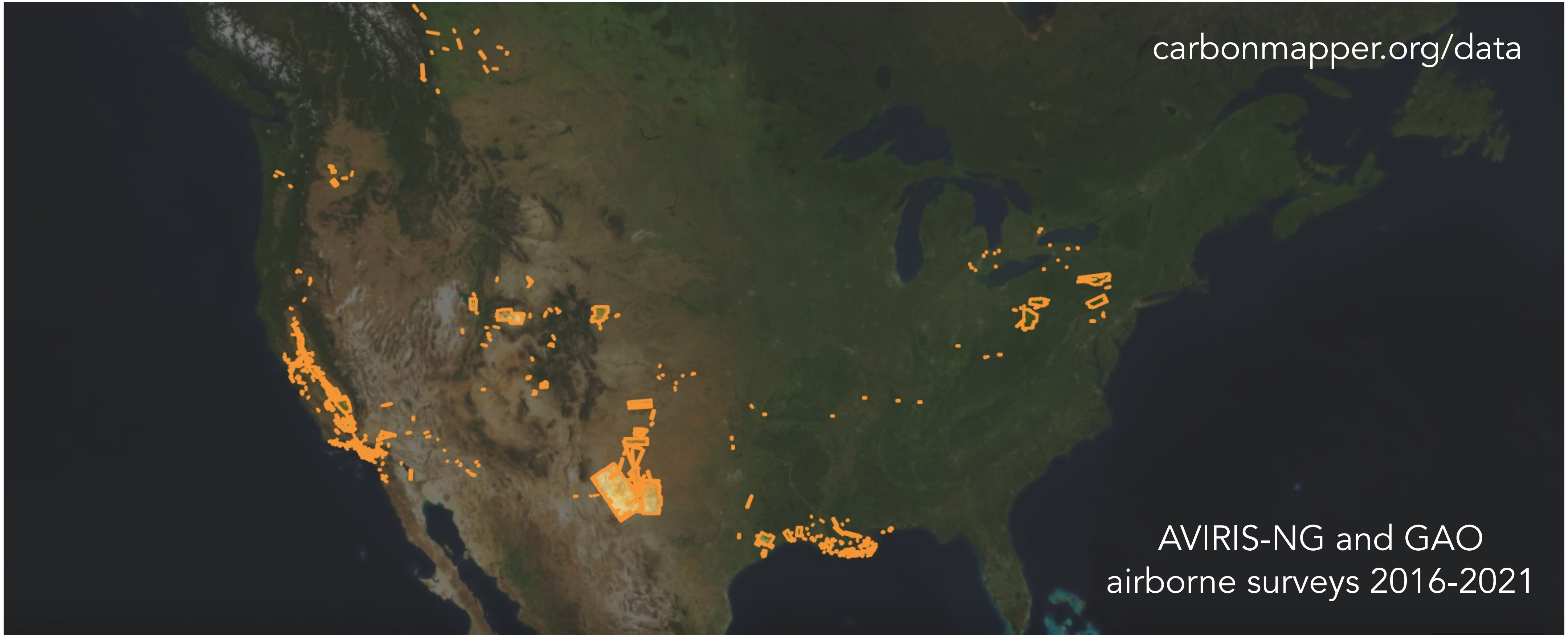
Strong methane point sources contribute a disproportionate fraction of total emissions across multiple basins in the U.S.



