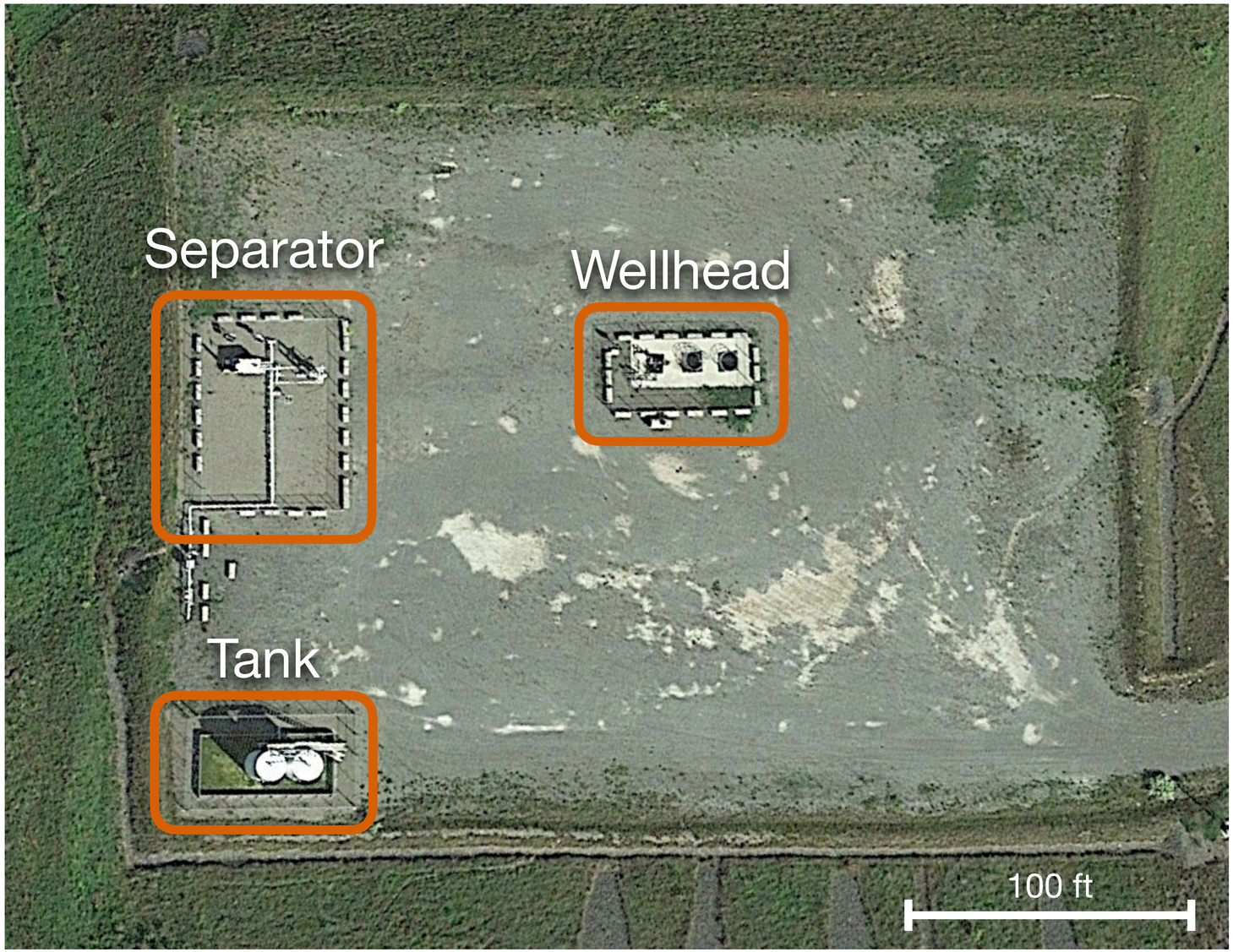
CMS Series #4:
Estimating methane emission durations on oil and gas sites

William Daniels

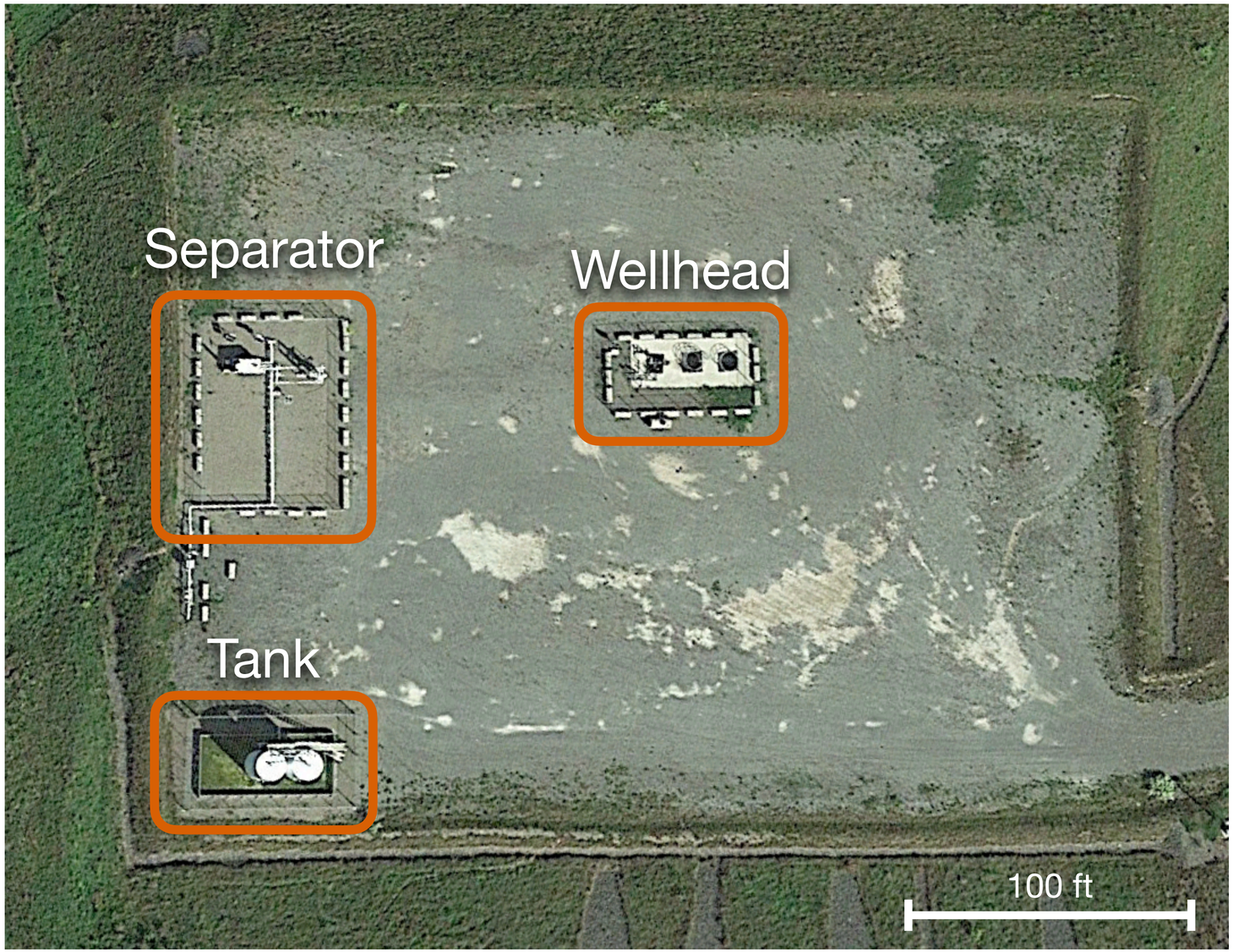
Department of Applied Mathematics and Statistics

