Methane Remote Sensing & Leak Detection

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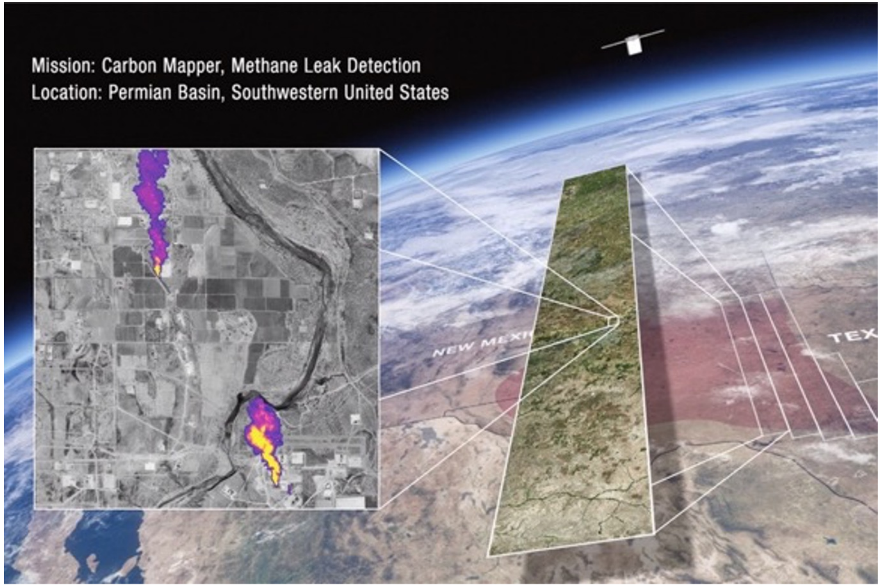
carbonmapper.org

Carbon Mapper

- Carbon Mapper the non-profit: public good mission to deliver actionable CH_4 and CO_2 data
- Carbon Mapper satellite program: public-private partnership to build and operate satellite constellation
- Phase 1: Launch first 2 satellites in 2023 – operate through at least 2024
- Phase 2: Goal to expand constellation to enable daily to bi-weekly monitoring in coming years
- Goal: track 90% of high emitting CH_4 & CO_2 point sources at facility scale globally
- Rapid leak detection service from Planet
- All quantitative CH_4 & CO_2 emissions data publicly available from Carbon Mapper
- Continuing airborne surveys prepare for and support satellites

Integration

Policy | Technology | Technology | Science | Policy

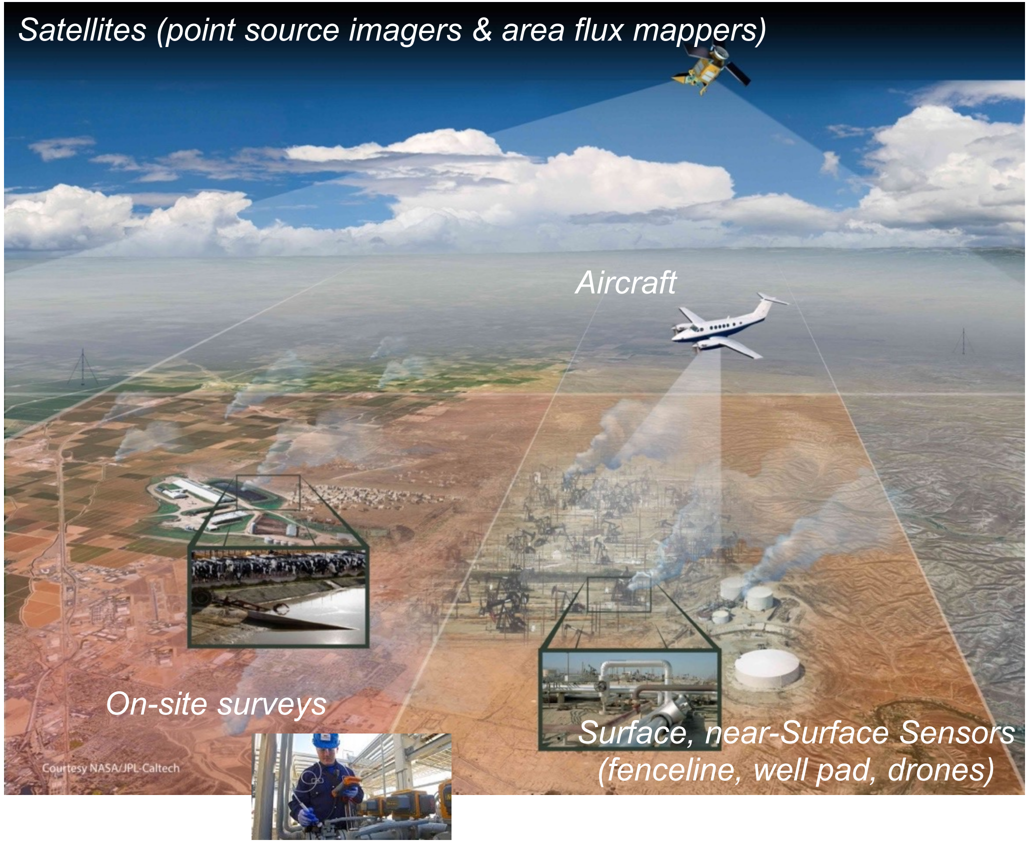


Emerging global system of systems for methane monitoring

- Two primary types of monitoring
  - Type 1: aggregate accounting, inventories
  - Type 2: direct mitigation guidance
- Rapid technological progress
  - Many diverse actors
  - Some major pilot projects
- Barriers to operationalization
  - Timeliness (latency)
  - Completeness (space, time)
  - Data accessibility, transparency
  - Stakeholder awareness, capacity
  - Finance (scale-up and sustain)