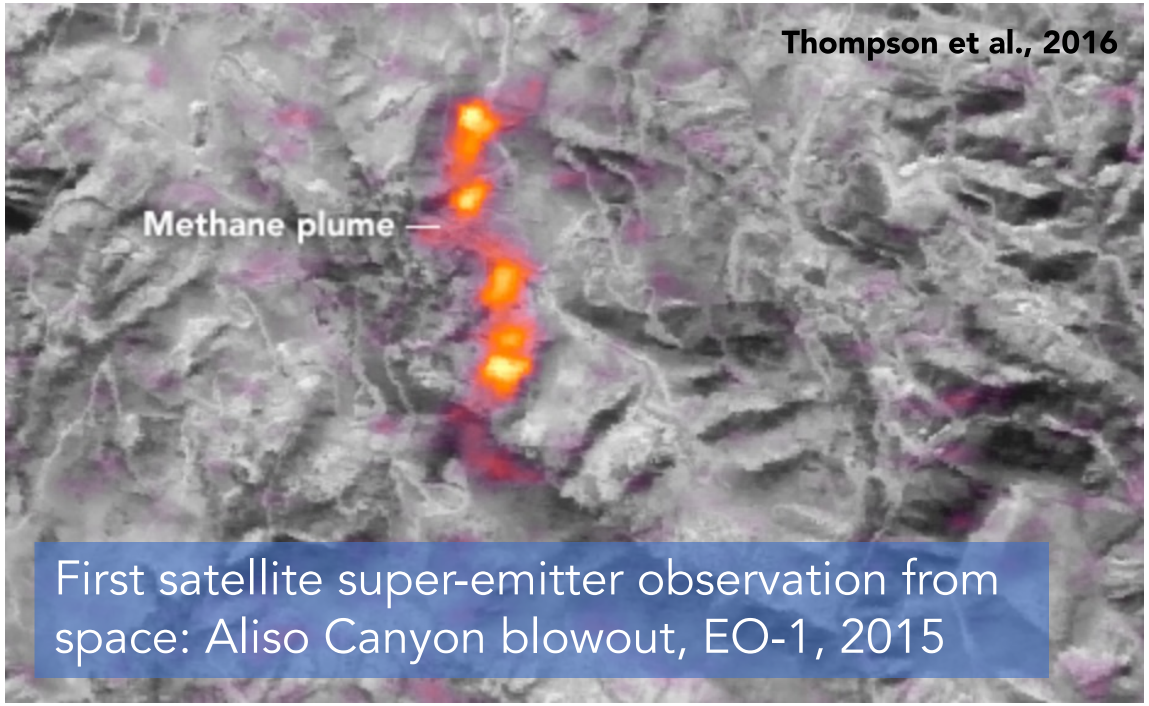
Daniel Cusworth, Andrew K. Thorpe, Alana K. Ayasse, David Stepp, Joseph Heckler, Gregory P. Asner, Charles E. Miller, Vineet Yadav, John W. Chapman, Michael L. Eastwood, Robert O. Green, Benjamin Hmiel, David Lyon, and Riley M. Duren

Carbon Mapper
The University of Arizona
ASU
NASA
Jet Propulsion Laboratory
California Institute of Technology

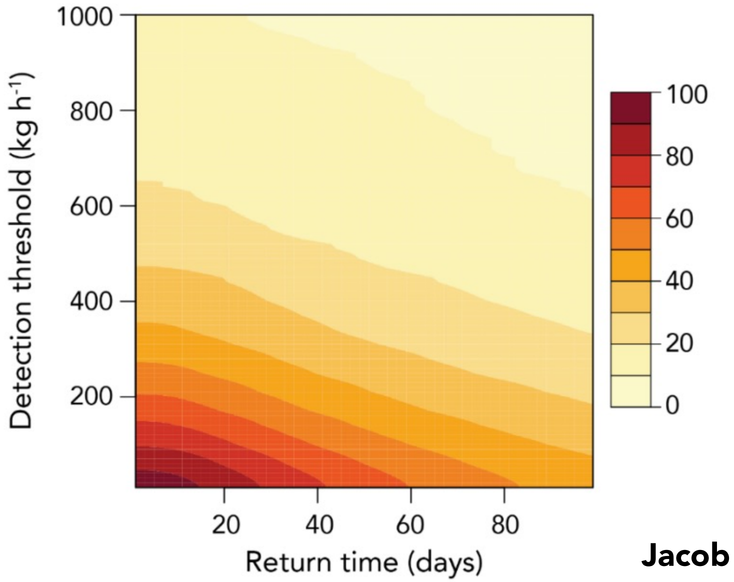
Last 5 years has seen huge advancements in ability to detect and quantify methane "super-emitters" at high spatial resolution from airborne and satellite platforms.

A task for now and the future: **impact of super-emitters on regional and global emission budgets.**

Need high-frequency observations with broad spatial coverage (observing completeness).



