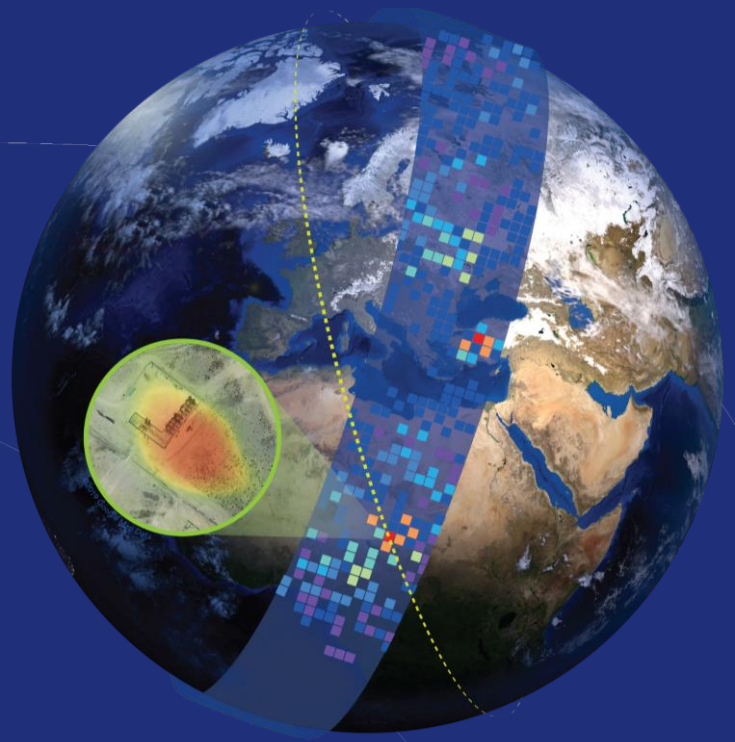
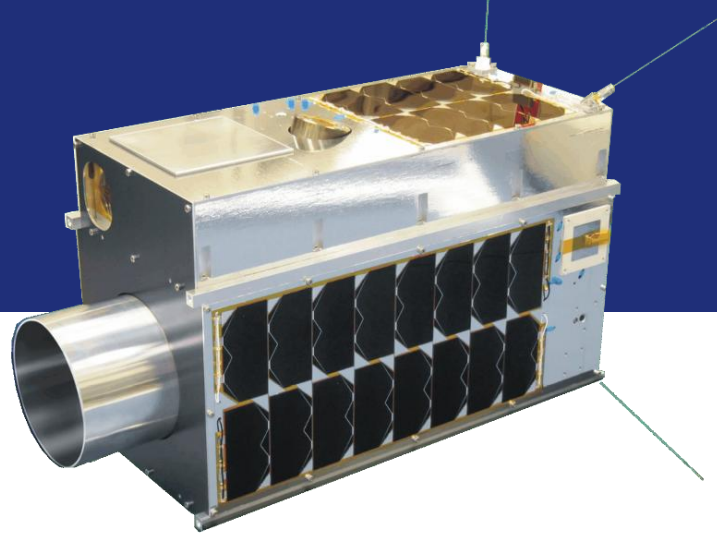


ESTIMATING THE O&G EMISSION RATE DISTRIBUTION WITH MULTIPLE SATELLITE SYSTEMS

Dylan Jervis, M. Girard, J.-P. MacLean, J. McKeever, D. Marshall, F. Piedboeuf, A. Ramier, J. Sampson, M. Strupler, E. Tarrant, D. Young