No single system can address all methane use-cases; need a portfolio of methods

Multi-tiered Observing System & Analytic Frameworks*

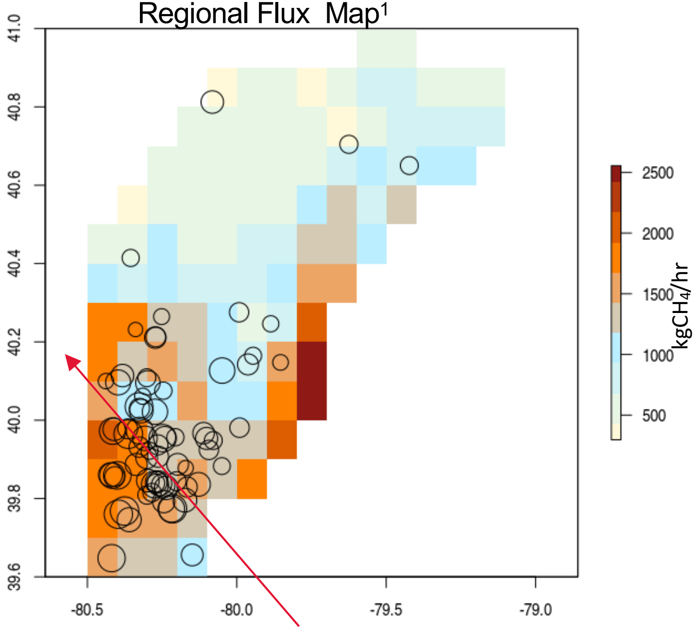


*10+ years of research funded by NASA, CARB, NIST et al

Methods: multi-scale/multi-sensor remote sensing

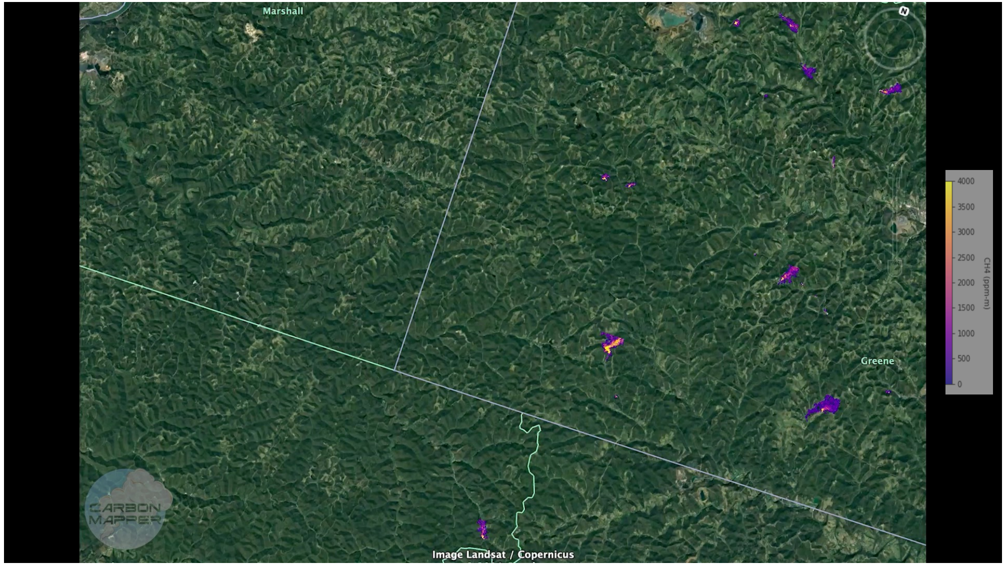
(CH_4 example for Southwest Pennsylvania)

Regional Flux Map[1]



Cusworth *et al., PNAS*, 2022

High-emission point sources[2]



Net regional emissions: 113,000 +/- 32,000 kg CH_4/hr

Point source emissions: 65,000 +/- 26,000 kg CH_4/hr

Net Regional Emissions

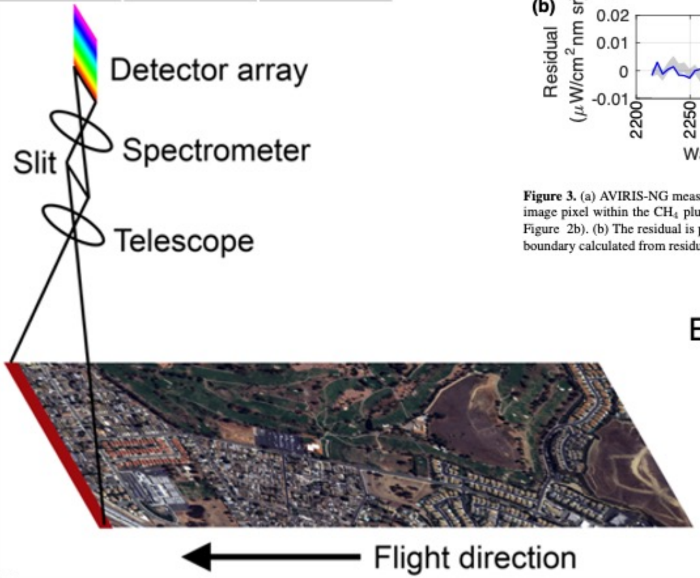
High-emission point sources + Area Emission Sources

[1]Regional flux inversion using Sentinel 5P/TROPOMI satellite observations [2]Point source imaging spectroscopy (e.g., ASU Global Airborne Observatory, NASA AVIRIS-NG)

Point source focus: infrared imaging spectroscopy detects and quantifies strong CH_4 and CO_2 point source emissions & flares

AVIRIS-NG (next generation Airborne Visible/Infrared Imaging Spectrometer) and GAO (Global Airborne Observatory): 5 nm spectral resolution, 380-2510 nm spectral range, SNR 400, ground sample distance (GSD) and swath width vary with altitude

Alt (km)	Swath (km)	GSD (m)
3	1.7	3
5.5	3	5.5
8	4.4	8



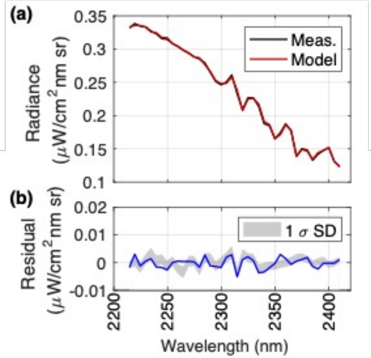


Figure 3. (a) AVIRIS-NG measured and modeled radiance for one image pixel within the CH_4 plume used for the CH_4 retrieval (see Figure 2b). (b) The residual is plotted with 1 σ standard deviation boundary calculated from residuals for the entire scene.

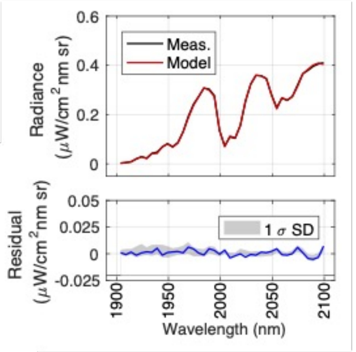
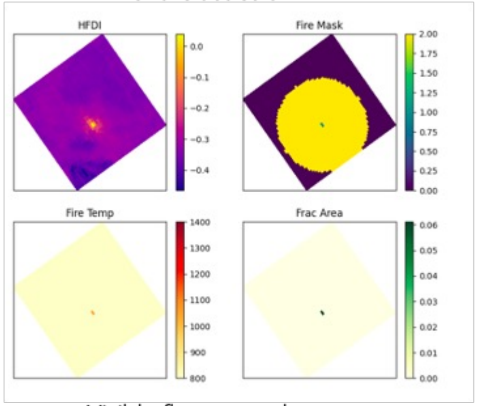


Figure 7. (a) AVIRIS-NG measured and modeled radiance for one image pixel within the CO_2 plume for the CO_2 retrieval (see Figure 6b). (b) The residual is plotted with 1 σ standard deviation boundary calculated from residuals for the entire scene.

Flare detection



Visible flare extends across multiple pixels

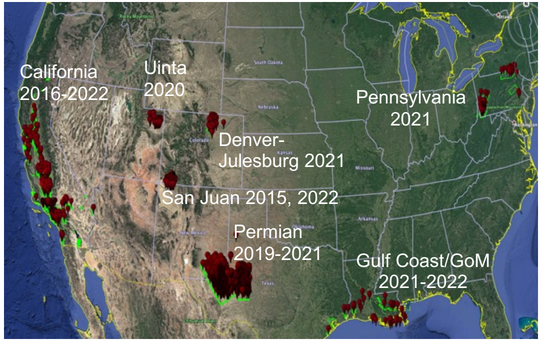
Enhancement + wind speed → Emission rate

$$IME_{r_c} = k \sum_{i=0}^{n} \alpha(i) S(i) \qquad Q = \left(\overline{IME}/r\right) U_{10}$$

Thorpe *et al., AMT*, 2017; Thompson *et al., GRL*, 2016; Frankenberg *et al., PNAS*, 2016; Duren *et al., Nature*, 2019

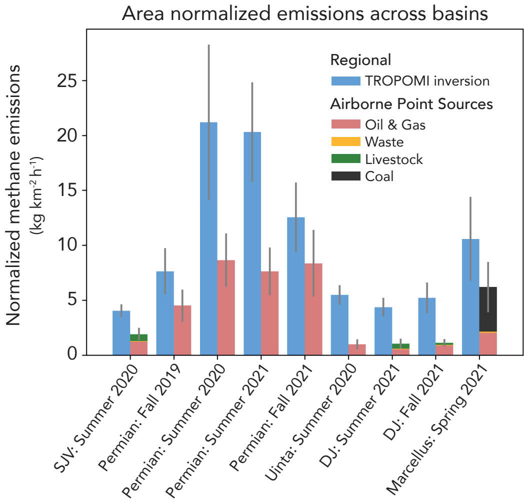
Lessons from multi-scale CH_4 studies in 7 US regions

