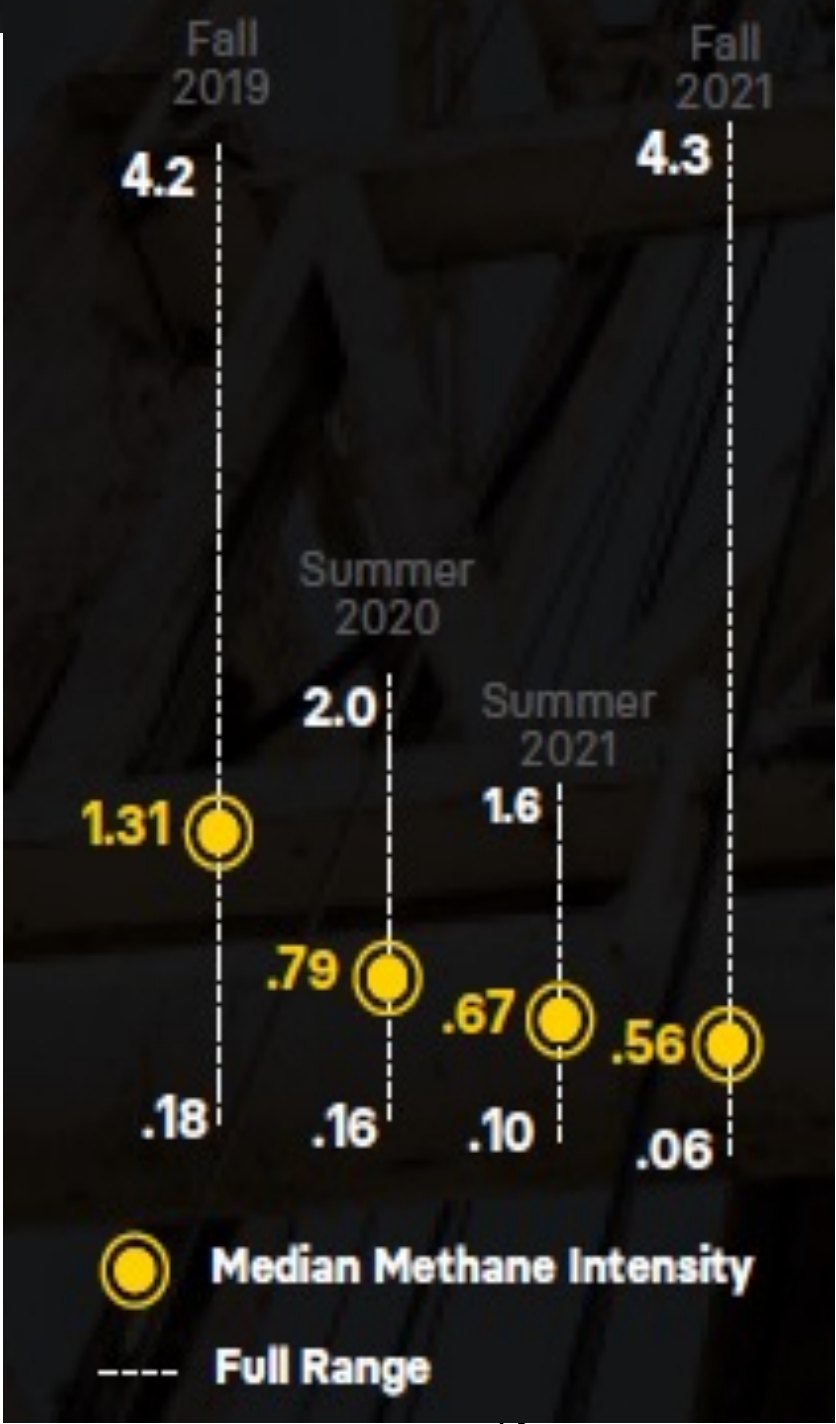
Average % of gas lost from super-emitting sites during aerial campaigns

0%			2.7%
LOW	MEDIUM	HIGH	
.1% - .7%	.7% - 1.4%	1.4% - 2.7%	
Chevron Coterra EOG Exxon Pioneer	ConocoPhillips Diamondback Occidental Shell	BP BTA Devon Endeavor Mewborne	