First satellite super-emitter observation from space: Aliso Canyon blowout, EO-1, 2015

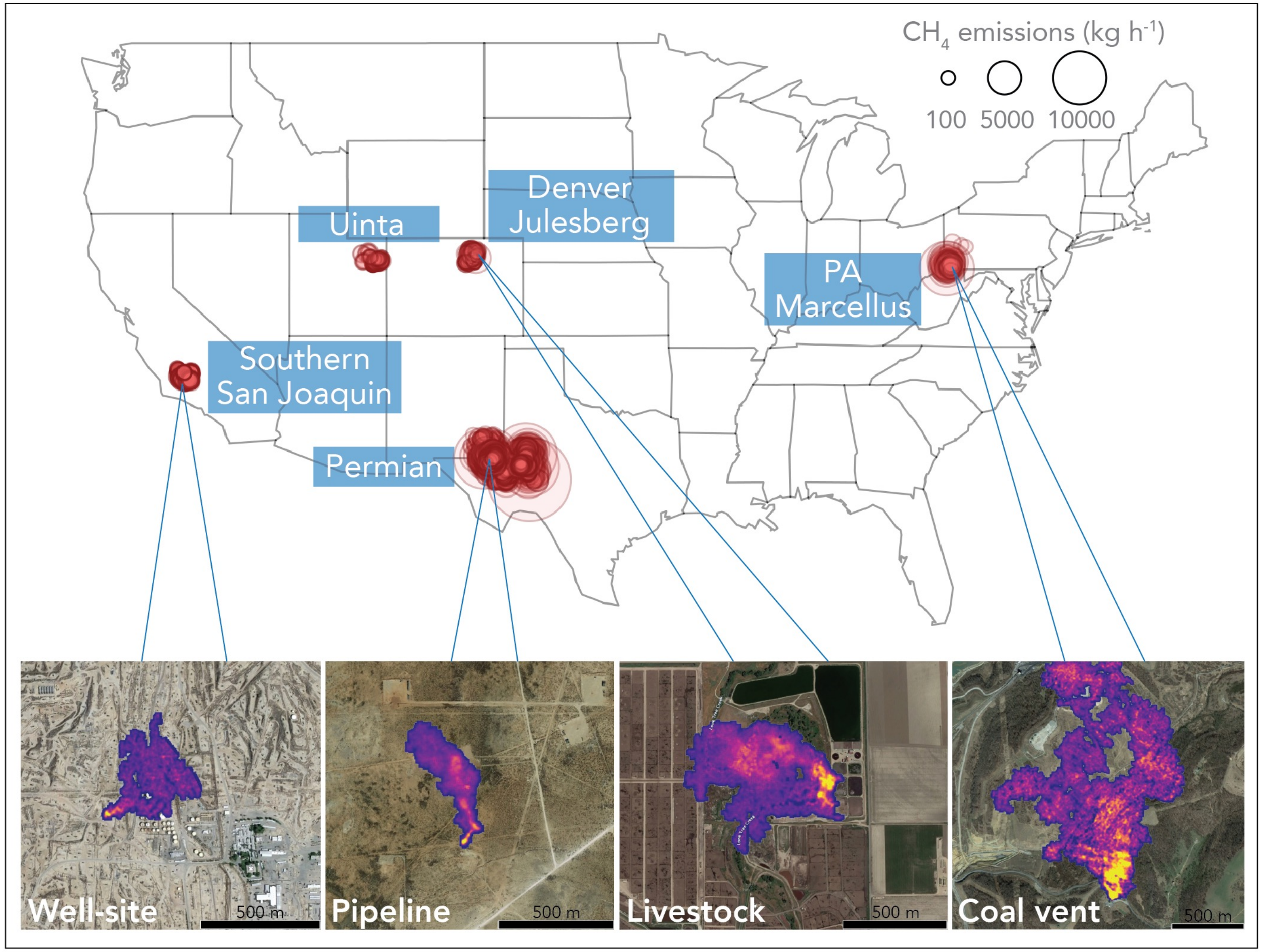


Super-emitter observing completeness for different observing platforms

Jacob et al., 2022

We flew AVIRIS-NG and Global Airborne Observatory (GAO) – similar instrument design - over several basins across U.S fr.om 2019-2021

