

Reconciling bottom-up inventories and top-down measurements on individual oil and gas sites using continuous monitoring systems

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COLORADO SCHOOL OF MINES

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Push towards site-level measurement and reconciliation

H. R. 5376 (Inflation Reduction Act)

SEC. 136. (a) The Administrator shall impose and collect a fee from the owner or operator of **each applicable facility** that is required to report methane emissions ...

SEC. 136. (g)(2) ... calculation of fees under subsection (c) of this section, are based on **empirical data** and accurately reflect the total methane emissions from the applicable facilities.

United States

Push towards site-level measurement and reconciliation

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United States

Amendments adopted by the European Parliament on 9 May 2023 on the proposal for a regulation of the European Parliament

... importers must provide a report with the following information for **each site** from which the import to the Union has taken place ...

... information specifying the exporter's, or where relevant, the producer's **direct measurements of site-level methane emissions**, conducted by independent service provider ...

European Union

Push towards site-level measurement and reconciliation

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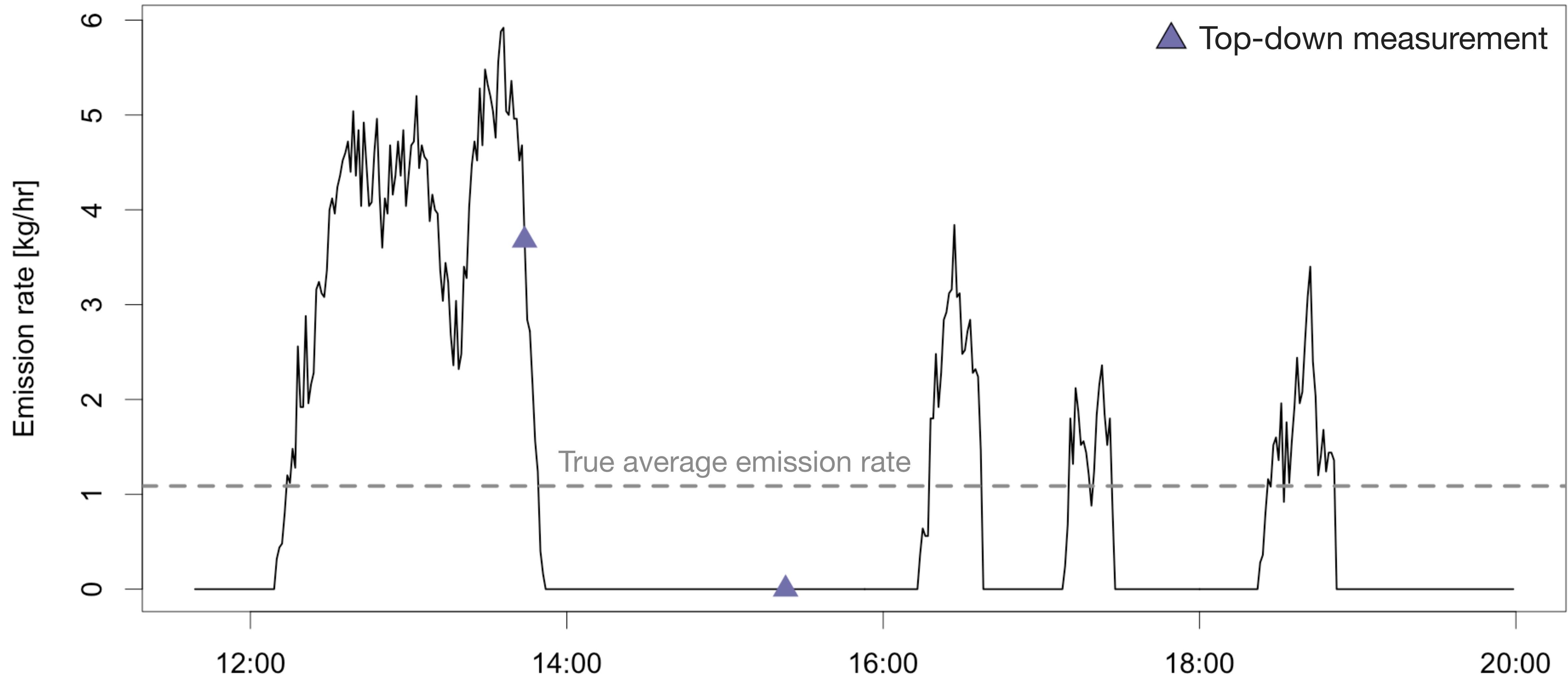
The Oil & Gas Methane Partnership 2.0 (OGMP 2.0)

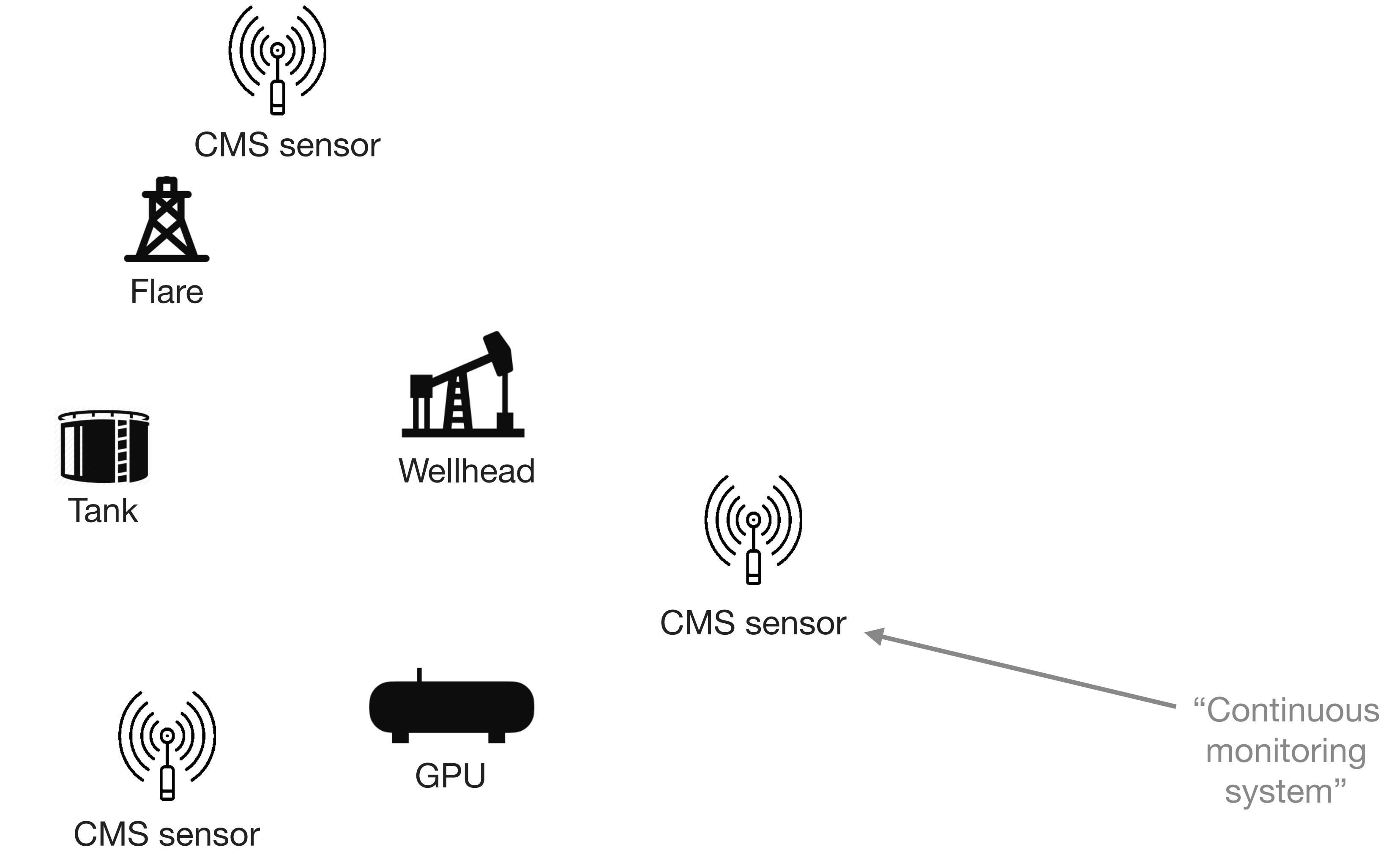
Level 5 – Emissions reported similarly to Level 4, but with the addition of **site-level measurements** (measurements that characterize site-level emissions distribution for a statistically representative population)

Global Initiatives

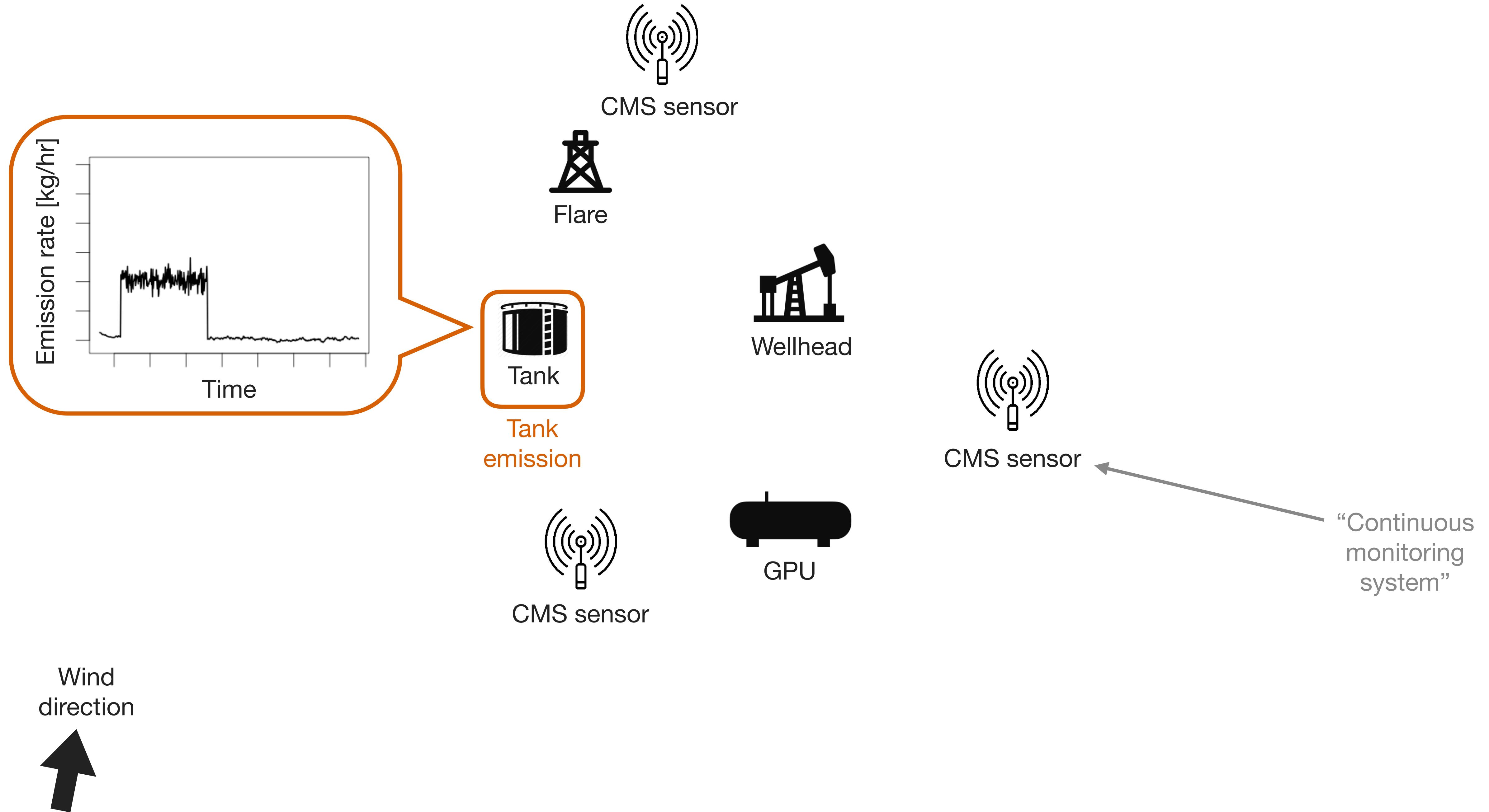
Emissions can have high temporal variability

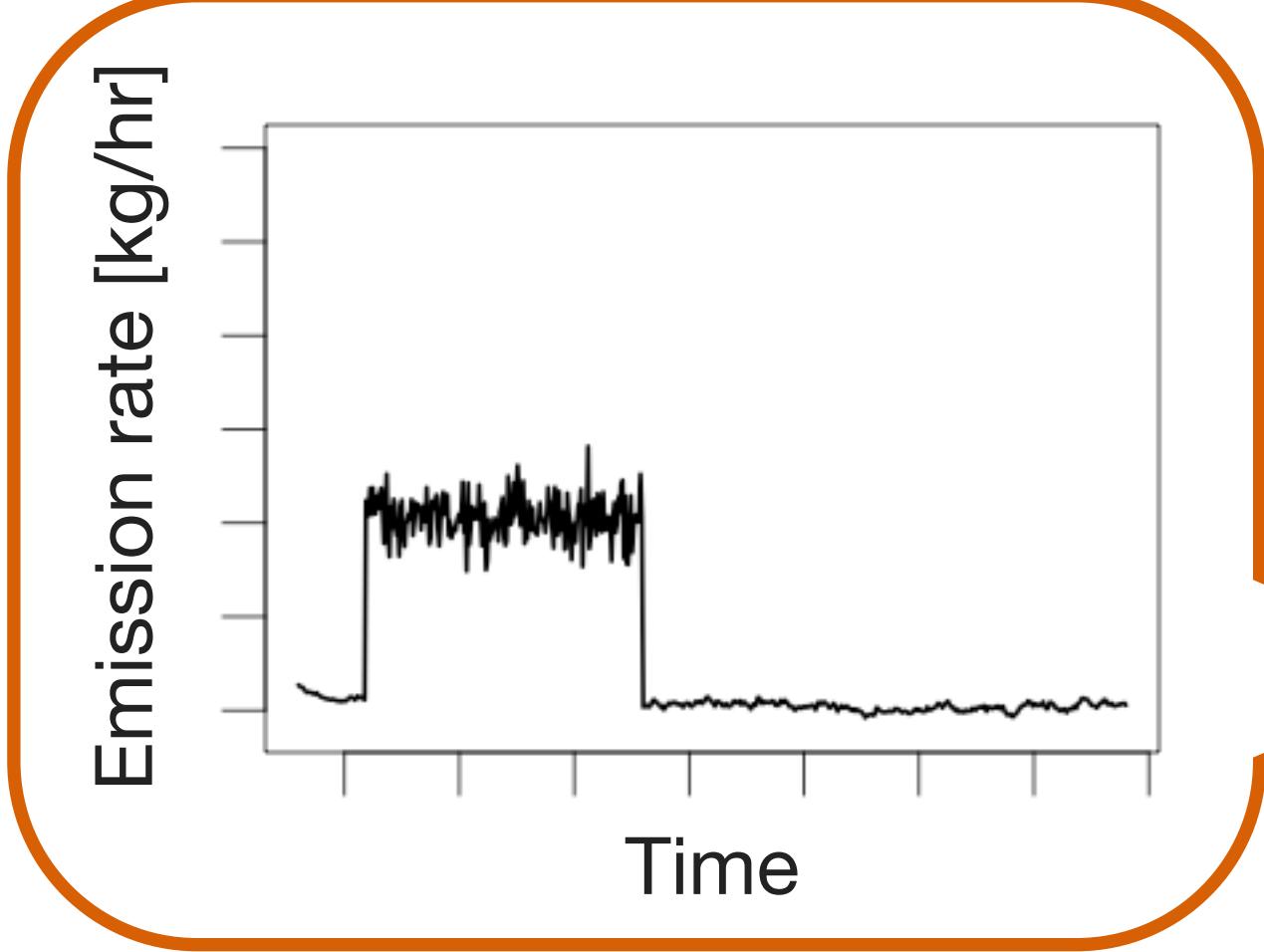
Challenging to interpret small number of measurements using only data from given site





The continuous monitoring inverse problem



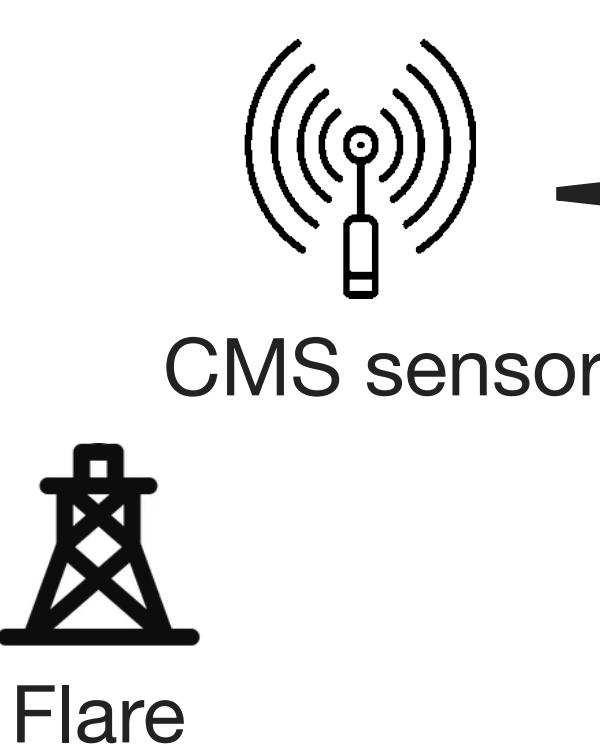
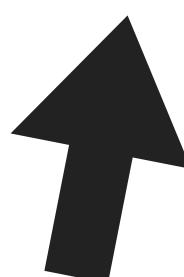