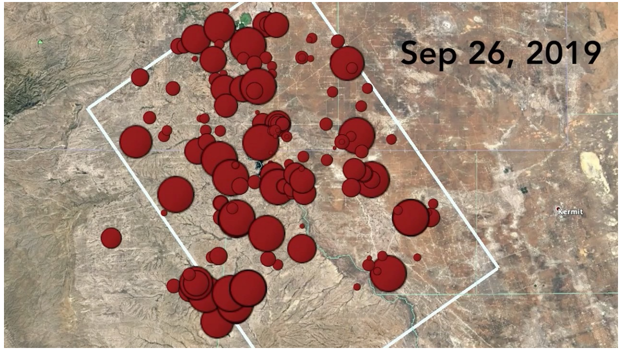
- Small number of CH_4 high emission sources >10 kg/h contribute 20-60% of net regional emissions
- Highly skewed distributions seen both for onshore & offshore oil & gas production
- Mix of persistent **<u>& intermittent</u>** emissions (bi-modal distribution)



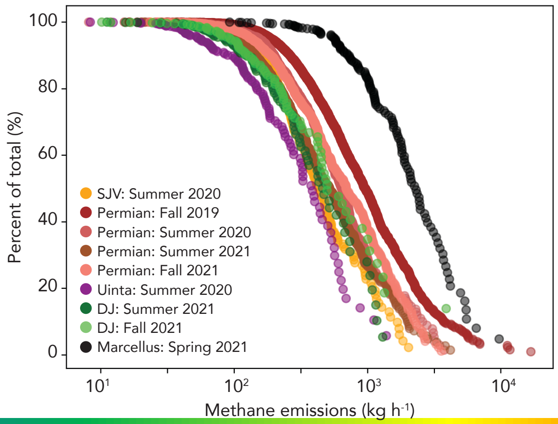
Cusworth *et al., PNAS,* 2022; Duren *et al*, Nature, 2019

Area normalized emissions across basins

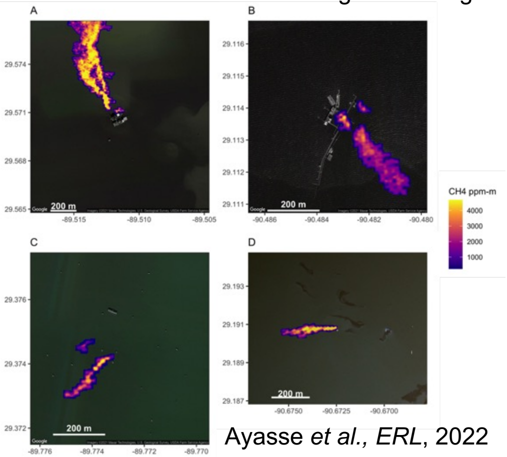




Cumulative distribution of plume emissions across basins

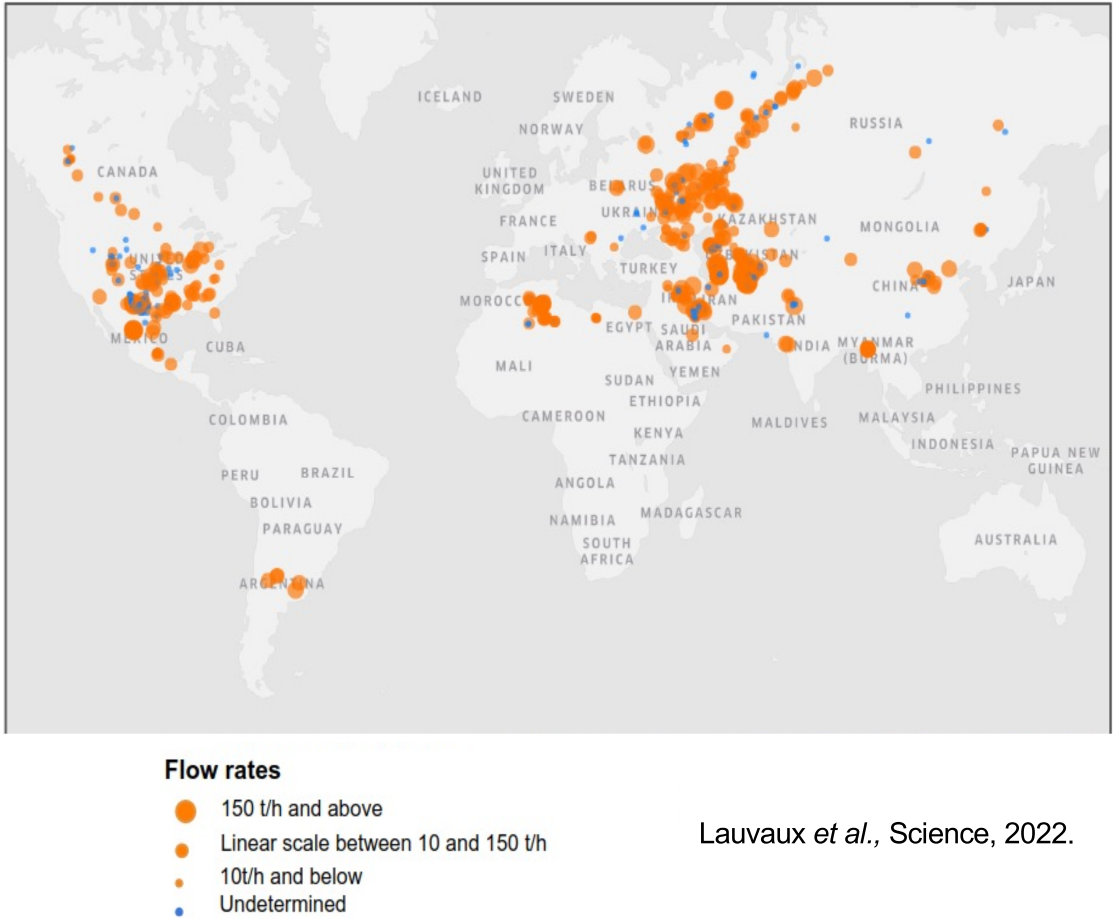


Offshore emissions with ocean glint tracking



Ayasse *et al., ERL*, 2022

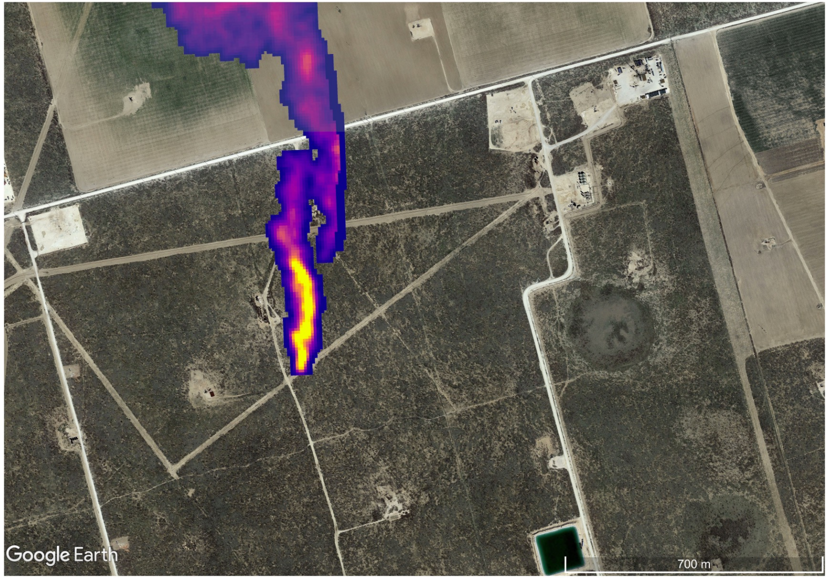
Lessons from global satellite observations: “Ultra-emitters”



Lauvaux *et al.*, Science, 2022.