Hmiel et al., 2023

CHANGES IN METHANE EMISSION INTENSITY

Four assessments conducted between 2019-2021



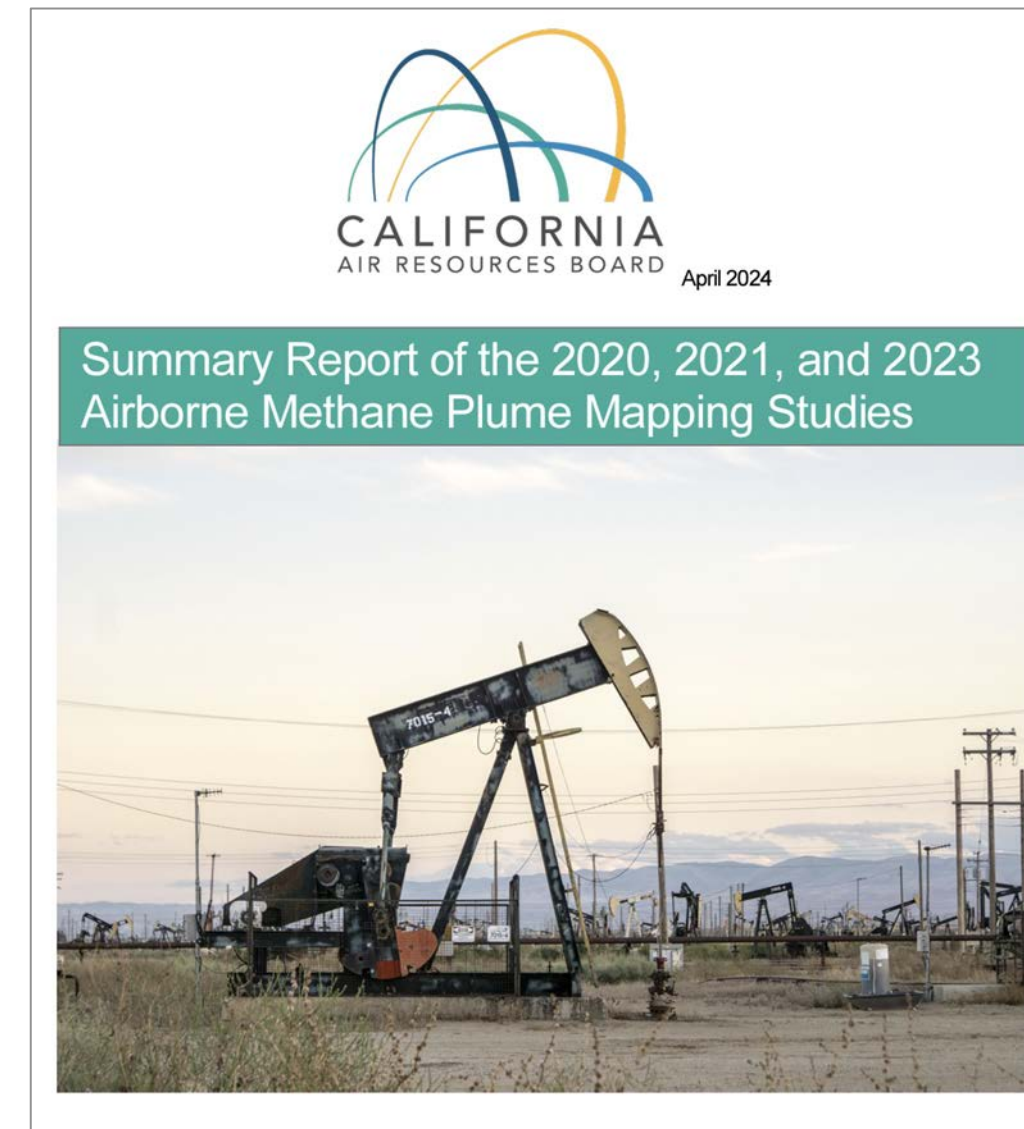
TRANSLATING DATA INTO ACTION

Supporting national and sub-national governments

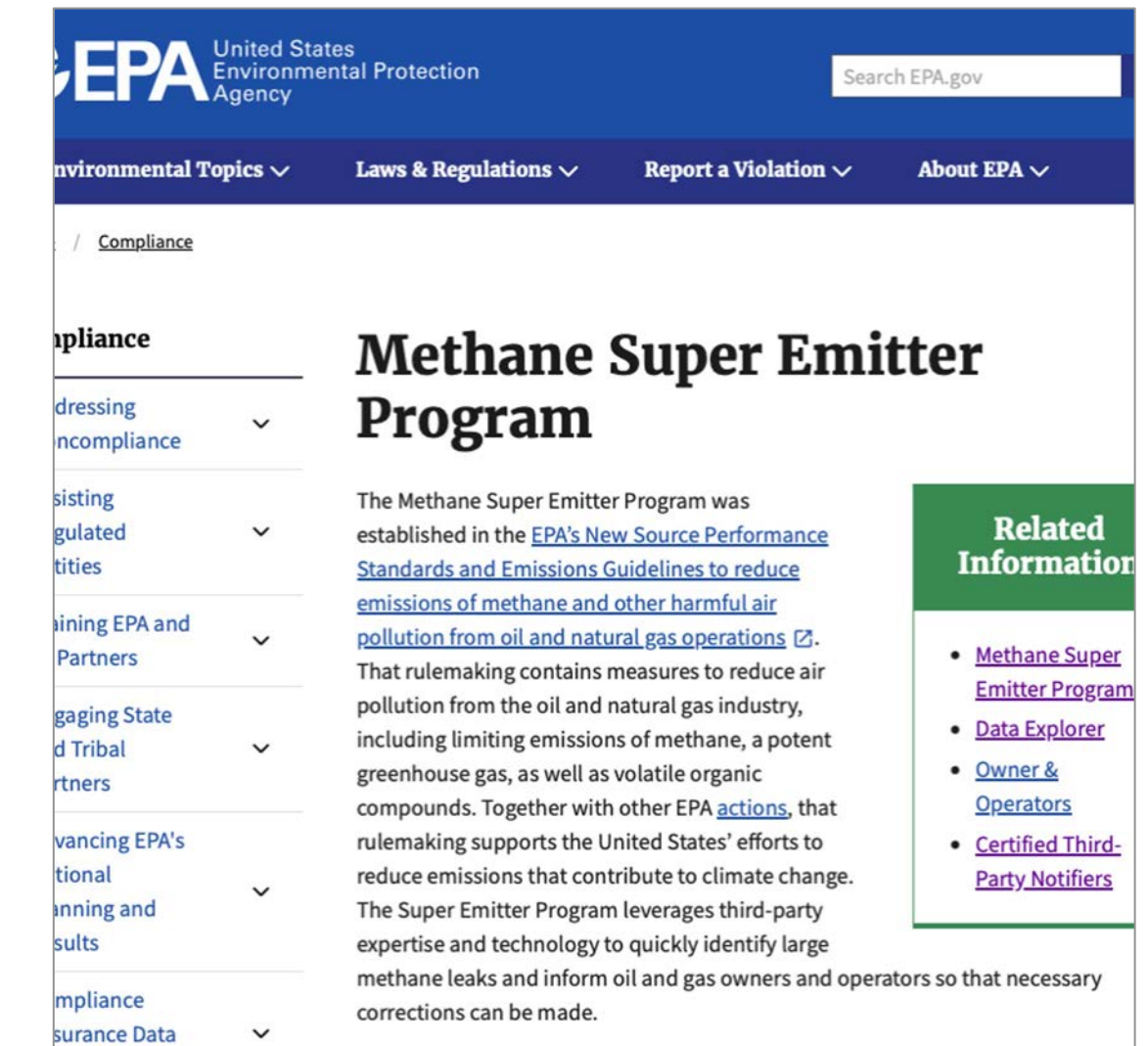
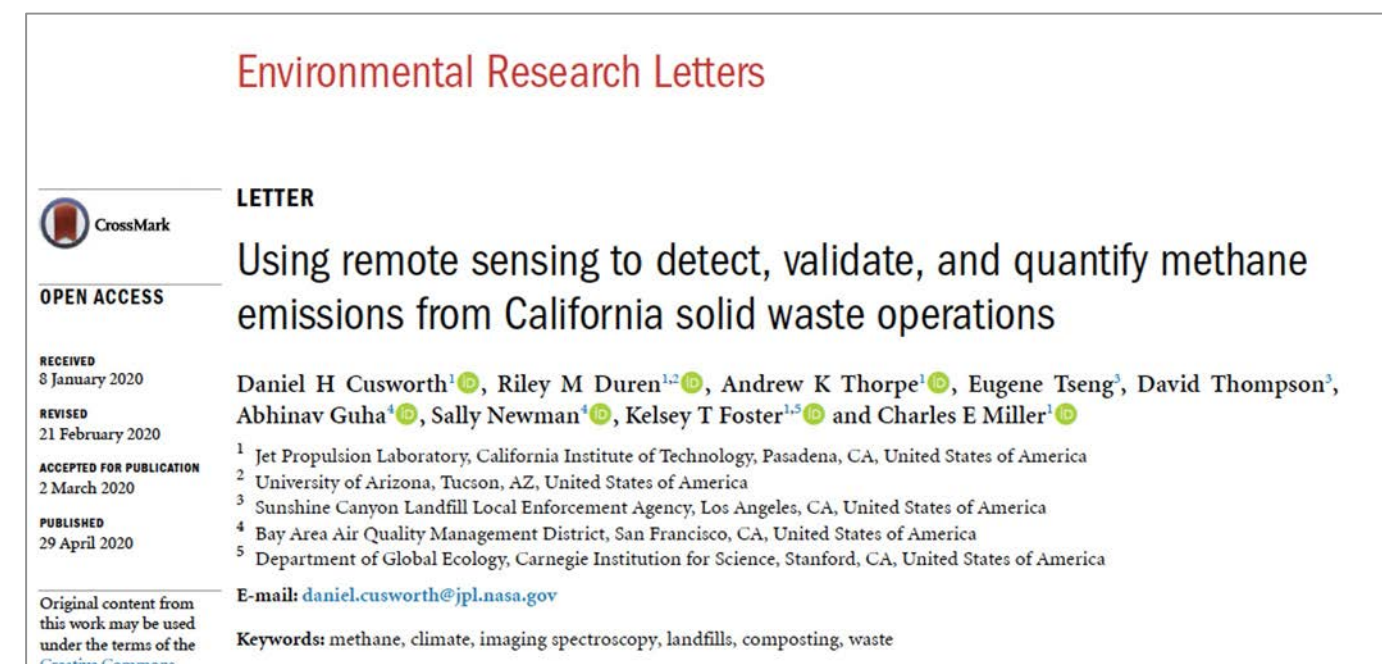
Our data empowers decision-makers with the granularity needed to pinpoint where emissions are coming from and the speed to enable rapid action.