Basins surveyed between 2019-2021



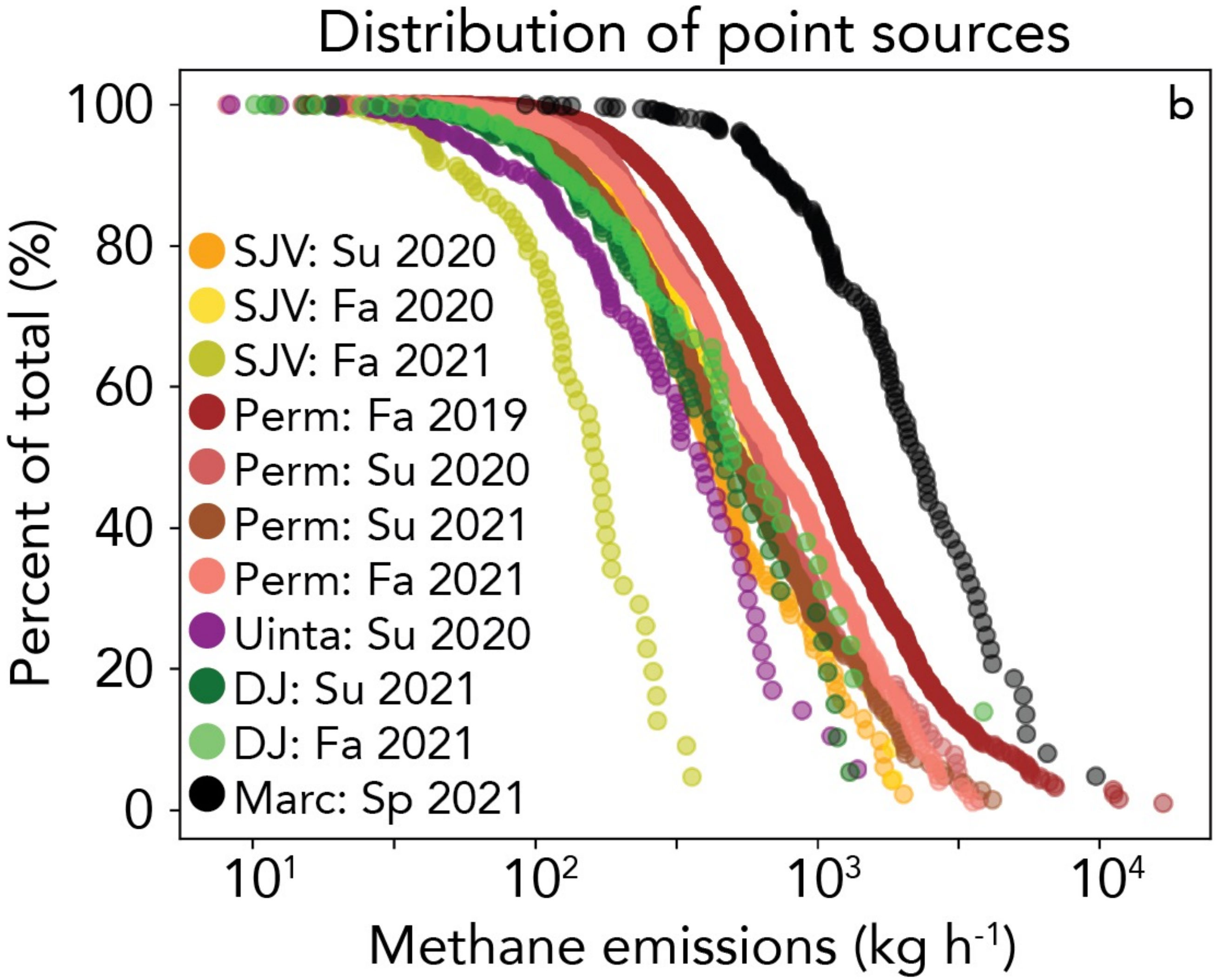
Sensitive to point sources above 10 kg/h

Each basin mapped at least 4 times to assess intermittency of emissions

Mix of emission sources: oil, gas, coal, waste, manure

San Joaquin Valley	Summer 2020, Fall 2020, Fall 2021
Permian	Fall 2019, Summer 2020, Summer 2021, Fall 2021
Uinta	Summer 2020
Denver-Julesburg	Summer 2021, Fall 2021
Pennsylvania Marcellus	Spring 2021

We consistently found power-law emission distributions across basins and sectors.