Tank
emission



CMS sensor

Wind
direction



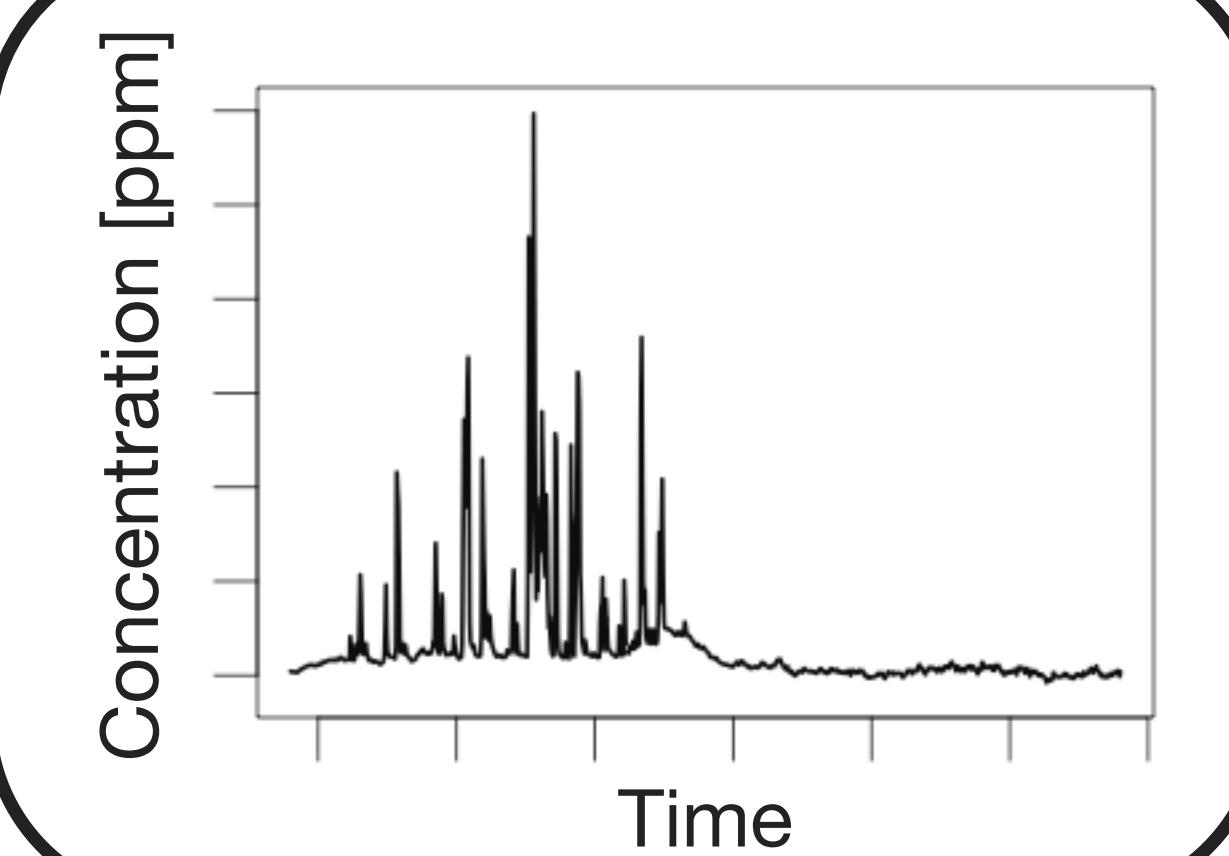
CMS sensor



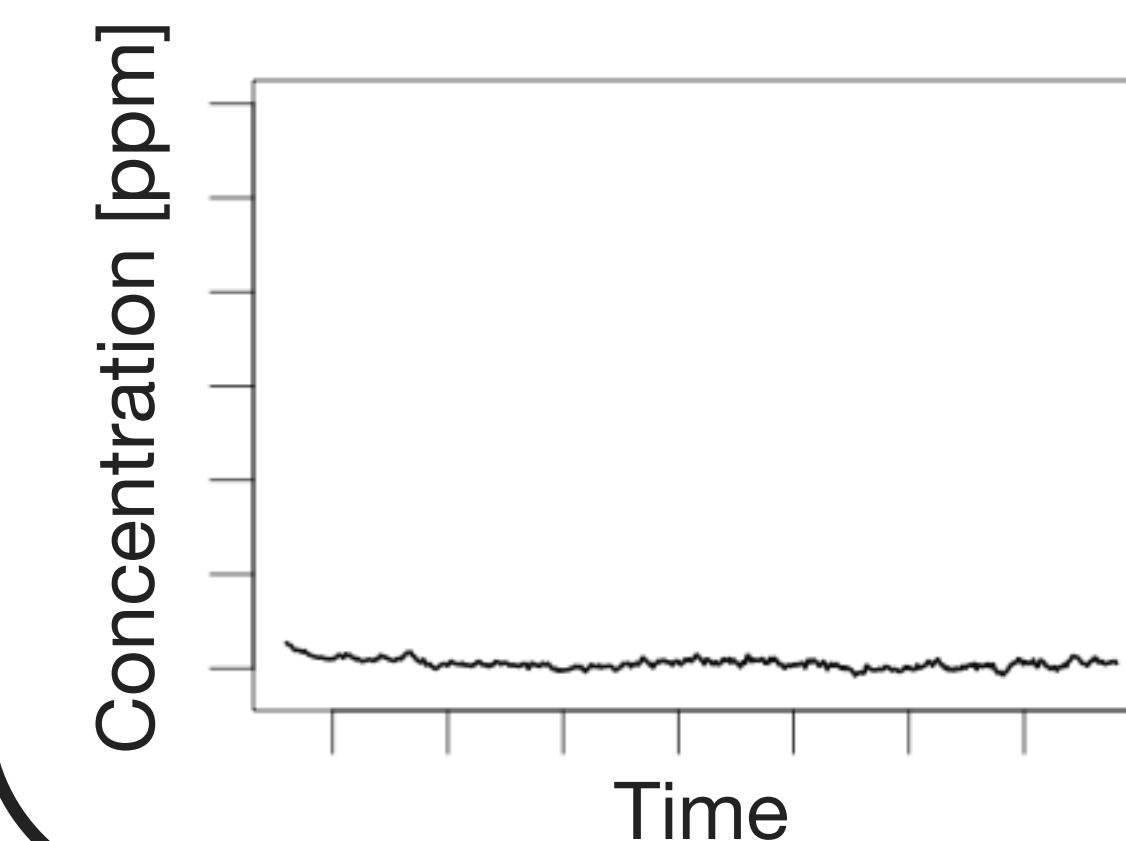
Wellhead

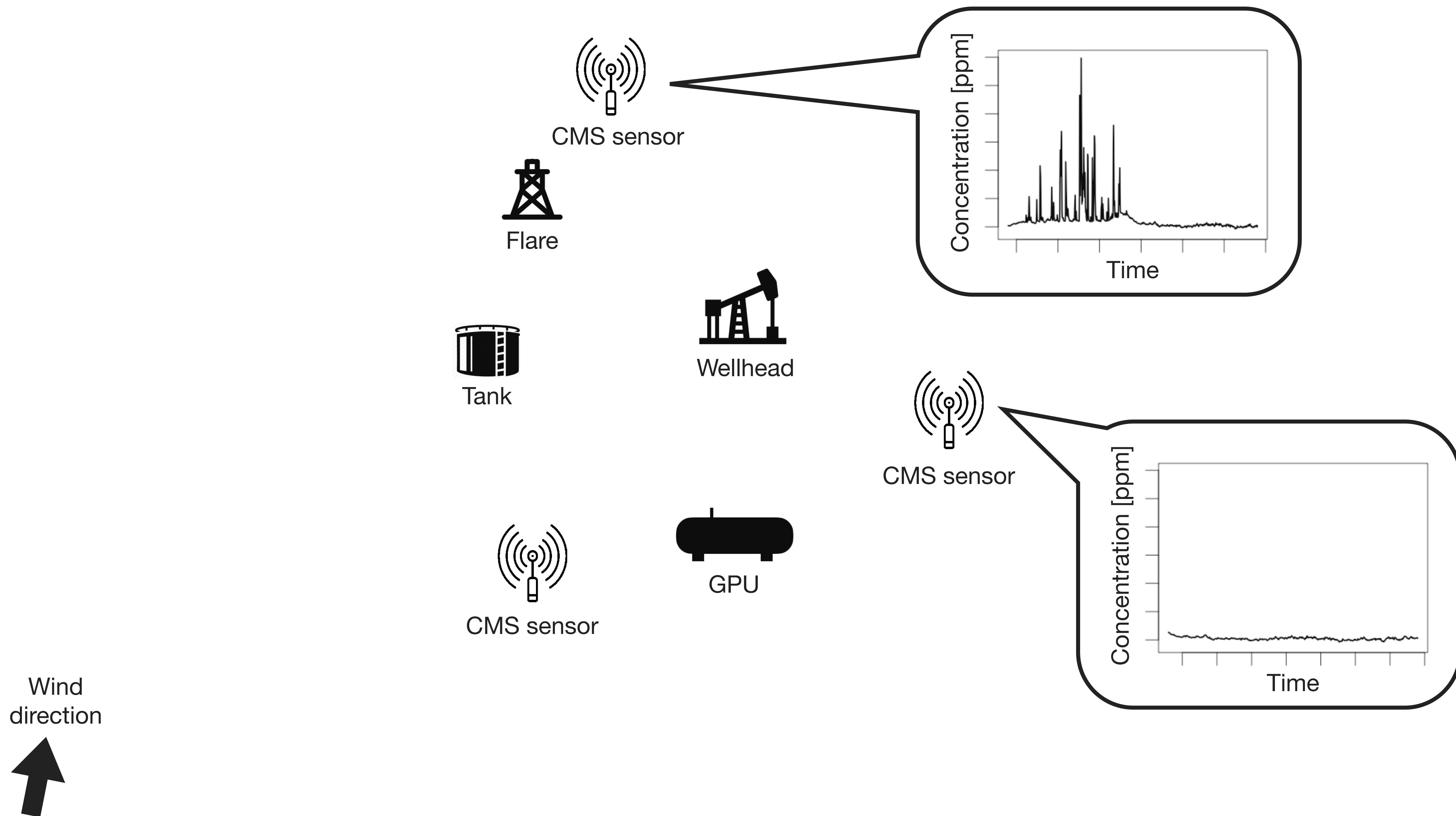


GPU

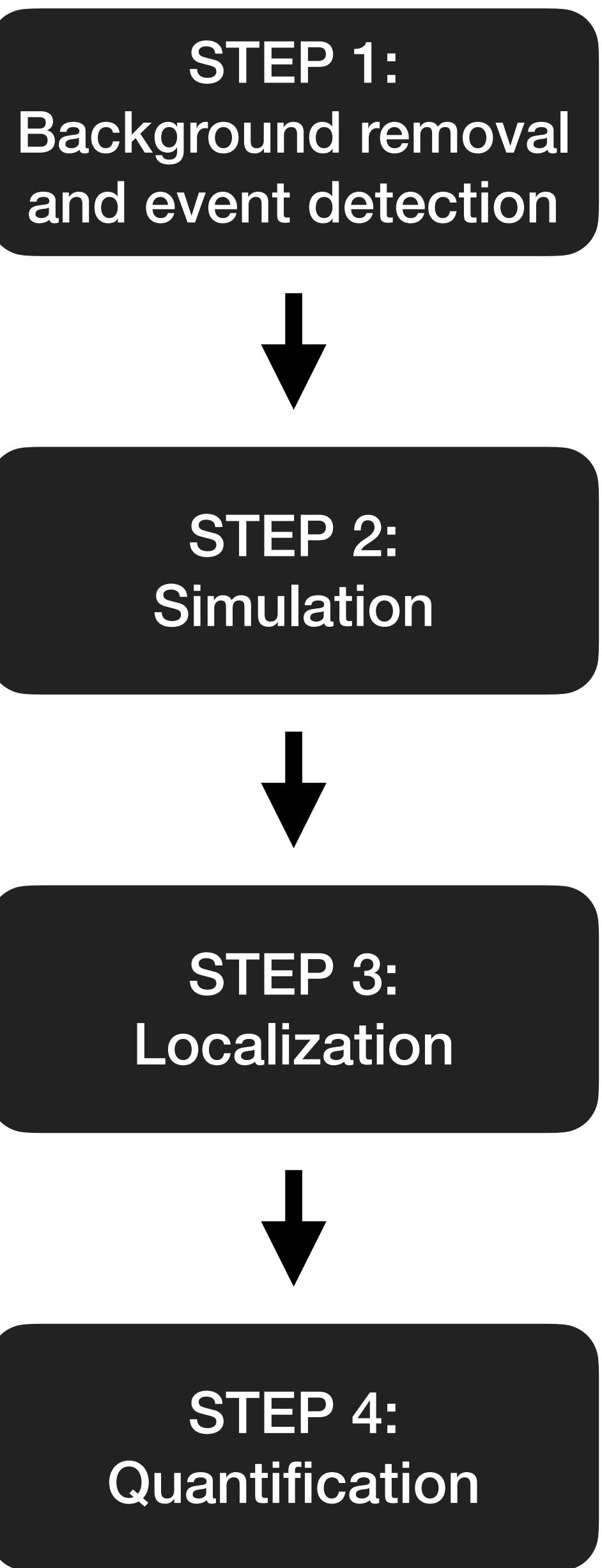


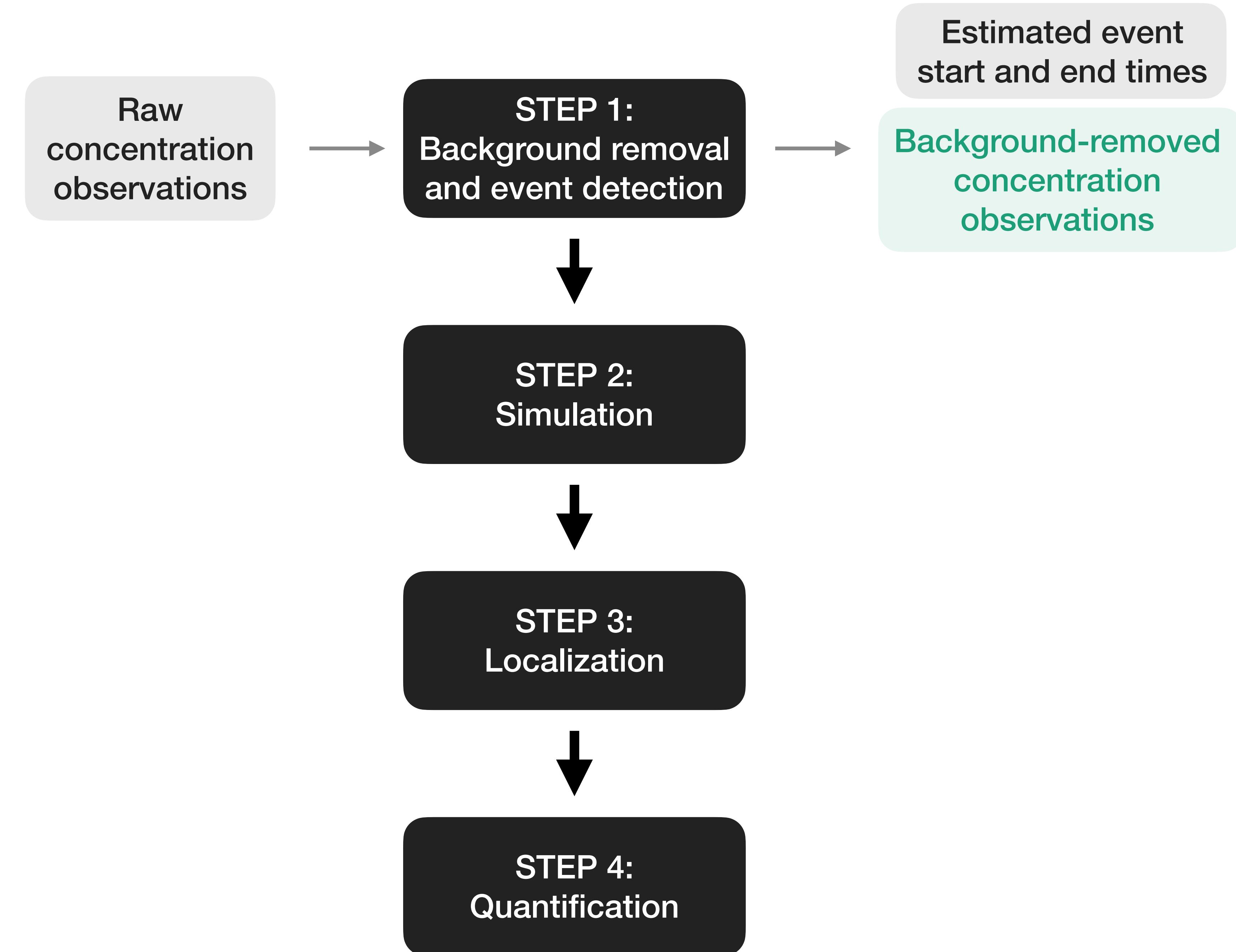
CMS sensor

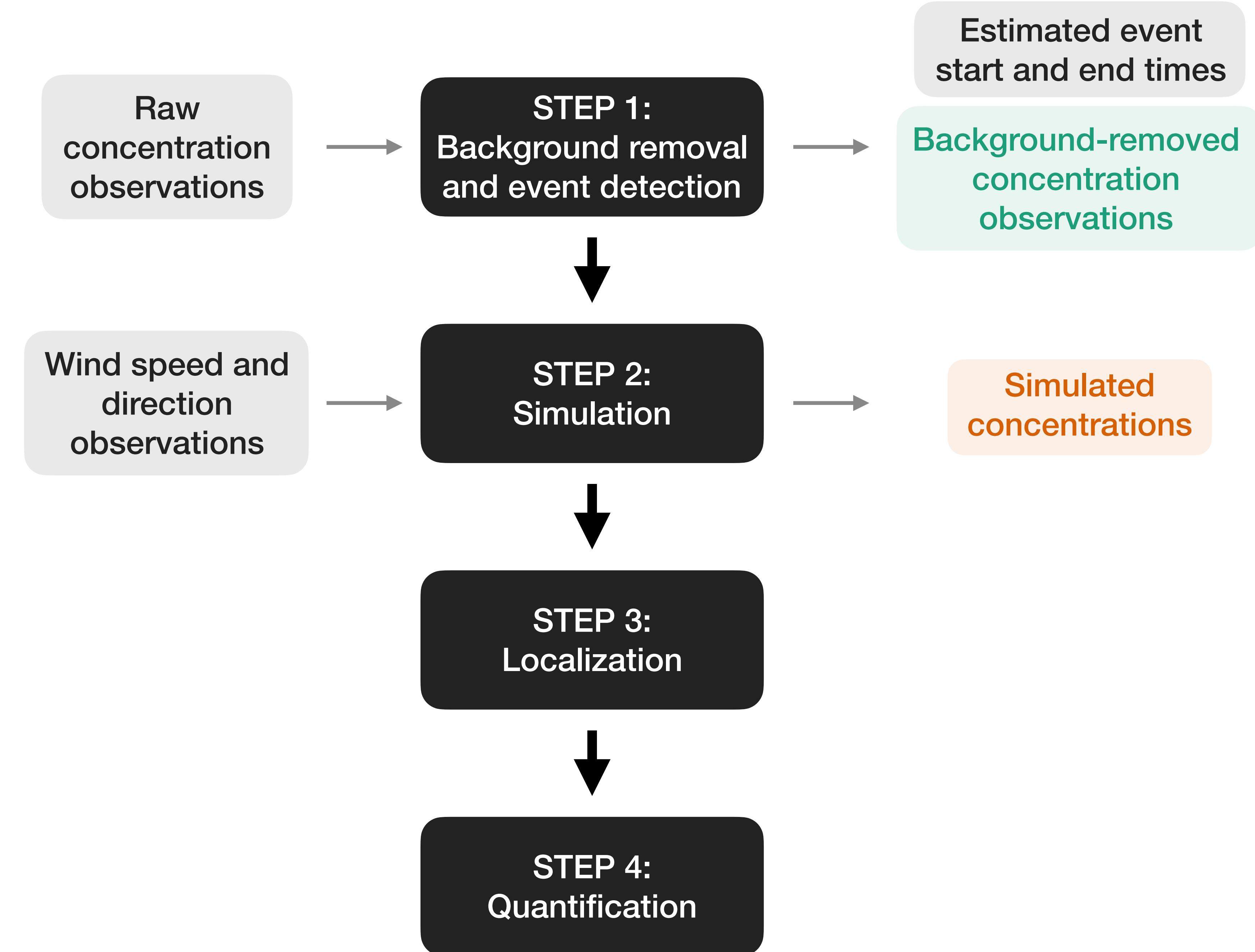


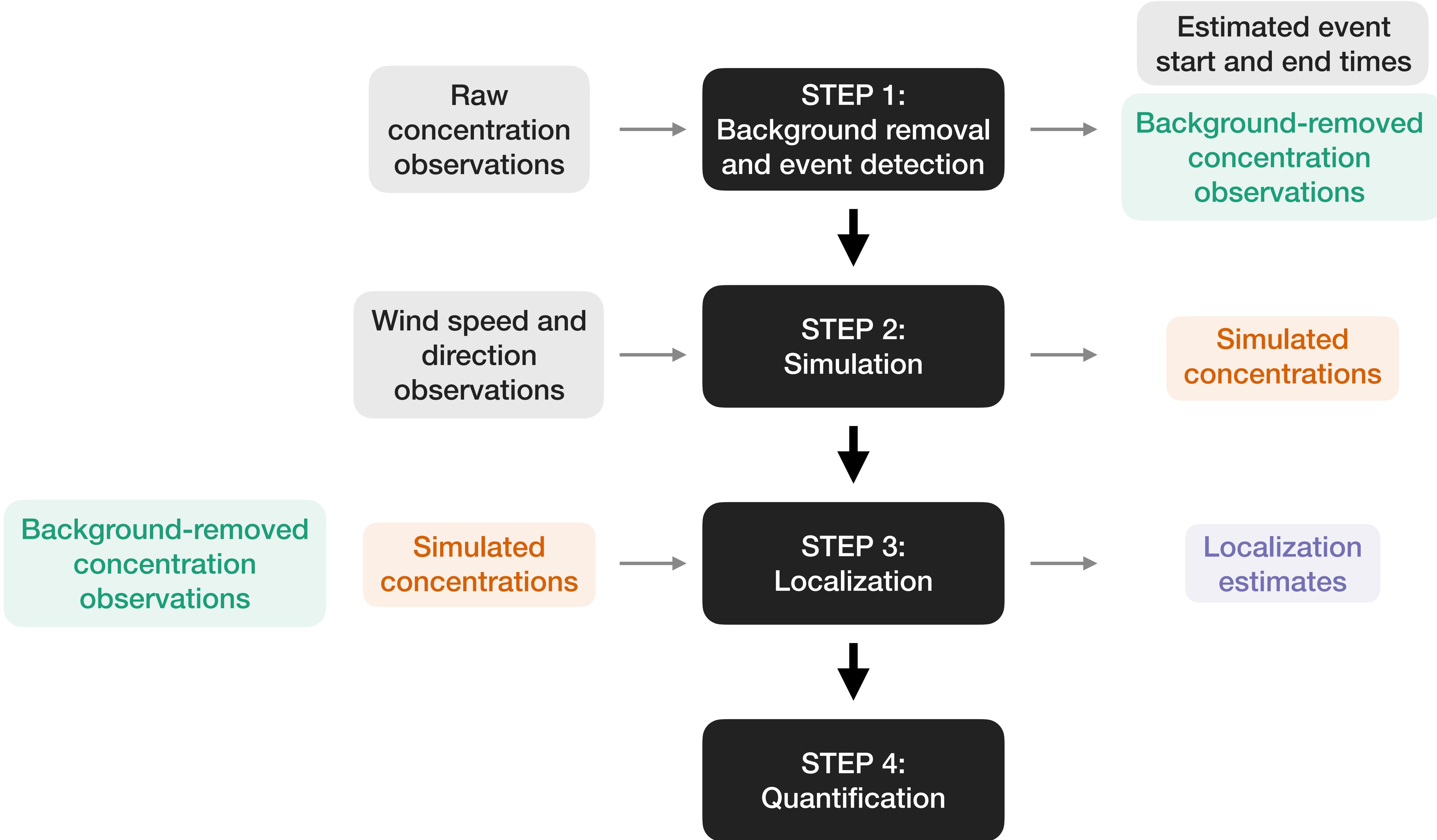


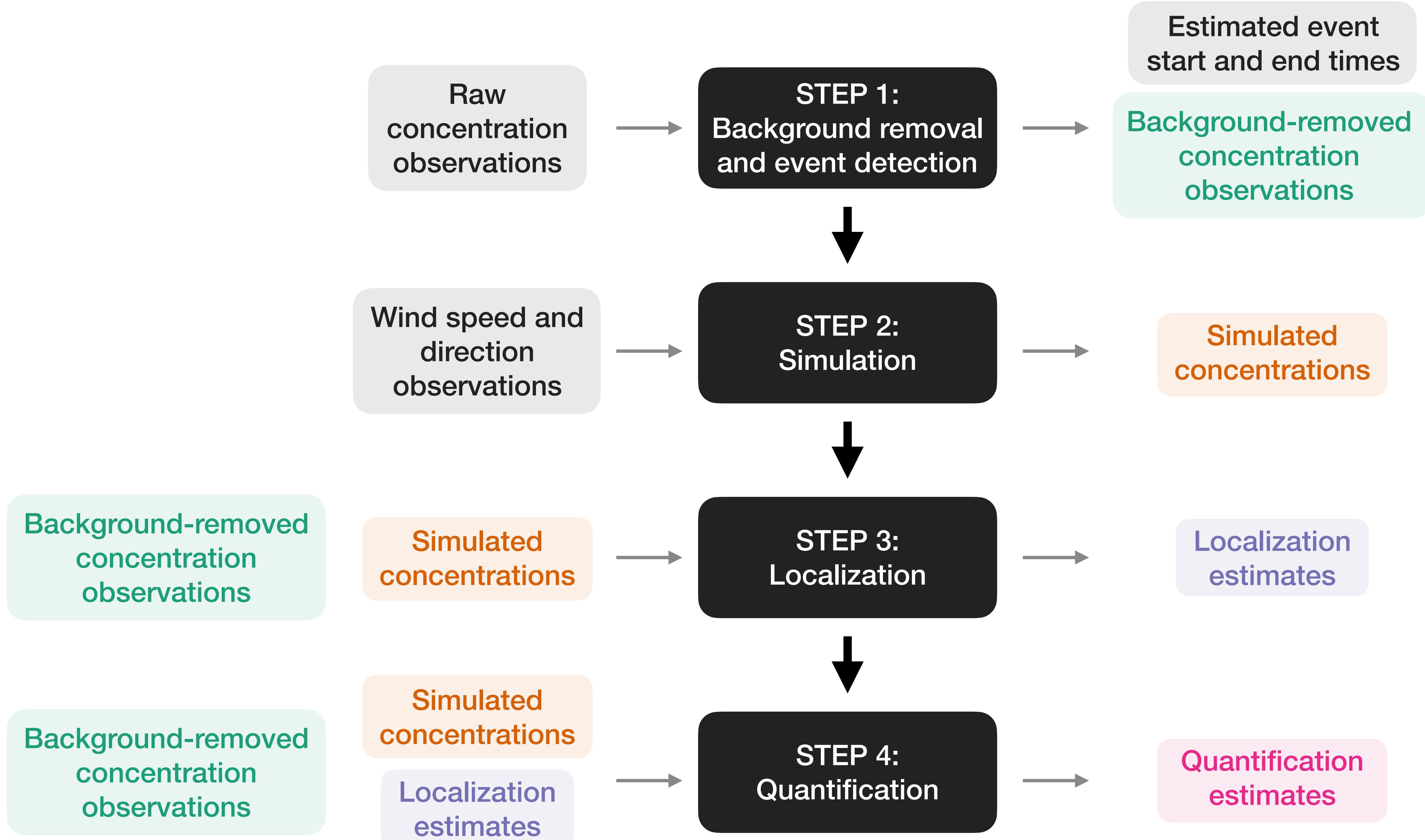
Framework for emission event detection, localization, and quantification using CMS