10% of global O&G methane from intermittent “ultra-emitters” (> 50 tons/hour) from pipeline/compressor maintenance;
estimate $1.6B in benefits with marginal abatement cost of -$100M/tonne methane in the US

Gathering line leaks



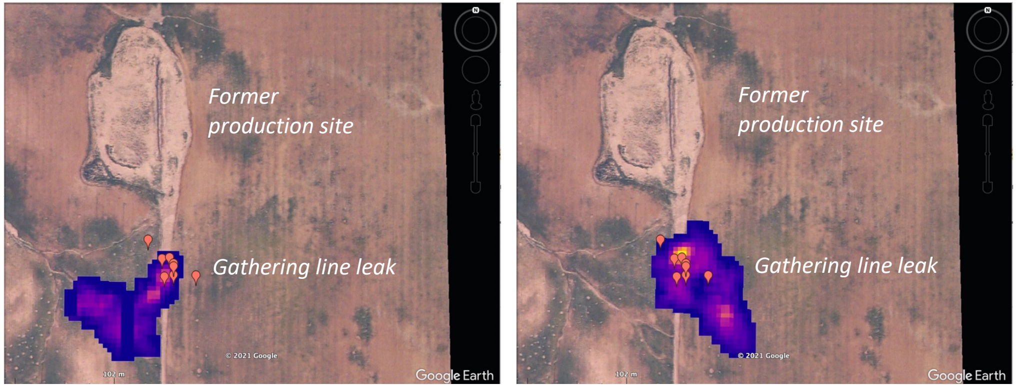
Carbon Mapper overflights (multiple days)

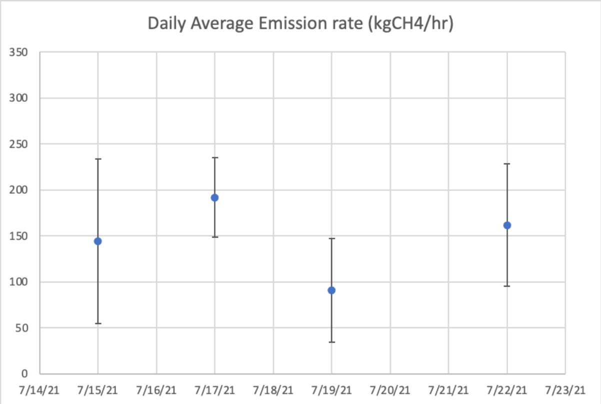
FLIR movie courtesy EDF

Handoff challenge
(CH_4 persistently detected, location pin-pointed – now what?)

(older) Google Earth image

Methane plume images fused with high resolution context camera image





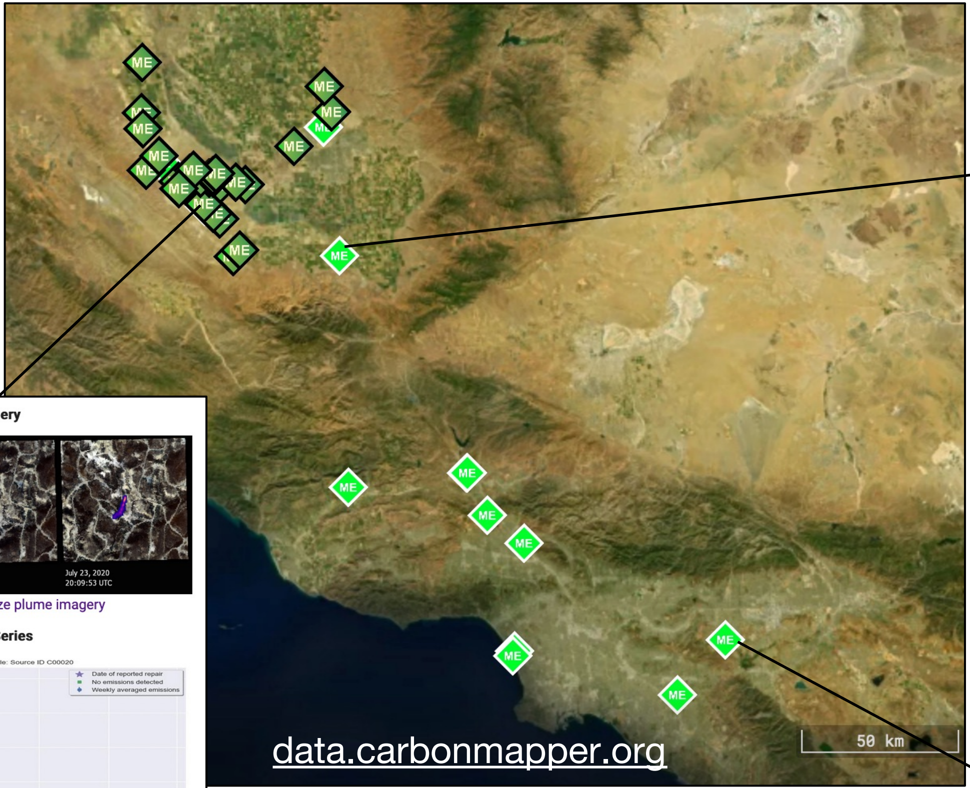
7/15 first overflight
7/18 reported 1st detection (8 total over 1 week)
7/26 Follow-up site visit by CSU and COGCC

- 65x45 ft of dead vegetation, surface expression
- Plume not detected by IR camera
- Extended search with gas analyzer found leak
- Determined to be a gathering line
- Operator notified; gathering line shut-in and blown down

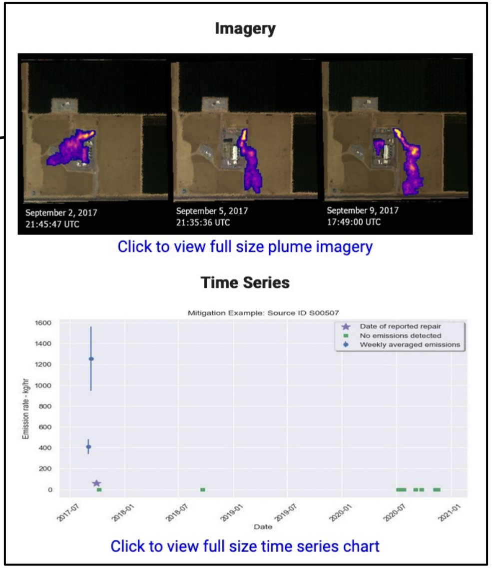
7/28 excavation, remediation reported complete

6 potential first-responder organizations

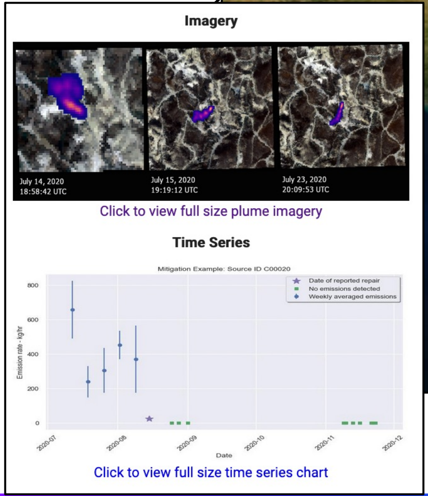
Mitigation successes: >1.2 million metric tons CO_2e eliminated through voluntary repairs by operators



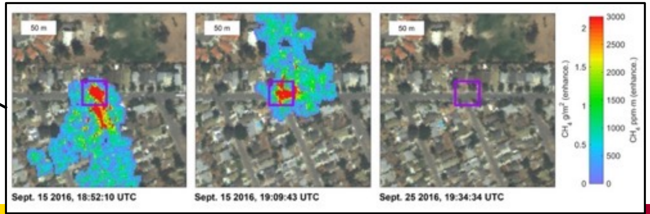
Compressor station repair



Fuel Line repair

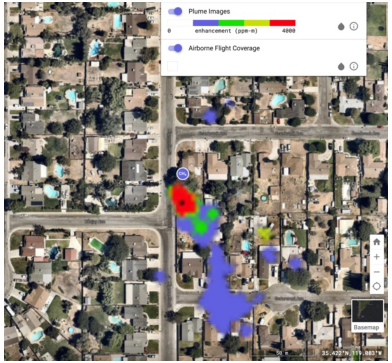


Distribution pipeline leak repair

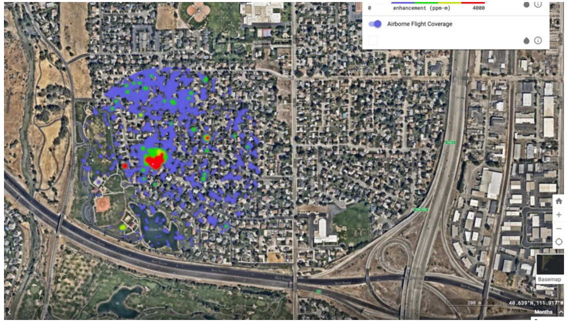


Examples of natural gas leak repairs

Distribution line (Bakersfield)