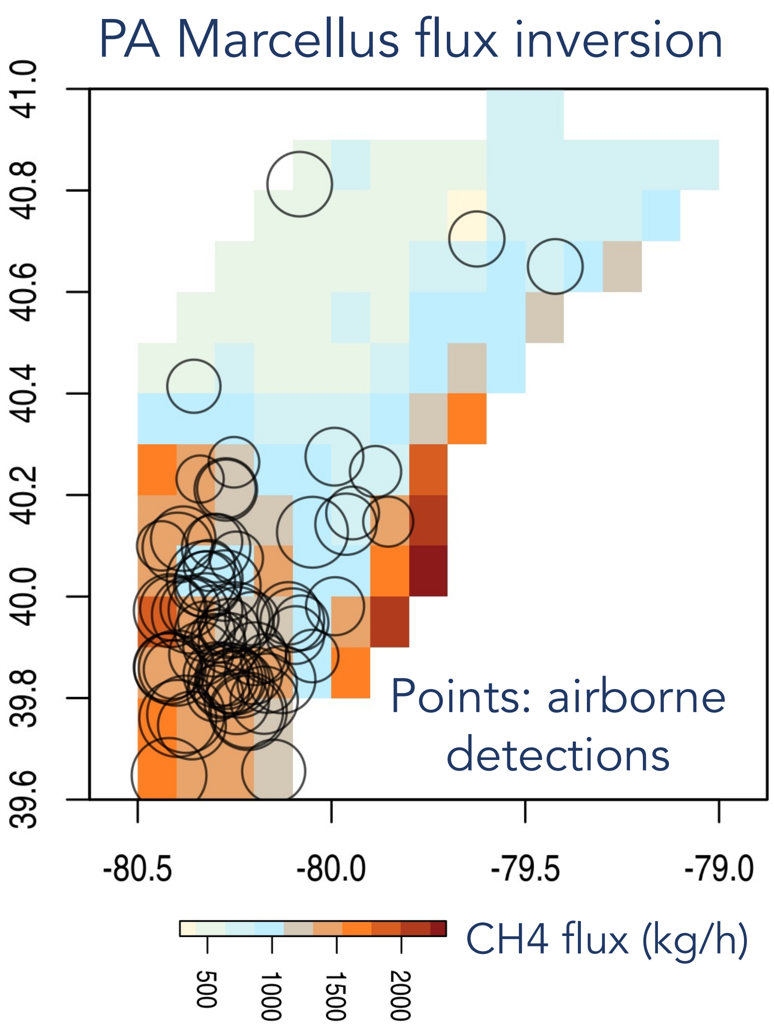


Corroborates previous findings from independent campaigns:

Even among super-emitter populations, disproportionate contribution from largest sources.

Emissions calculated following Integrated Methane Enhancement (IME) approach and HRRR 10-m winds (following Duren et al., 2019)

We perform simultaneous TROPOMI regional CH4 flux inversions over flight domains to contextualize super-emitters against regional CH4 totals.



Available prior inventories out-of-date or lack spatial/temporal resolution:

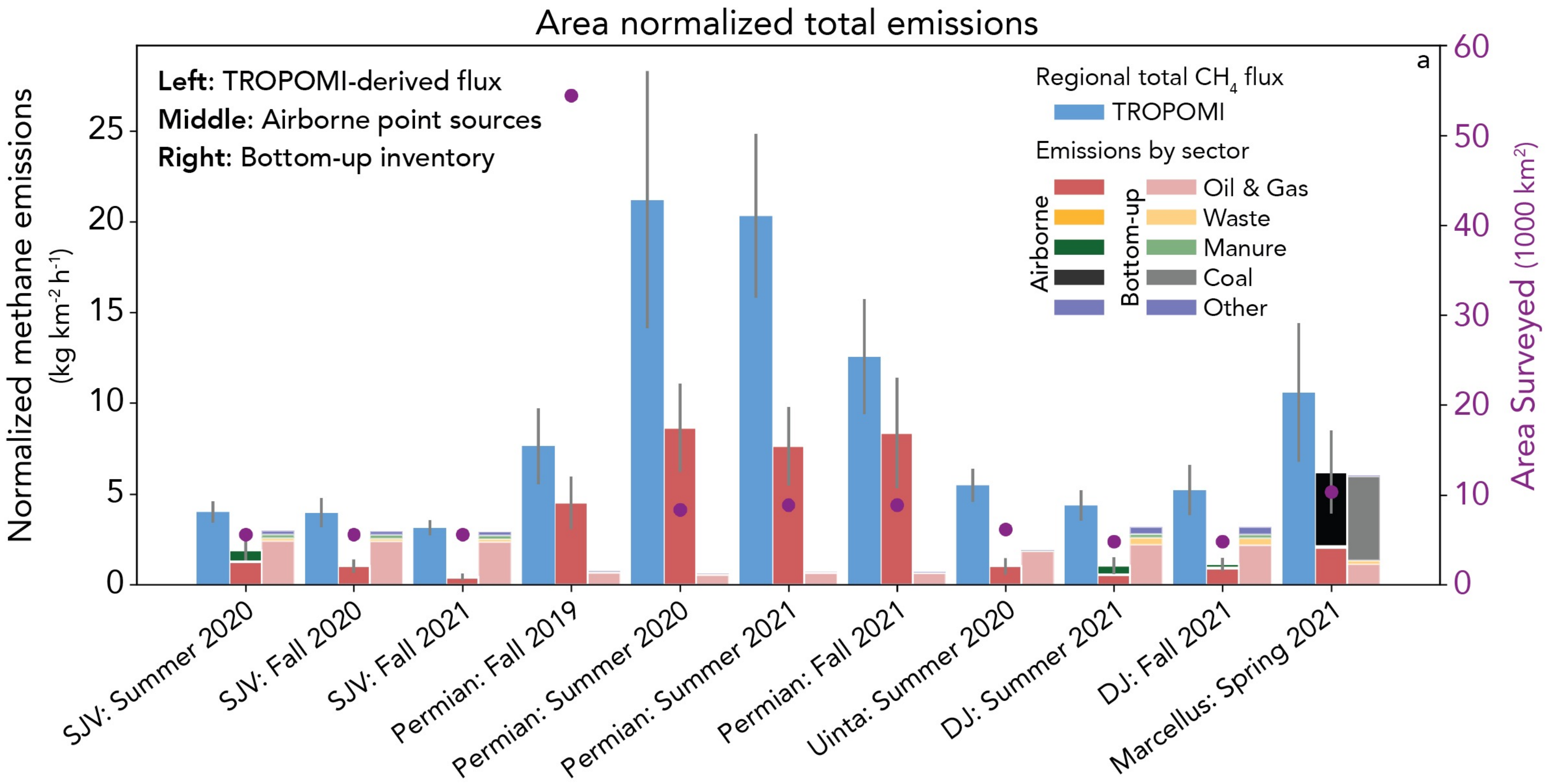
Instead, opt for Tikhonov Regularization approach to estimate CH4 fluxes from TROPOMI XCH4

$$\hat{\mathbf{x}} = \min_{\mathbf{x}} \left\{ \left\| \mathbf{R}^{-1/2}(\mathbf{y} - \mathbf{H}\mathbf{x}) \right\|_2^2 + \lambda^2 \|\mathbf{x}\|_2^2 \right\}$$