Data is one piece of the puzzle - our science and impact teams work with stakeholders and partners to **bridge the data-to-action gap.**

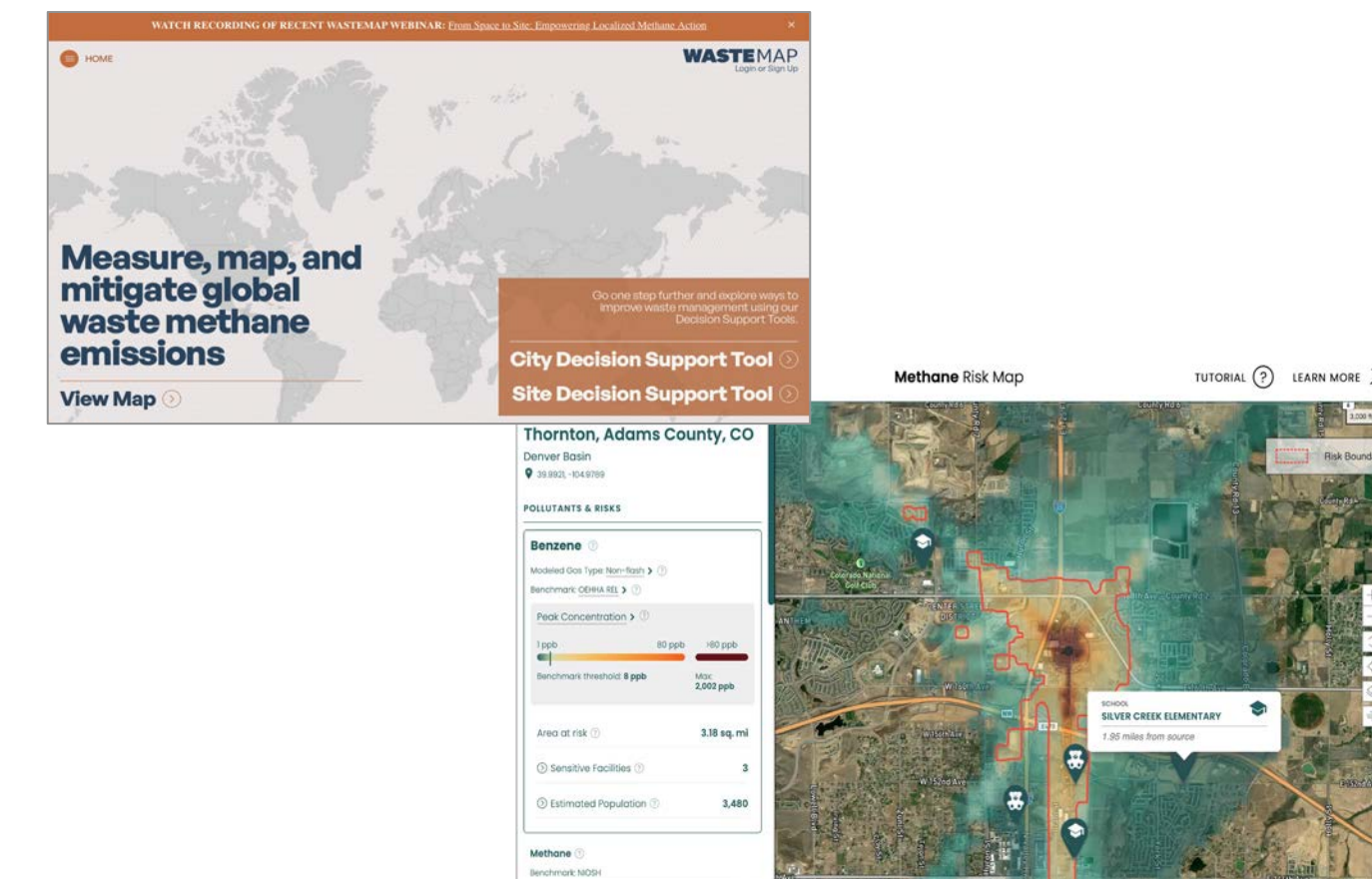
Working to expand international partnerships with IMEO, OLADE, GMH et al



Working with private and public operators

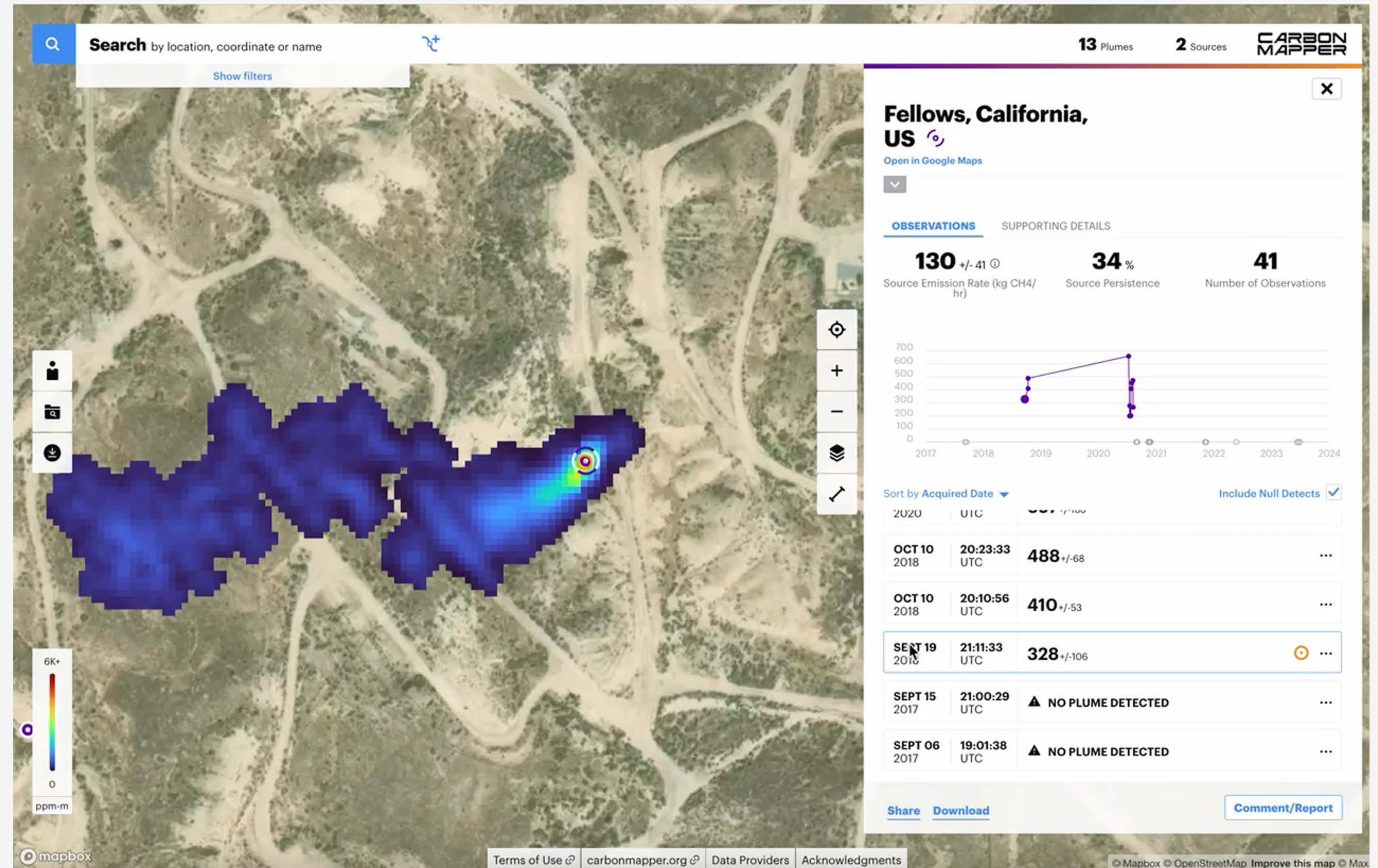


Partnering with civil society on data-to-action tools



LEAK DETECTION & REPAIR SUCCESSES

- Over 300 incident engagements with regulators and emitters in US to date
- Pinpoint within 30 meters; notify in < 72 hs for subscribers, 30 days for all
- Operator feedback: half of reported super-emitters previously unknown
- Over 150 voluntary leak repairs to date
- Many verified with follow-up monitoring
- Planned expansion with IMEO MARS



