Comprehensive aerial survey in the New Mexico Permian Basin reveals missing super emitters

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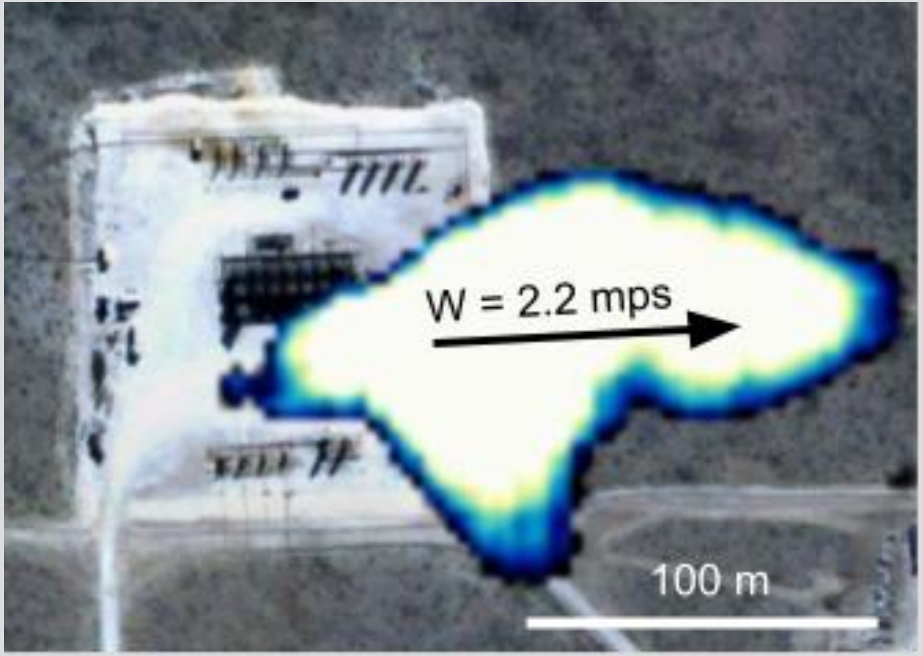
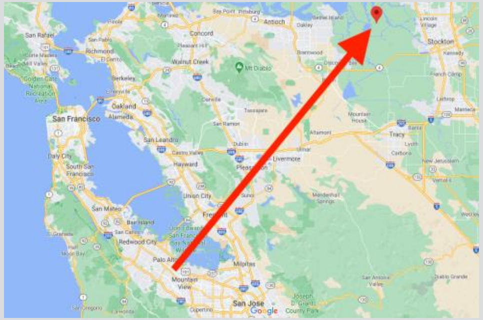
Kairos Aerospace hyperspectral methane sensing