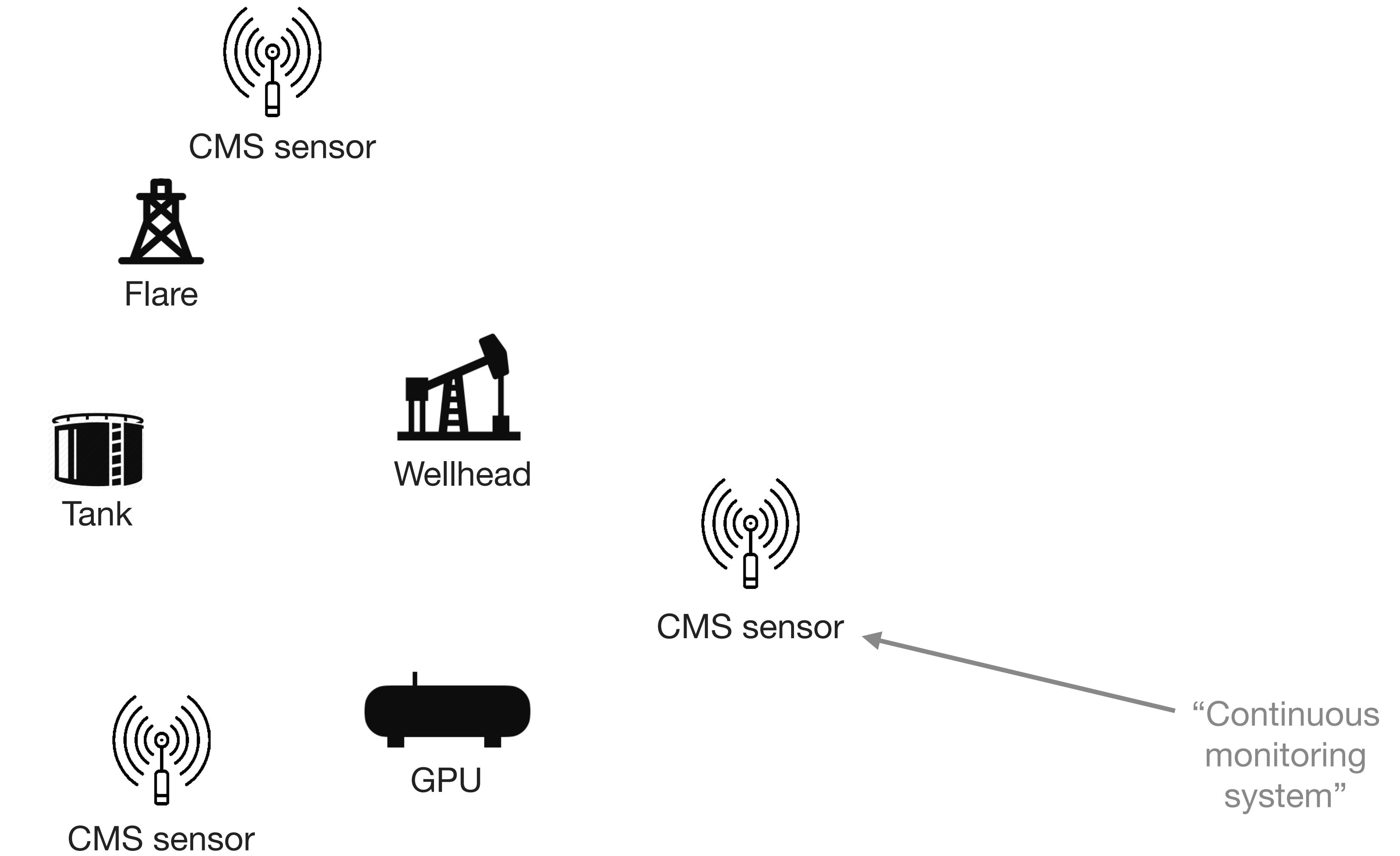




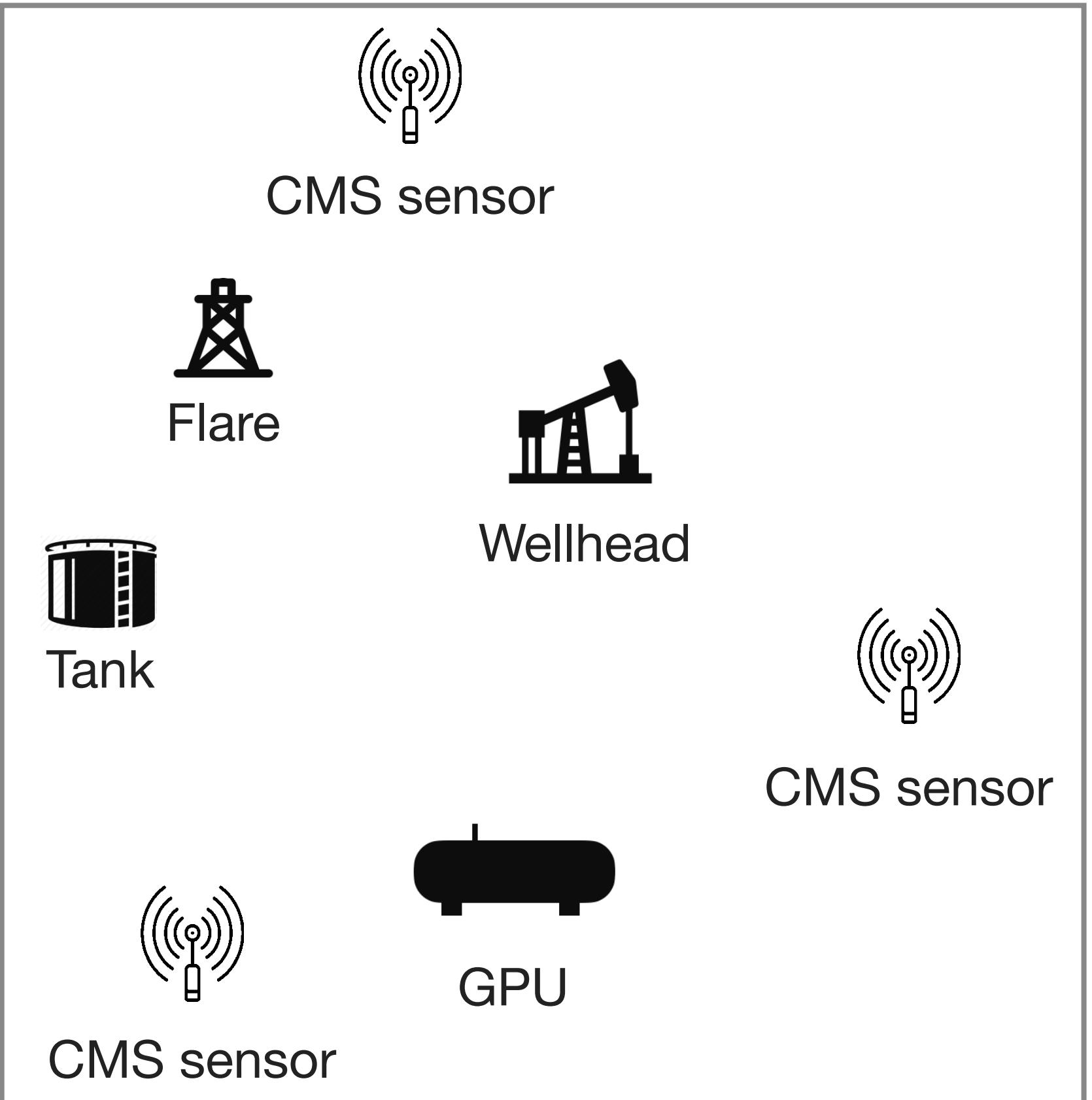




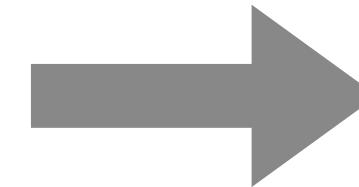




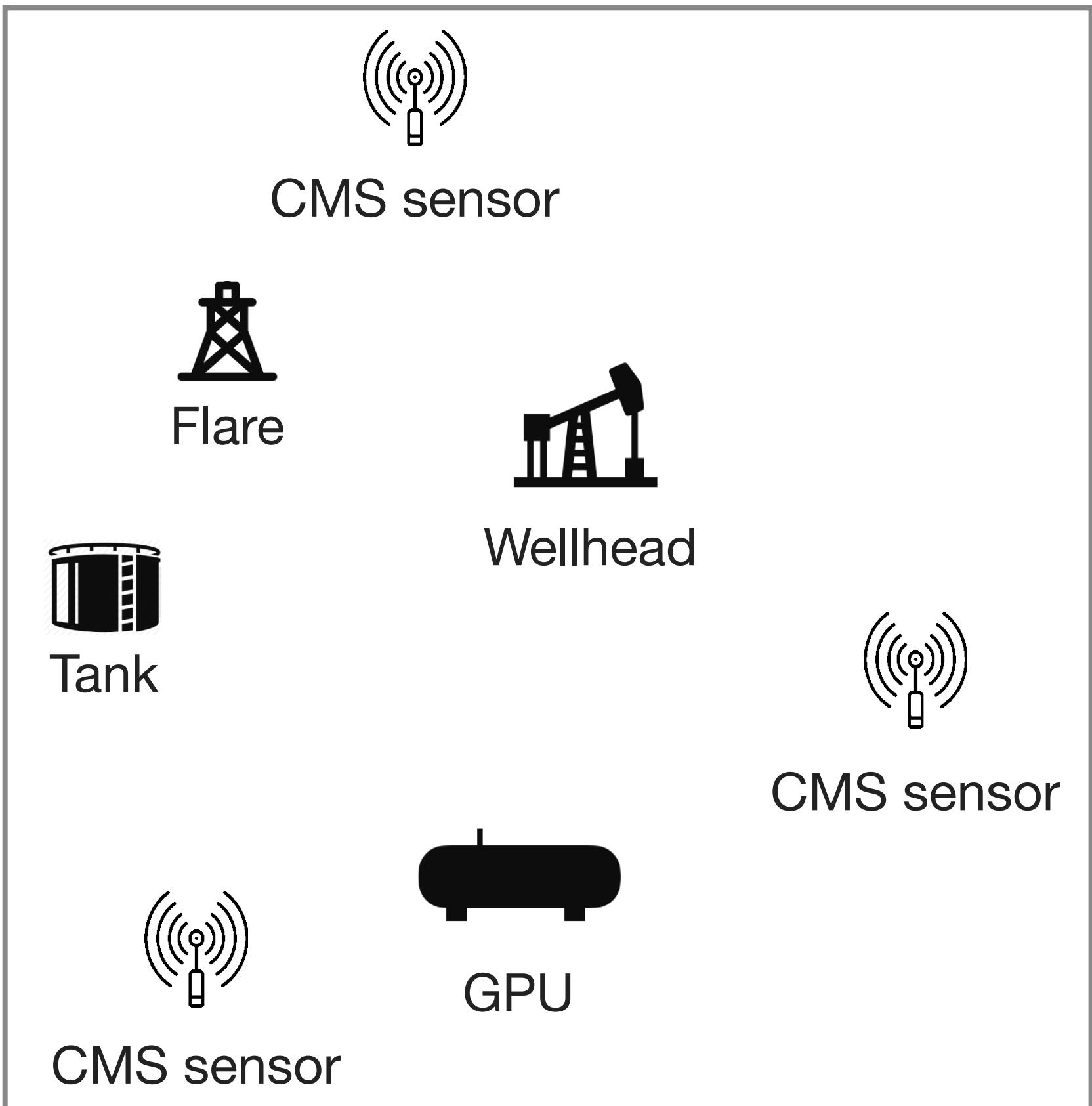
Site-level reconciliation case study



13 top-down
measurements
over 4 days



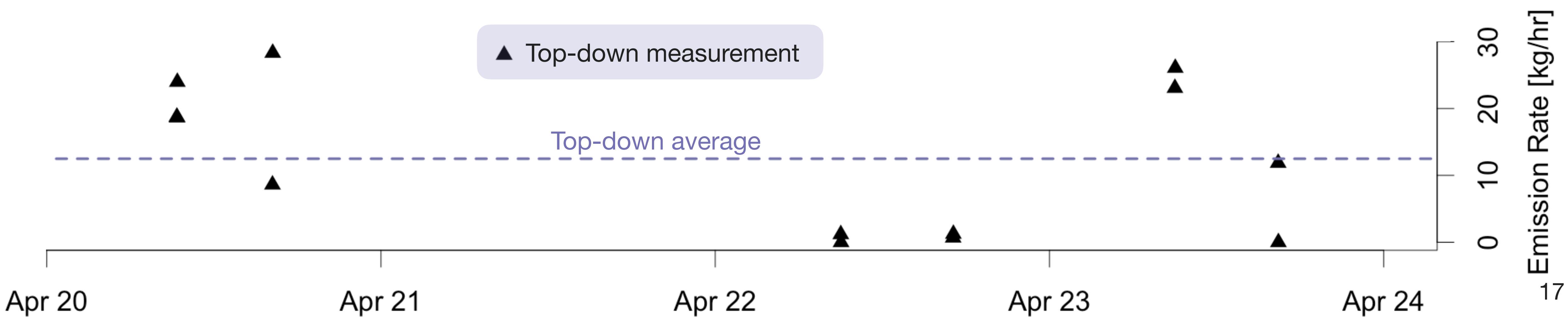
average = 12.5 kg/hr

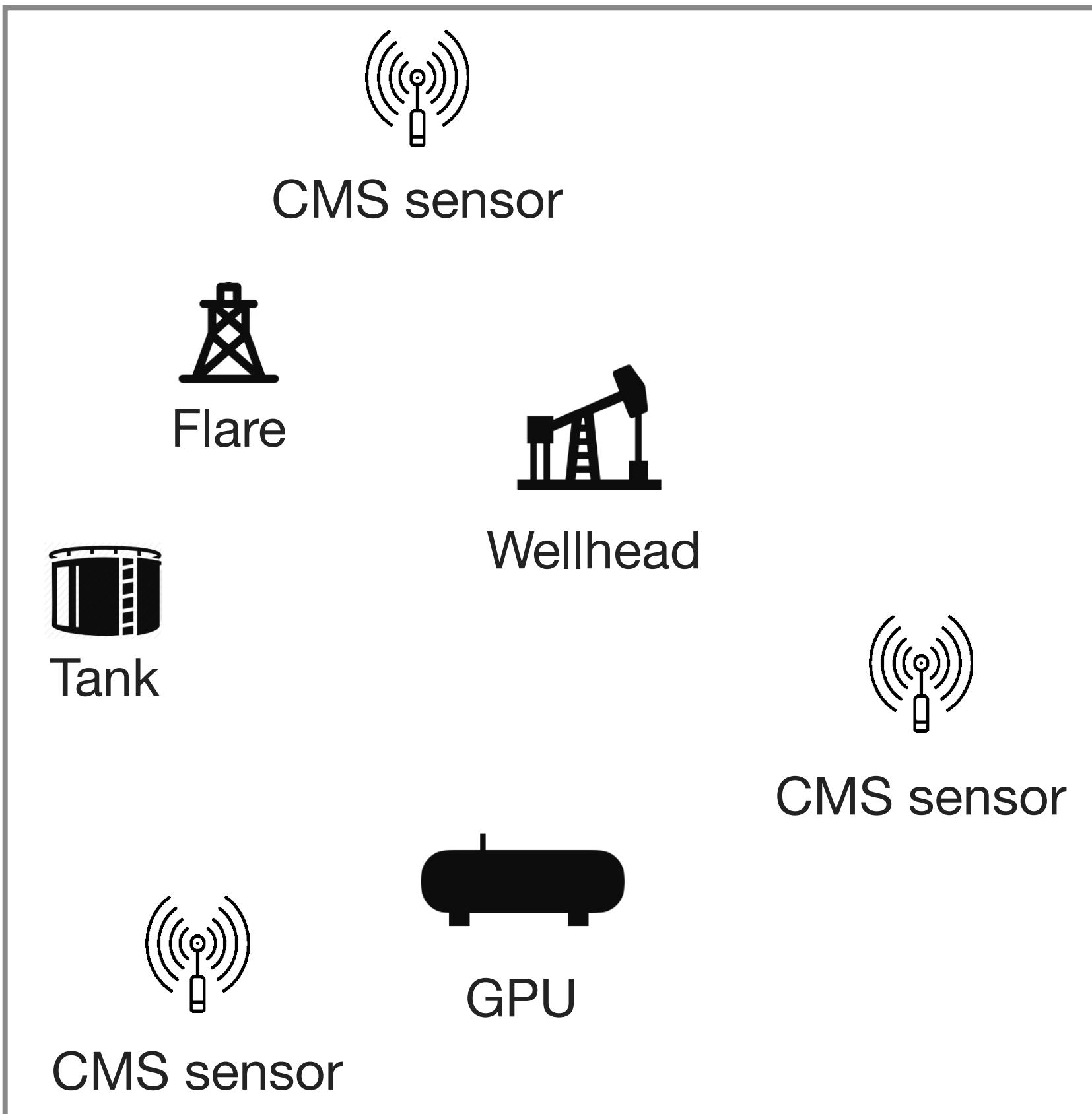


13 top-down measurements over 4 days

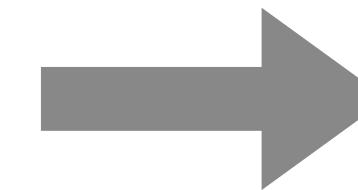


average = 12.5 kg/hr





13 top-down measurements over 4 days

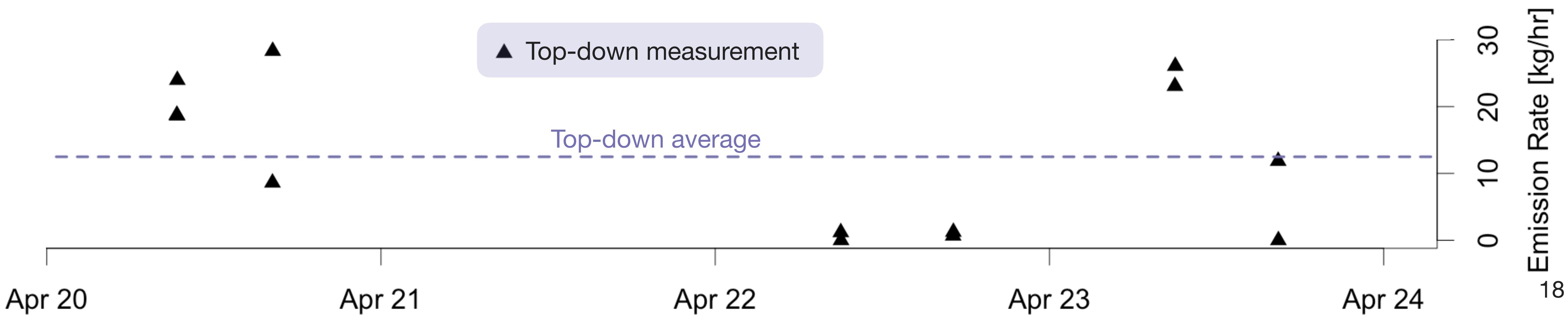


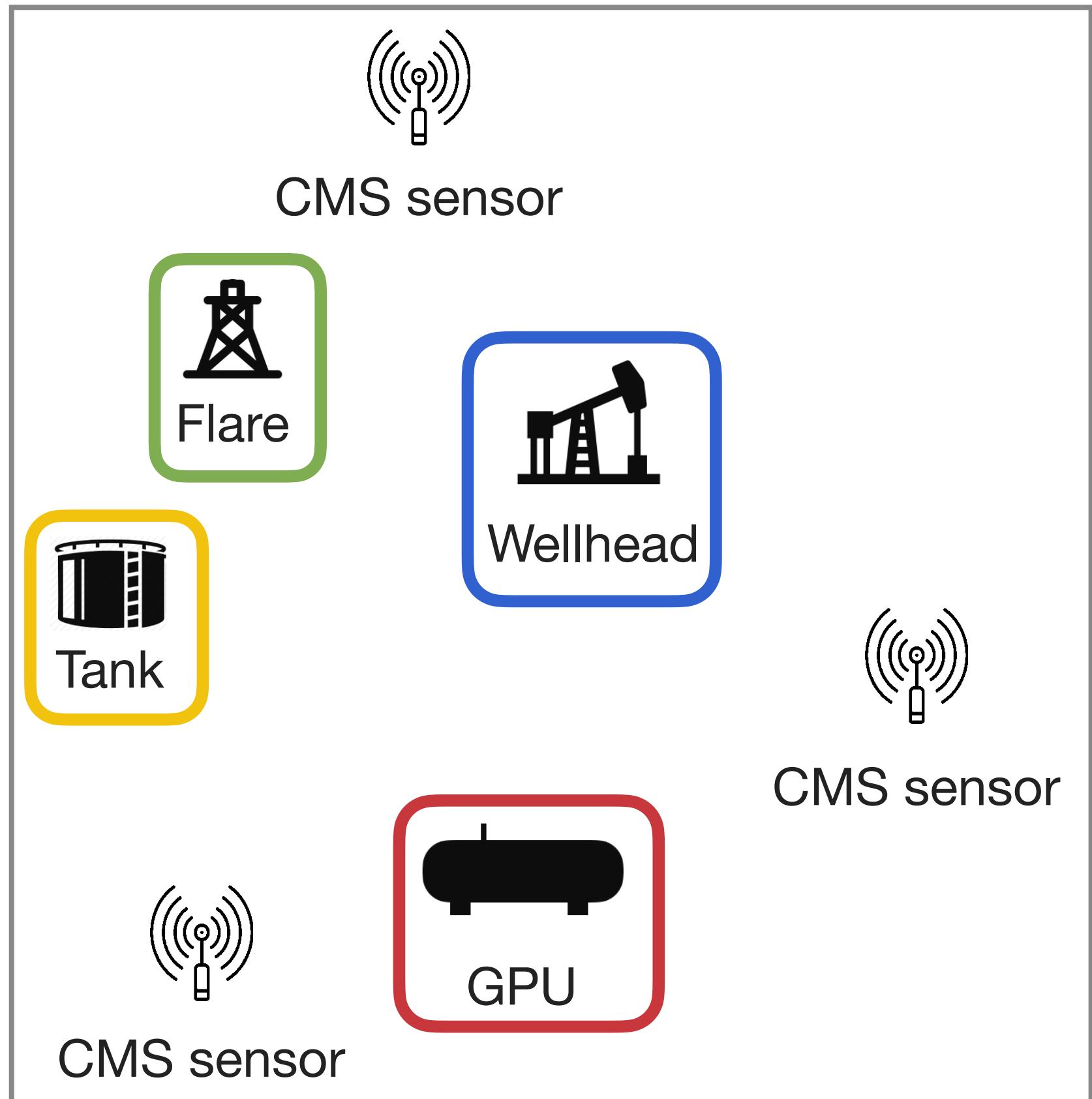
average = 12.5 kg/hr

Bottom-up inventory during top-down measurements



0.8 kg/hr





- Tank
- GPU
- Wellhead
- Flare
- No emissions

Mar 1