COLORADO SCHOOL OF MINES

Example production oil and gas site

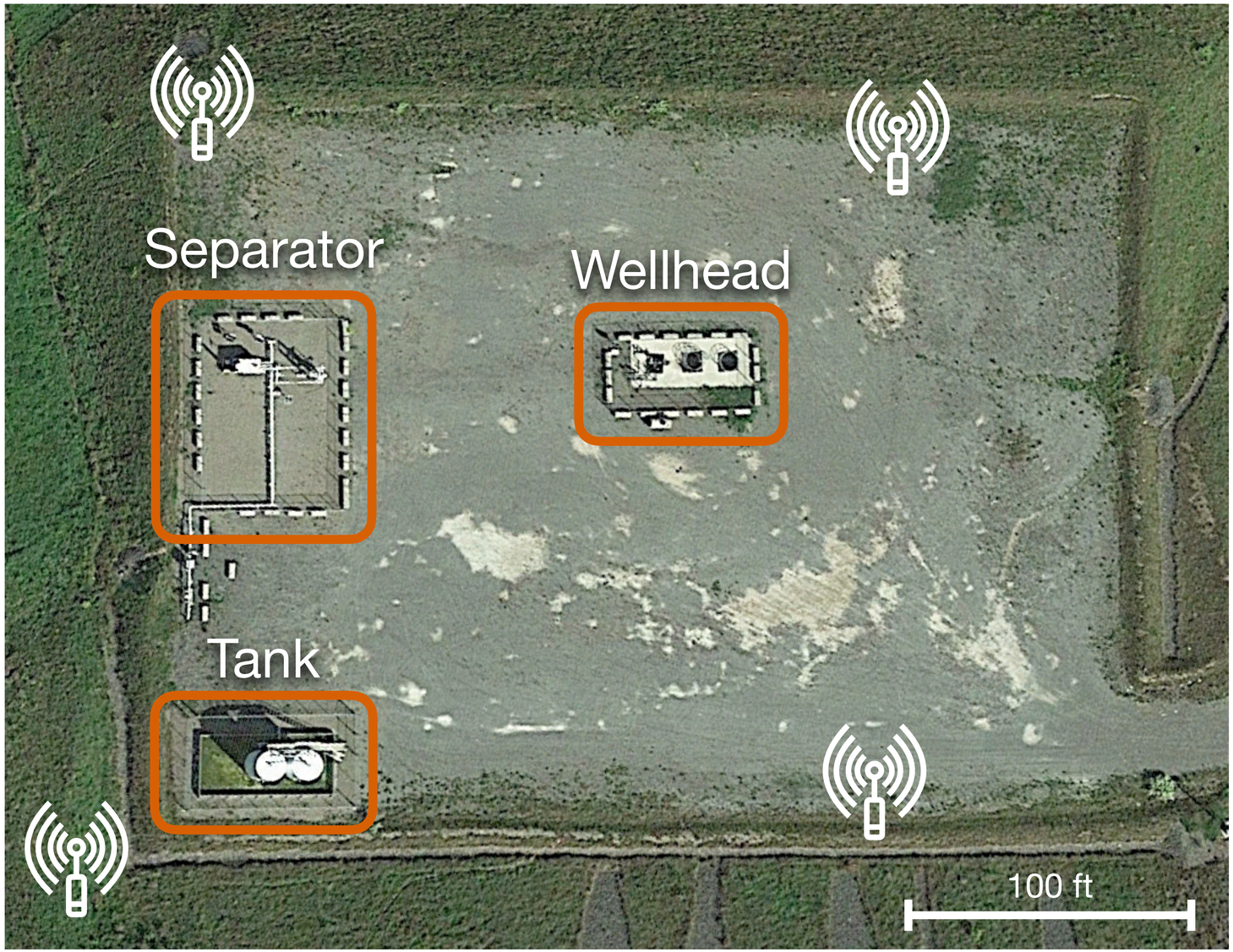


Example production oil and gas site



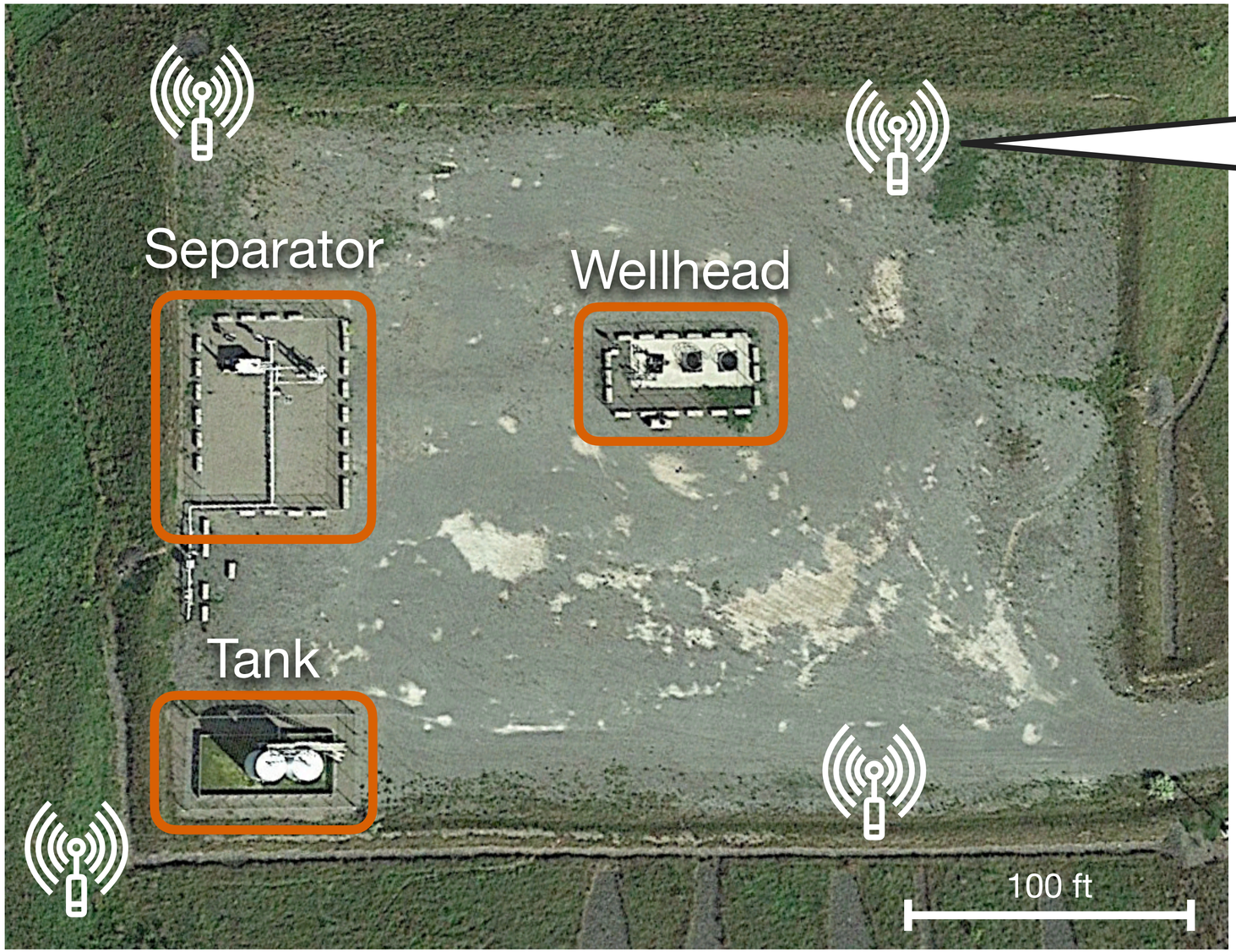
Continuous monitoring system (CMS)