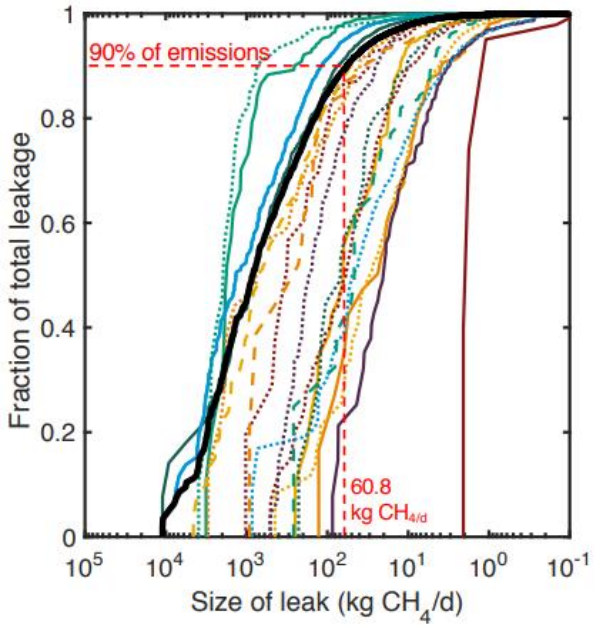
IWGGMS
2025



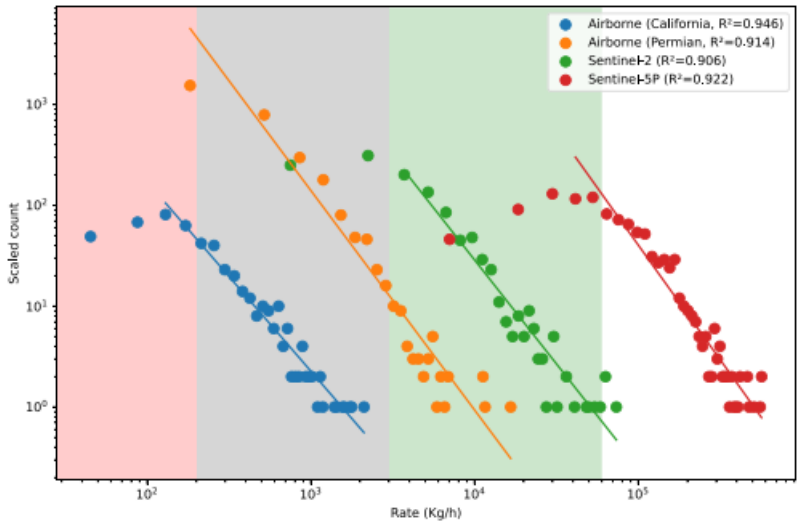
GHGSAT

UNDERSTANDING METHANE EMISSION RATE DISTRIBUTION

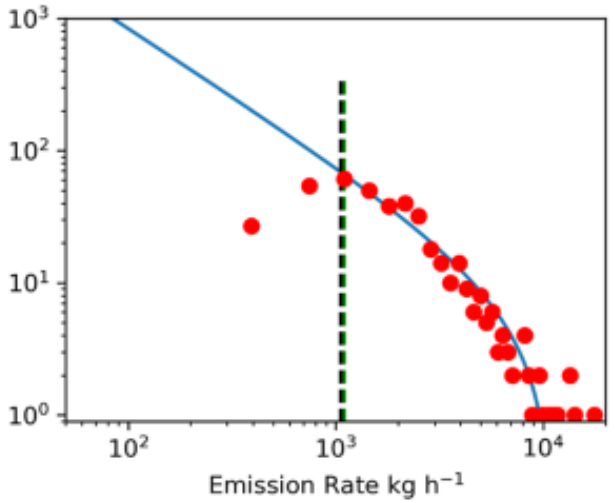
- What portion of emissions occur at what emission rates?
- Revealed “super-emitter” contributions, often missed in inventories
- Accurately estimating the emission rate distribution could enable cost-effective abatement strategies and set detection-technology requirements