Mar 3

Mar 5

Mar 7

Mar 9

Mar 11

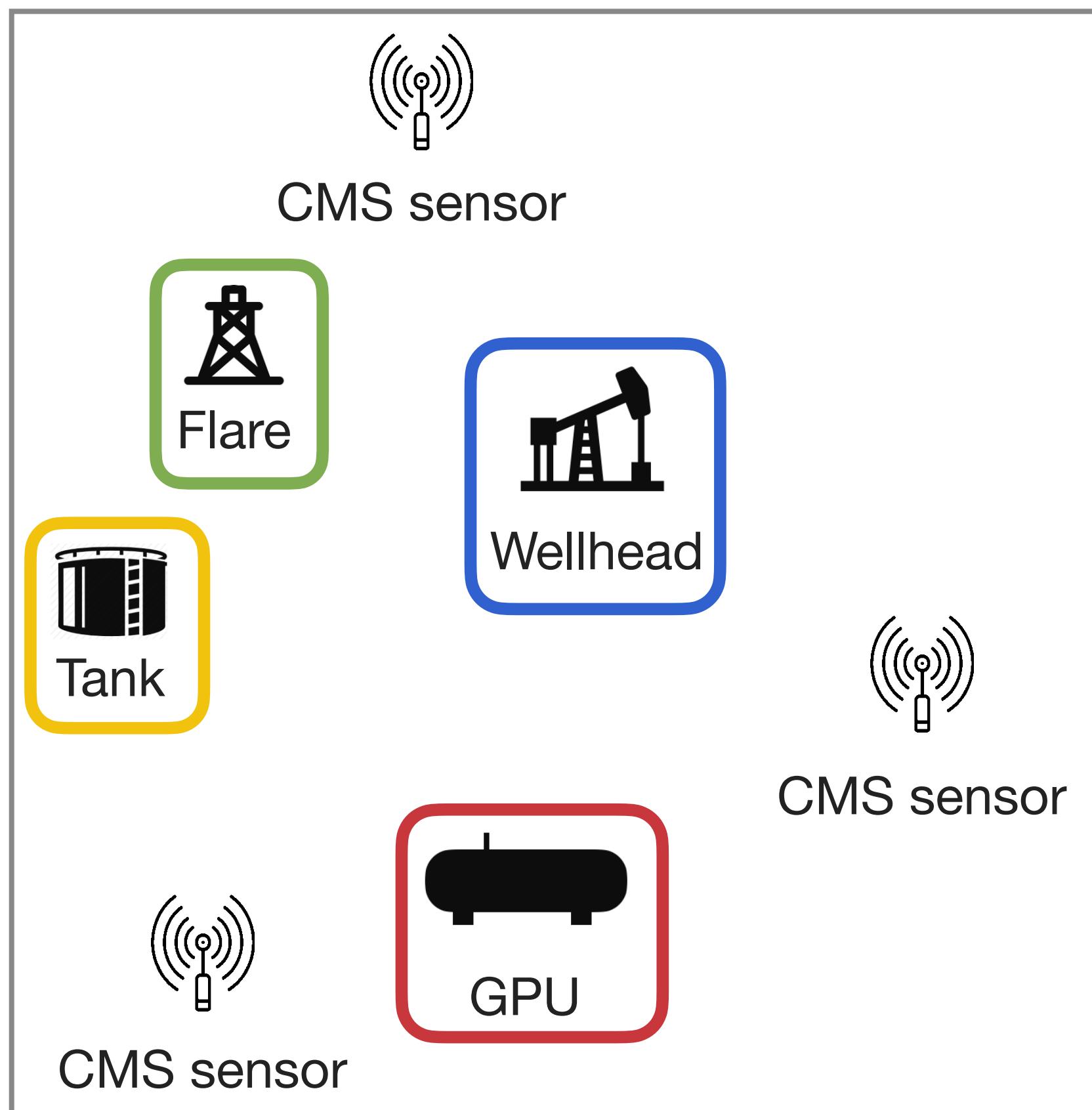
Mar 13

Mar 15

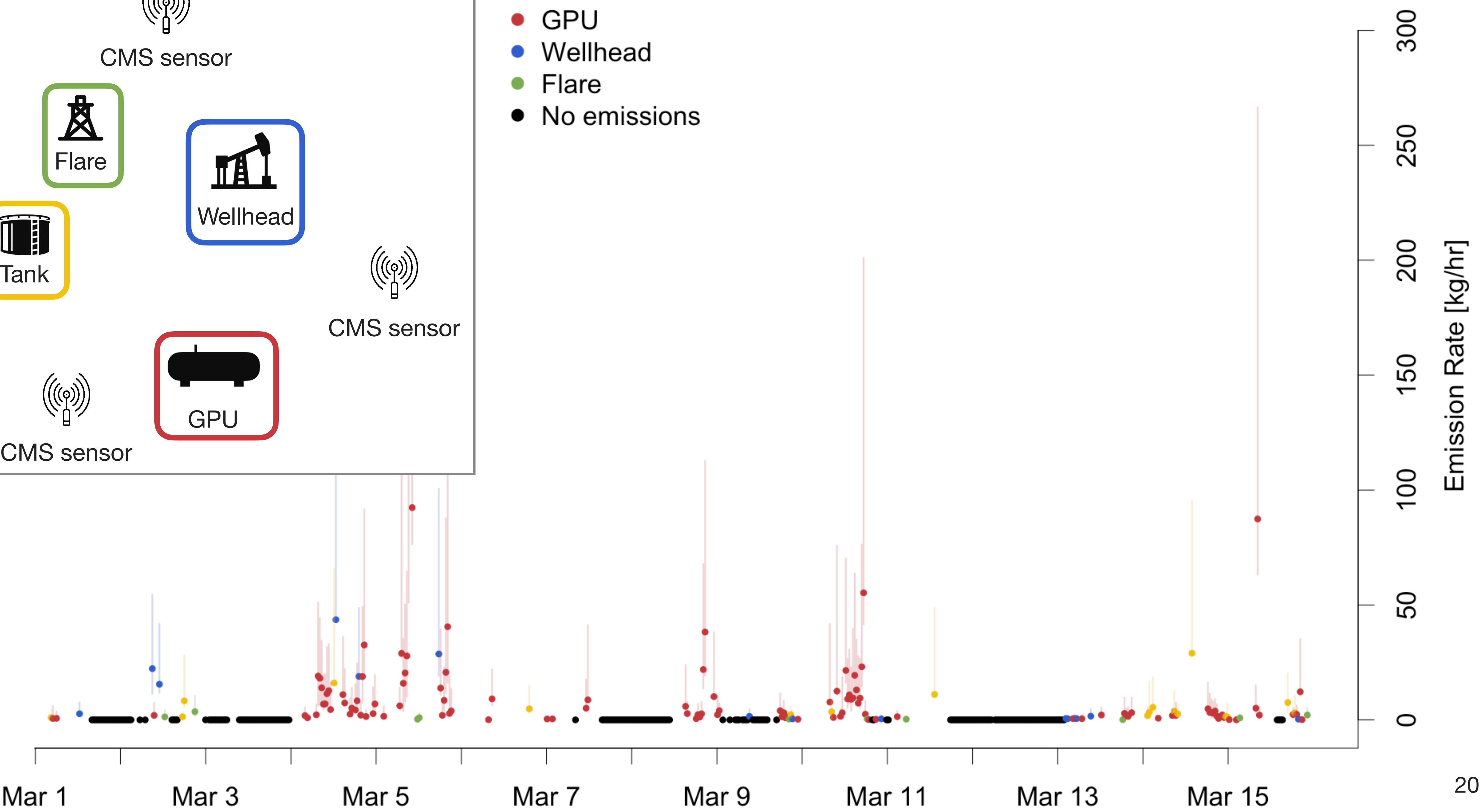
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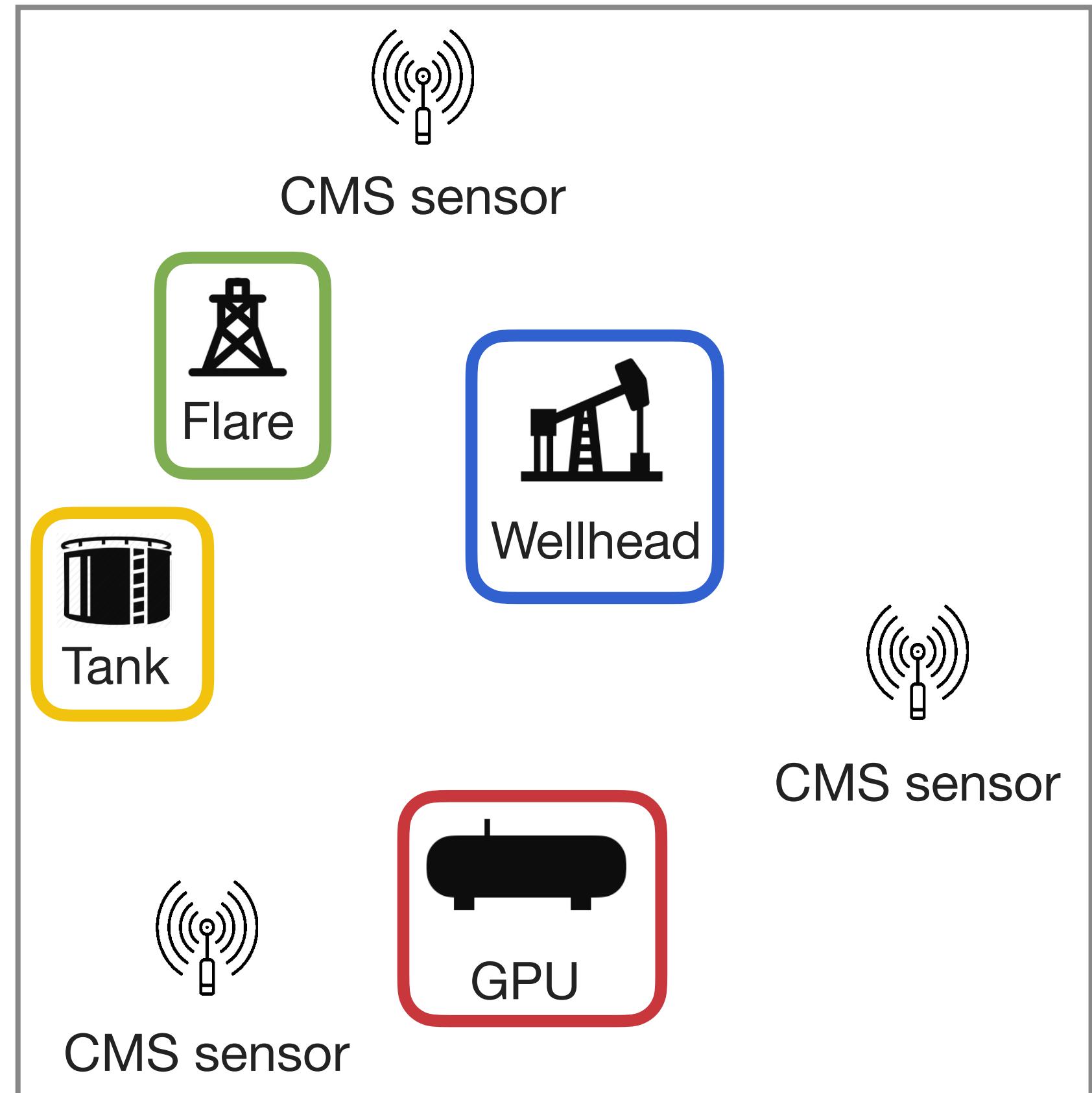
300
250
200
150
100
50
0

Emission Rate [kg/hr]



- Tank
- GPU
- Wellhead
- Flare
- No emissions





Oct

Nov

Dec

Jan

Feb

Mar

Apr

12

10

8

6

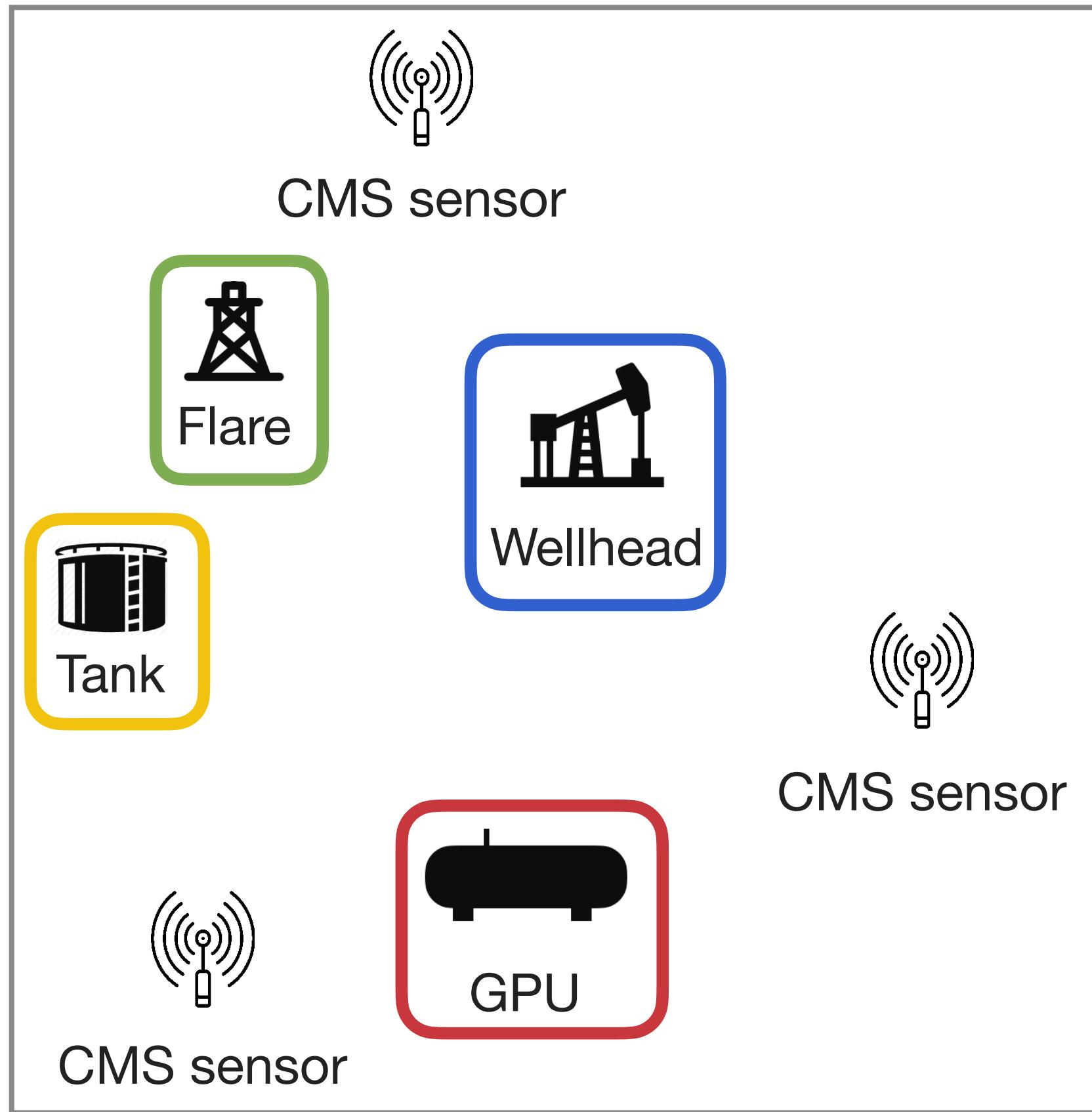
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2

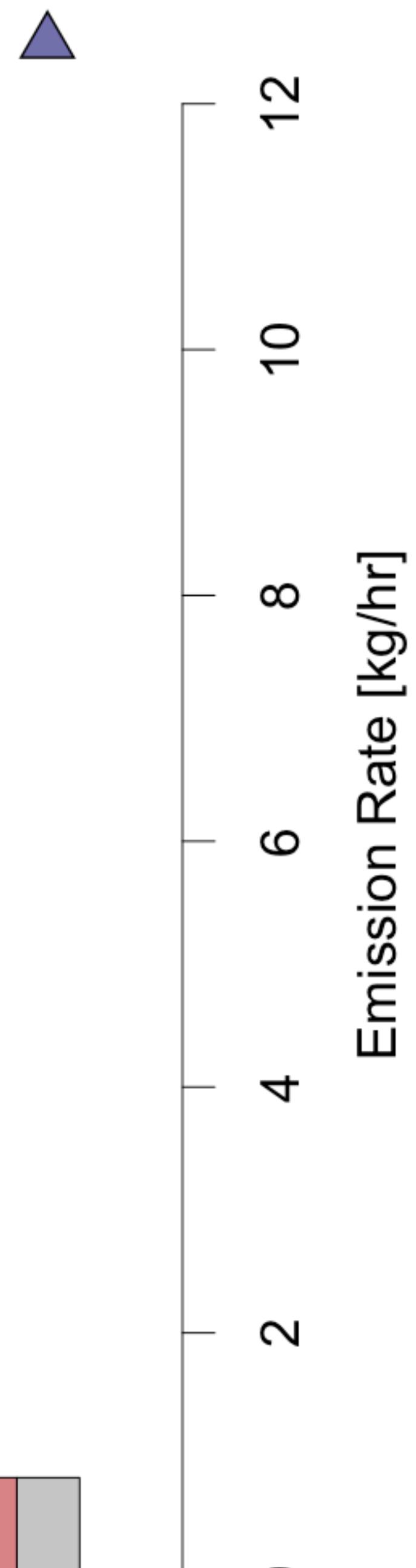
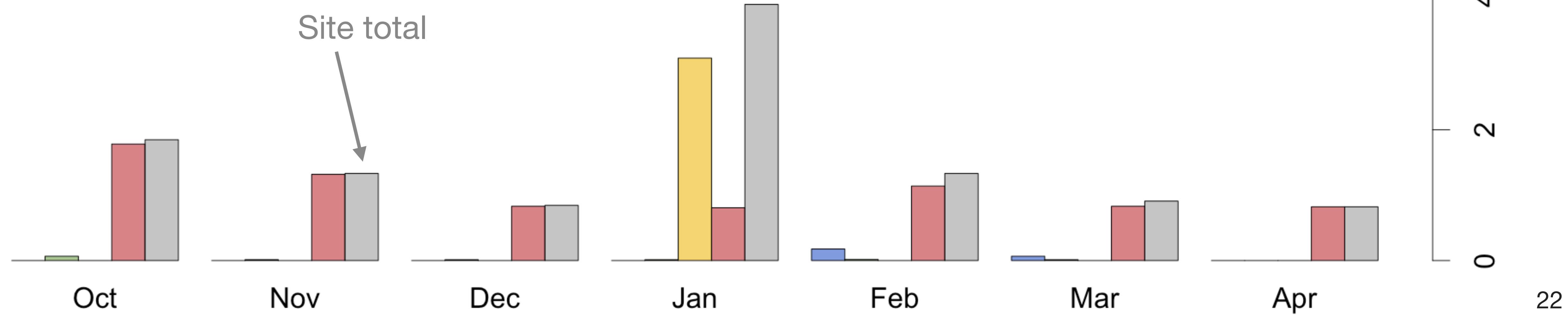
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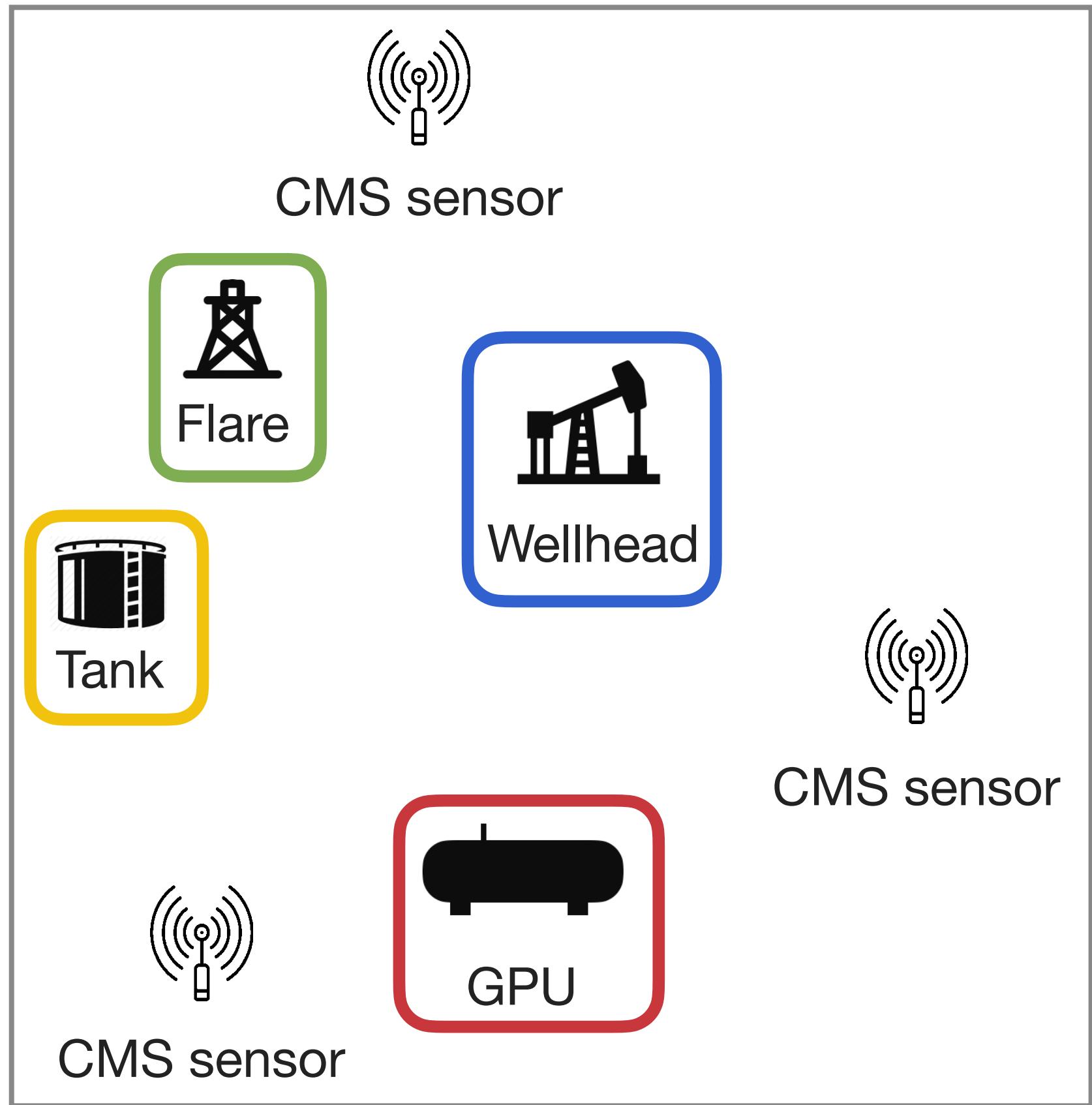
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Emission Rate [kg/hr]