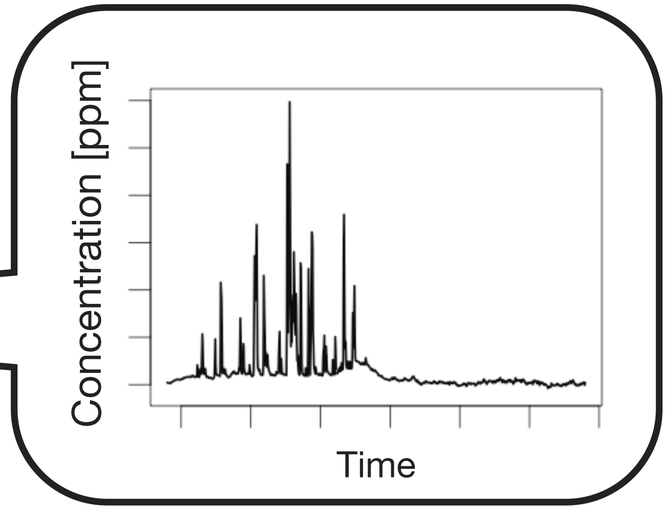
Example production oil and gas site



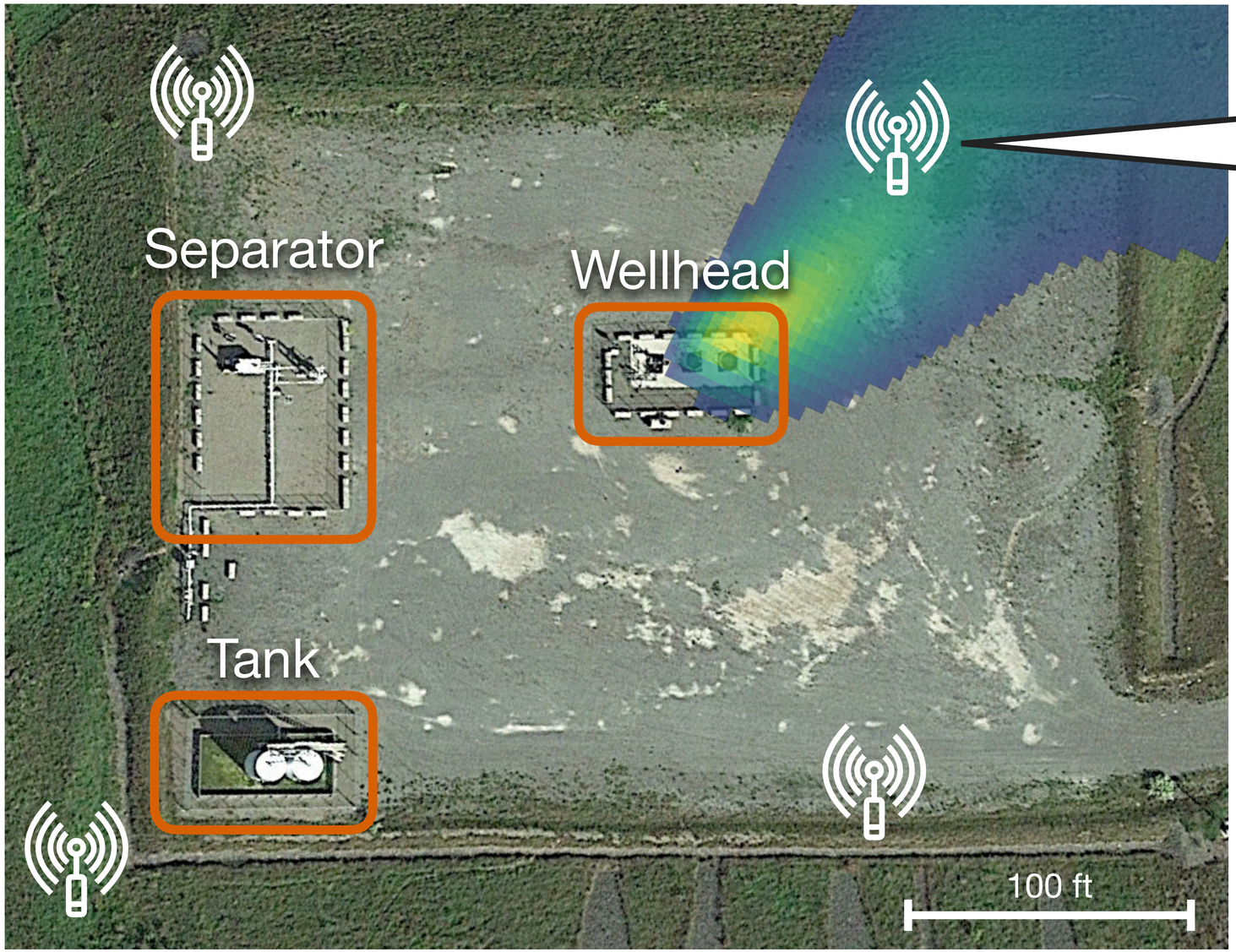
Continuous monitoring system (CMS)