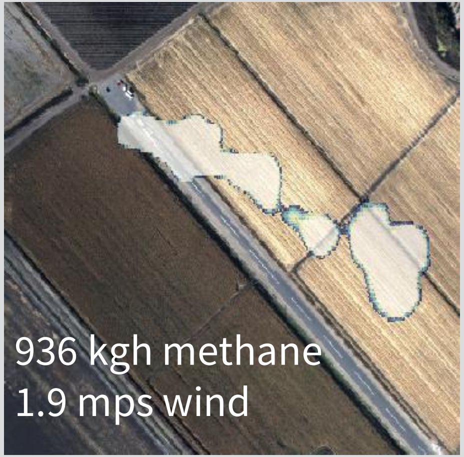


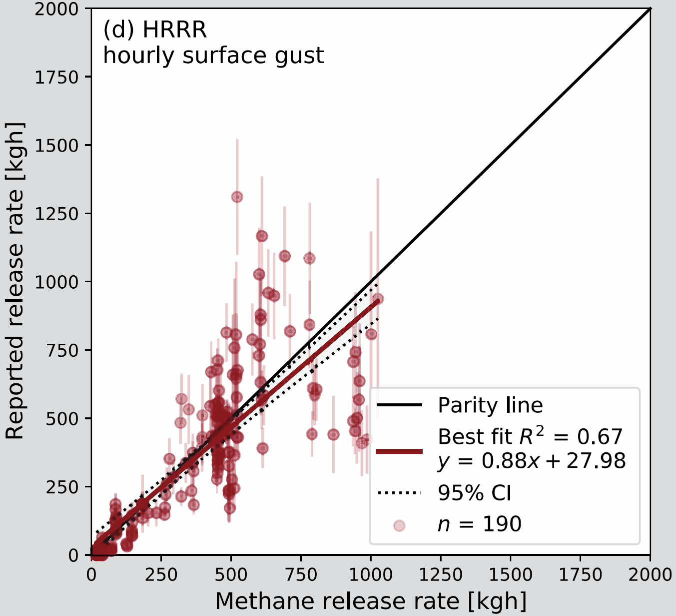
KAIROS AEROSPACE

Verified quantification performance via single-blind testing



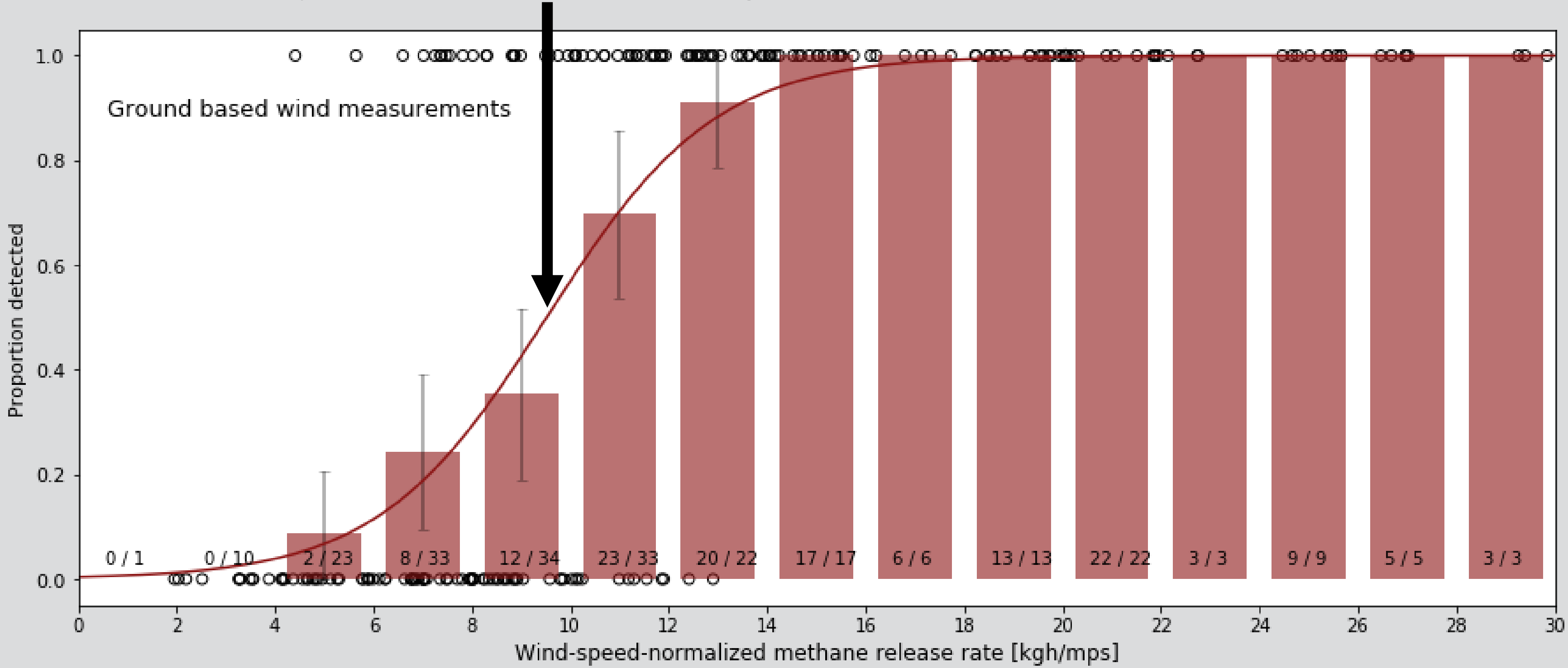
- 5 days in the field, October 2019
- 234 data points
- 18-1025 kgh (~10x other studies)