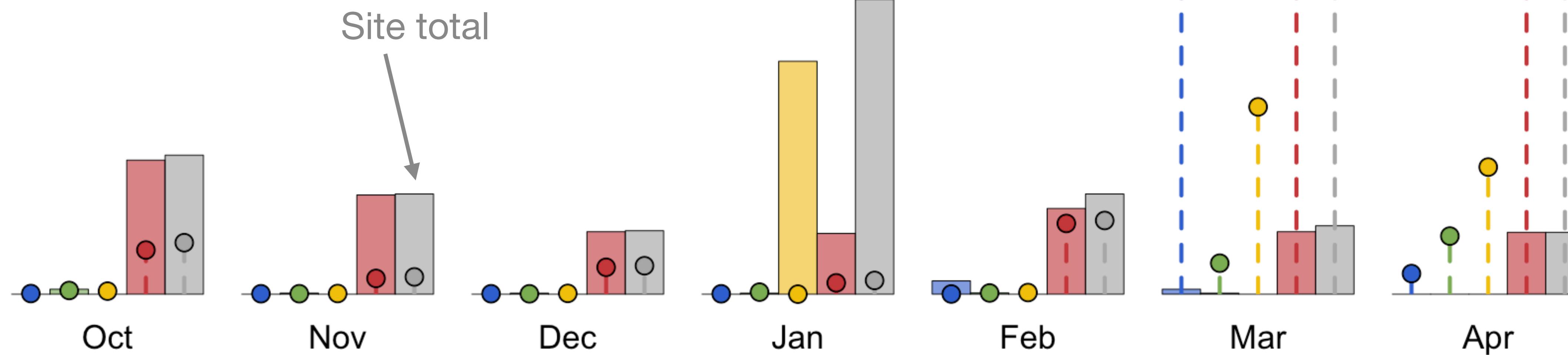


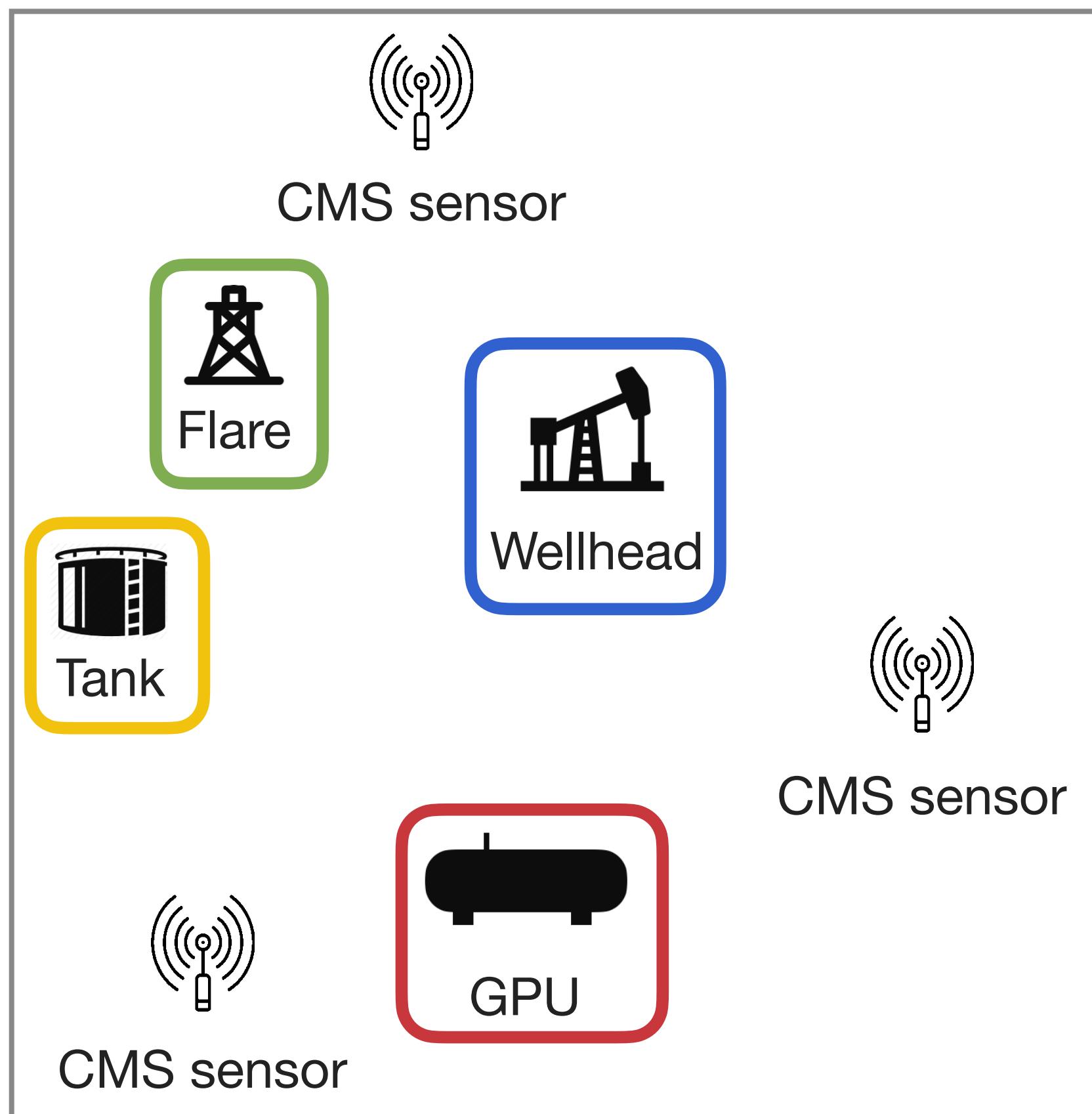
▲ Top-down average
 ■ Company emissions inventory (shown as bars)





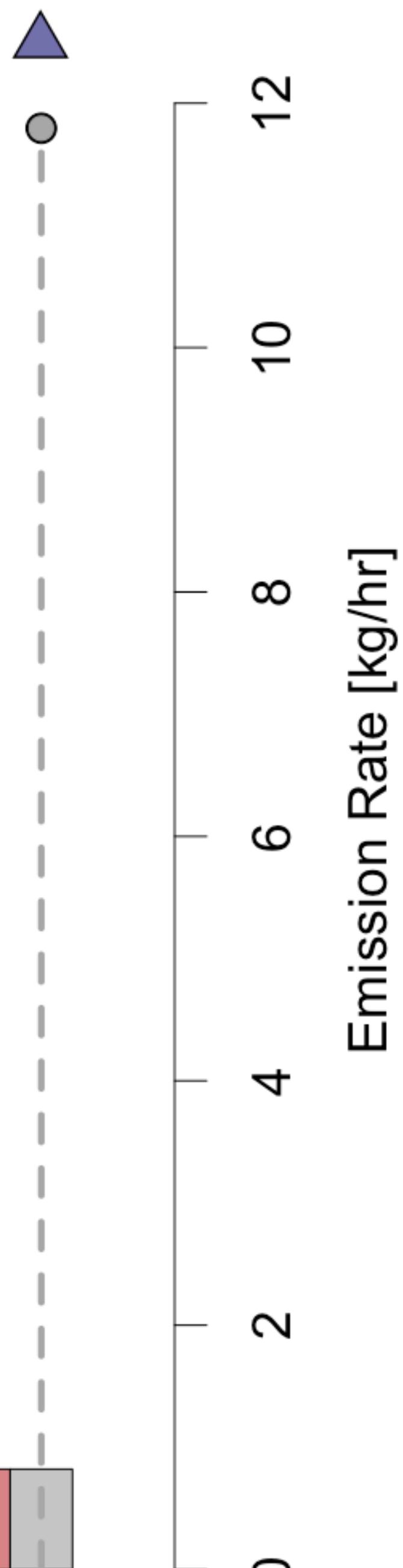
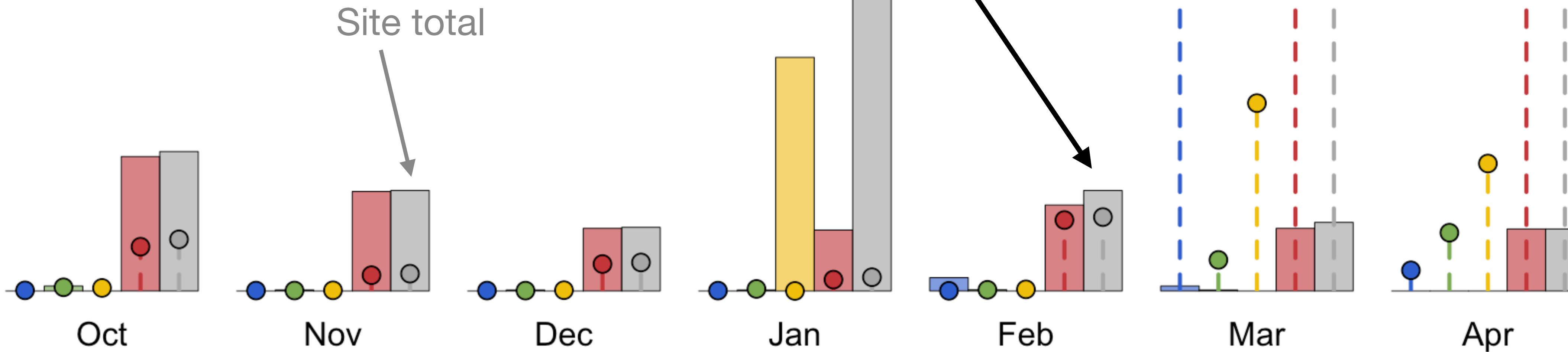
- ▲ Top-down average
- Company emissions inventory (shown as bars)
- CMS-based inventory estimate





- ▲ Top-down average
- Company emissions inventory (shown as bars)
- CMS-based inventory estimate

Equipment change on
February 23rd



Agreement between top-down and CMS-based estimates during time of top-down measurement

High frequency data useful for reconciliation at the site-level

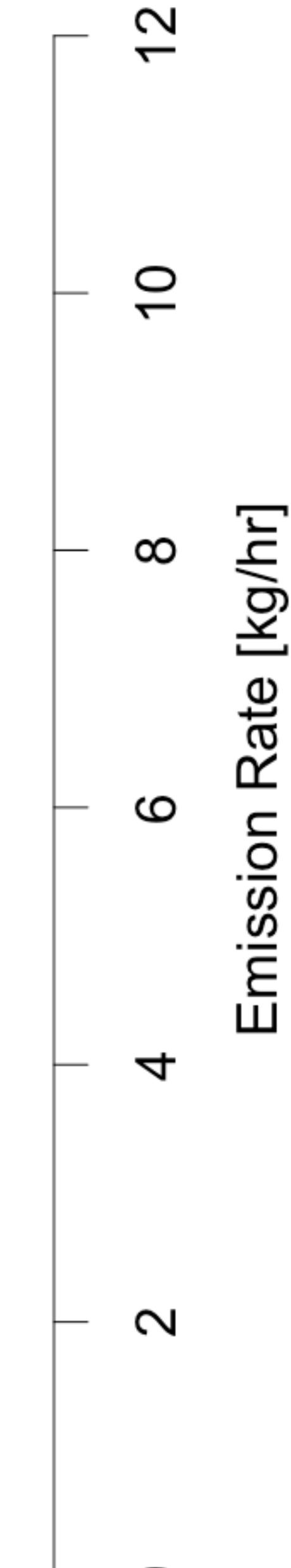
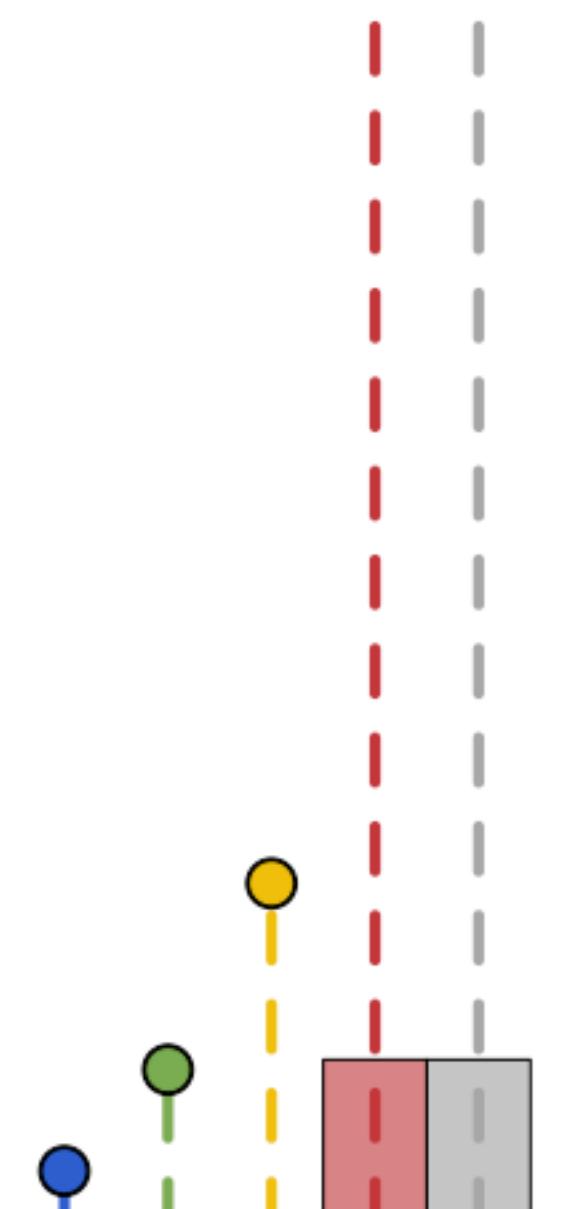
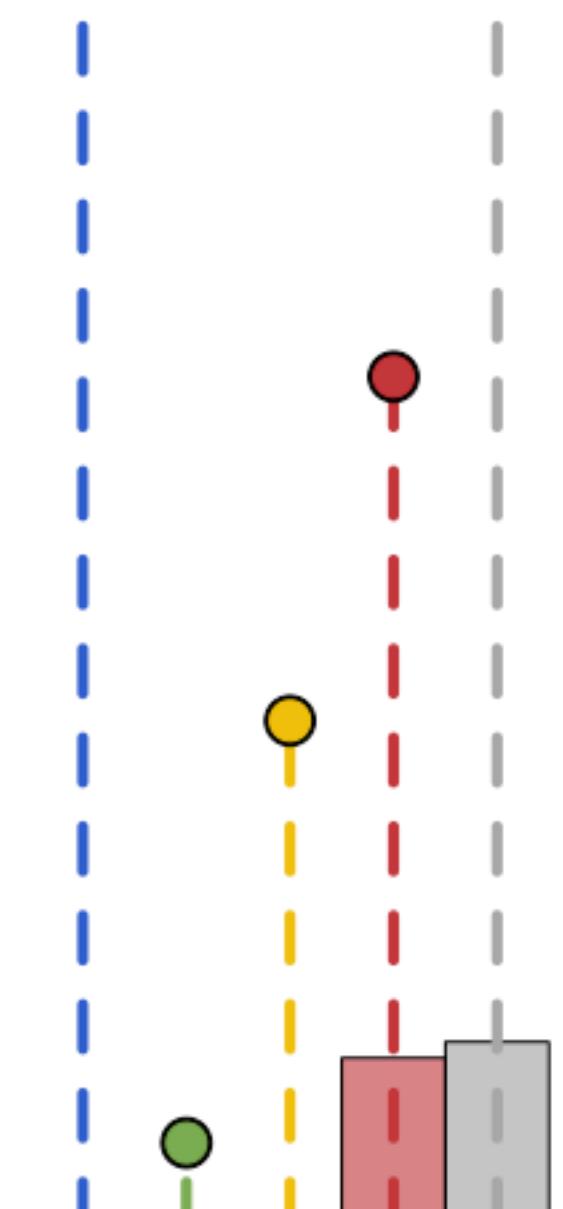
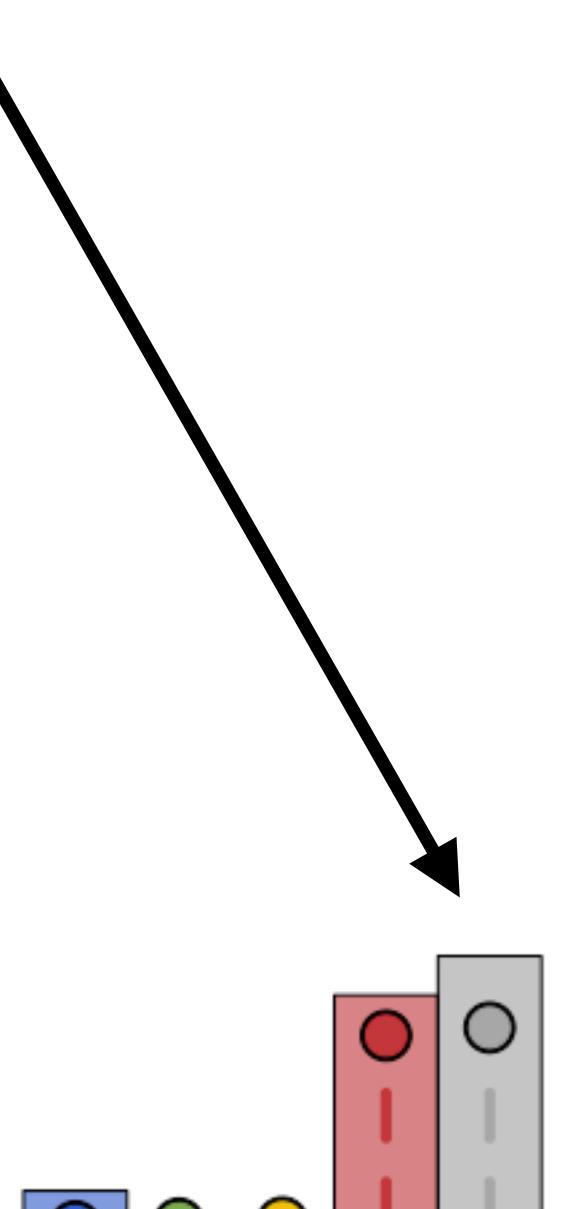
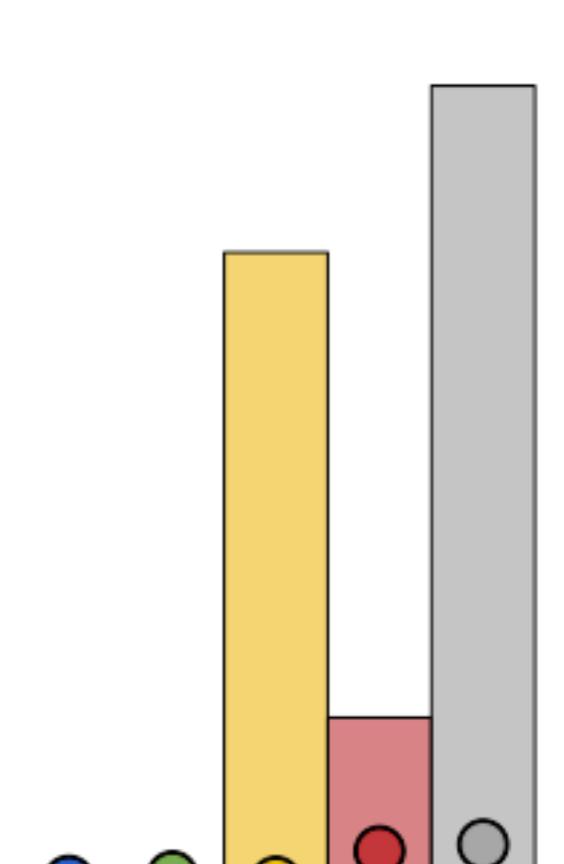
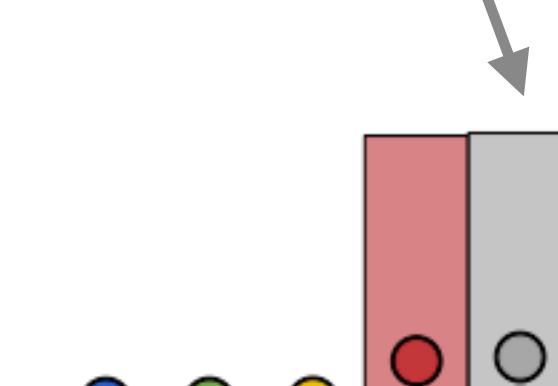
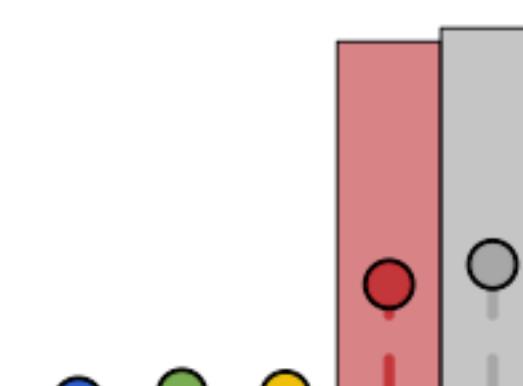
▲ Top-down average

■ Company emissions inventory (shown as bars)

● CMS-based inventory estimate

Equipment change on
February 23rd

Site total



Thank you!



**COLORADO SCHOOL OF
MINES**



TEXAS
The University of Texas at Austin

CHENIERE

Thank you!

Questions?



Detection, localization, and quantification of single-source methane emissions on oil and gas production sites using point-in-space continuous monitoring systems.

William Daniels, Meng Jia, Dorit Hammerling. *Elementa*, under revision, (2023).

Towards multiscale measurement-informed methane inventories: reconciling bottom-up site-level inventories with top-down measurements using continuous monitoring systems.

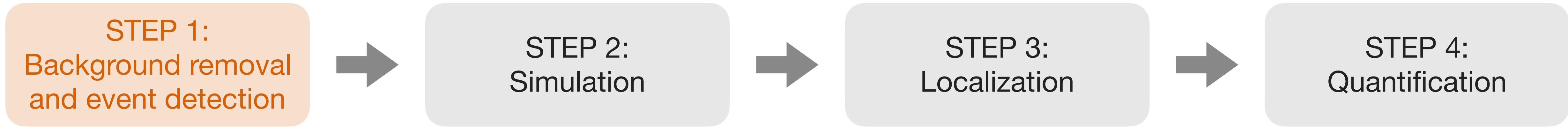
William Daniels, Jiayang (Lyra) Wang, Arvind Ravikumar, Matthew Harrison, Selina Roman-White, Fiji George, Dorit Hammerling. *Environmental Science and Technology*, (2023).