Brandt et al., ES&T, 2016



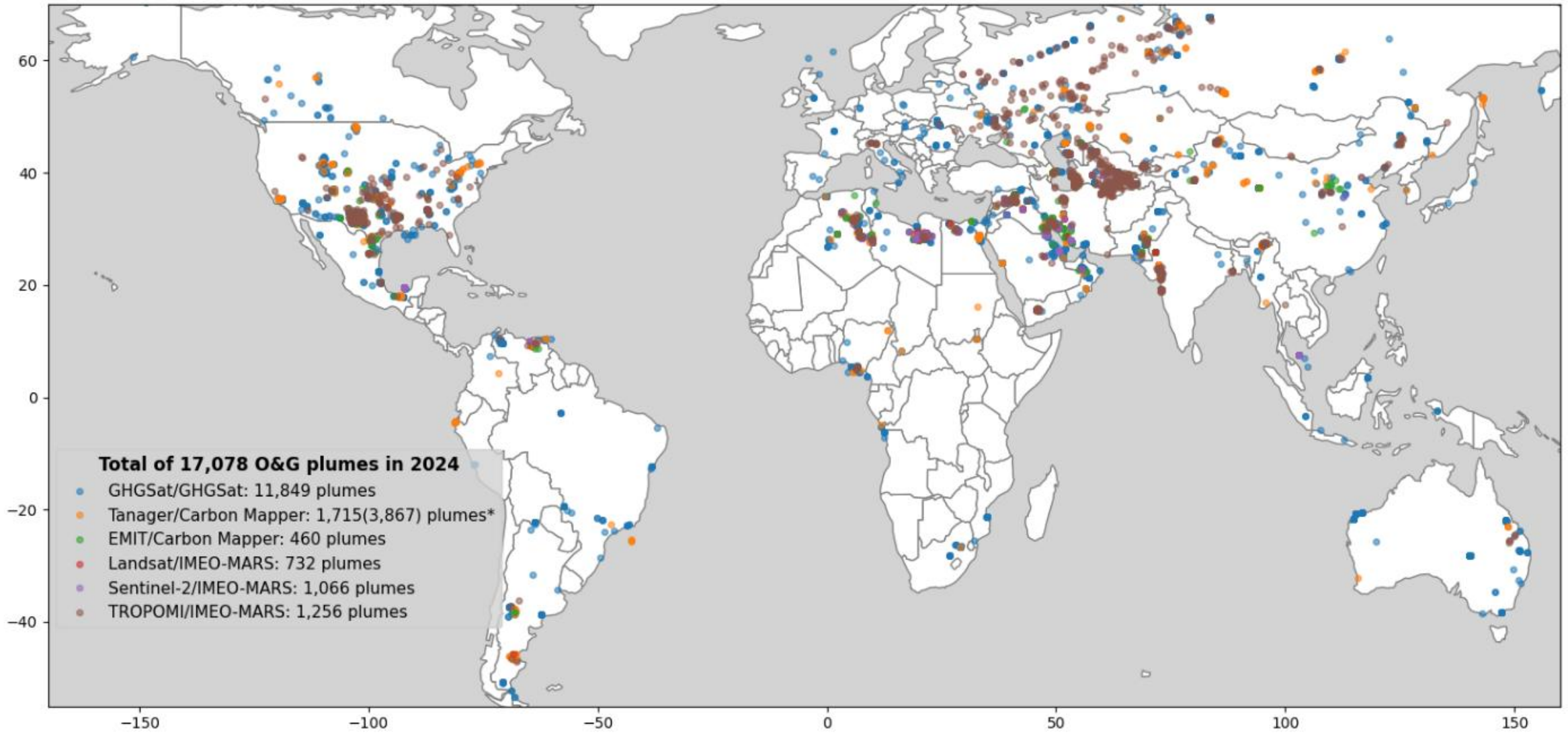
AVIRIS, S2, TROPOMI: Ehret et al., ES&T, 2022