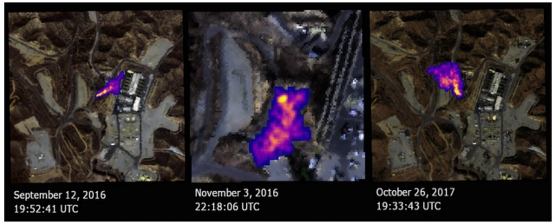


Distribution line (Salt Lake City)



Storage facility (Honor Rancho)

Imagery



Click to view full size plume imagery

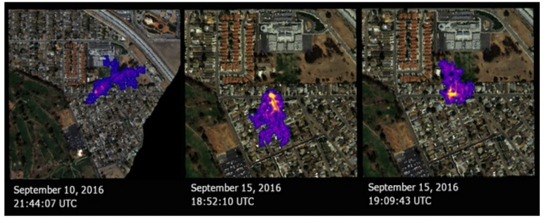
Time Series

Click to view full size time series chart

Each leak was pin-pointed to within 10 meters by the aircraft, then confirmed and repaired by ground crews

Distribution line (Chino Hills)

Imagery

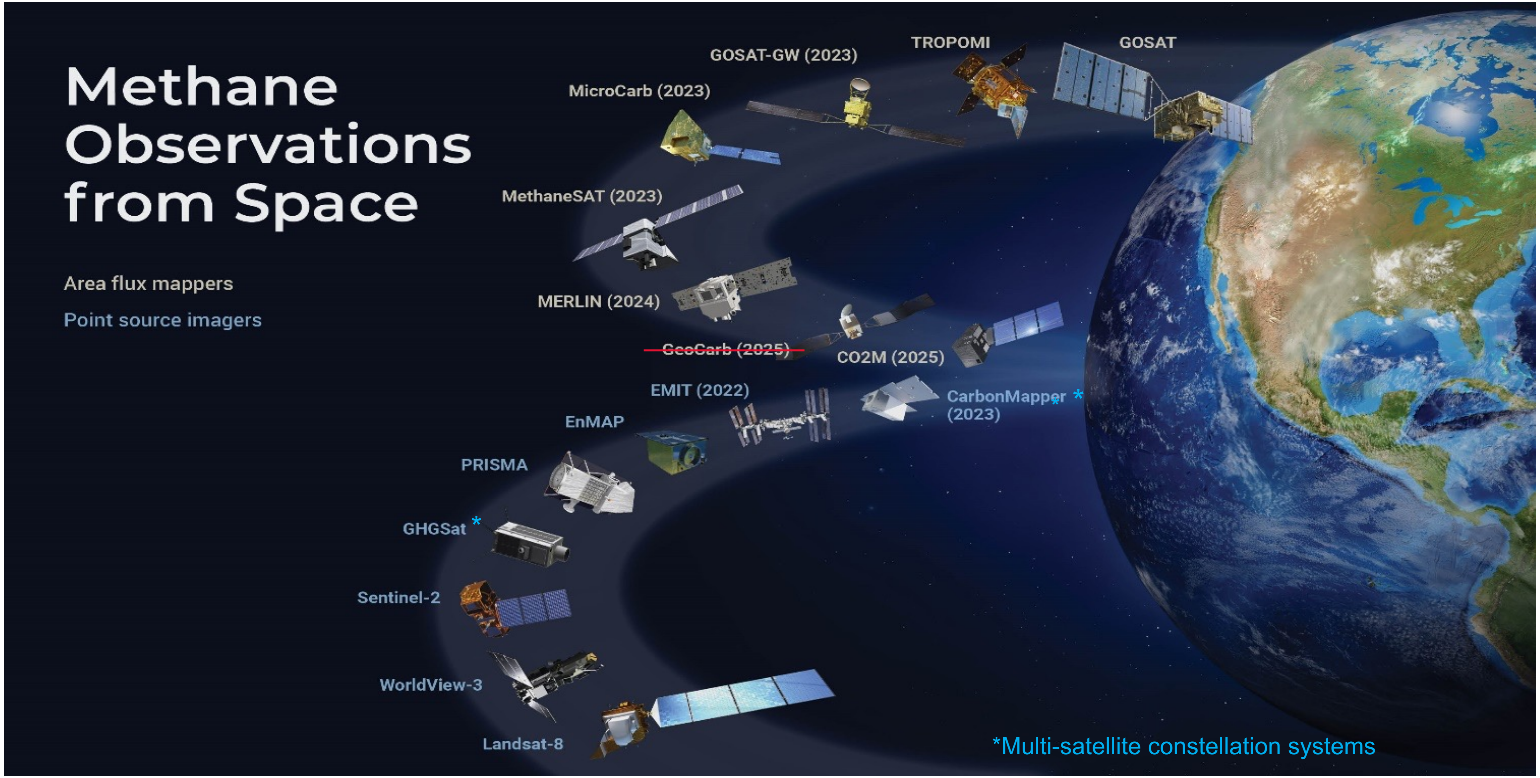


Click to view full size plume imagery

Time Series

Click to view full size time series chart

Advances in methane-sensing satellites



Jacob *et al.*, 2022, *ACP*

Satellites vary in terms of their <u>completeness</u>, ability to pinpoint individual emitters, and data availability

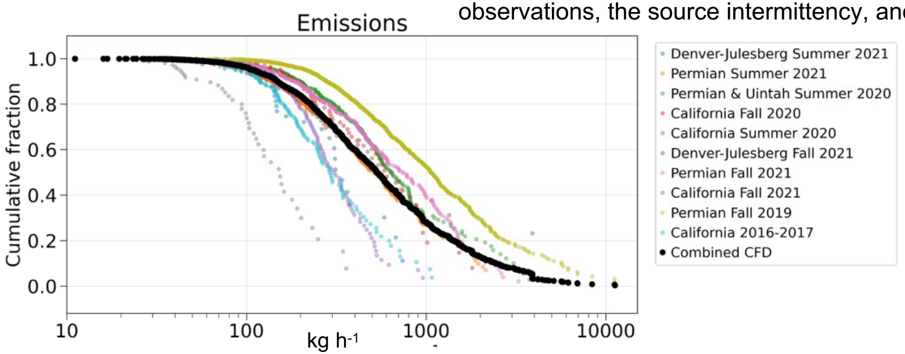
Observing system completeness

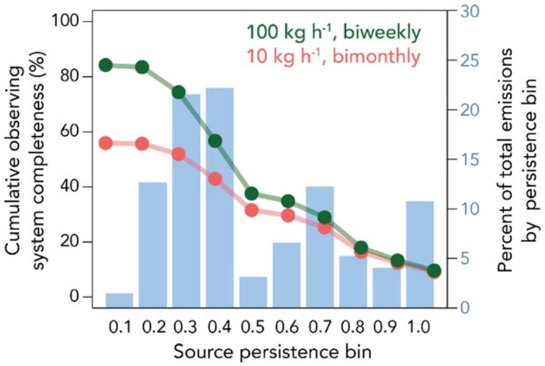
$$C = C_D \times C_S \times C_T$$

C_D (sensitivity): fraction of point sources that can be detected based on the detection threshold – varies by region