KEY MESSAGE: Emitters can be responsive and take action when properly incentivized, resourced, & engaged by notifiers

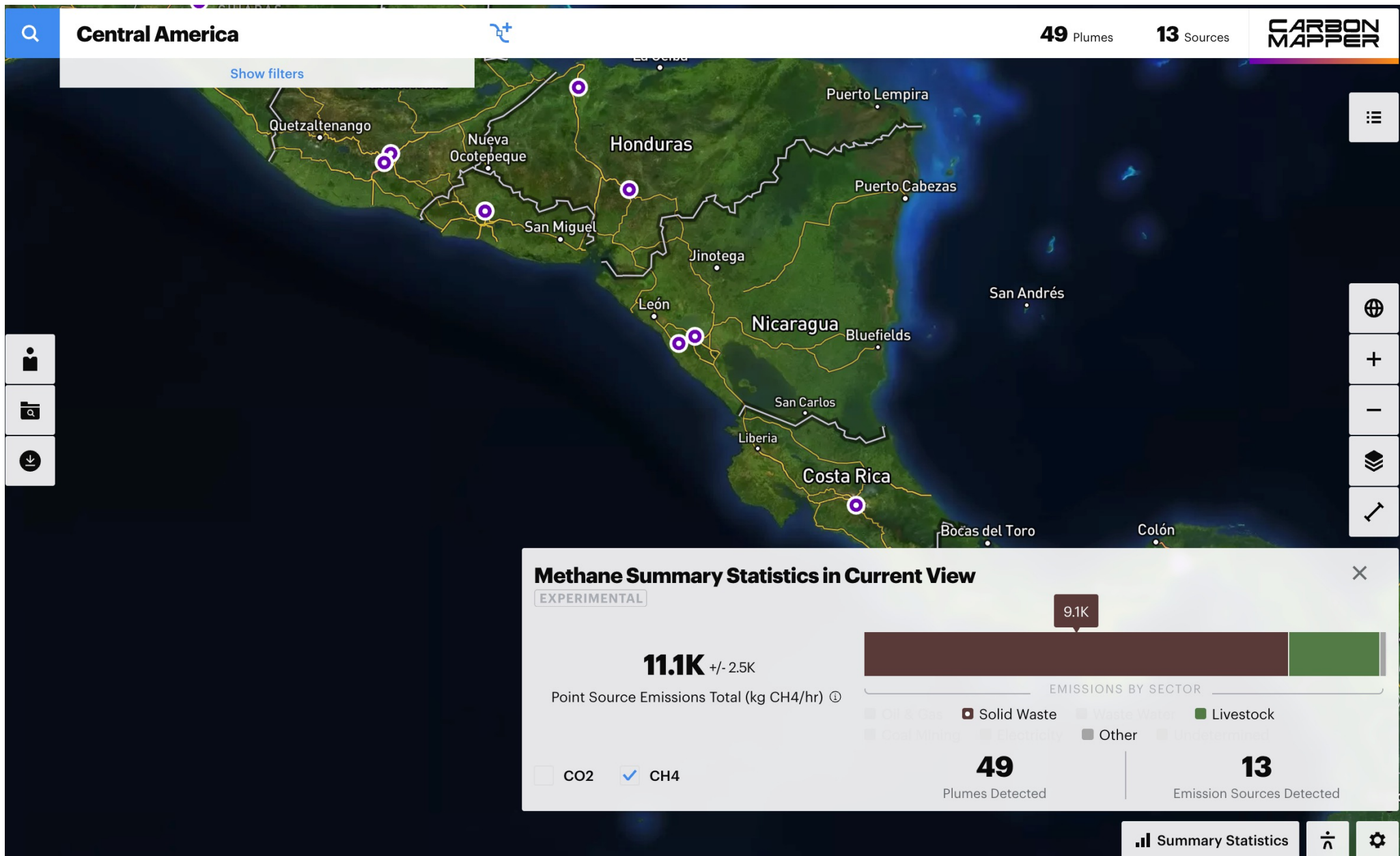