EMIT: Ayasse et al., ES&T, 2024

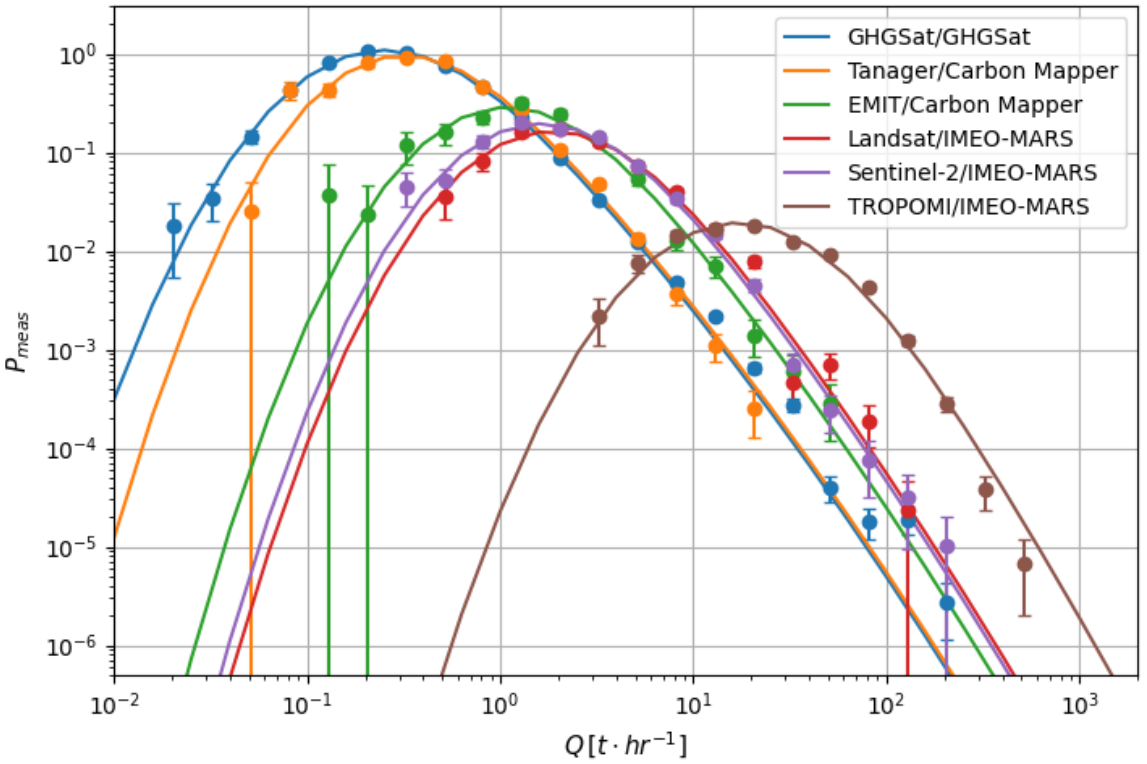
- **Combine 15,421 plume measurements from 6 satellite systems to estimate a global parent 2024 O&G emission rate distribution**
  - As a byproduct, can estimate “survey-mode” metrics for the detection probability and coverage of each satellite system

METHANE SATELLITE ECOSYSTEM IS EXPANDING AND MATURING



**For Tanager/Carbon Mapper, we take plume detections from from Sept 19th, 2024 (immediately after launch) until June 15th, 2025. The number of plumes in paranthesis is our estimate of the total annual O&G emissions Tanager/Carbon Mapper would have detected in a full calendar year.*

MEASURED EMISSION RATE DISTRIBUTIONS



Fit model is the product of the satellite system k specific detection probability and a common parent distribution:

$$P_{k;meas}(Q; \mathbf{z}_k, \mathbf{z}_{parent}) = POD_k(Q; \mathbf{z}_k) P_{parent}(Q; \mathbf{z}_{parent})$$

Log-normal CDF

Log-normal PDF

Optimize the combined function:

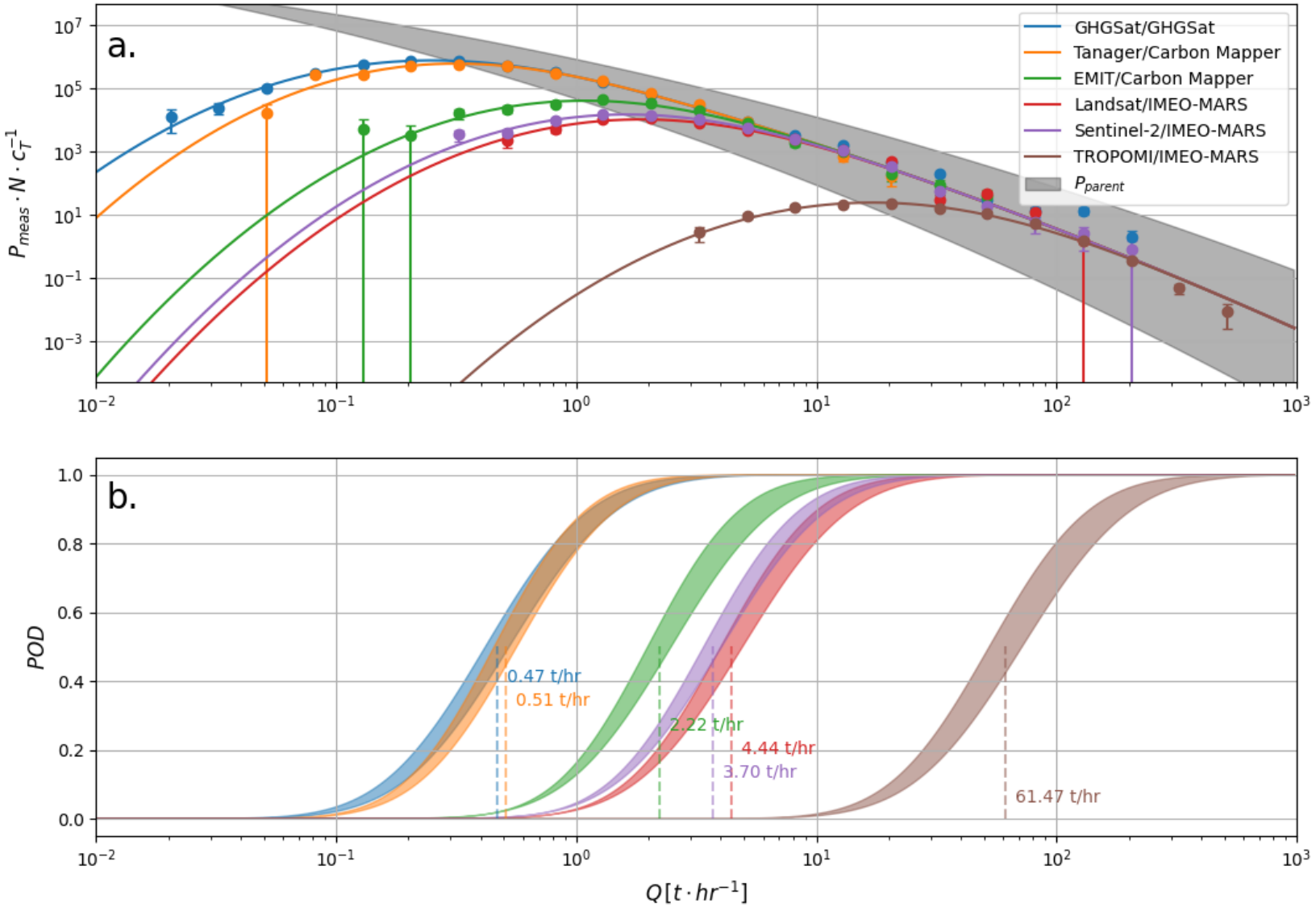
$$f(Q; \mathbf{z}_k, \mathbf{z}_{parent}) = \sum_k a_k P_{k;meas}(Q; \mathbf{z}_k, \mathbf{z}_{parent})$$

Jervis et al., in prep

SURVEY-MODE DETECTION PROBABILITY

Estimate O&G parent distribution log-normal parameters:

$$(\hat{\mu}, \hat{\sigma}) = (-4.66 \pm 1.12, 2.19 \pm 0.19)$$



Jervis et al., in prep

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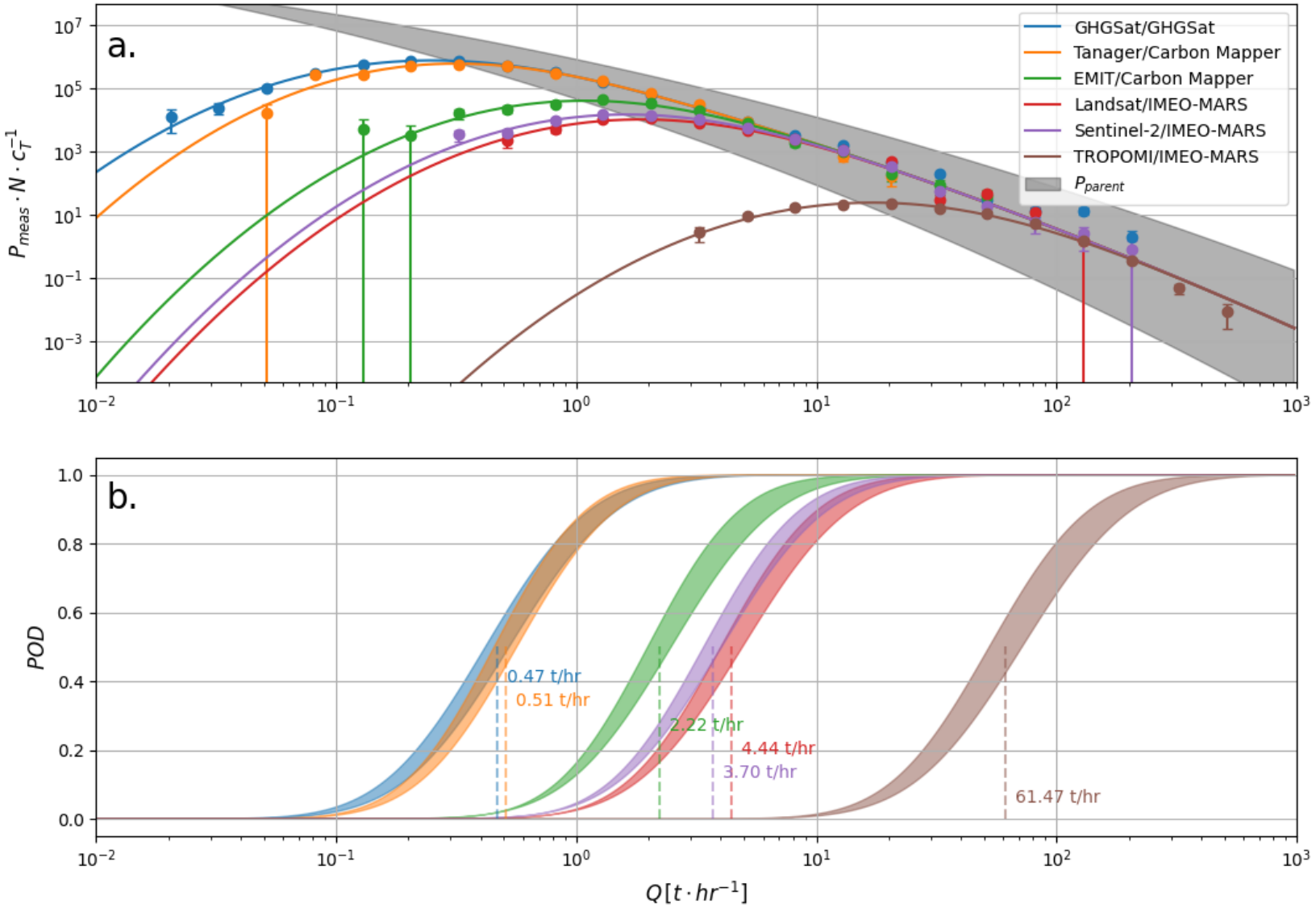

"Survey-mode" detection probability:

- Averaged over all observing conditions (albedo, wi speed, solar zenith angle, etc.)
- Weak prior information on source locations
- 50%: **(GHGSat, EMIT) = (470 kg/hr, 2220 kg/hr)**

...vs "Target-mode" detection probability:

- Strong prior information on source locations and/c more inspection attention
- Similar to controlled release situation
- 50%: **(GHGSat, EMIT) = (103 kg/hr*, ~700 kg/hr**)**
  - ...@ 3 m/s wind speed

**See Jason McKeever's talk*
***Ayasse et al., ES&T, 2025*

Jervis et al., in prep

RELATIVE SYSTEM COMPLETENESS

Jacob et al., ACP, 2022

Estimate the spatiotemporal coverage of each satellite system k:

The number of plumes in each bin is given by:

$$N_k P_{k;meas}\left(Q; \hat{\mathbf{z}}_k, \hat{\mathbf{z}}_{parent}\right)$$

If all systems had same coverage, would expect to see same number of plumes at very large emission rates (i.e. above detection limits):

$$C_{k;ST} = N_k P_{k;meas}\left(Q; \hat{\mathbf{z}}_k, \hat{\mathbf{z}}_{parent}\right)\Big|_{Q=250\ t\ hr^{-1}}$$

Relative spatiotemporal completeness:

$$c_{k;ST} = C_{k;ST} / C_{max;ST}$$

Ehret et al., E&T, 2022

Jervis et al., in prep

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Jacob et al., ACP, 2022

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Relative spatiotemporal completeness:

$$c_{k;ST} = C_{k;ST}/C_{max;ST}$$

Ehret et al., E&T, 2022

Estimate the relative fraction of emissions observed by each system:

$$N_{k;tot} \propto \int_0^\infty POD_k(Q; \hat{\mathbf{z}}_k) P_{parent}\left(Q; \hat{\mathbf{z}}_{parent}\right) dQ$$