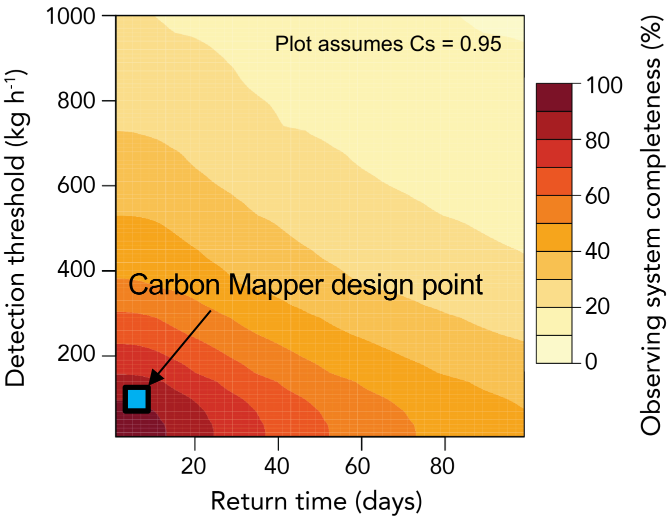
C_S (spatial coverage): fraction of those point source emitters that is observed within a given time interval

C_T (temporal completeness) = probability for an observed source to be actually detected within a time interval; function of N observations, the source intermittency, and the fraction *f* of clear-sky observations





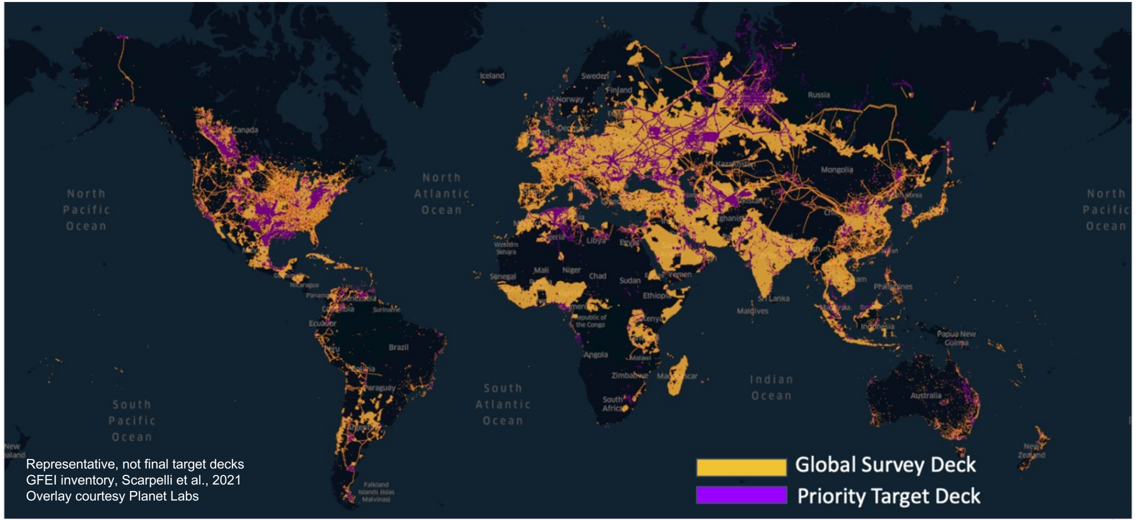
Jacob *et al.*, 2022, *ACP*



Completeness ultimately constrains mitigation potential but can trade-off sample frequency and detection limit

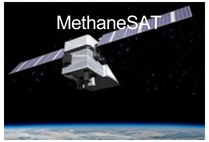
Carbon Mapper observing strategy

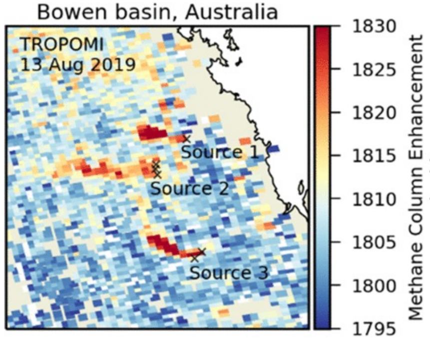
Carbon Mapper: (1) periodic global surveys and (2) sustained frequent monitoring of priority areas



Includes wide-area monitoring of offshore O&G platforms and ships using ocean glint tracking

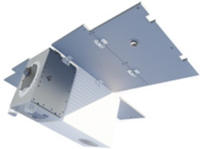
Regional CH_4 hotspots detected by other satellites (area flux mappers)