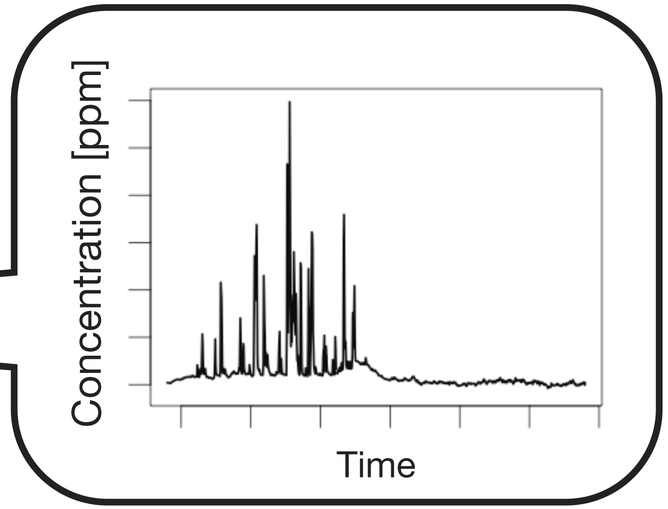
Example production oil and gas site





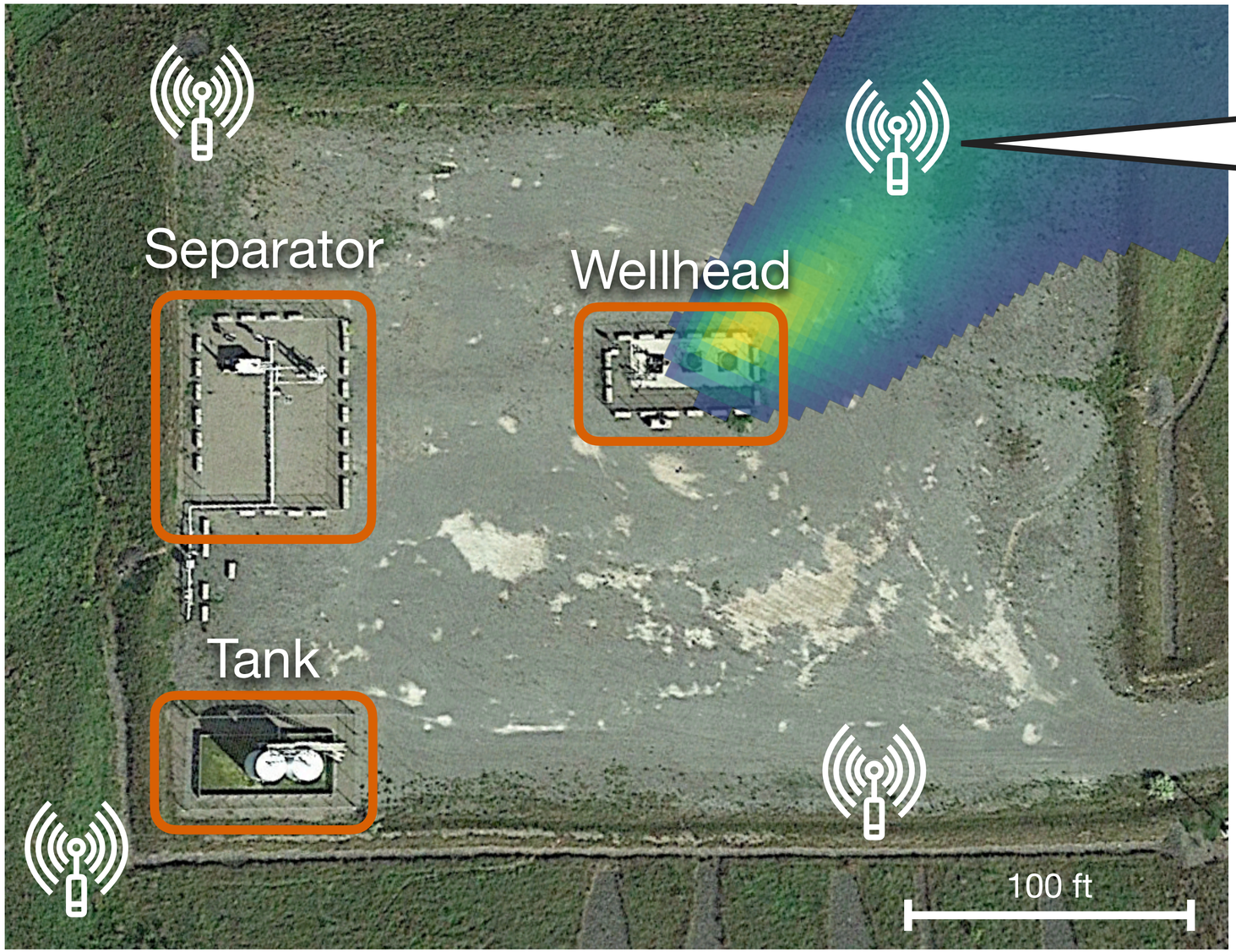
Example production oil and gas site

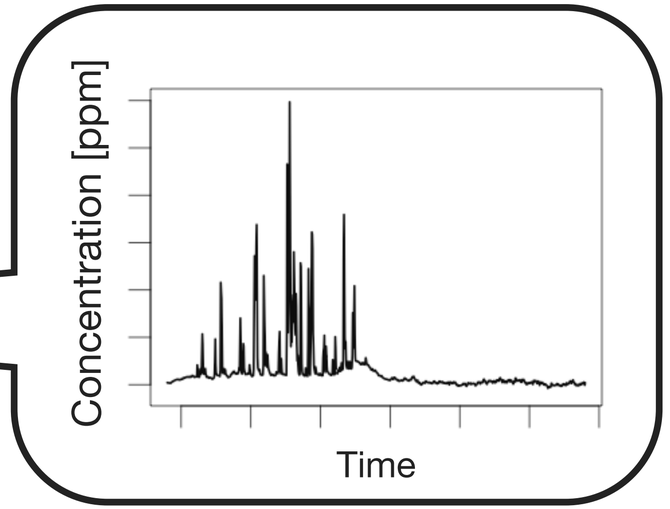




Aerial measurement technology

Example production oil and gas site



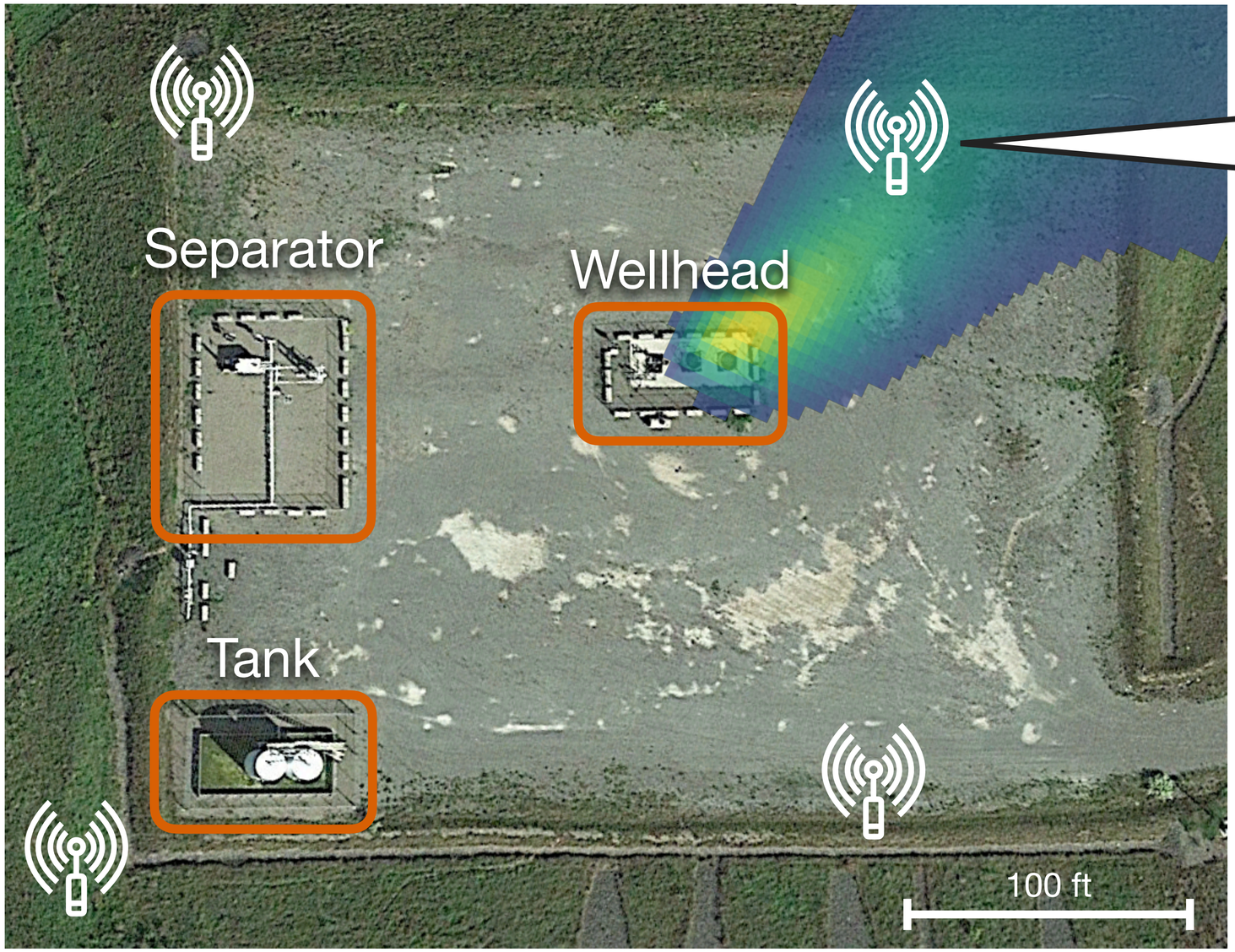


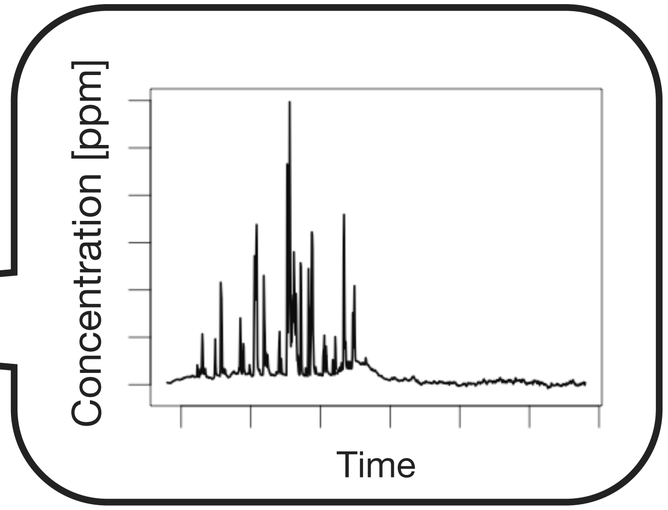
Aerial measurement technology

Bottom-up inventory estimate =

1 wellhead	x	wellhead emission factor	+
1 separator	x	separator emission factor	+
1 tank	x	tank emission factor	

Example production oil and gas site





Event detection:
When is an emission happening?

Localization:
Where is the emission coming from?

Quantification:
How much is being emitted?

Chapter 5:

Robust duration estimates

A policy driven research project

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 98

[EPA–HQ–OAR–2023–0234; FRL–10246–01–OAR]

RIN 2060–AV83

Greenhouse Gas Reporting Rule: Revisions and Confidentiality Determinations for Petroleum and Natural Gas Systems

AGENCY: Environmental Protection Agency (EPA).

ACTION: Proposed rule.

SUMMARY: The Environmental Protection Agency (EPA) is proposing to amend requirements that apply to the petroleum and natural gas systems source category of the Greenhouse Gas Reporting Rule to ensure that reporting is based on empirical data, accurately reflects total methane emissions and waste emissions from applicable facilities, and allows owners and operators of applicable facilities to submit empirical emissions data that appropriately demonstrate the extent to which a charge is owed. The EPA is also proposing changes to requirements that

Federal eRulemaking Portal. www.regulations.gov (our preferred method). Follow the online instructions for submitting comments.

Mail: U.S. Environmental Protection Agency, EPA Docket Center, Air and Radiation Docket, Mail Code 28221T, 1200 Pennsylvania Avenue NW, Washington, DC 20460.

Hand Delivery or Courier (by scheduled appointment only): EPA Docket Center, WJC West Building, Room 3334, 1301 Constitution Avenue NW, Washington, DC 20004. The Docket Center's hours of operations are 8:30 a.m.–4:30 p.m., Monday-Friday (except Federal holidays).

Instructions: All submissions received must include the Docket Id. No. for this proposed rulemaking. Comments received may be posted without change to *www.regulations.gov/*, including any personal information provided. For detailed instructions on sending comments and additional information on the rulemaking process, see the "Public Participation" heading of the **SUPPLEMENTARY INFORMATION** section of this document.

The virtual hearing, if requested, will be held using an online meeting platform, and the EPA will provide information on its website

EPA may publish any comment received to its public docket. Do not submit to the EPA's docket at *www.regulations.gov* any information you consider to be confidential business information (CBI), proprietary business information (PBI), or other information whose disclosure is restricted by statute. Multimedia submissions (audio, video, etc.) must be accompanied by a written comment. The written comment is considered the official comment and should include discussion of all points you wish to make. The EPA will generally not consider comments or comment contents located outside of the primary submission (*i.e.,* on the web, cloud, or other file sharing system). Commenters who would like the EPA to further consider in this rulemaking any relevant comments that they provided on the 2022 Proposed Rule regarding proposed revisions at issue in this proposal must resubmit those comments to the EPA during this proposal's comment period. Please visit *www.epa.gov/dockets/commenting-epa-dockets* for additional submission methods; the full EPA public comment policy; information about CBI, PBI, or multimedia submissions, and general guidance on making effective comments.