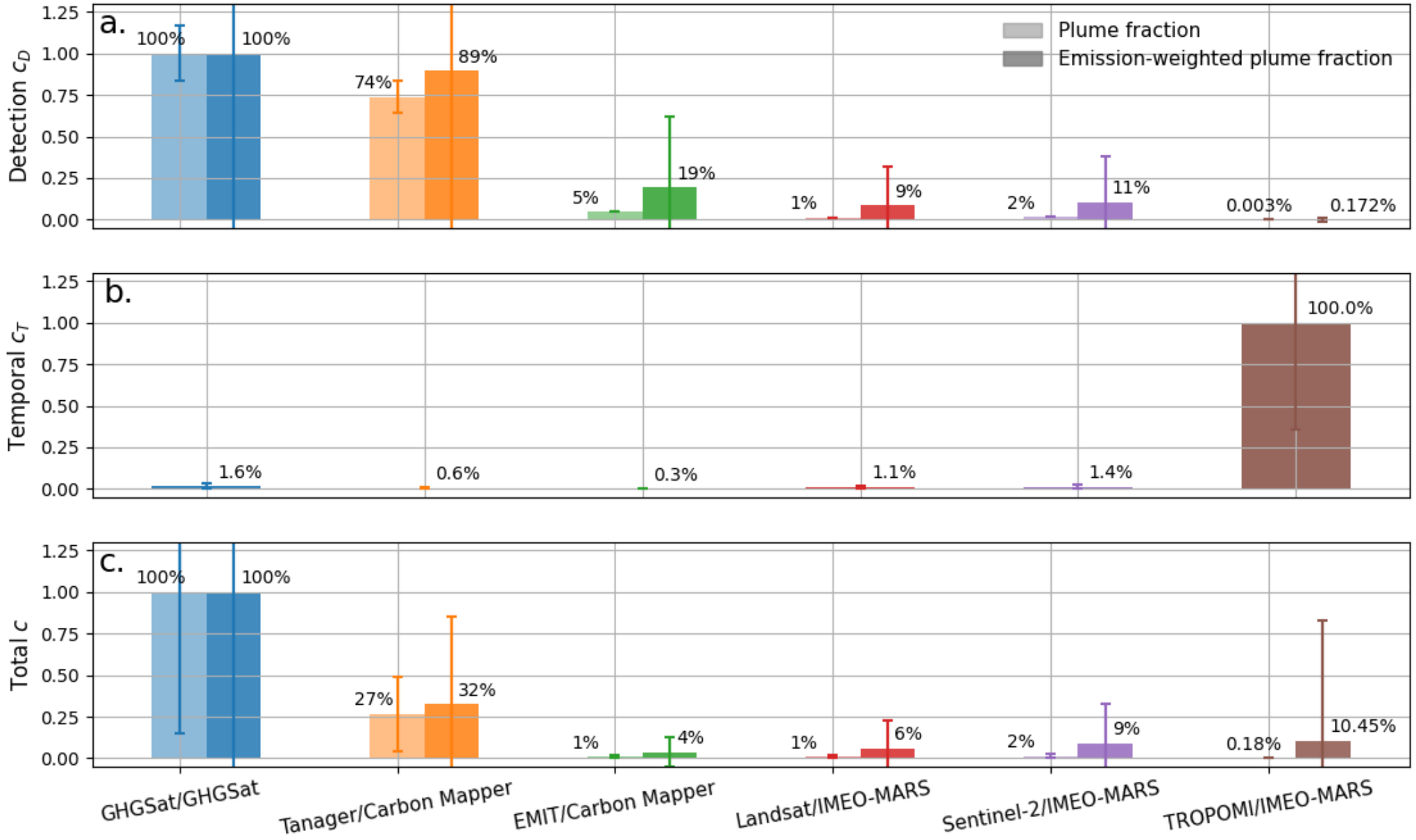
$$Q_{k;tot} \propto \int_0^\infty Q \cdot POD_k(Q; \hat{\mathbf{z}}_k) P_{parent}\left(Q; \hat{\mathbf{z}}_{parent}\right) dQ$$