50% detection probability at ~10 kgh/mps

At 3 mps wind, would see ~30 kgh about half the time



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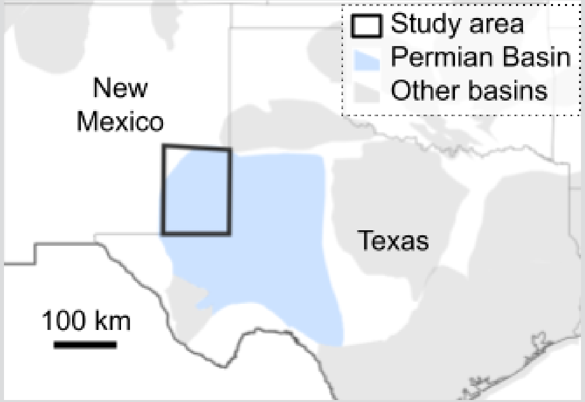
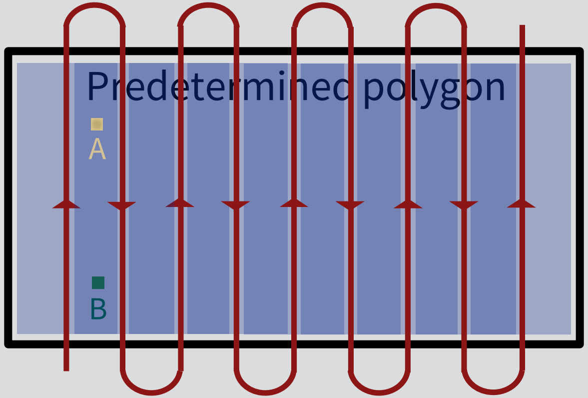
Repeated comprehensive survey in New Mexico Permian





- 35,923 km^2
- 29,683 wells
- 15,000+ km pipelines

- 115 flight days in Oct 2018 – Jan 2020
- 4.0±2.8(2σ) overflights per point source
- 117,658 well visits
- ~1000 wells per flight day

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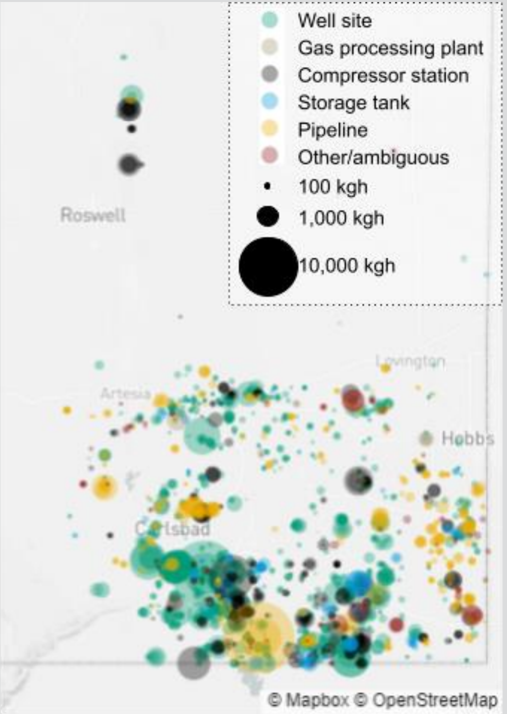
1985 plumes from 958 sources



Persistence averaged emission rates of 958 emission sources

e.g. Four observations of a single source at (100, 0, 300, 0) kgh → persistence = ½ and persistence averaged source size = 100 kgh

1985 plumes and wind data → Calibrate and adjust based on controlled releases → Select one plume for each emission source and account for intermittency → Directly measured emissions → Account for undetected emissions within partial detection range and below detection limit → Extrapolate to all assets in the survey area → Survey area total emissions