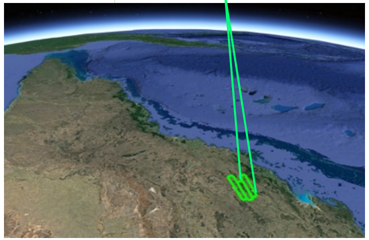


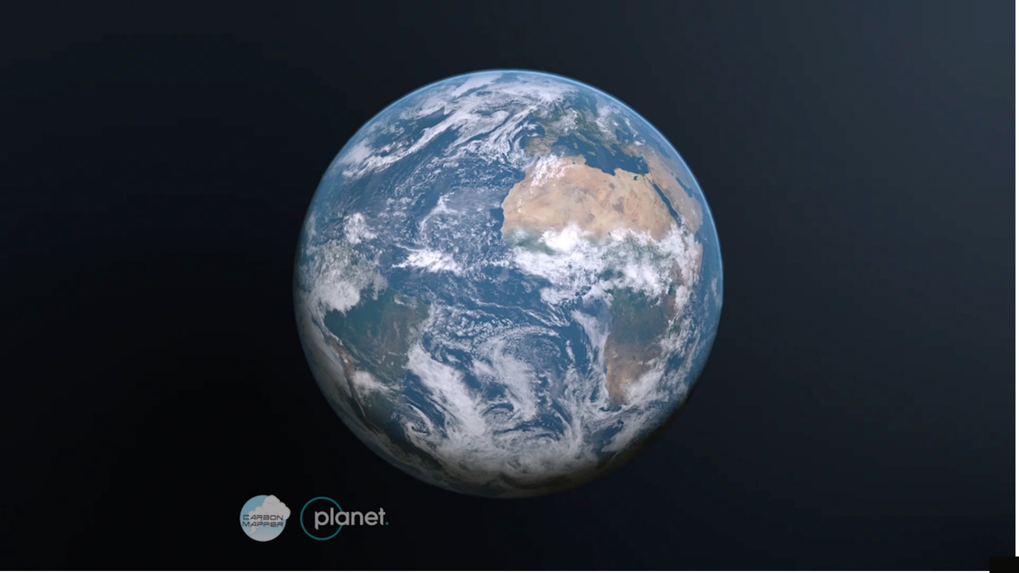


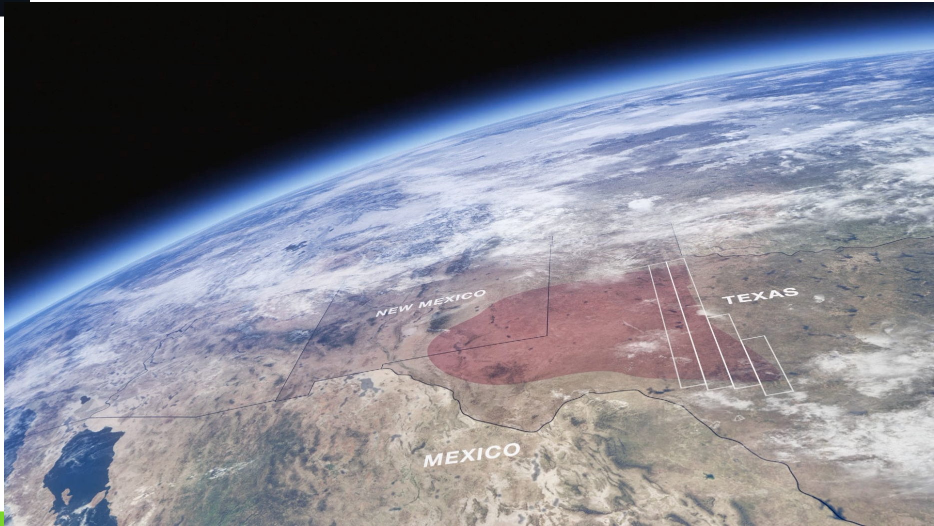
Sadavarte *et al.* 2021

(3) Carbon Mapper: agile tip & cue tasking

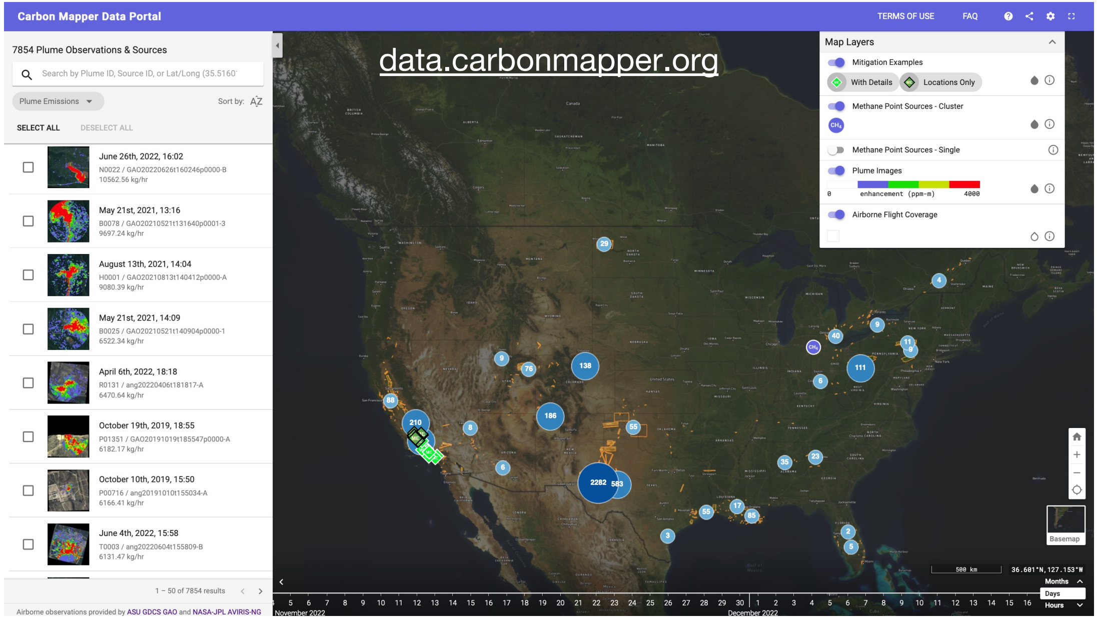


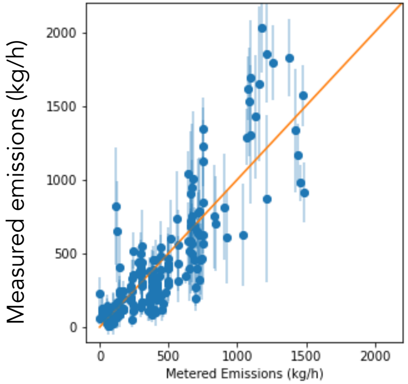



CARBON MAPPER
planet.

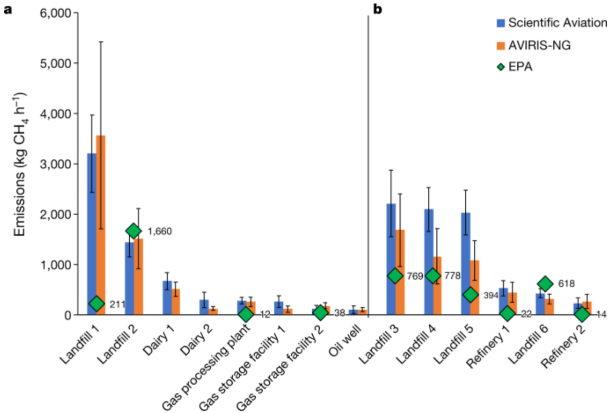

NEW MEXICO
TEXAS
MEXICO

Data sharing and validation



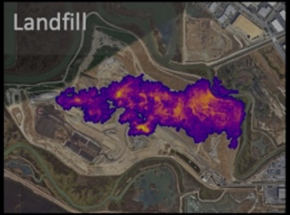


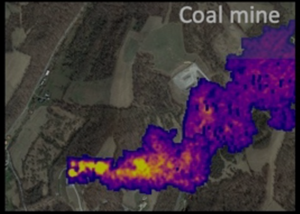
OLS fit $y = 1.04x - 26;\ R^2 = 0.71$

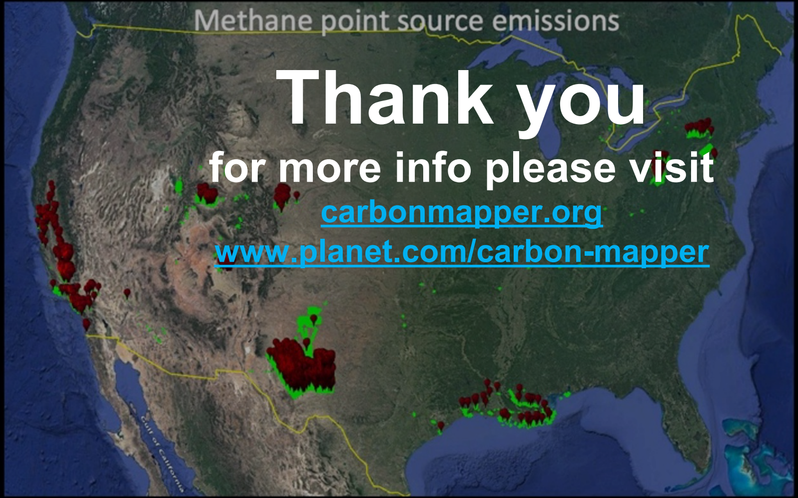


Carbon Mapper Data policies

- All airborne CH_4 data since 2016 available on public portal (nearly 8000 CH_4 plumes to date)
- Carbon Mapper: quantitative, QC reviewed CH_4 and CO_2 data from satellites and aircraft within 90 days
- Planet: qualitative leak detection service within 72 hours