A policy driven research project

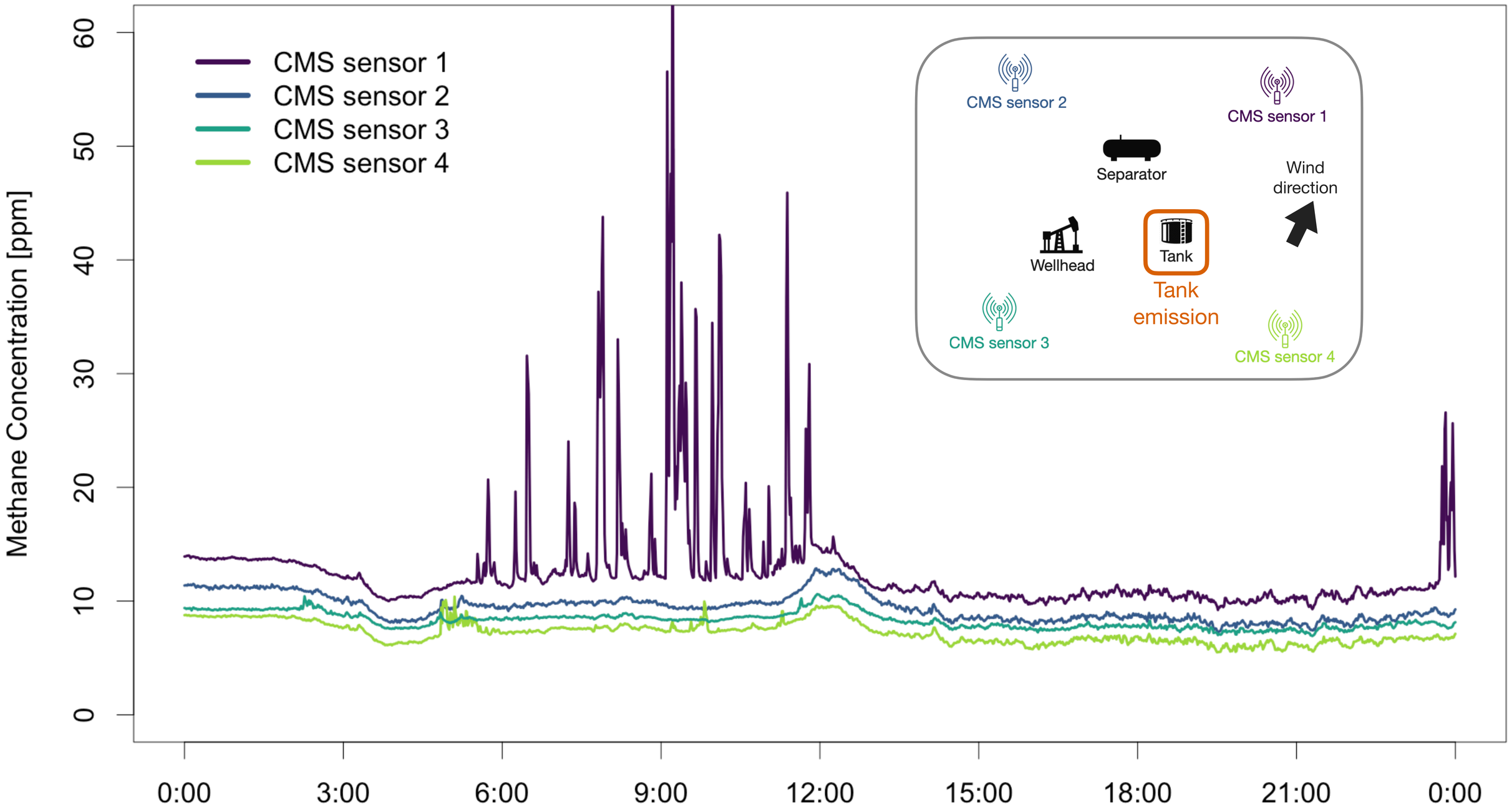
40 CFR Part 98:
Proposed updates to the EPA's Greenhouse Gas Reporting Program (GHGRP) to take effect January 2025

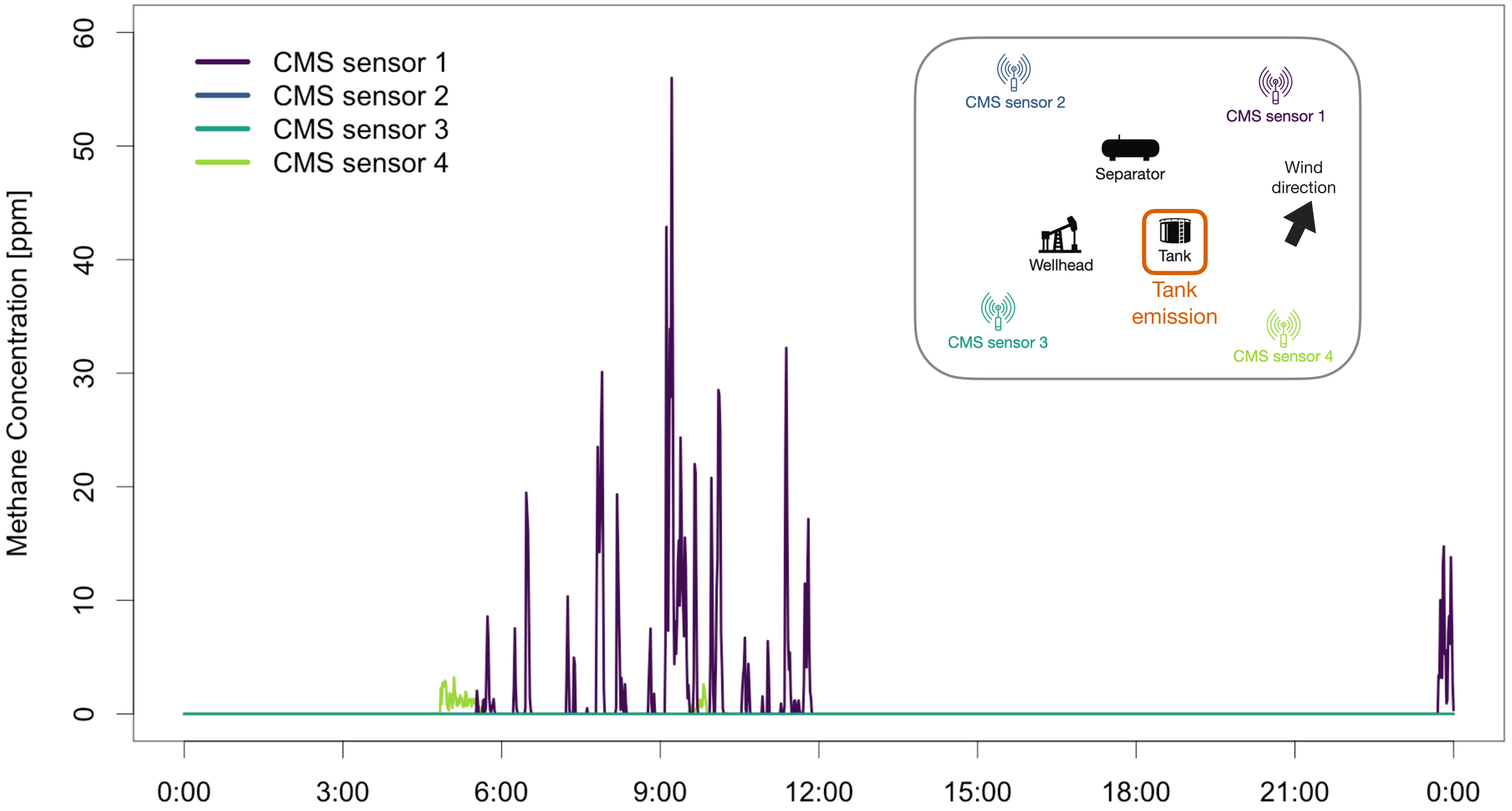
… also proposing a **100 kg/hr CH_4 emission threshold** to align with the super-emitter response program proposed in the NSPS OOOOb. These emissions are generally intermittent, with widely varying durations …