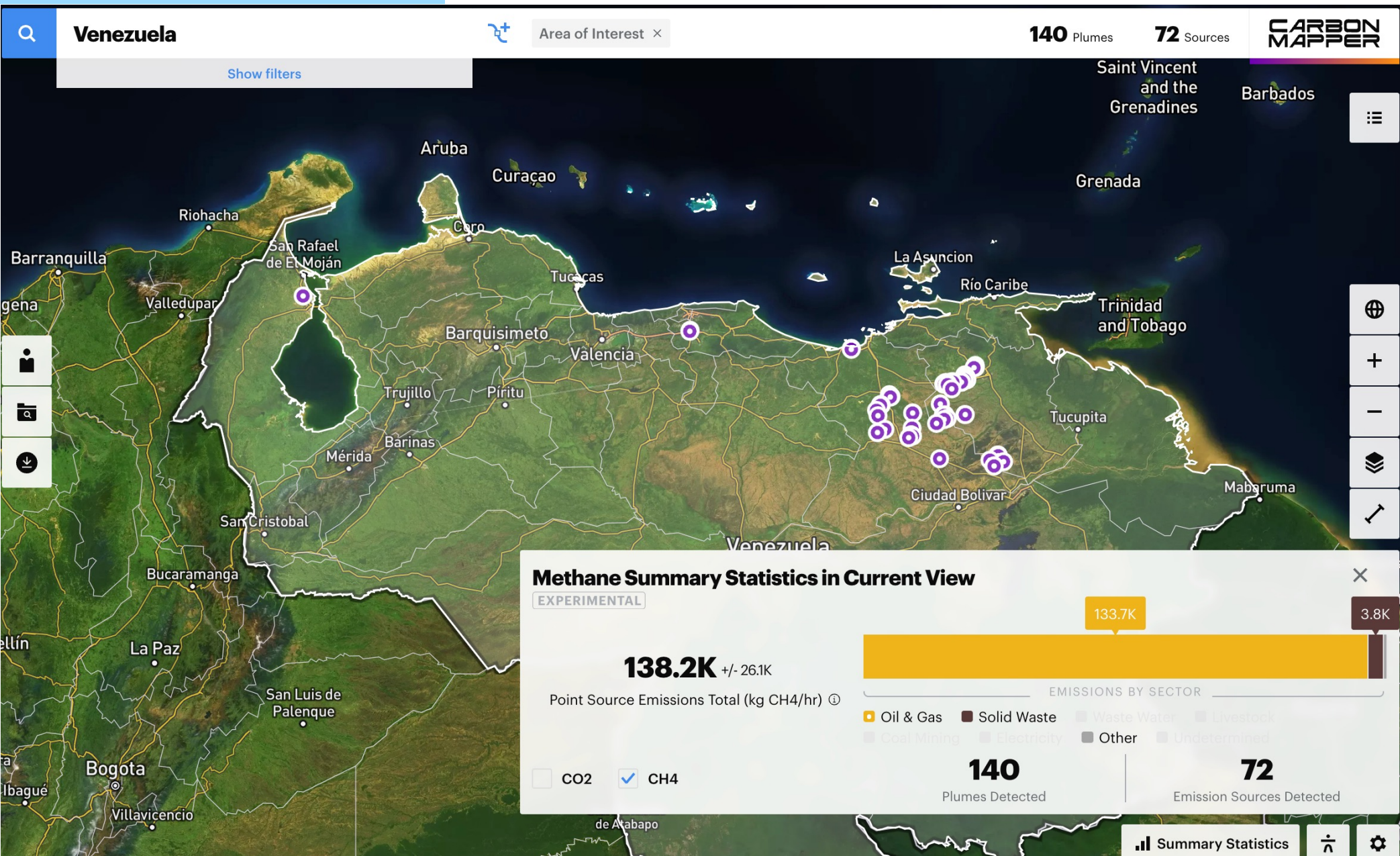
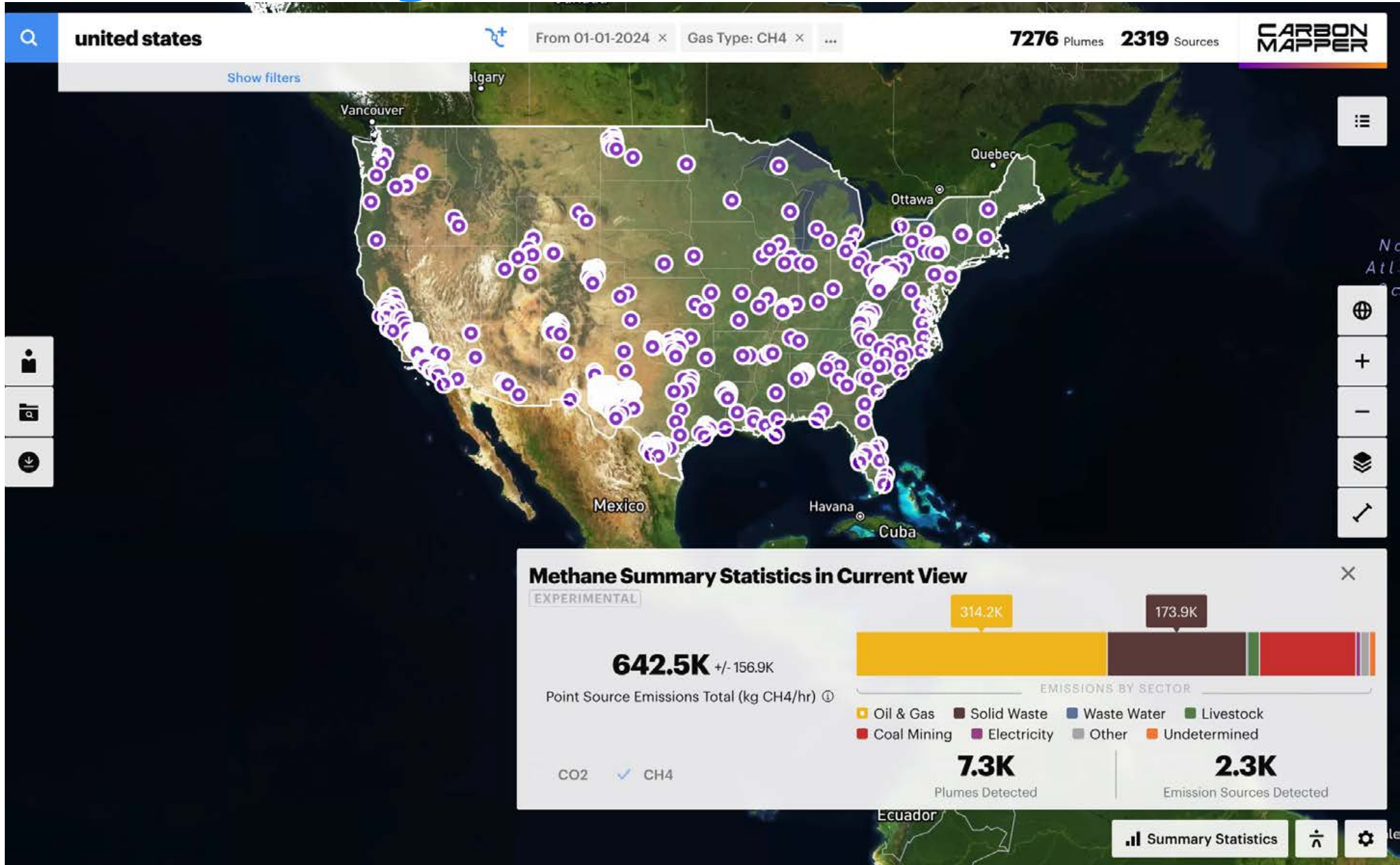
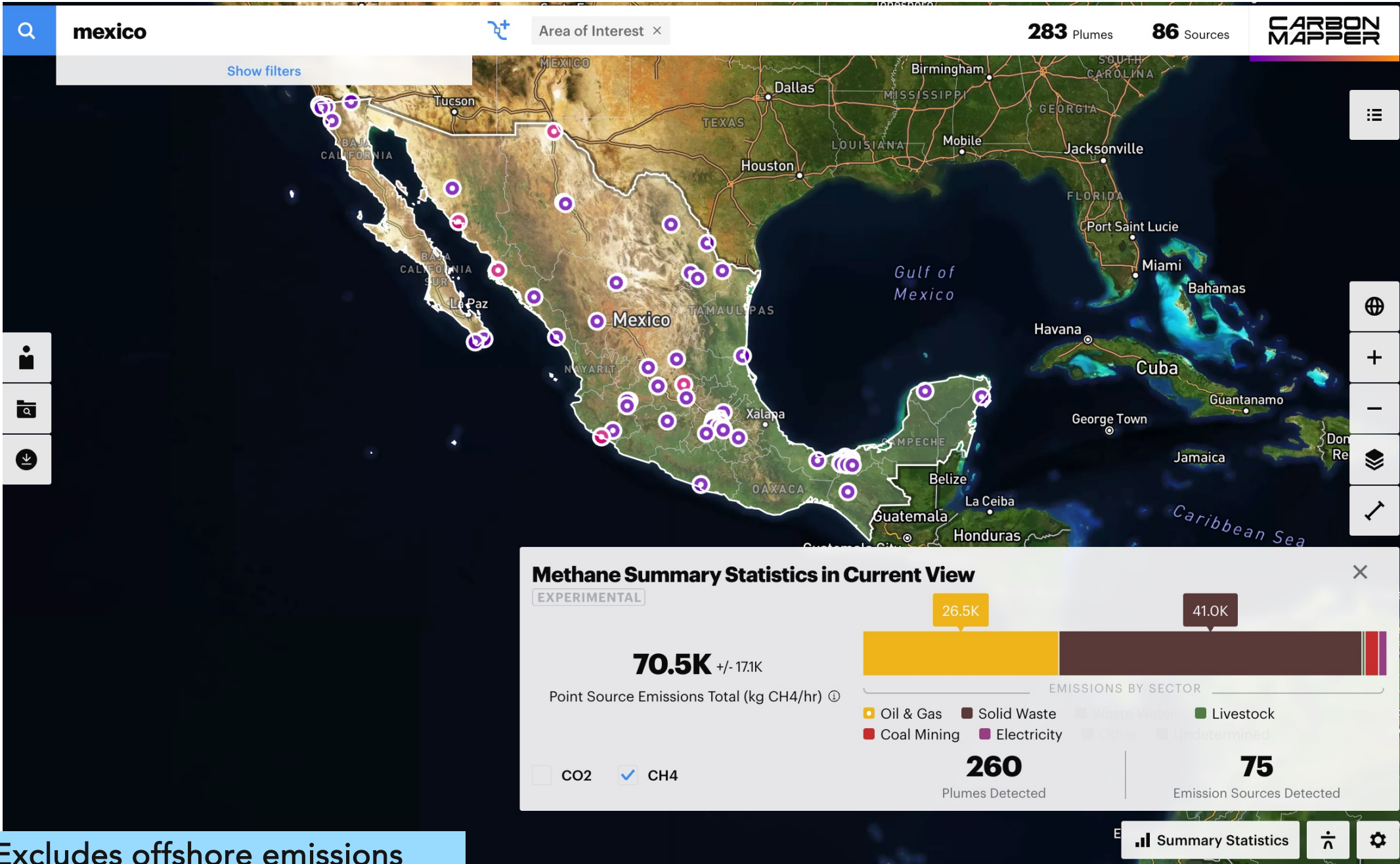
**CARBON
MAPPER**

Thank You!