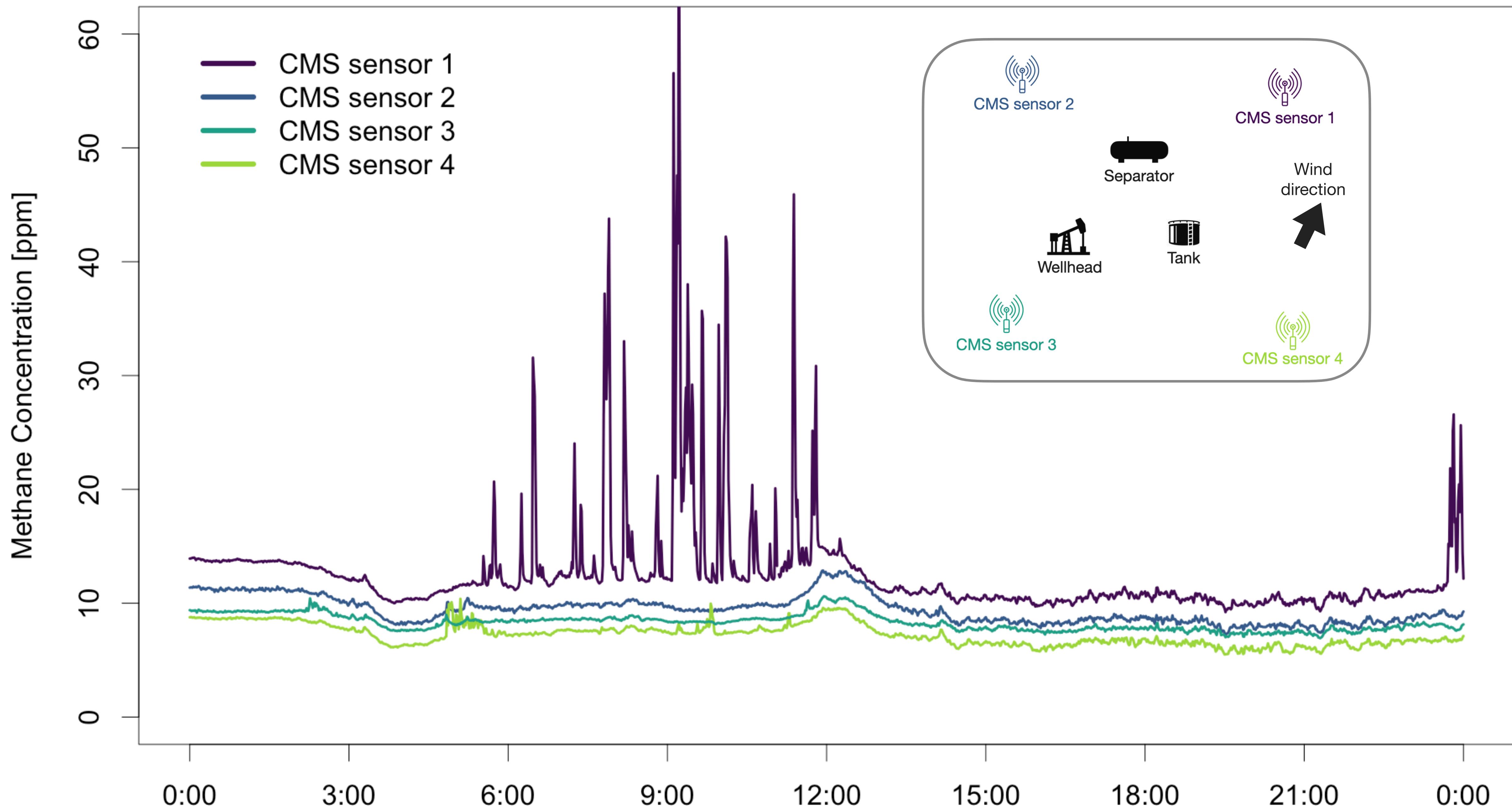


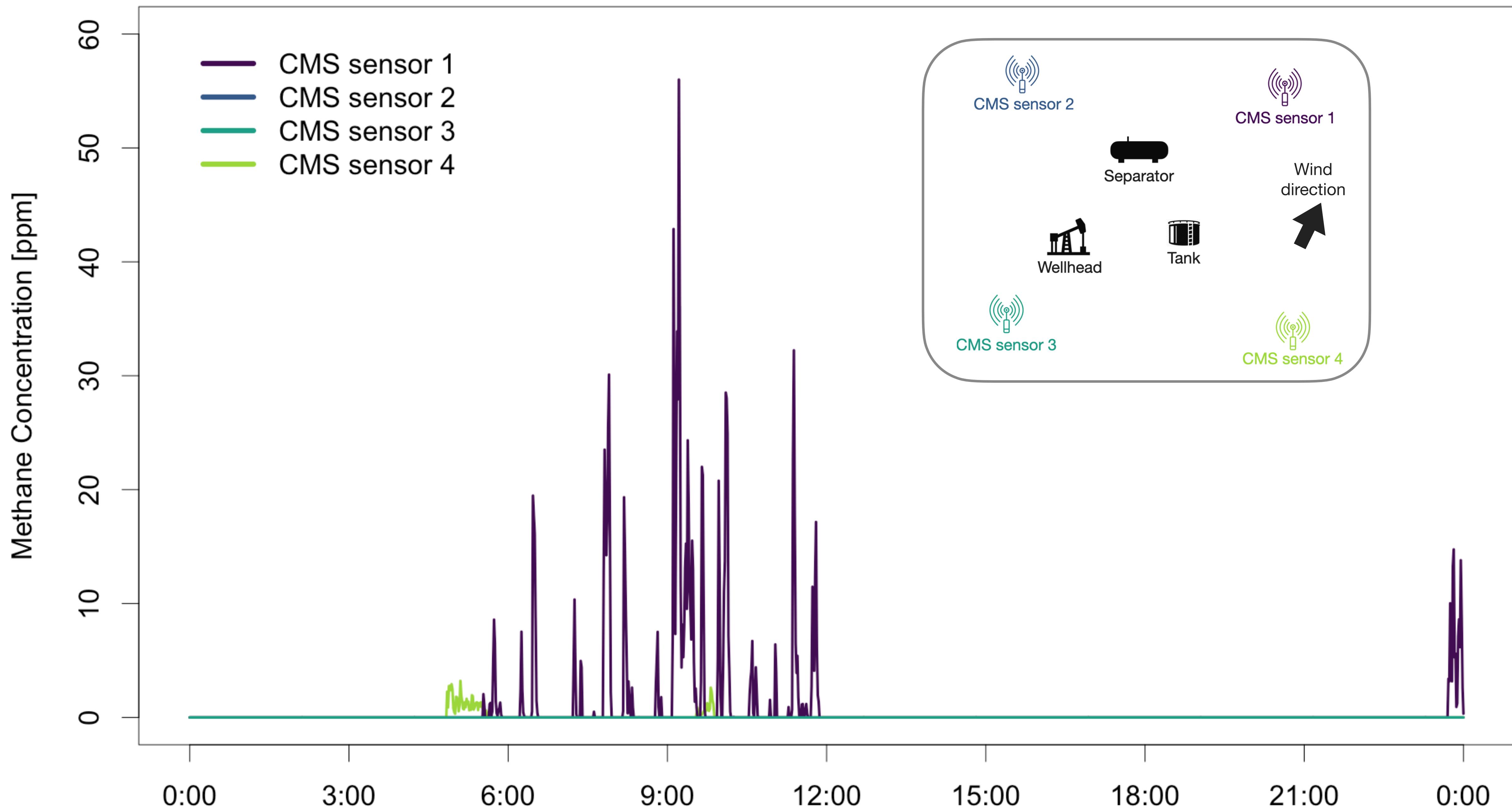
wdaniels@mines.edu

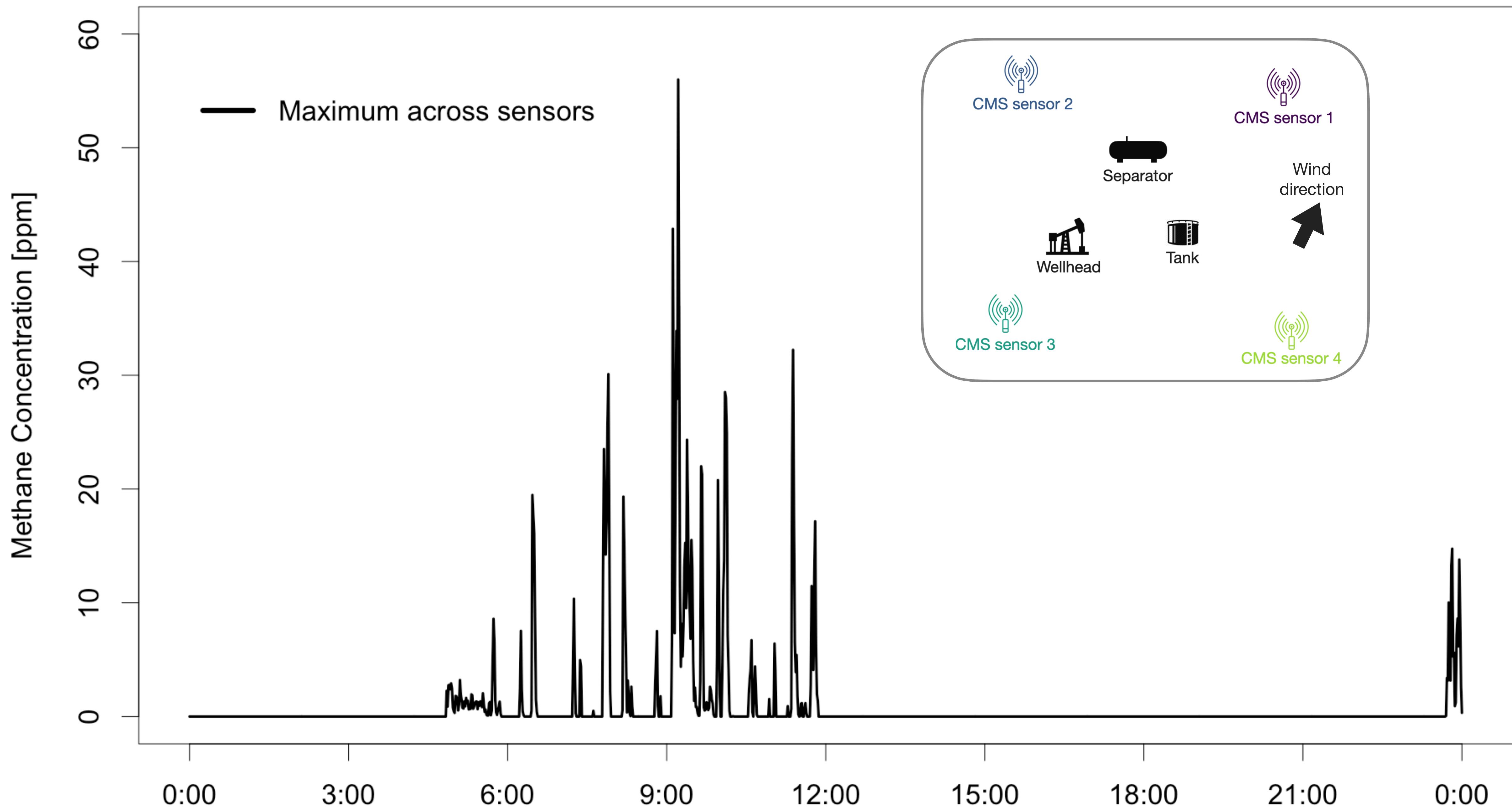
Backup

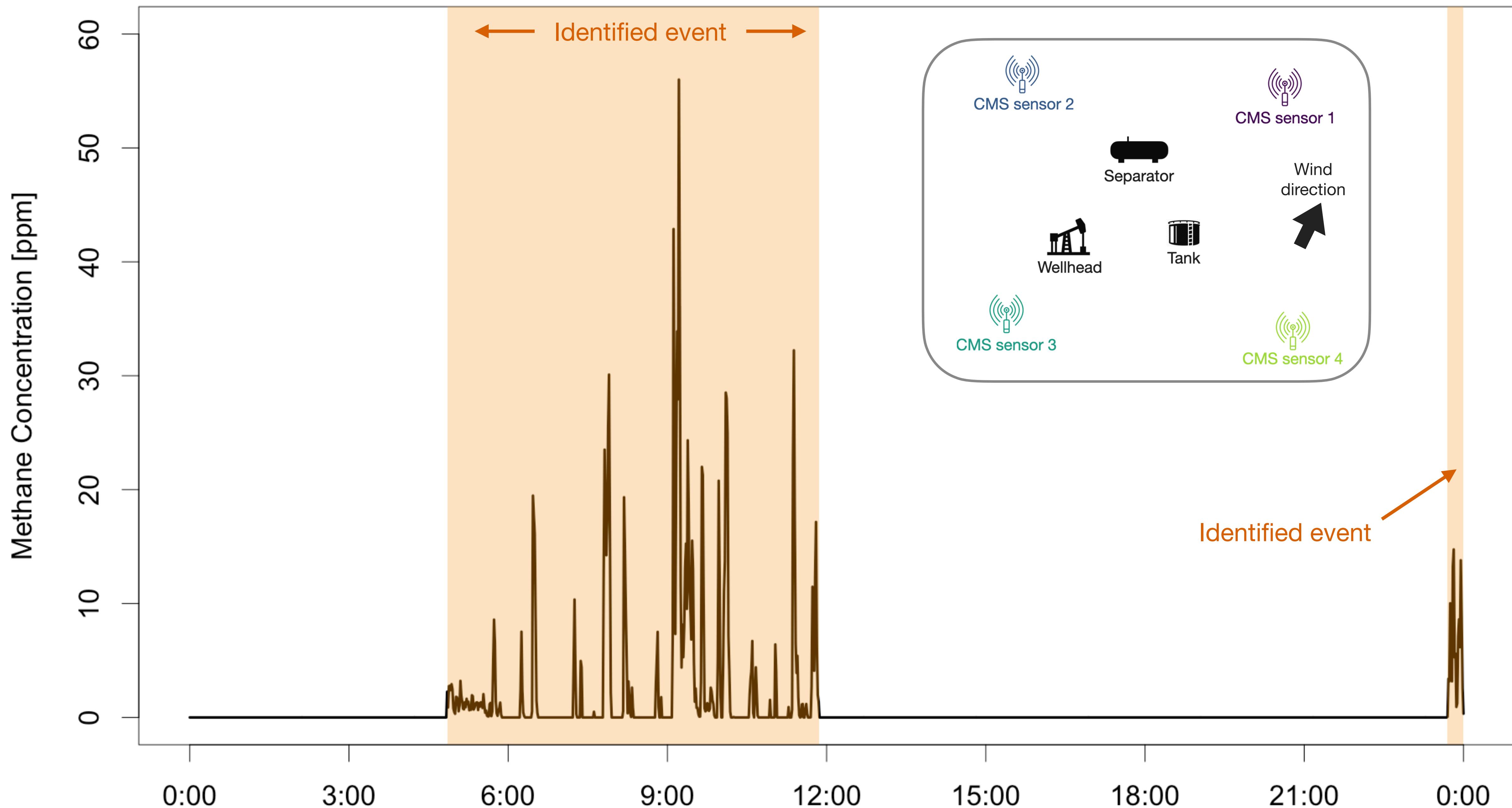
Open source framework for solving inverse problem



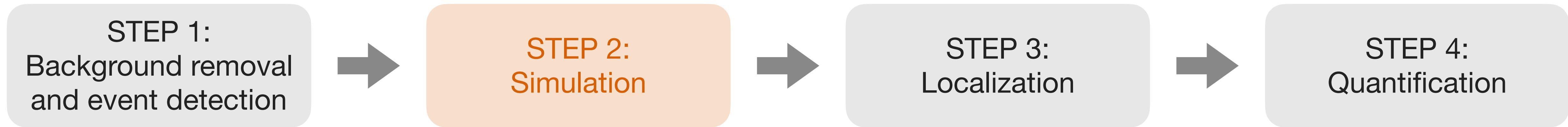








Open source framework for solving inverse problem



Gaussian puff atmospheric dispersion model

$$c_p(x, y, z, t) = \frac{Q}{(2\pi)^{3/2} \sigma_y^2 \sigma_z} \exp\left(-\frac{(x - ut)^2 + y^2}{2\sigma_y^2}\right) \left[\exp\left(-\frac{(z - H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z + H)^2}{2\sigma_z^2}\right) \right]$$

Total volume of methane contained in puff p

Concentration contribution of puff p

Decay in puff concentration in horizontal plane (x,y)

Decay in puff concentration in vertical dimension (z)

Gaussian puff atmospheric dispersion model

$$c(x, y, z, t) = \sum_{p=1}^P c_p(x, y, z, t)$$

Total volume of methane contained in puff p

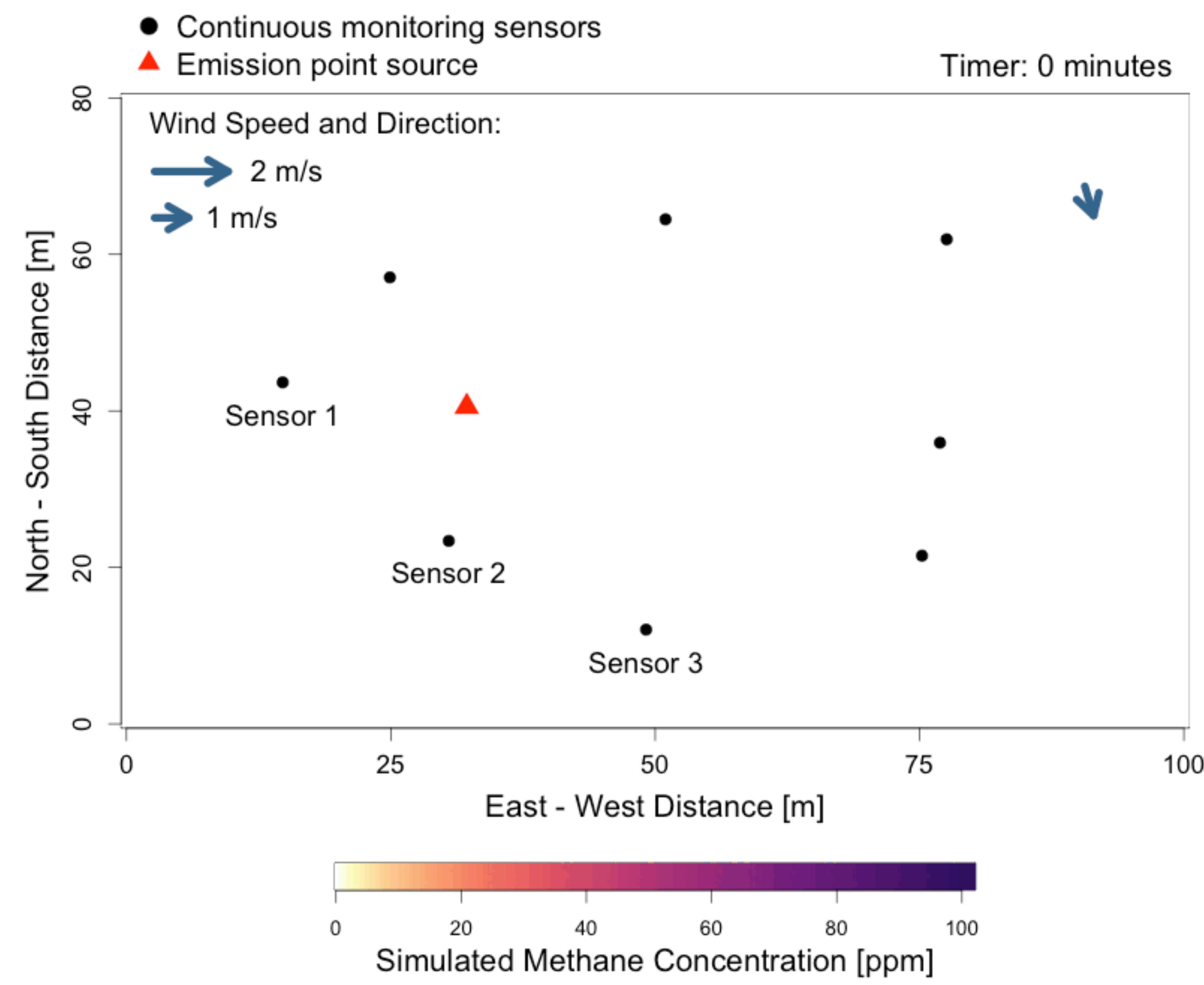
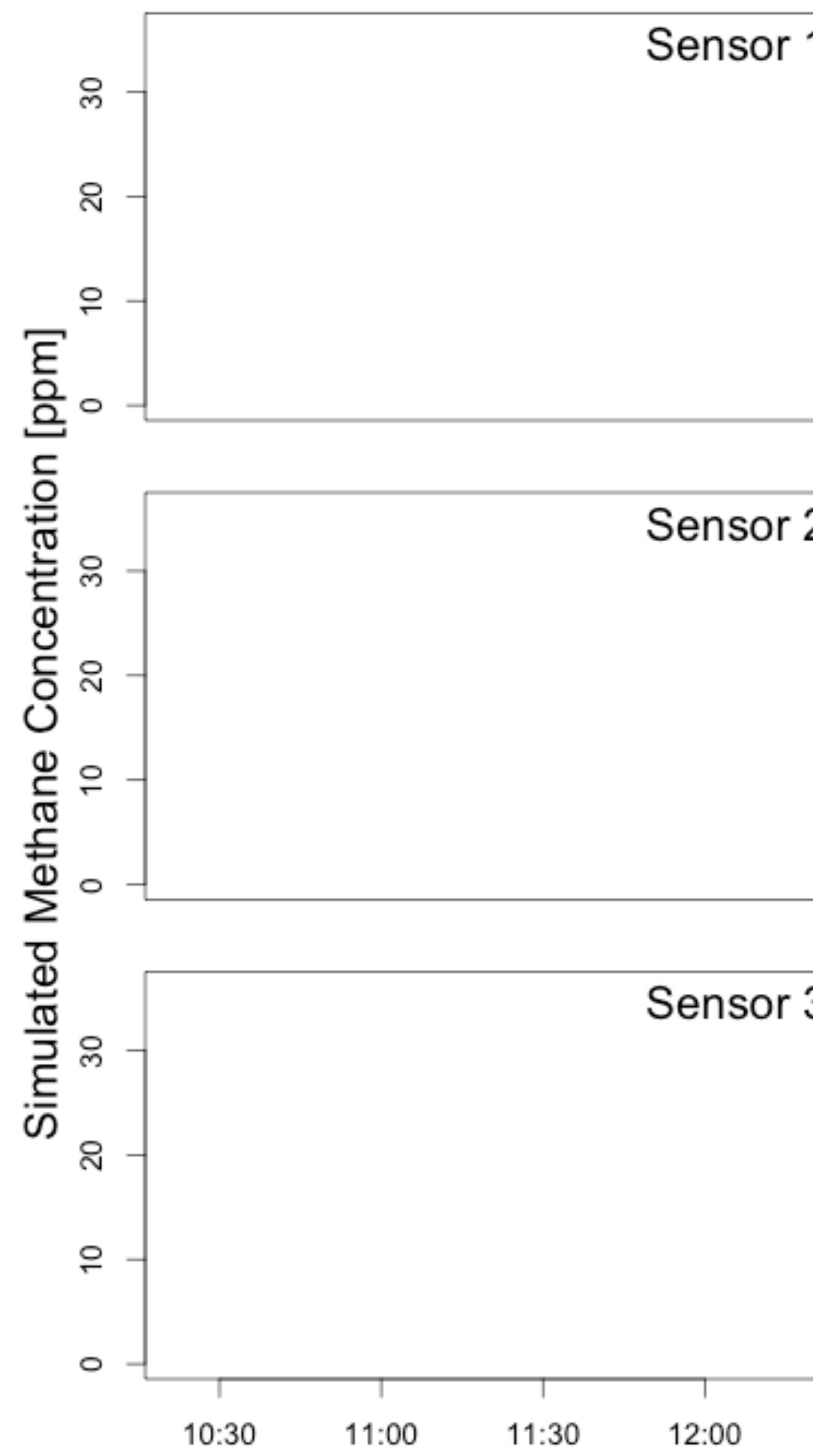
$c_p(x, y, z, t) = \frac{Q}{(2\pi)^{3/2} \sigma_y^2 \sigma_z} \exp\left(-\frac{(x - ut)^2 + y^2}{2\sigma_y^2}\right) \left[\exp\left(-\frac{(z - H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z + H)^2}{2\sigma_z^2}\right) \right]$