λ determined from elbow in L-curve

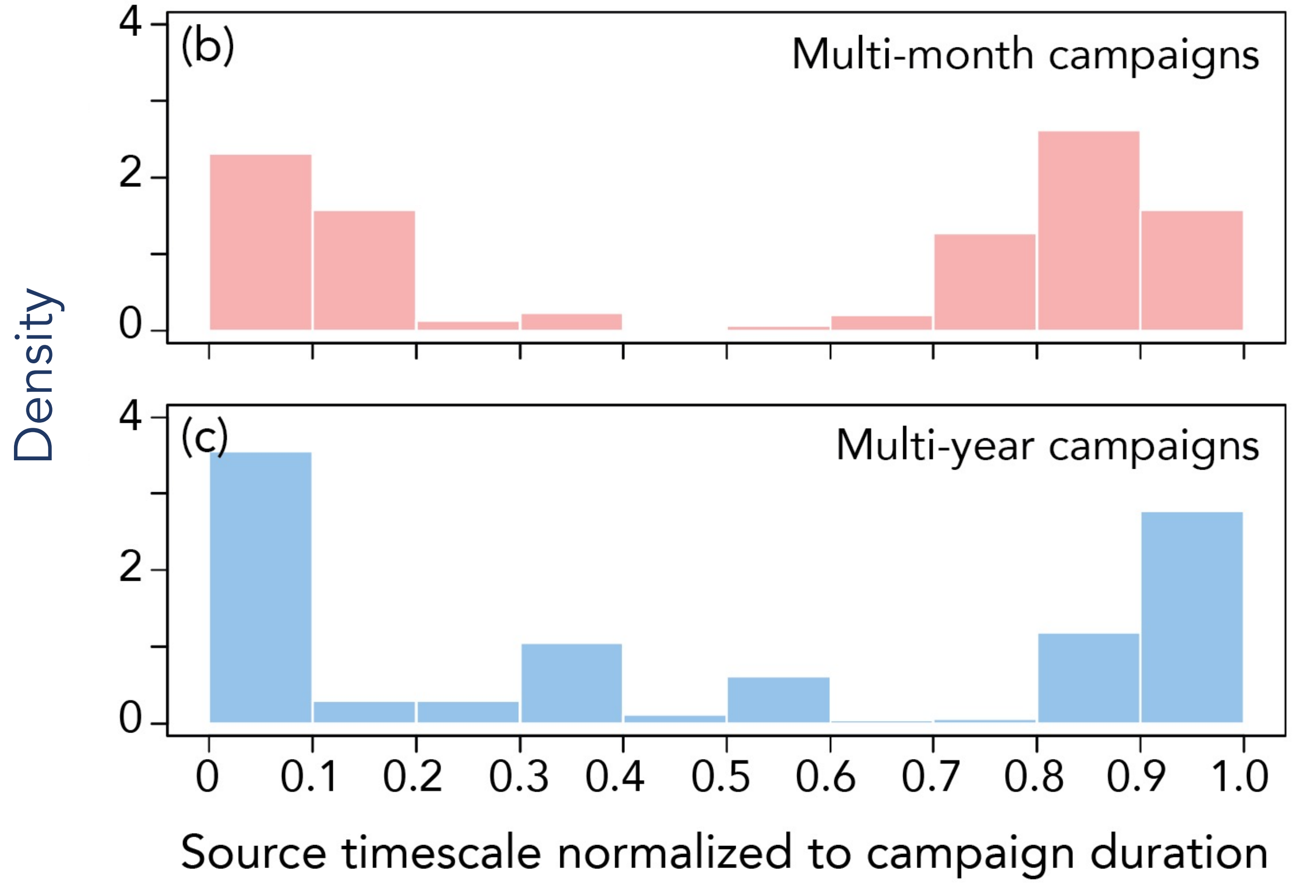
Inversions validated with simultaneous aircraft mass-balance flights (Denver, Permian) and tower-based inversions (Permian, Unita)

Comparison between TROPOMI flux inversions and aircraft results show that super-emitters make up 13-60% of budget across basins.



These super-emitters generally only make up 1% of infrastructure in a basin.

In some basins, we have statistics going back several months to years. This allows us to look at the timescales that emissions persist.



Two modes that contribute equally to total budget:

(1) "Short-lived" – we see a source 1-2 times, never again

(2) "Long-lived" – sources pop up multiple times across years

When thinking about mitigation potential – need a sampling strategy that captures temporal intermittency of emitters.

Conclusions

- GAO and AVIRIS-NG flew multiple basins across the U.S. during 2019-2021, covering oil&gas, coal, waste, and livestock sectors.
- Through comparison with TROPOMI flux inversions, we find super-emitters generally make up 20-60% of emissions in a basin but are a small fraction of infrastructure. Potential for mitigation.
- Revisit to these basins after months to years shows that sources generally pertain to two equally contributing categories: long-lived and short-lived. Need for sampling strategies that can cover both types of events.
- Replicating these types of analyses from space will require platforms or fusion efforts that can achieve sufficient detection limits, spatial completeness, and temporal revisit.