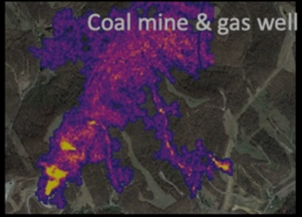


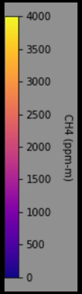
Thank you

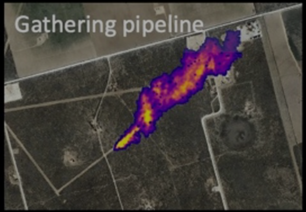
for more info please visit

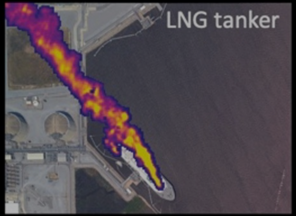
carbonmapper.org

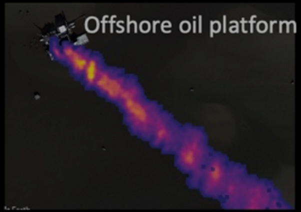
www.planet.com/carbon-mapper







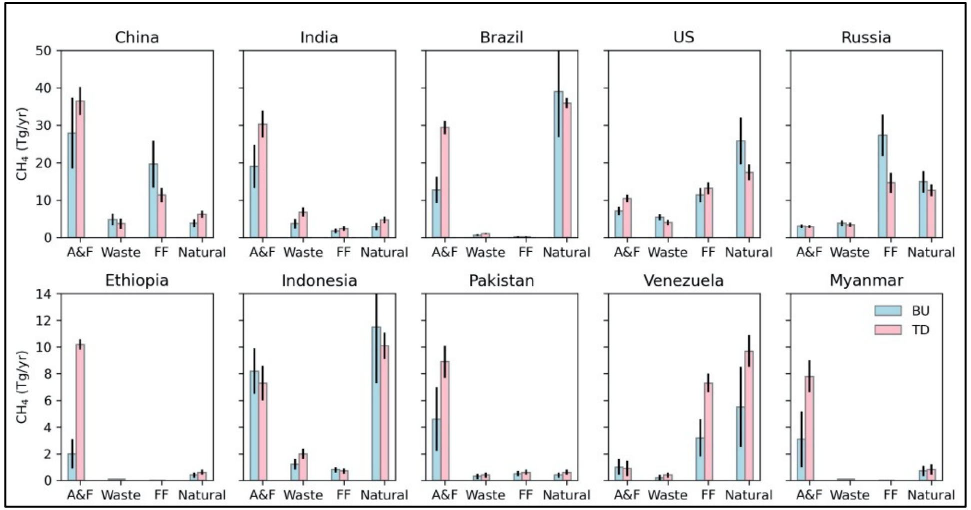




Use-cases for type 1 monitoring (inform GHG inventories and “stock-takes”)

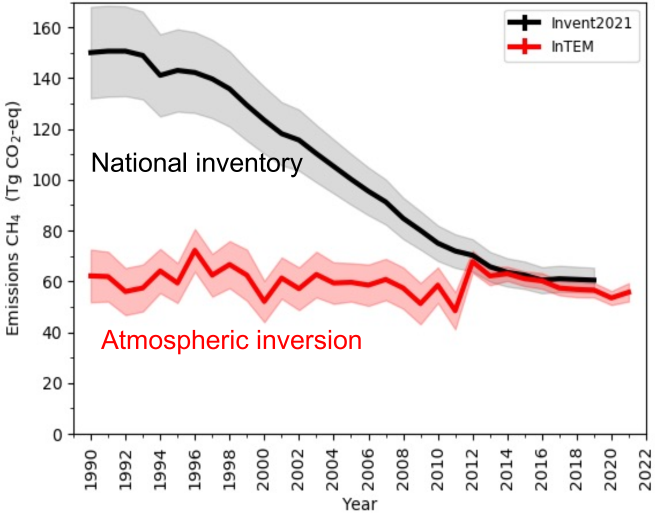
Worden *et al.*, 2022

Independent Country-level Quantification (Annual)



AF: agricultural and fires. FF: fossil fuels or coal, oil, and gas. Natural: wetlands, aquatic sources, and geological seeps. Blue bars: Bottom up (BU) inventory estimates. Red bars: Top down (TD) atmospheric estimates using GOSAT observations. Uncertainties in both quantities are shown as black lines.

Independent emissions trending (UK example)



Source: A. Manning, UK Met Office

Agreement between “top-down” and “bottom-up” varies by region and sector

Critical to establish accurate baselines for effective trending

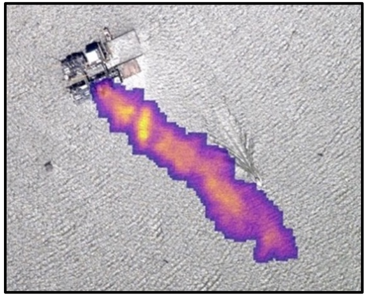
Use-cases for type 2 monitoring (mitigation guidance)

Oil & Gas: Leak Detection & Repair

Efficient screening for operators, regulators

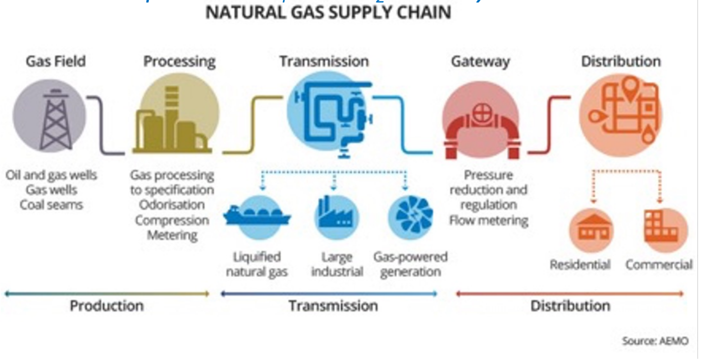
Coal, O&G CH_4: reduce legal but wasteful venting

Guide engineering, policy improvements



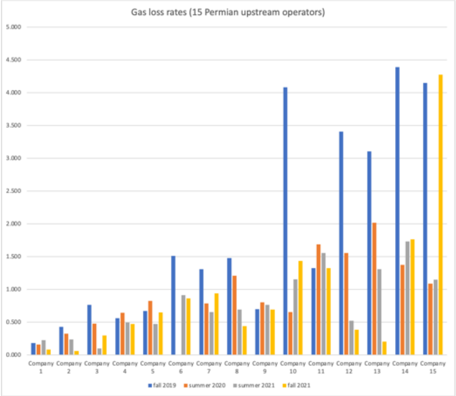
Differentiated gas supply-chains

Independent CH_4 and CO_2 intensity estimates



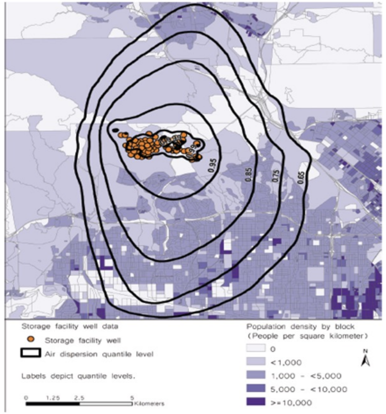
Methane trends & distributions

Improve accountability, assess progress



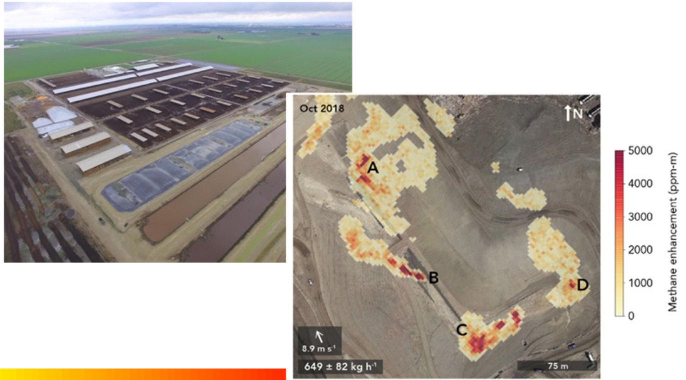
Public health, EJ: flag air-quality, gas hazards

Alert first responders and front-line communities



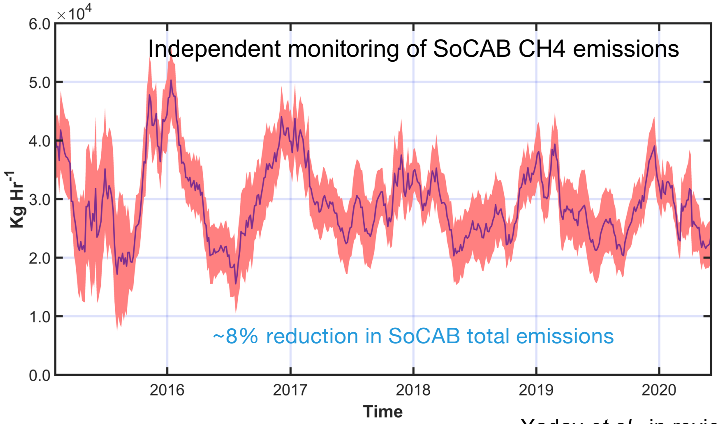
Landfills & Livestock: diagnose root cause

inform best practices & investment priorities



Southern California Experience: reductions about 50/50 biogas and natural gas

Translates to ~ 7% reduction in SoCAB total emissions



Yadav *et al.*, in review