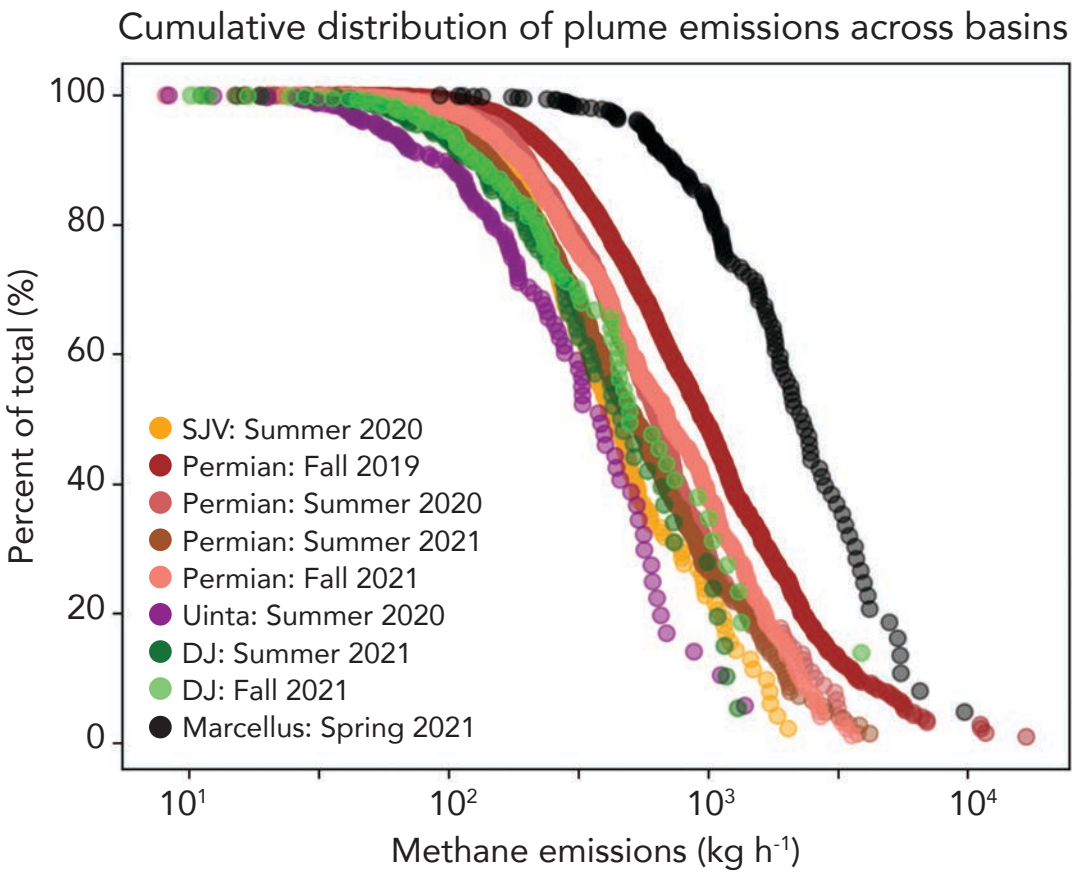
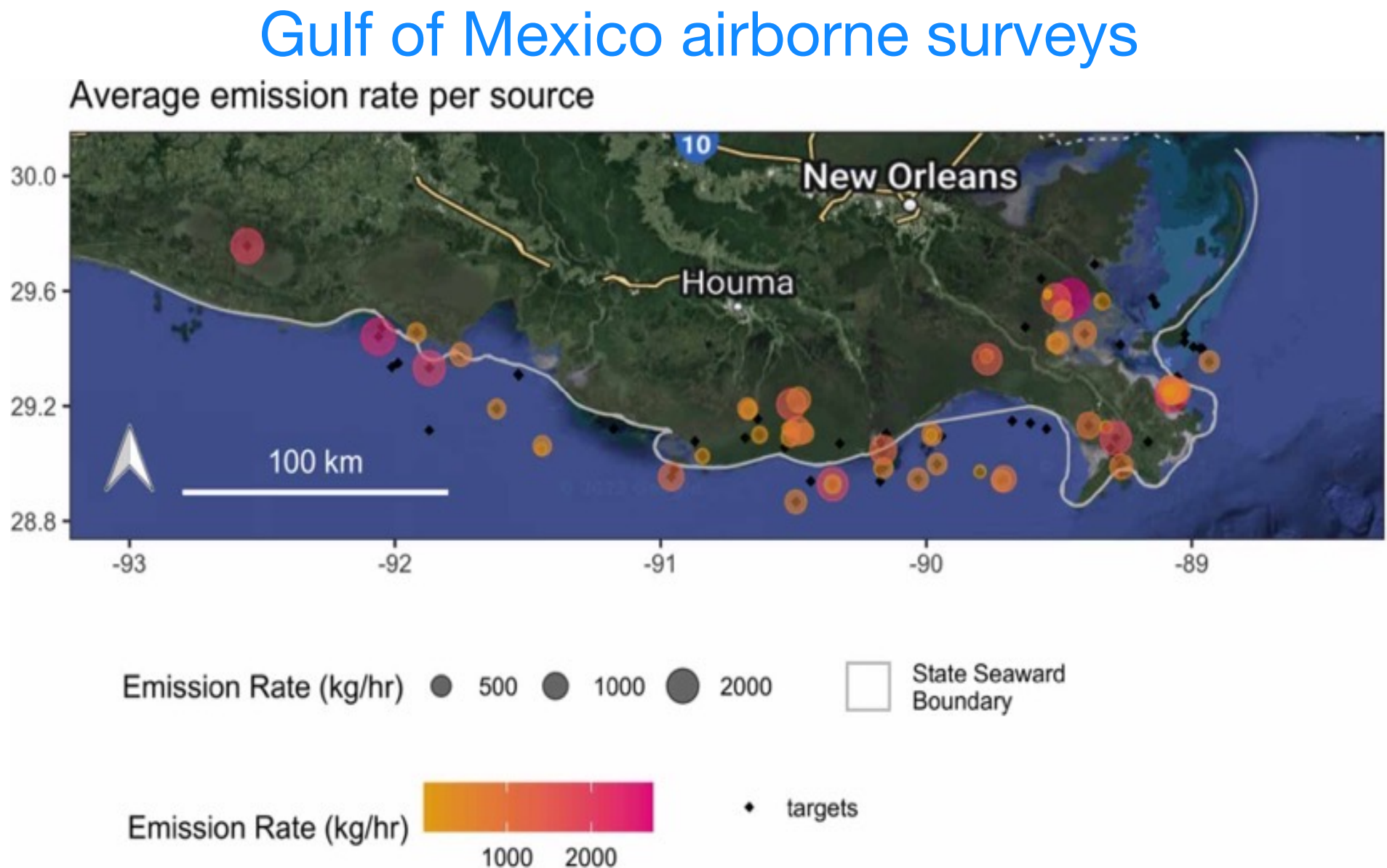
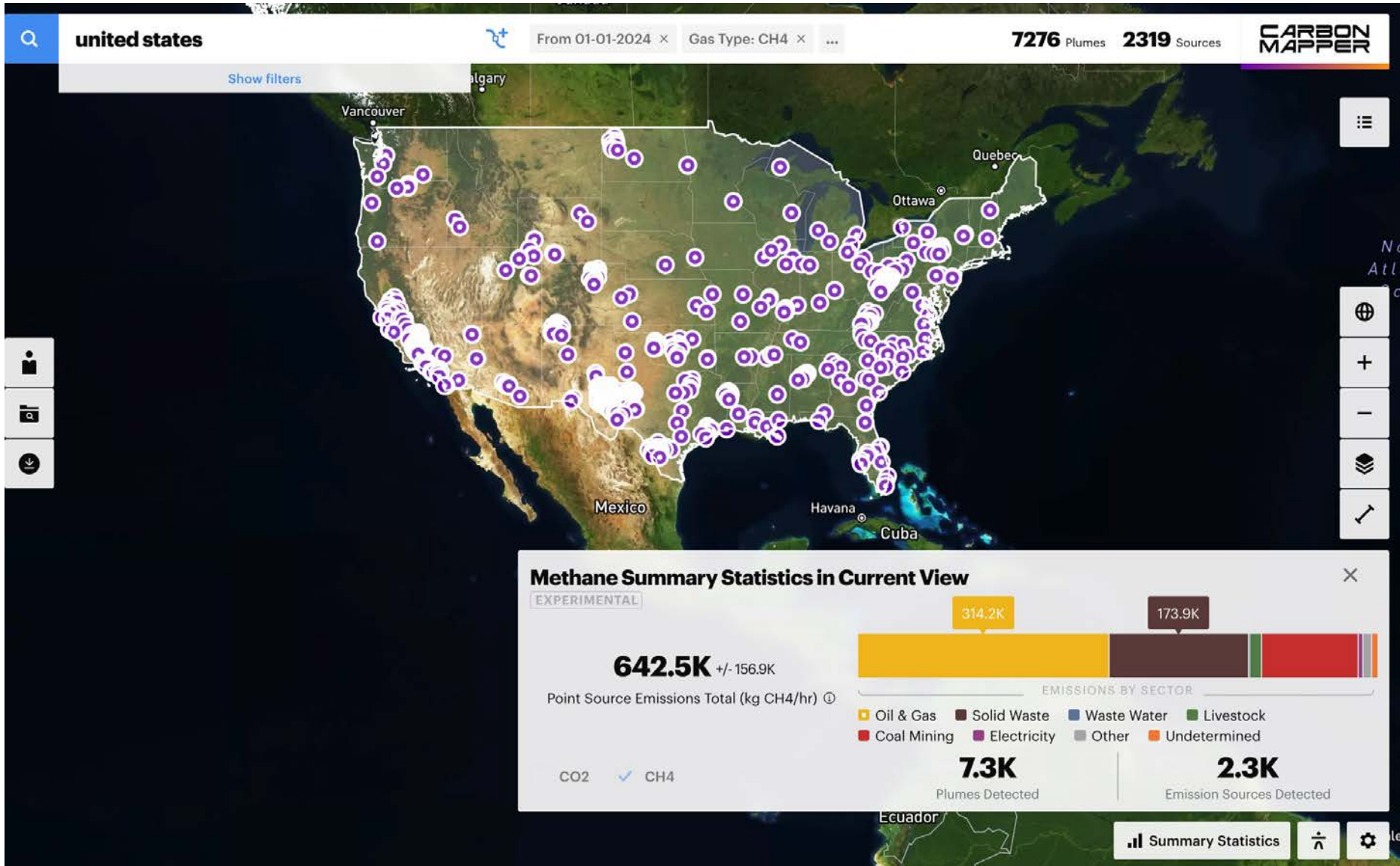