Concentration contribution of puff p

Decay in puff concentration in horizontal plane (x, y)

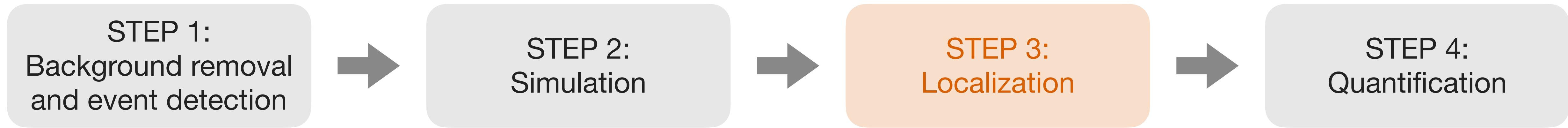
Decay in puff concentration in vertical dimension (z)

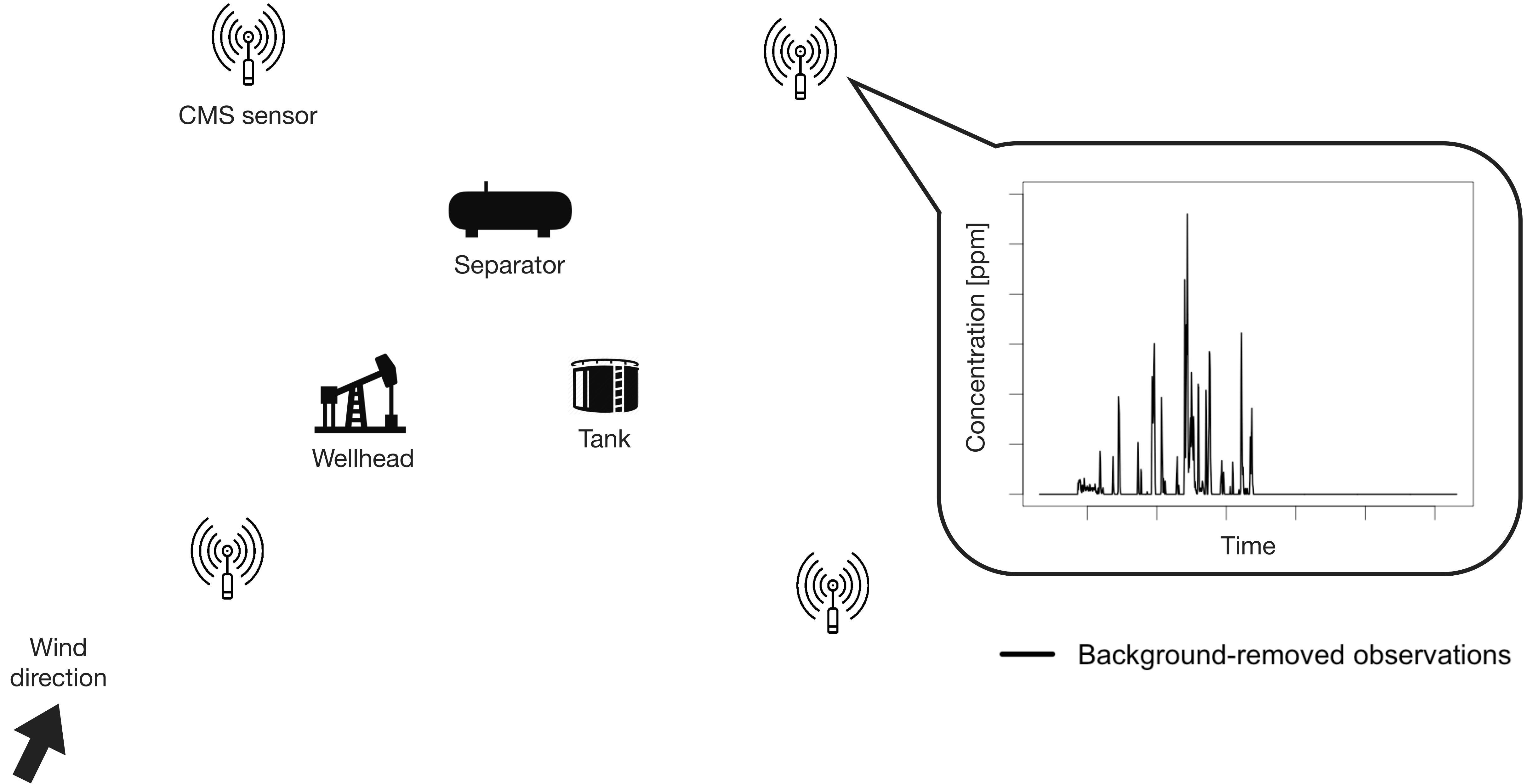
Total concentration at (x, y, z, t)

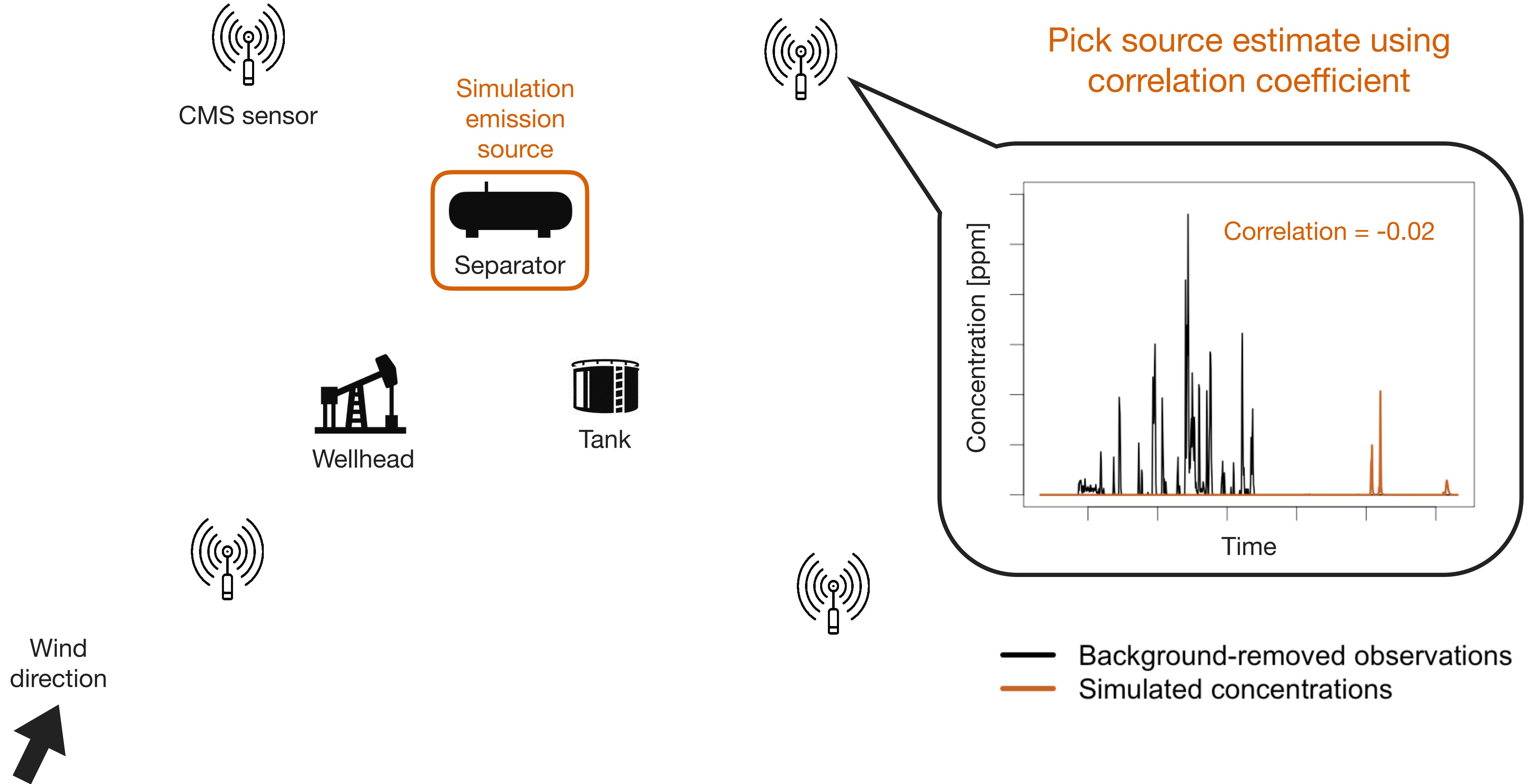


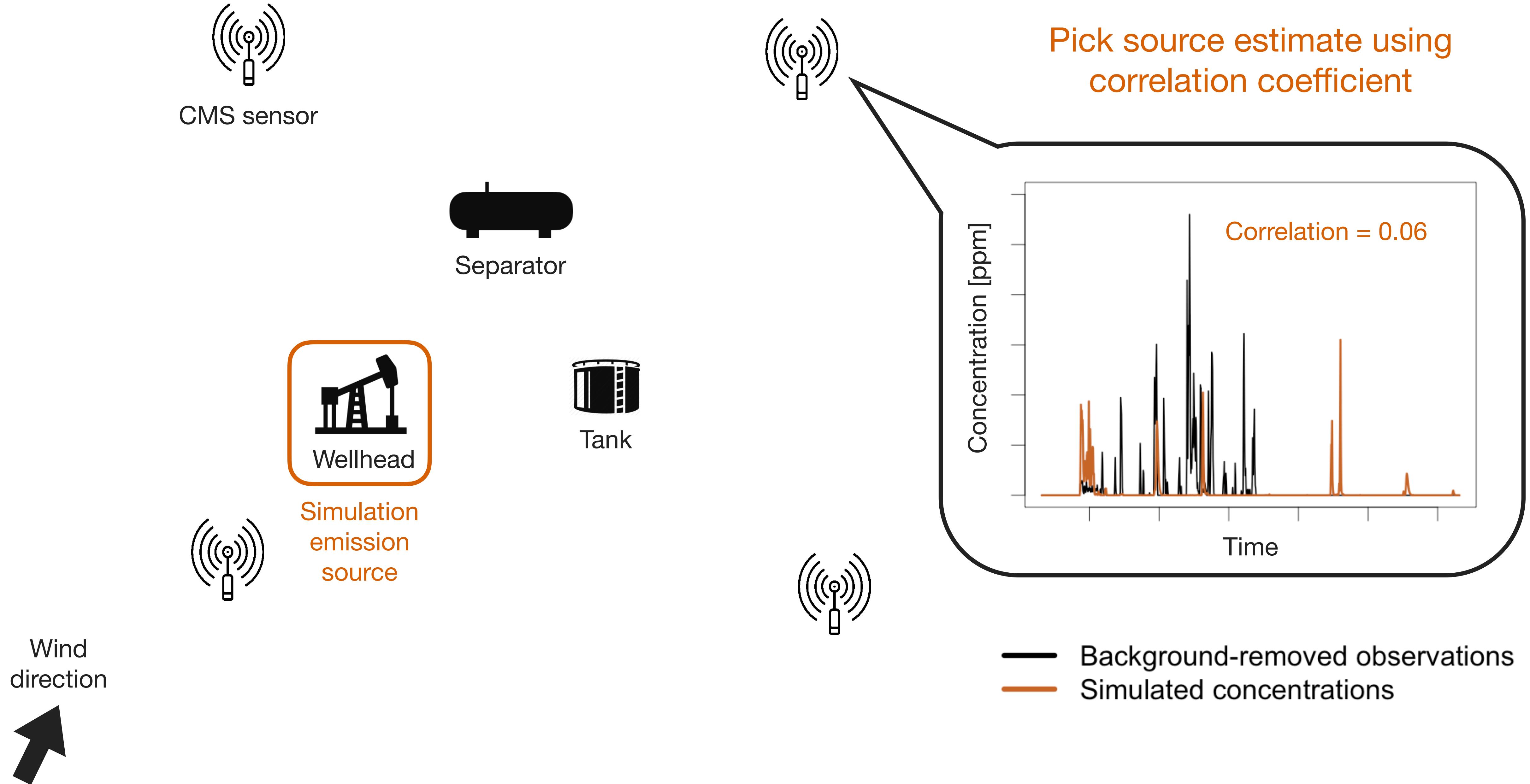


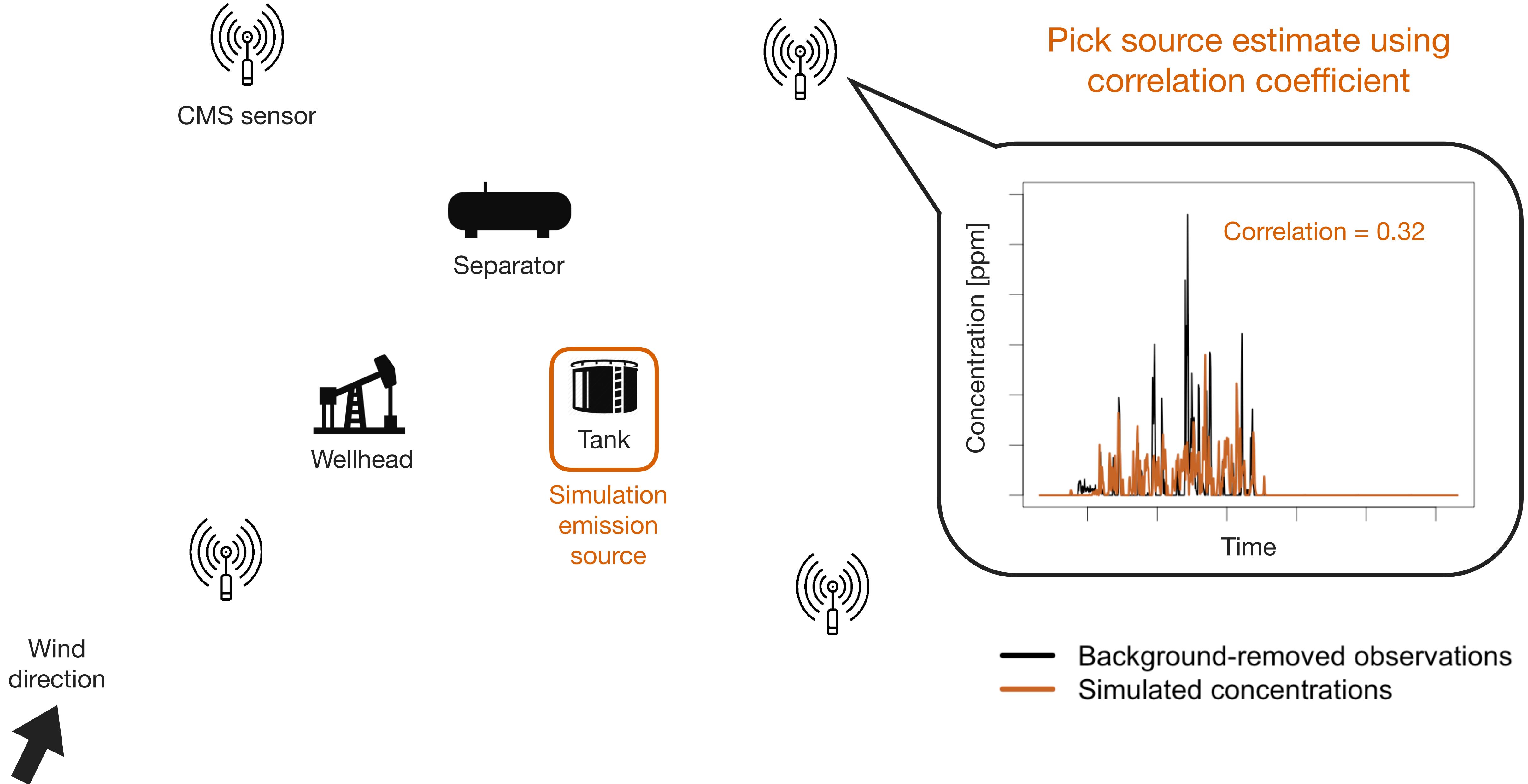
Open source framework for solving inverse problem



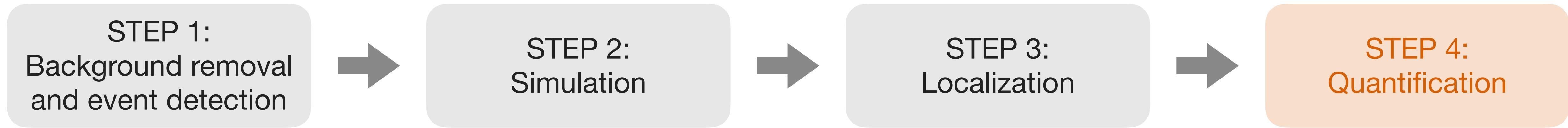








Open source framework for solving inverse problem



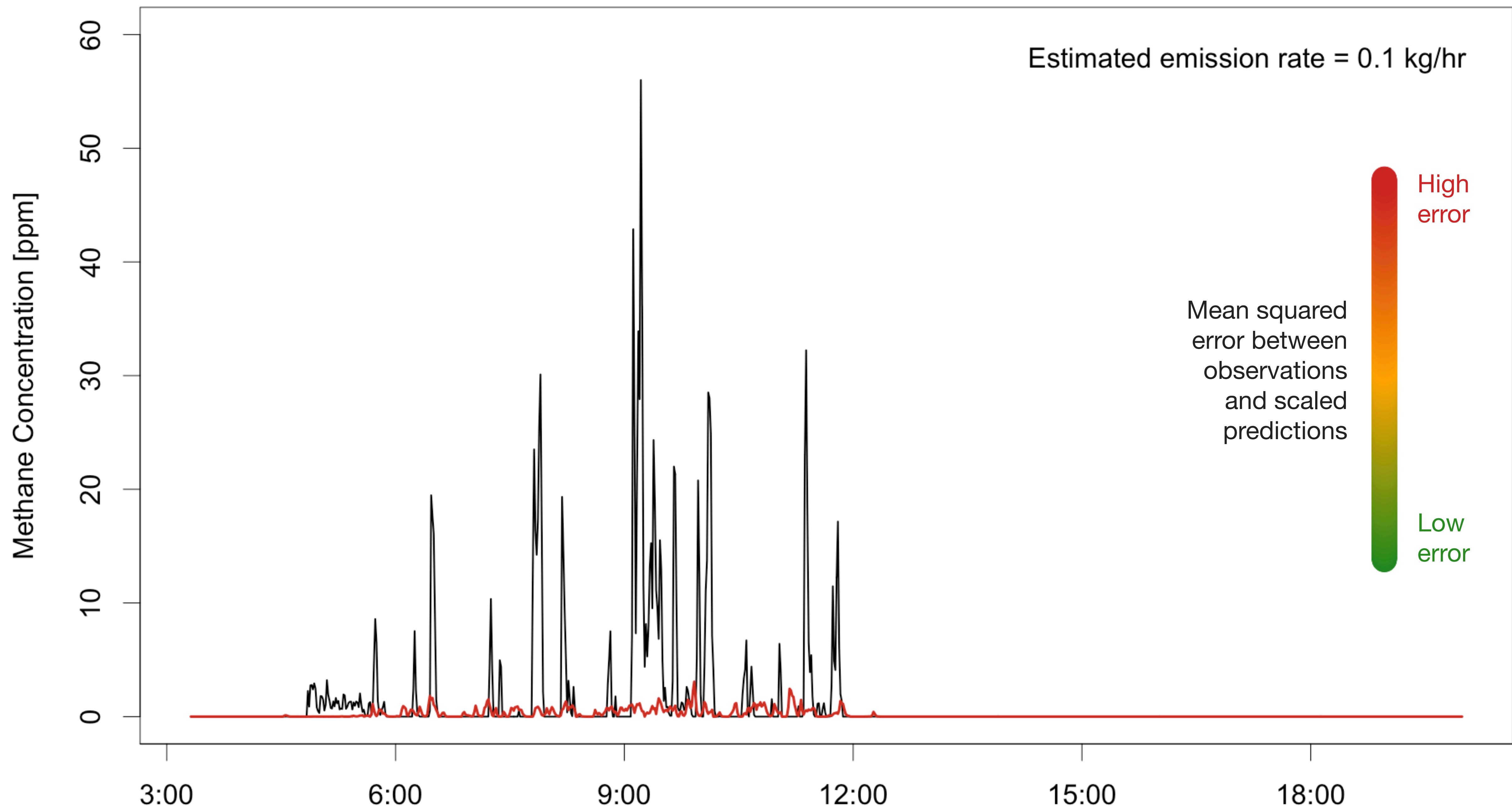
Simulation is a linear function of emission rate