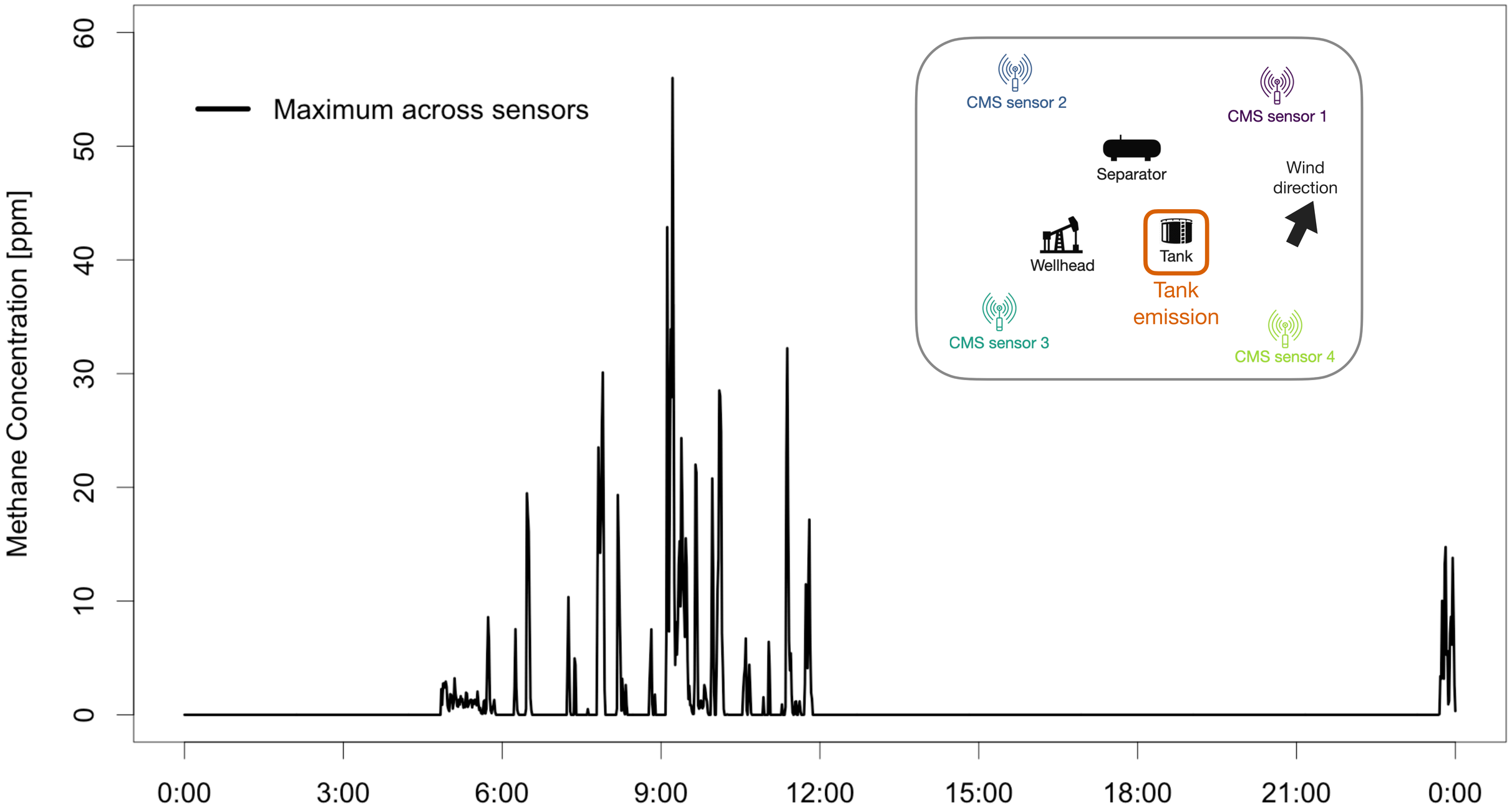
… also proposing that reporters would provide the start date and time of the release, **duration of the release**, and the method used to determine the start date and time …

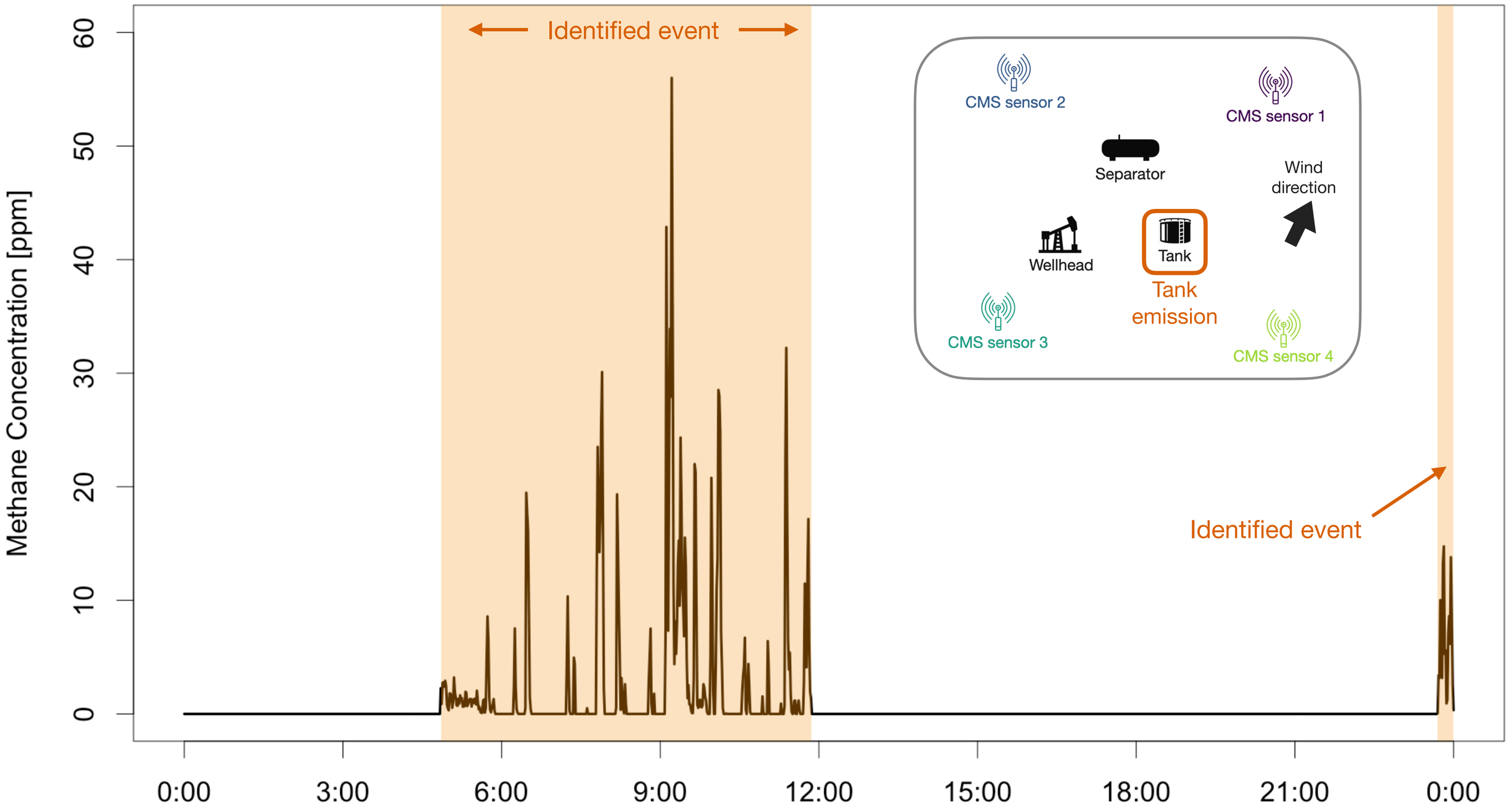
Oil and gas operators required to report all methane emissions > 100 kg/hr