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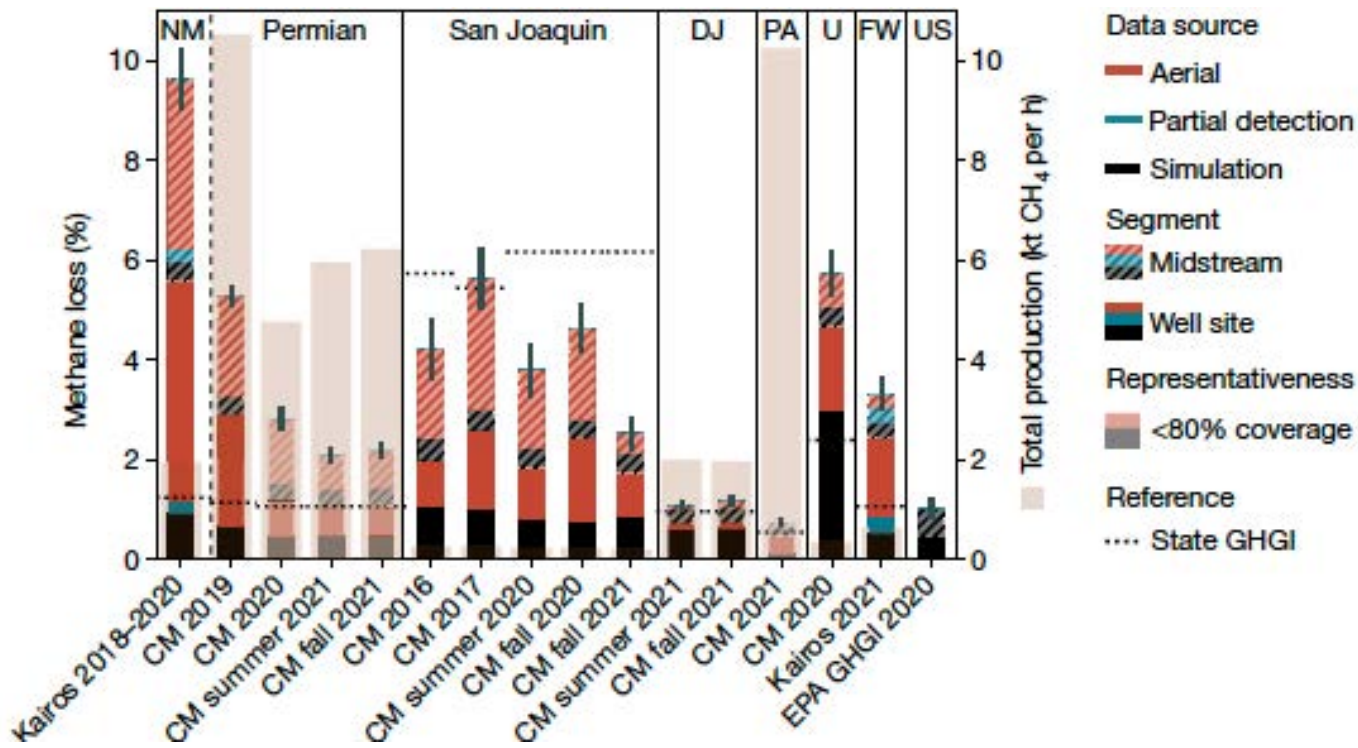
SUPER-EMITTER STATISTICS BY JURISDICTION(2)