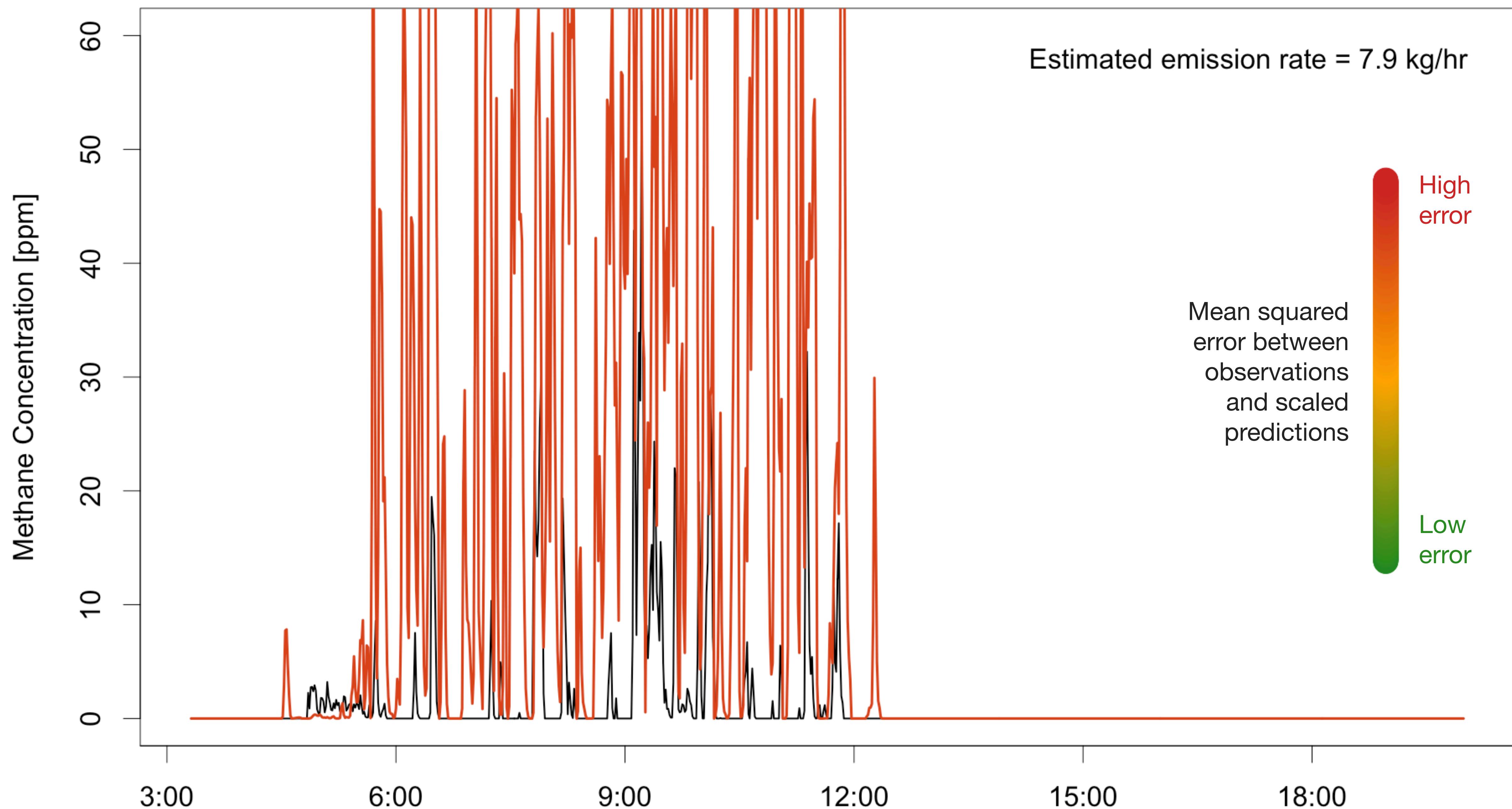
Emission rate

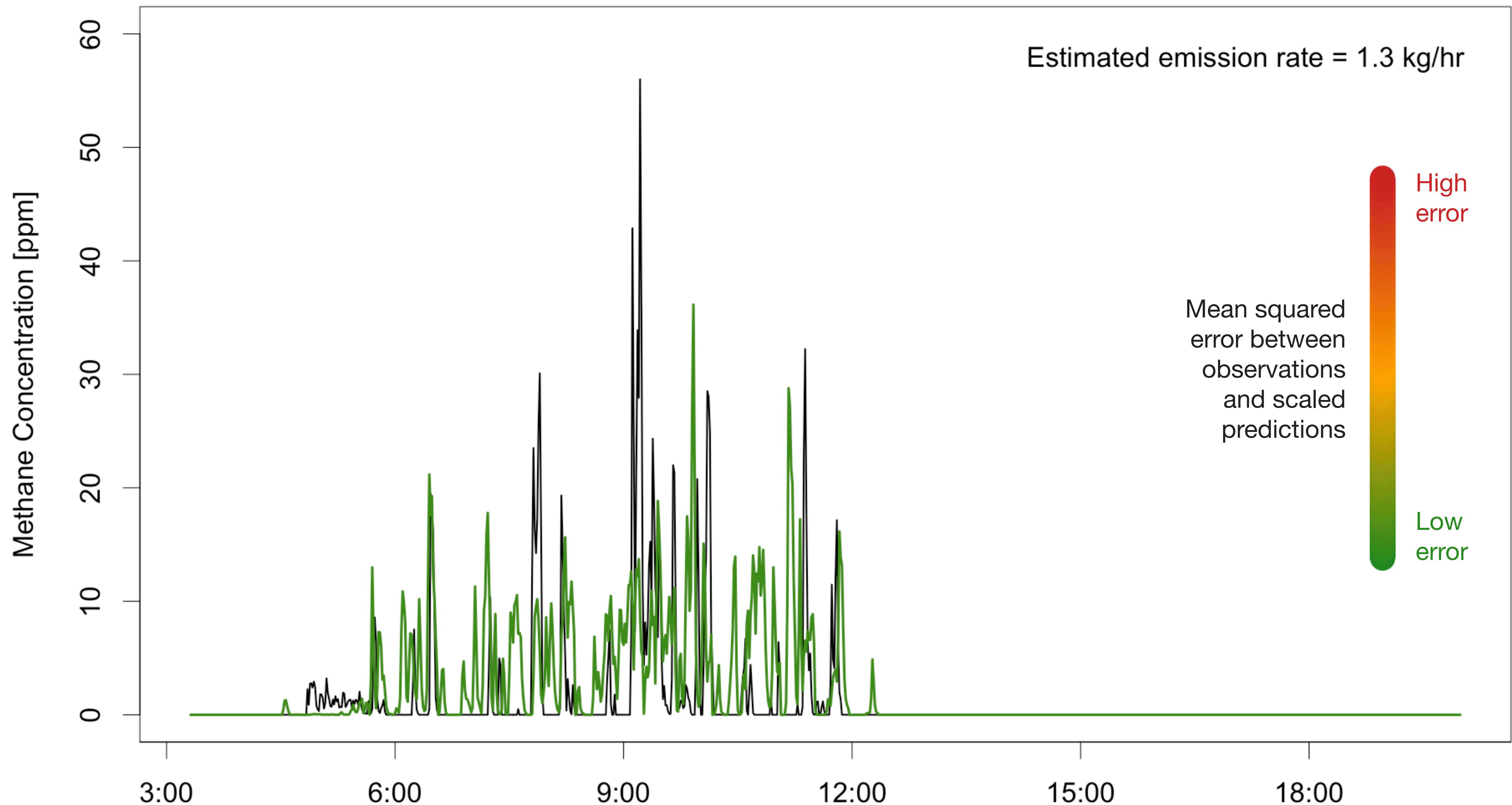
$$c_p(x, y, z, t) = Q \frac{1}{(2\pi)^{3/2} \sigma_y^2 \sigma_z} \exp\left(-\frac{(x - ut)^2 + y^2}{2\sigma_y^2}\right) \left[\exp\left(-\frac{(z - H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z + H)^2}{2\sigma_z^2}\right) \right]$$

Simulation output:
concentrations

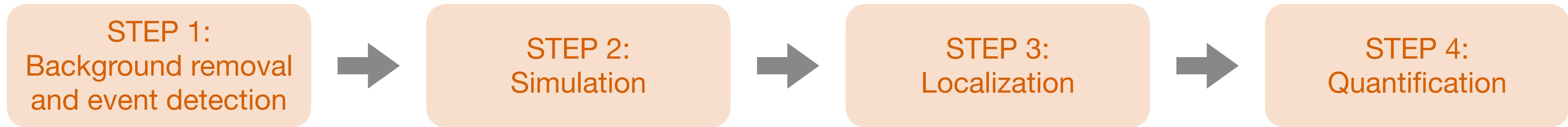
“Everything else”



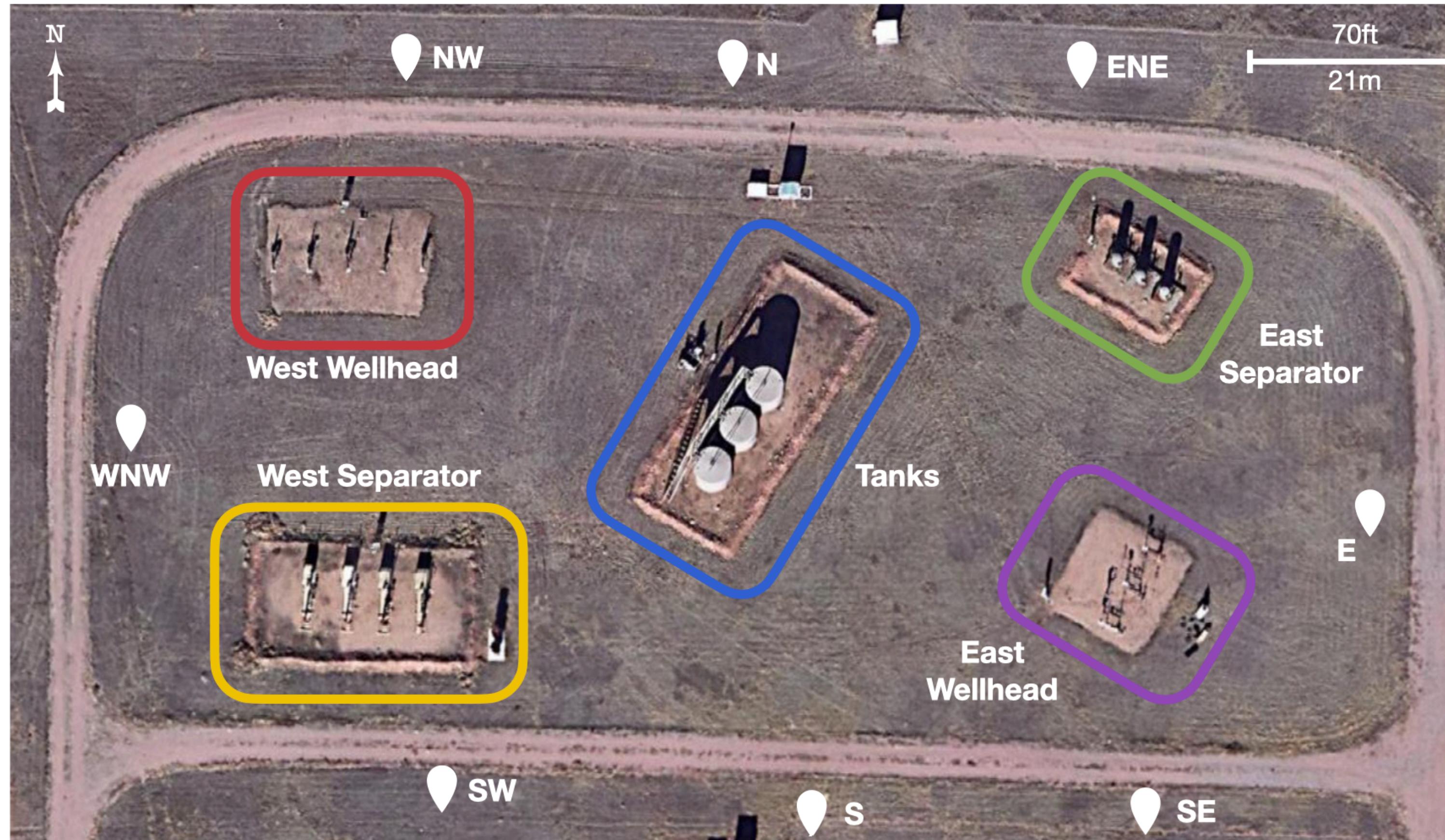




Open source framework for solving inverse problem



Evaluation on single-source controlled releases

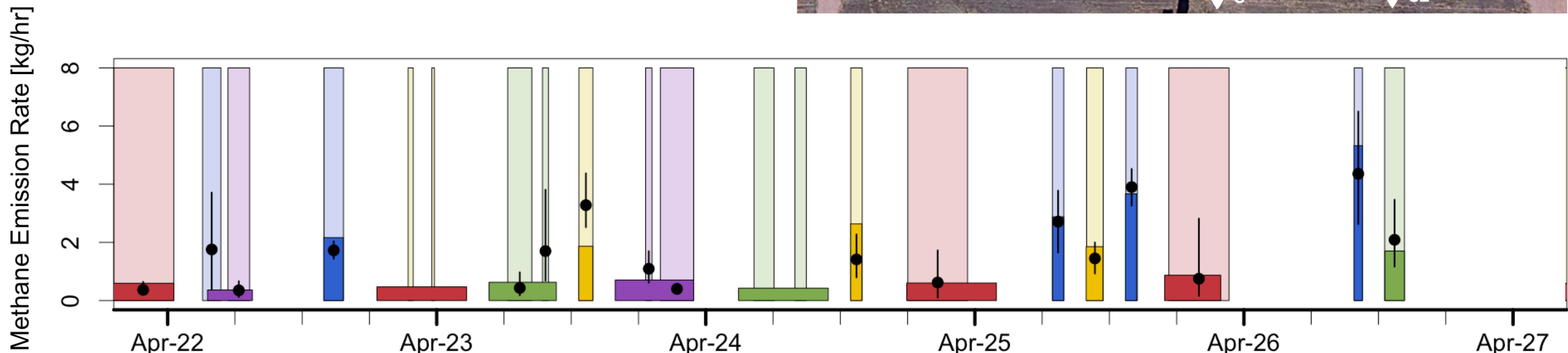
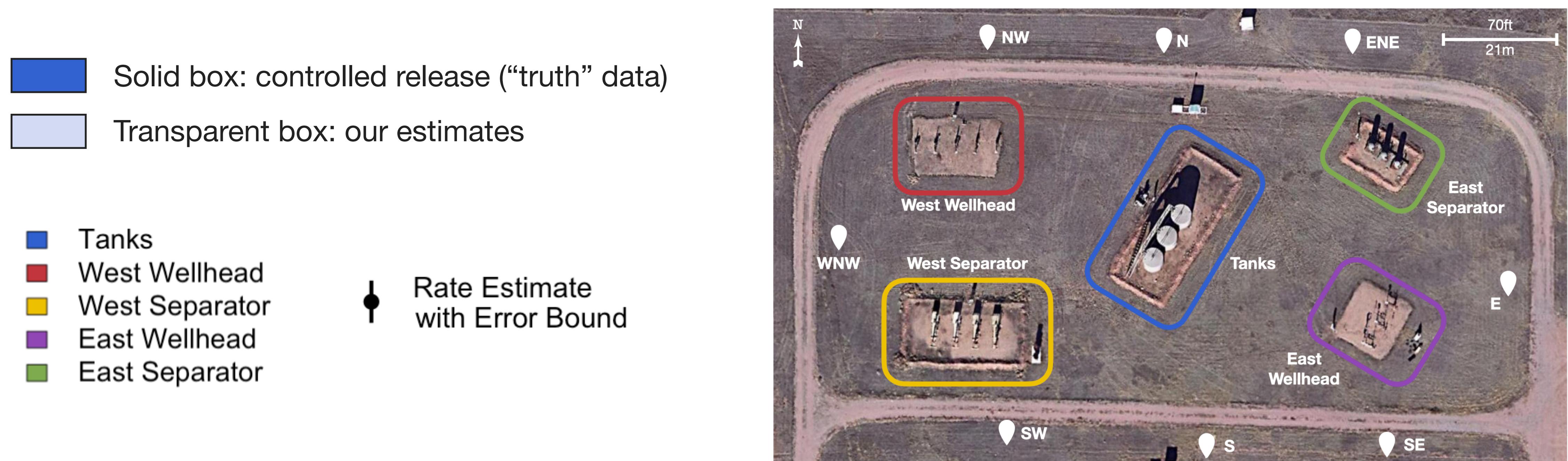


85 single-source controlled releases

Emission rates range from
0.2 to 6.4 kg/hr

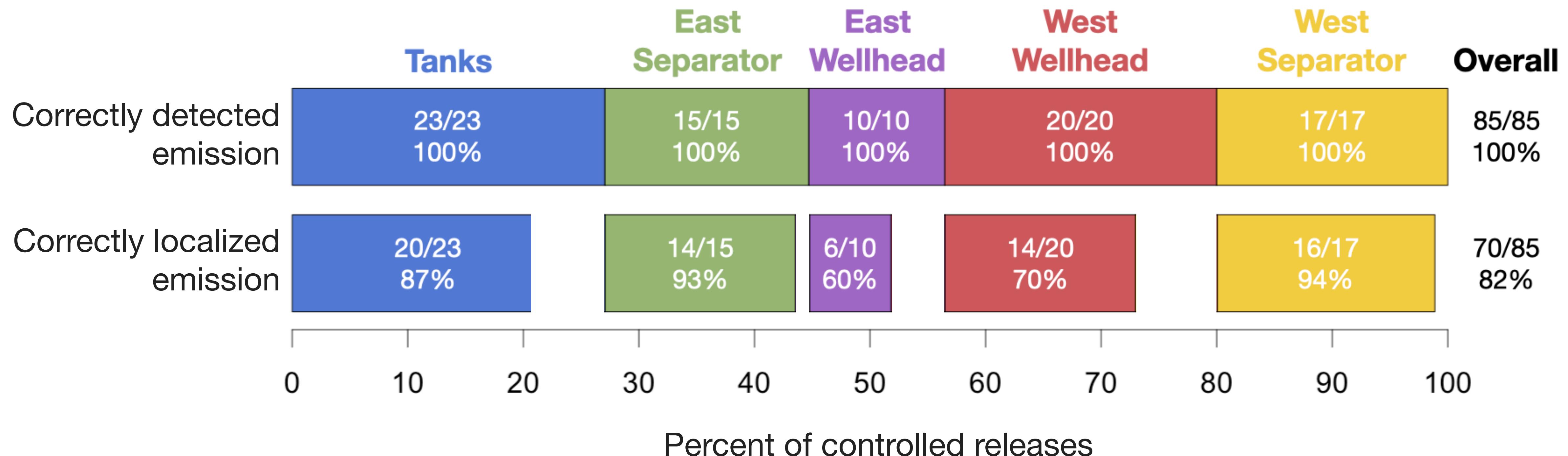
Emission durations range from
0.5 to 8.25 hours

Evaluation on single-source controlled releases

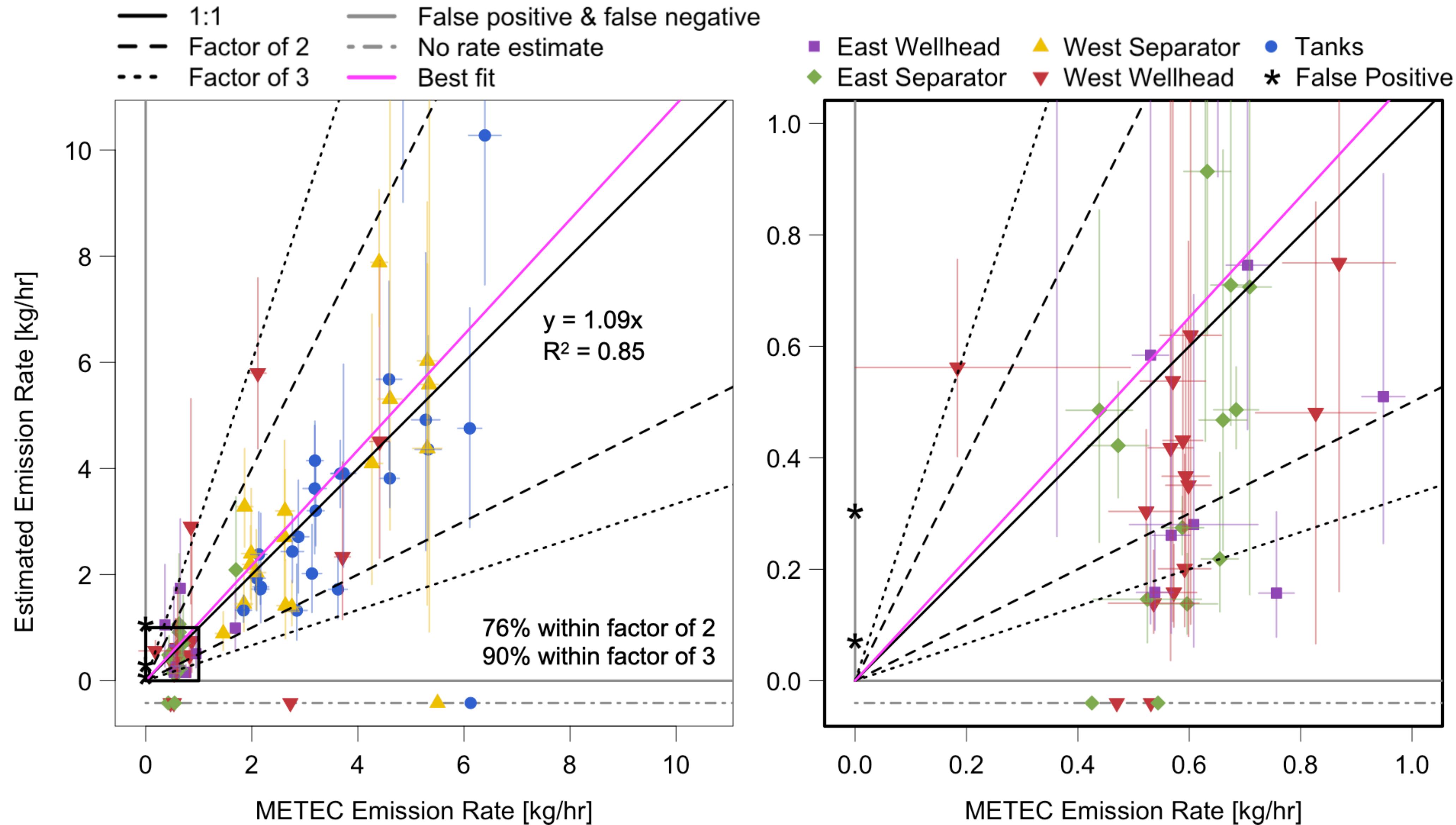


Evaluation on single-source controlled releases

Event-level false positive rate: 5.5%



Evaluation on single-source controlled releases



Evaluation on single-source controlled releases