For each of these emissions, the operator must estimate an emission duration

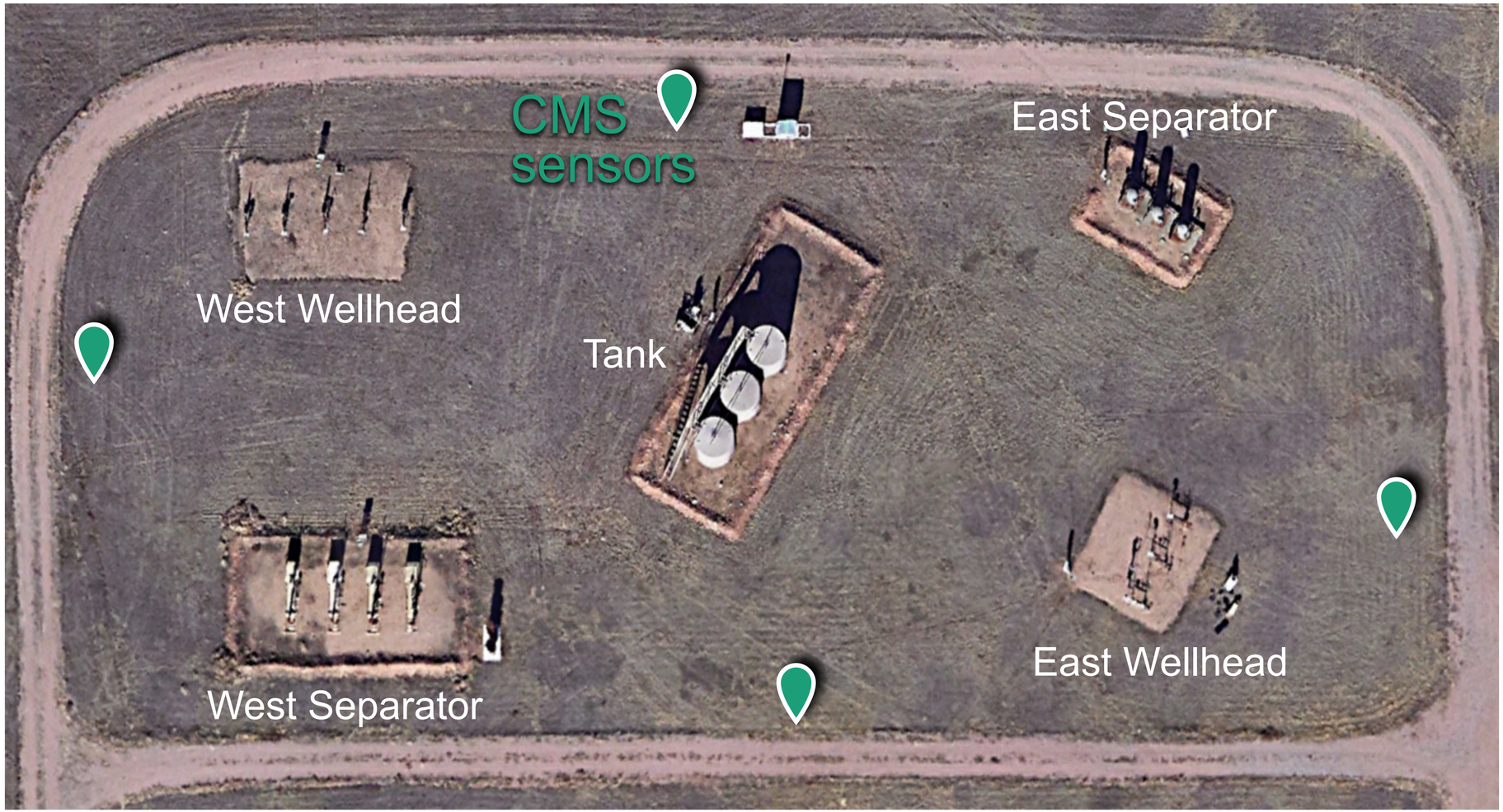

CMS sensor 1
CMS sensor 2
CMS sensor 3
CMS sensor 4
Methane Concentration [ppm]
0
10
20
30
40
50
60
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
CMS sensor 2
CMS sensor 1
Separator
Wind direction
Wellhead
Tank
Tank emission
CMS sensor 3
CMS sensor 4


CMS sensor 1
CMS sensor 2
CMS sensor 3
CMS sensor 4
Methane Concentration [ppm]
0
10
20
30
40
50
60
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
CMS sensor 2
CMS sensor 1
Separator
Wind direction
Wellhead
Tank
Tank emission
CMS sensor 3
CMS sensor 4

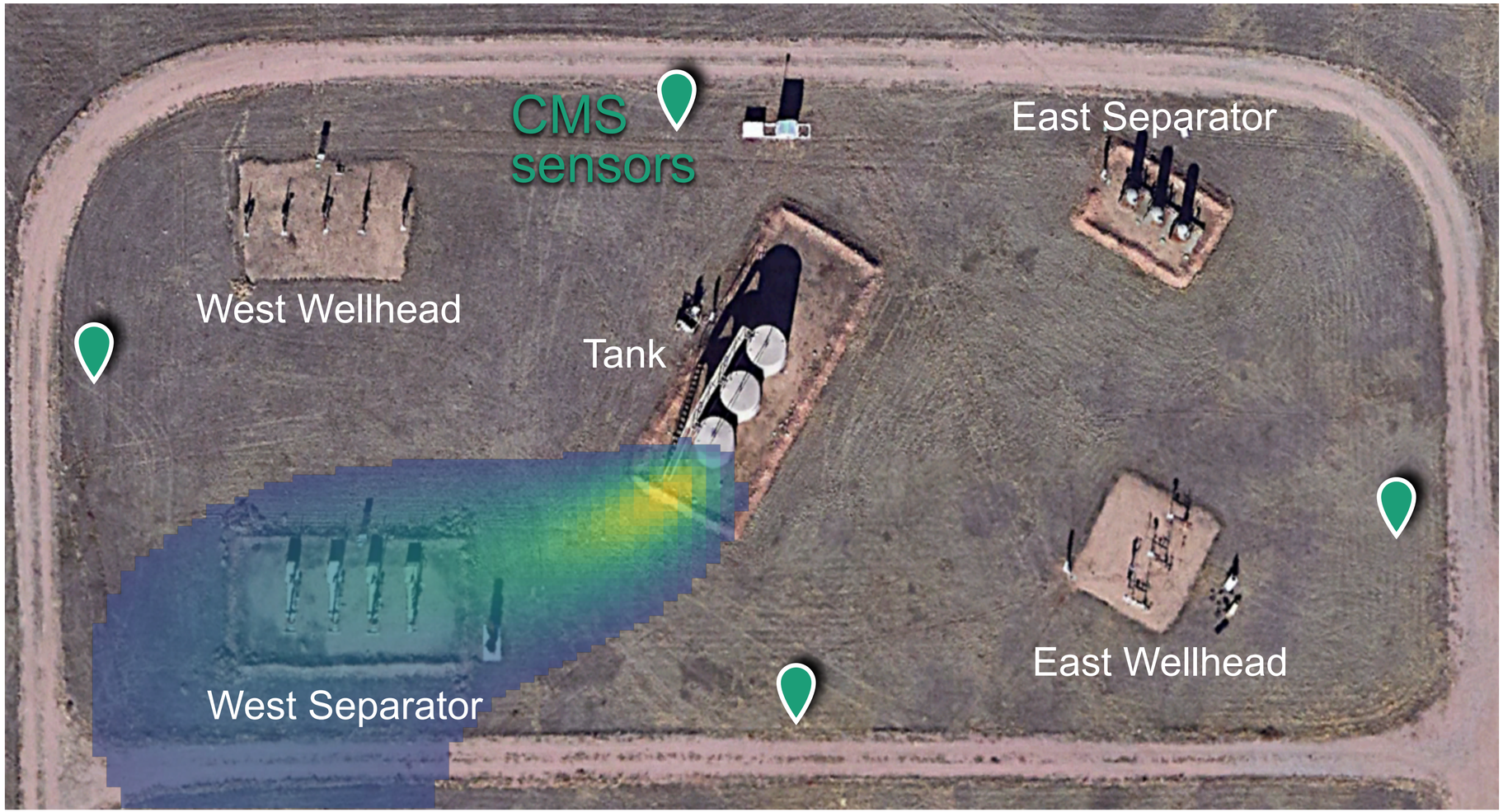

Maximum across sensors
Methane Concentration [ppm]
0
10
20
30
40
50
60
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
CMS sensor 2
CMS sensor 1
Separator
Wind direction
Wellhead
Tank
Tank emission
CMS sensor 3
CMS sensor 4


Identified event
CMS sensor 2
CMS sensor 1
Separator
Wind direction
Wellhead
Tank
Tank emission
CMS sensor 3
CMS sensor 4
Identified event
Methane Concentration [ppm]
0
10
20
30
40
50
60
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00