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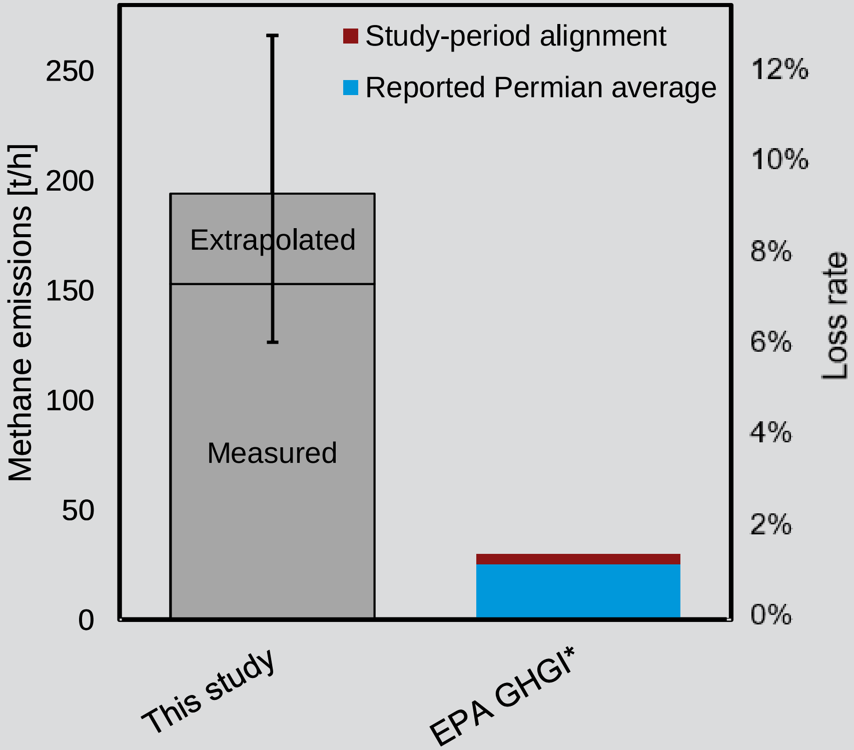
New Mexico Permian is 5.1 to 7.5 times leakier than GHGI estimates



- 153(+71/-70, 95% CI) t/h directly measured emissions, 7.4±3.4% of production
- 194(+72/-68) t/h total emissions, 9.4%(+3.5%/-3.3%) of production
- Sensitivity analysis show that mean loss rates range from 8.1% to 10.4%

- EPA GHGI estimates 25 t/h
- Study period alignment +5 t/h due to production growth

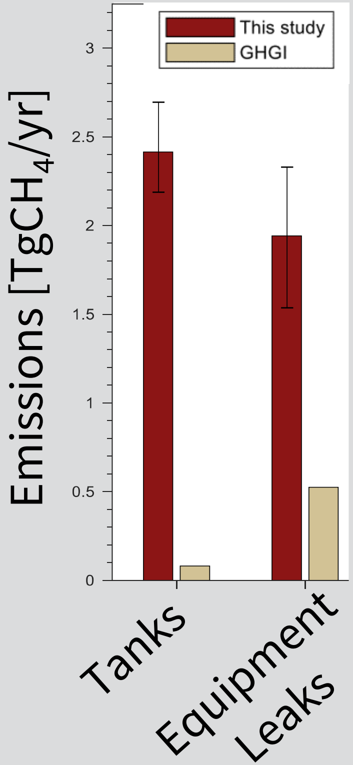
* Modified GHGI estimate published in Zhang et al. 2020, a TROPOMI and inverse modeling based study for the entire Permian Basin. This GHGI estimate is based on Maasakkers et al.'s gridded GHGI and is extrapolated with 2018 Enverus Drillinginfo data to reflect intensified production.

Why don't ground surveys see as many emissions?

Possible explanations:

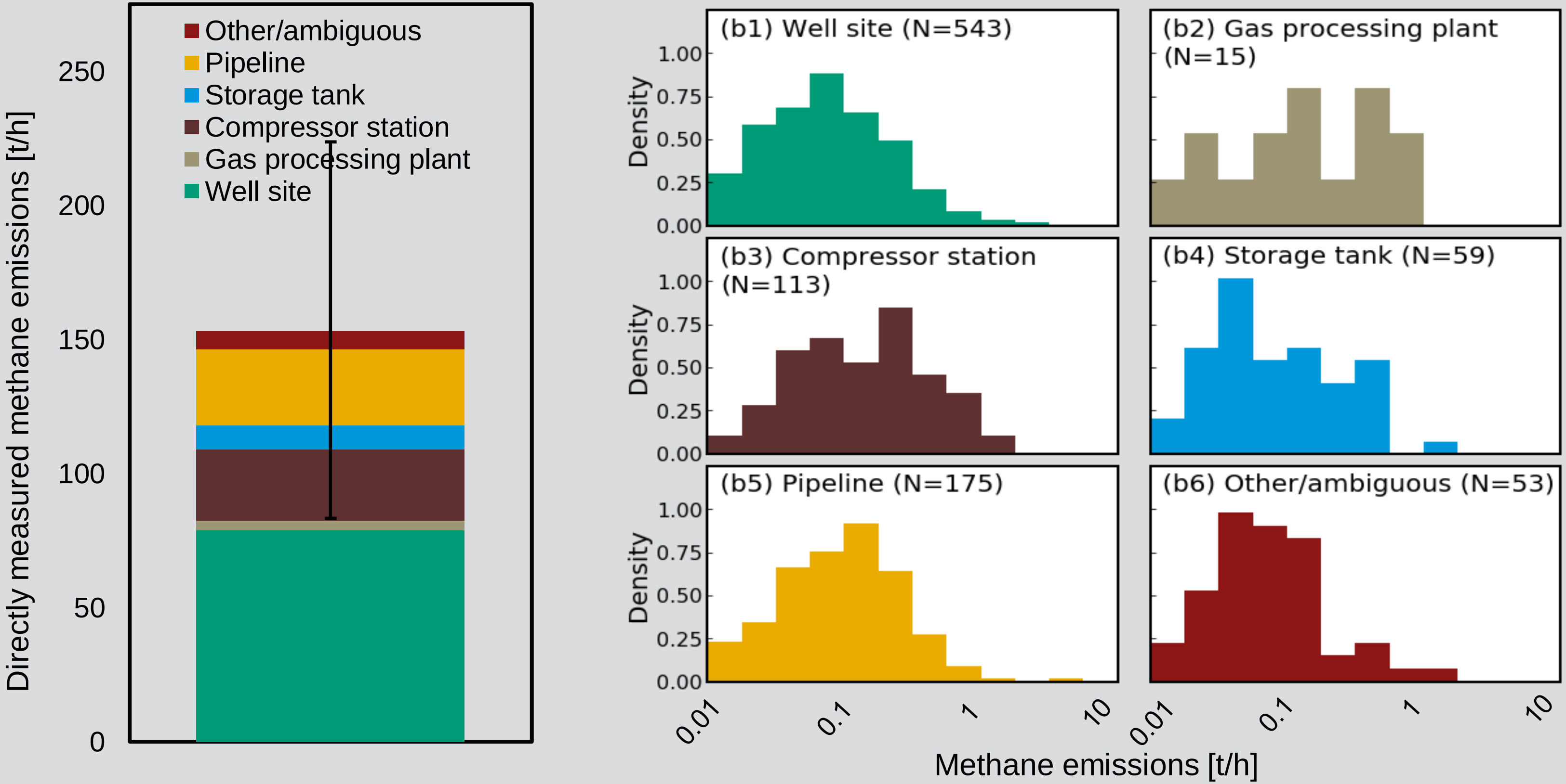
1. Ground surveys overlook tanks, unlit flares, and gathering lines
2. Operator consent for access on the ground may cause bias
3. Limited sample sizes do not fully capture the low-occurrence high-consequence super-emitting events
4. Ground quantification technologies (e.g. OTM-33A, high flow sampler) are not designed for the size of the aerially detected super-emitters
5. (Hopefully) New Mexico Permian is leakier than US average due to limited gas takeaway capacity