VARIATIONS IN SUPER-EMITTER DISTRIBUTIONS & INTENSITIES



(Cusworth *et al.*, PNAS, 2022)



(Sherwin *et al.*, Nature, 2024)

	Total persistence adjusted emissions (kg/hr)	Total Gas (MCF)	Total Oil (BBL)	Gas Loss rate (%)	Joules Lost (%)
Spring 2021					
State	3483	770,600	478,083	23.8 ± 9	3.9 ± 1.6
Federal	9941	2,195,730	689,963	23.8 ± 8	6.7 ± 2.3
Fall 2021					
State	21,660	1,723,527	556,522	66.2 ± 33.8	18.2 ± 9.4
Federal	9,893	1,804,186	373,858	27.9 ± 12.2	10.4 ± 4.4

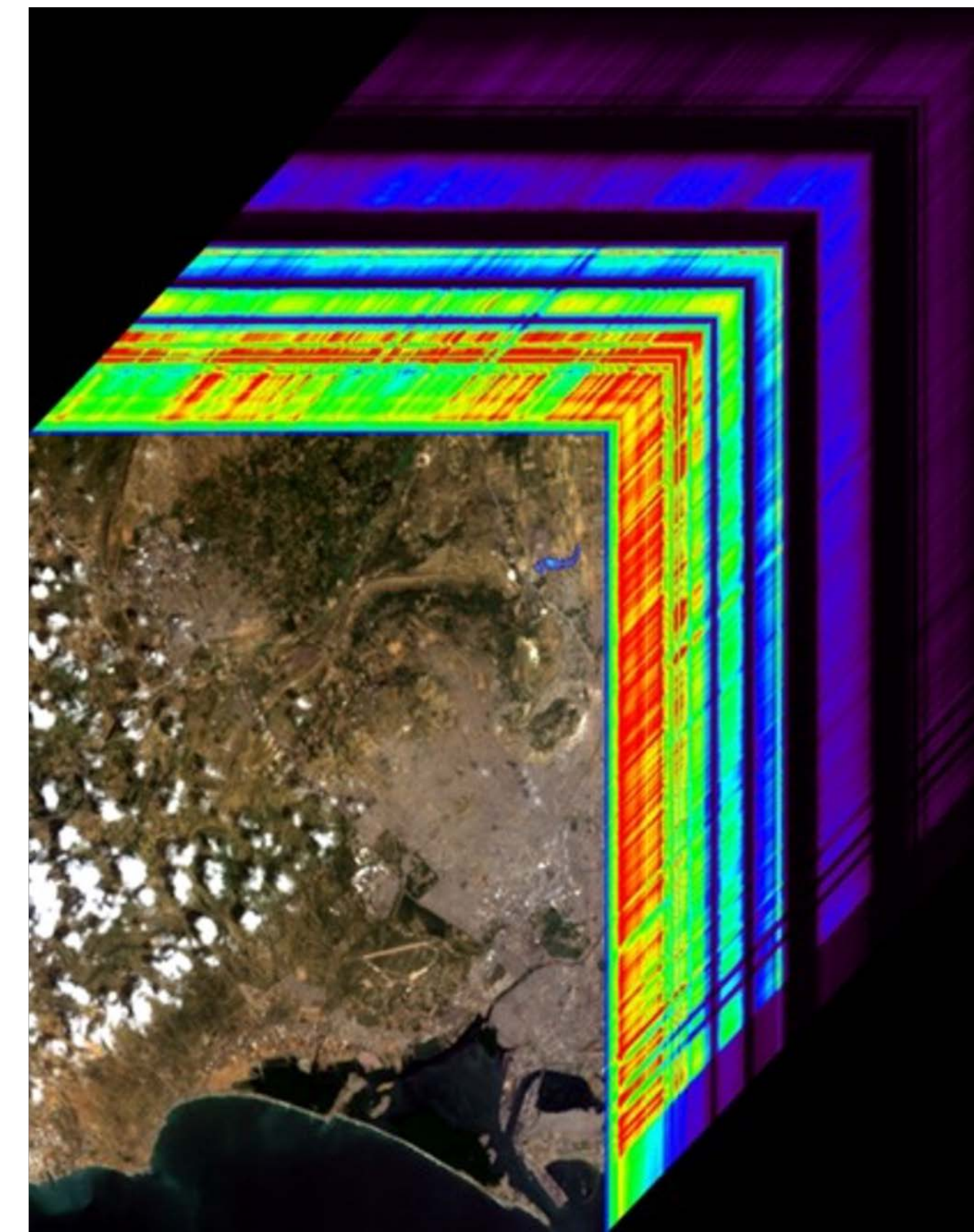
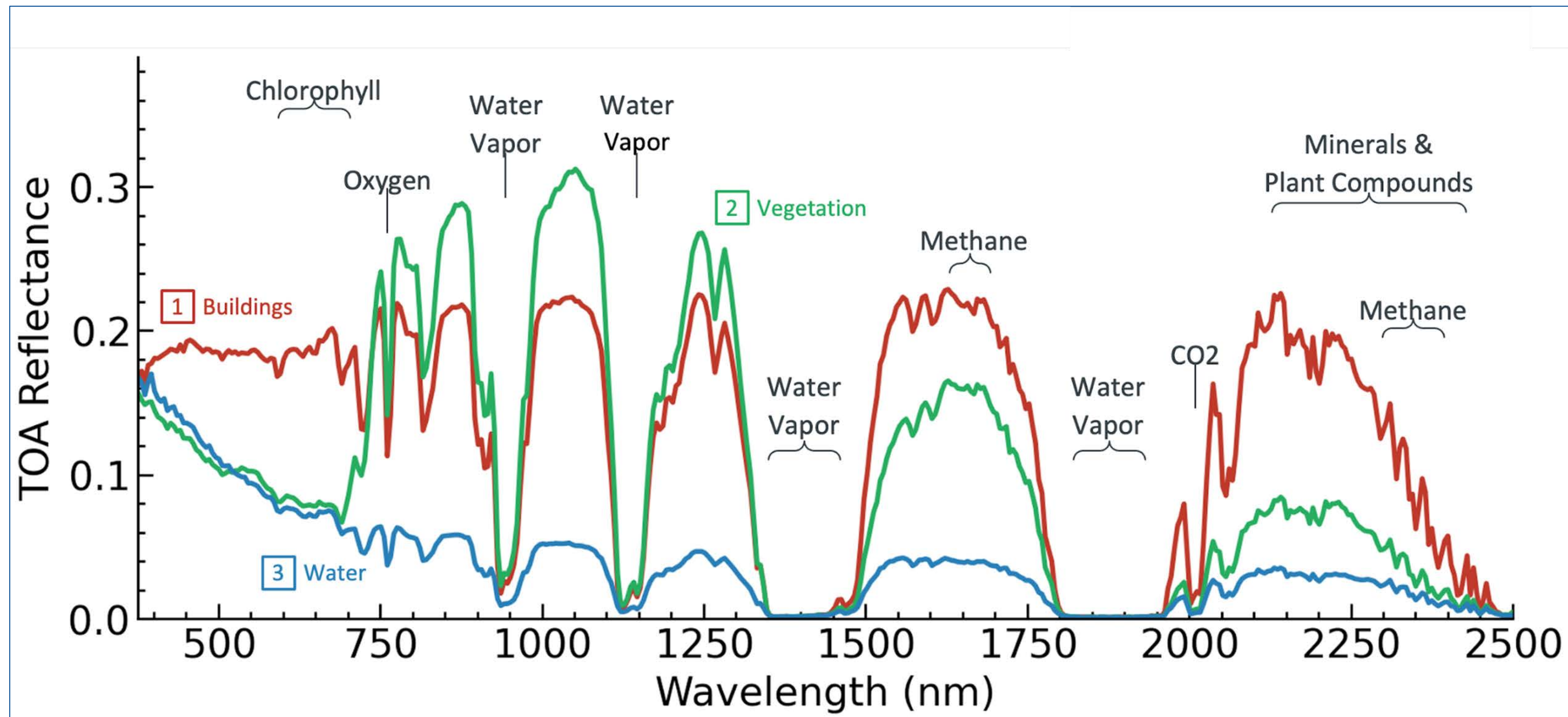
(Ayasse *et al.*, ERL, 2022)

Contributing factors:

- Presence (or lack) of regulations
- Operator size/resources
- Infrastructure age
- Commodity vs nuisance
- Infrastructure age
- Production rate

TANAGER SATELLITES

- Tanager-1 one year anniversary
- Interim altitude 430 km, 20 km swath
- Continued increases in observational density
- Tanager 2-4 are being prepared for launch
- Carbon Mapper methane quick-look analysis within 24 hours
- Low latency notifications to subscribers within 72 hours
- All methane, CO₂ data public within 30 days
- Many non-trace gas applications from Planet



Plots of full VSWIR Top Of Atmosphere (TOA) reflectance from 3 pixels in Karachi scene containing buildings [1], vegetation [2], and water [3] illustrating Tanager's hyperspectral sensitivity to CH₄, CO₂, flares, and multiple other environmental variables.