Relative detection completeness:

$$c_{k;D} = N_{k;tot}/N_{max} \text{ or } c_{k;D} = Q_{k;tot}/Q_{max}$$

Jervis et al., in prep

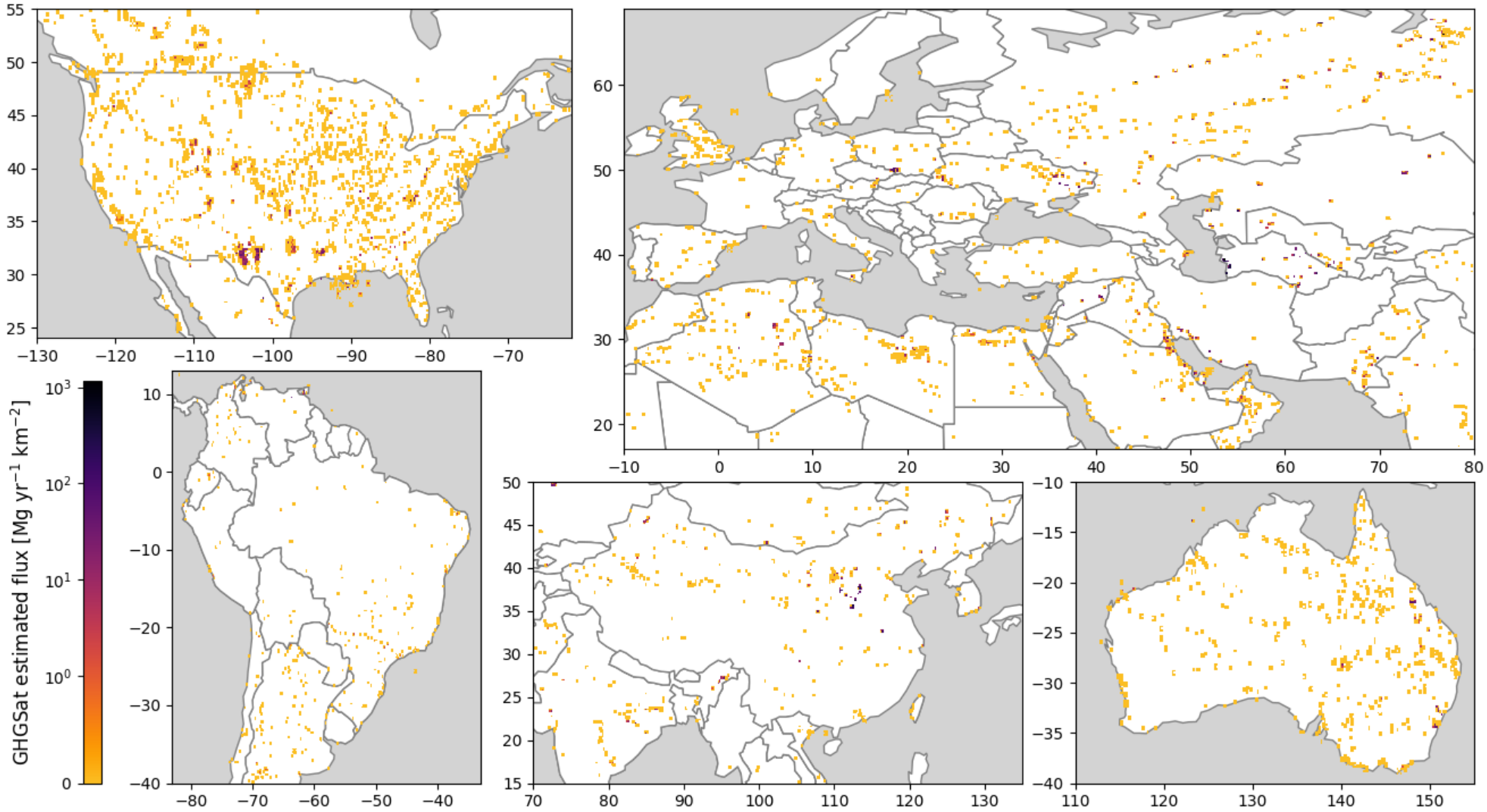
RELATIVE SYSTEM COMPLETENESS: 2024 O&G PLUMES



*For Tanager/Carbon Mapper, we use the estimate of the annual O&G plume count

Jervis et al., in prep

2023 O&G + COAL EMISSION ESTIMATES



Jervis et al., 2025, *in review*
Preprint: *https://doi.org/10.31223/X5V15D*

Data publicly available shortly

THANK YOU