Overlooked emission sources

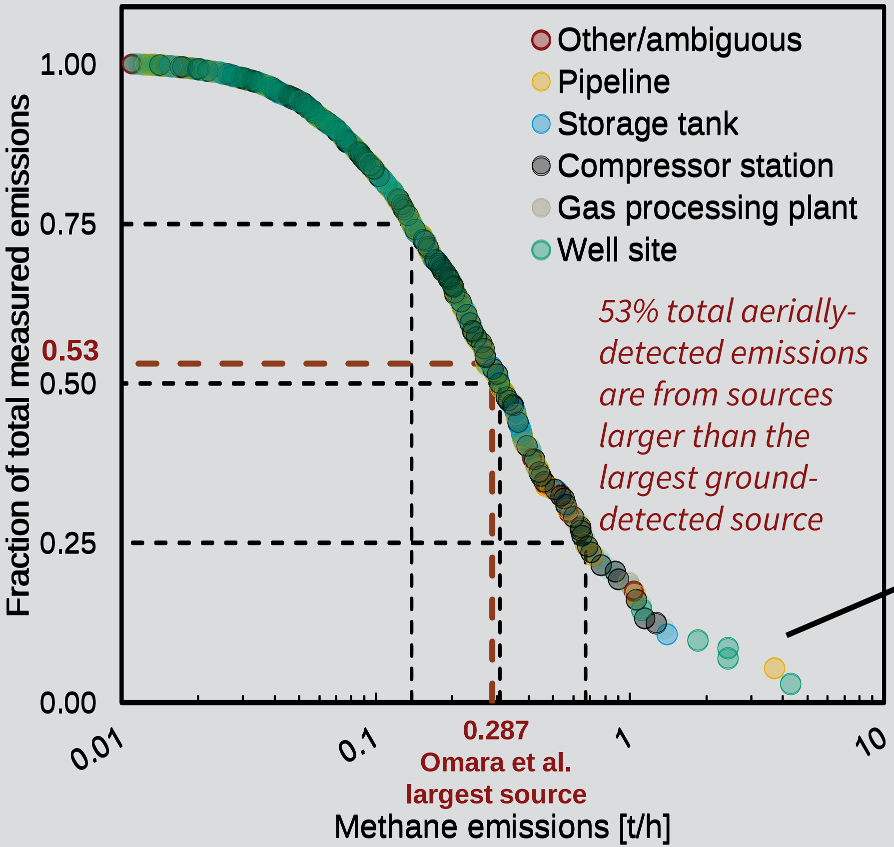


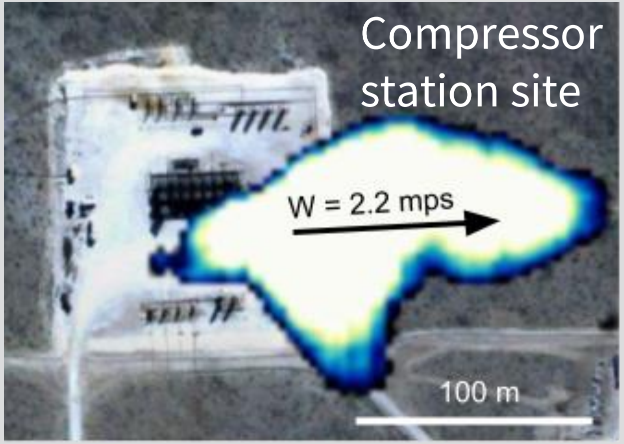
Sources: Rutherford et al. 2021, Rutherford & Sherwin fieldwork

Leaky midstream in New Mexico Permian



Site-level attribution

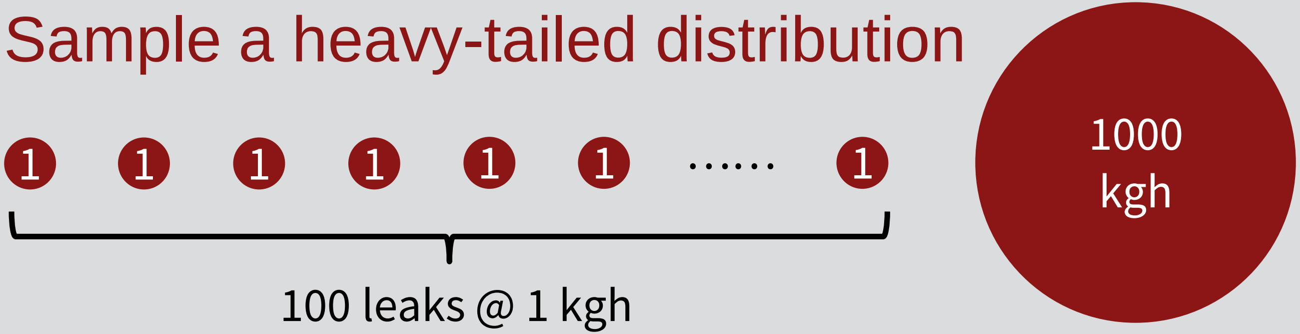




Top 10 emission sources:

- 5 well-sites, 2 of which look like unlit flare
- 1 (gathering) pipeline
- 1 tank site
- 3 compressor station sites

Sample a heavy-tailed distribution



$$\sum = 1{,}100\ kgh$$

	Strategy	Extrapolated total
1	Sample the entire population with sensitivity <1 kgh	1,100 kgh
2	Sample a subset of 5 leaks with sensitivity <1 kgh	P[101 kgh] = 95% P[20,080 kgh] = 5%
3	Sample the entire population with sensitivity >1 kgh	1,000 kgh

Better to be roughly correct than precisely wrong

Aerial survey unveils more super-emitters and leaky midstream infrastructure

- Emissions appear to be very high in the New Mexico Permian
- ~1000 sources from ~30,000 sites account for vast majority of emissions
- Compressor stations and gathering lines are substantial sources
- Population survey is key for sampling from a heavy tailed distribution
- Future GHGI updates should incorporate aerial survey results. How?

Works cited

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