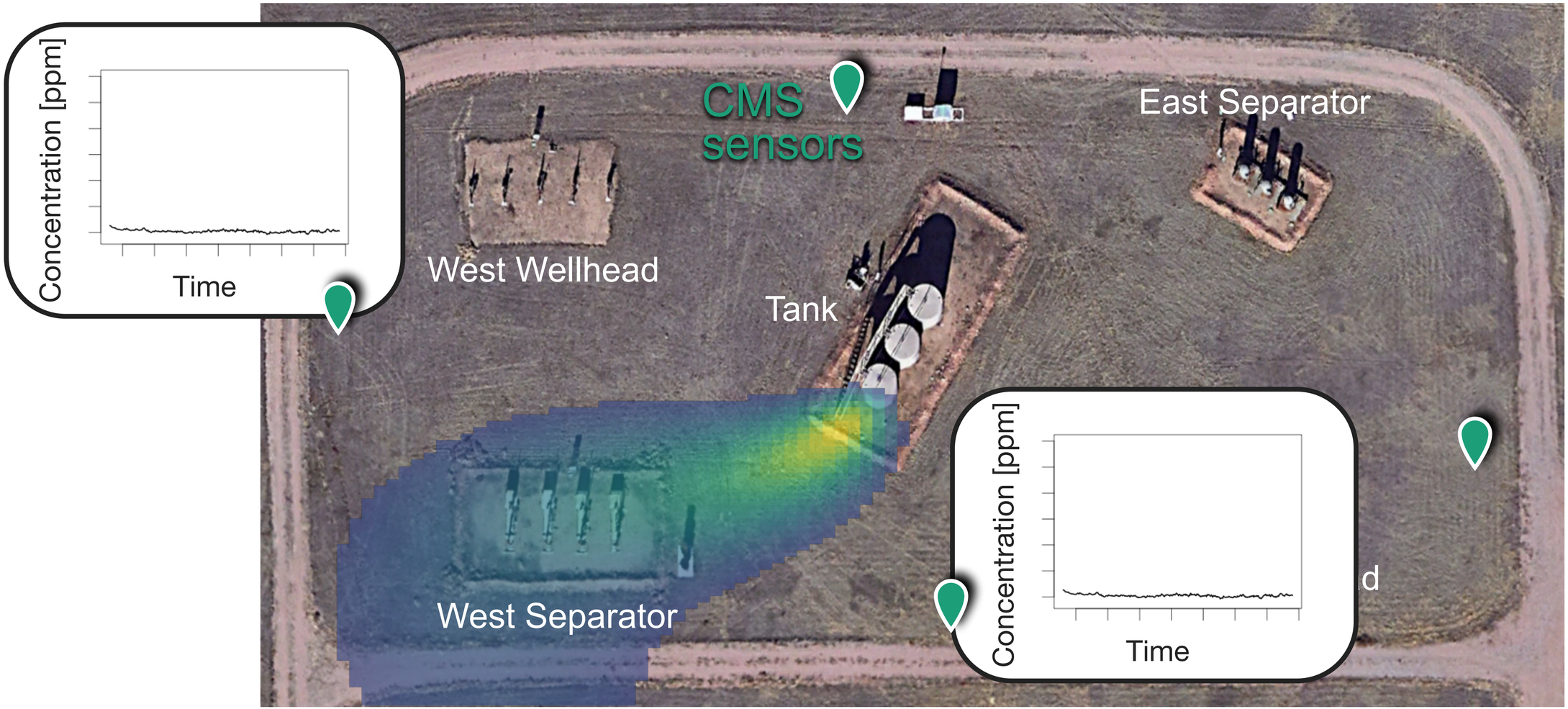
One problem… incomplete sensor coverage



One problem… incomplete sensor coverage



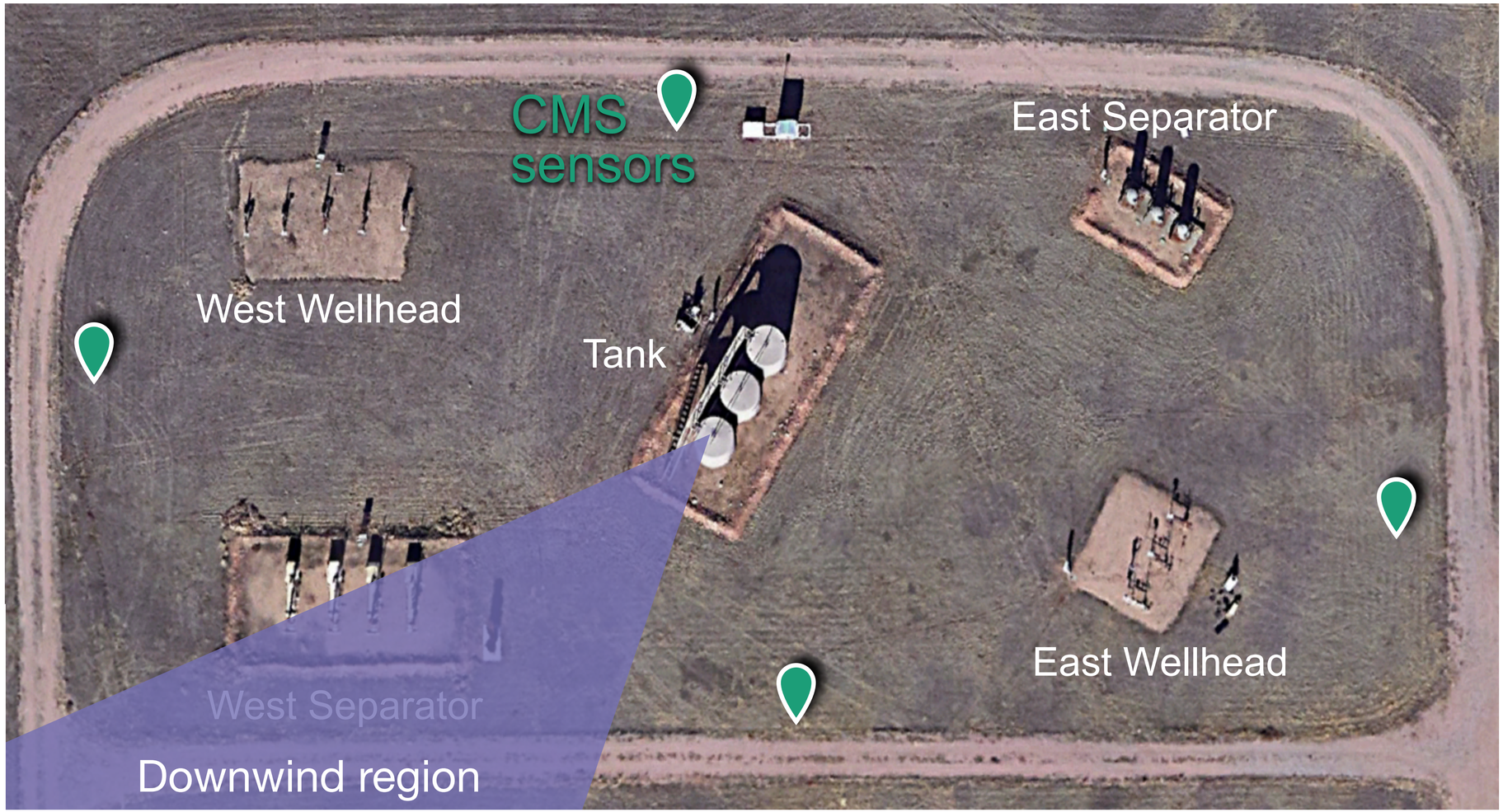
One problem… incomplete sensor coverage



CMS do not provide emission information when the wind blows between sensors

However, we can estimate when this happens!

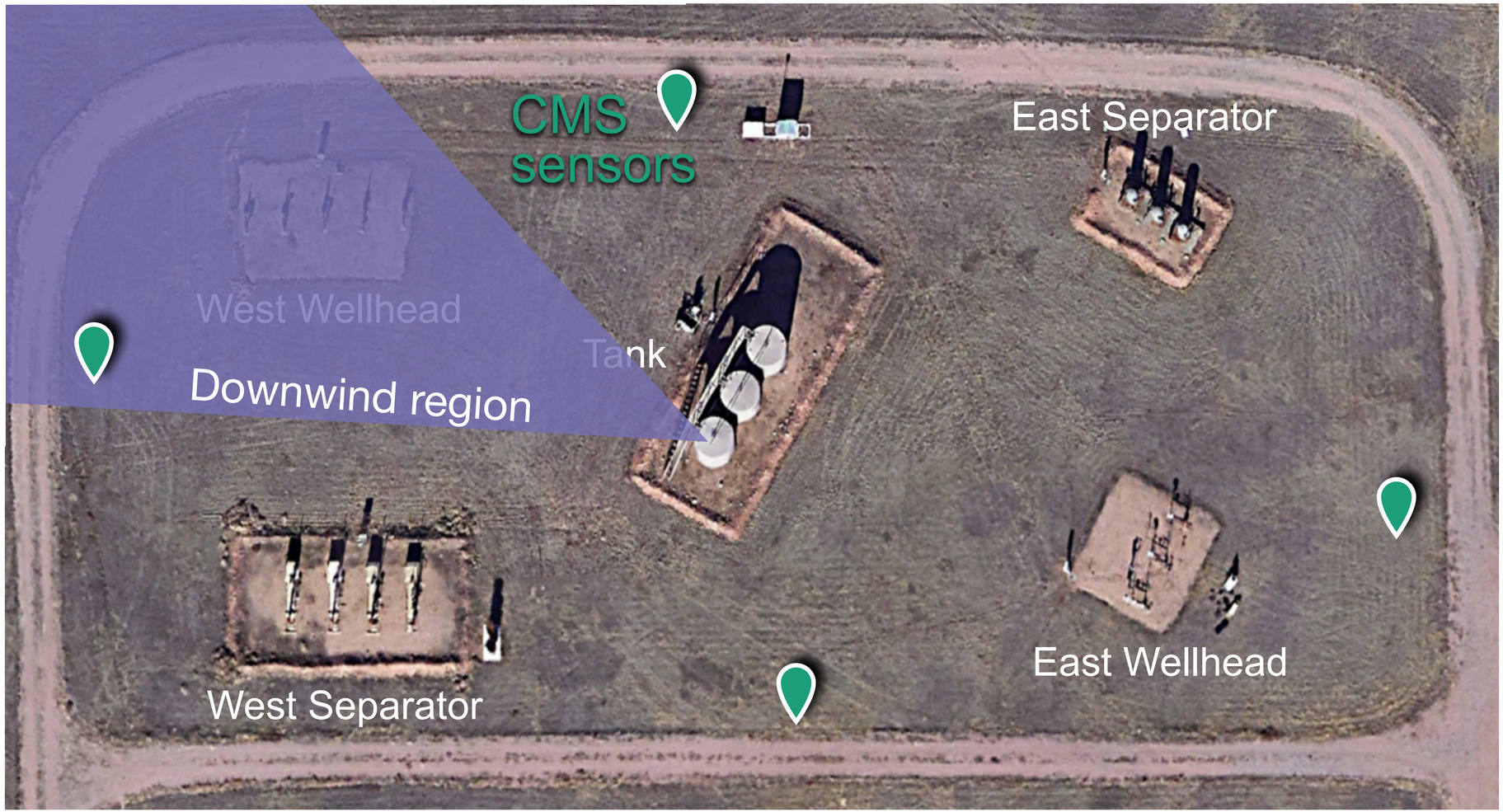
Wind direction



Downwind region **does not** overlap with CMS sensors = period of “**no information**”

However, we can estimate when this happens!

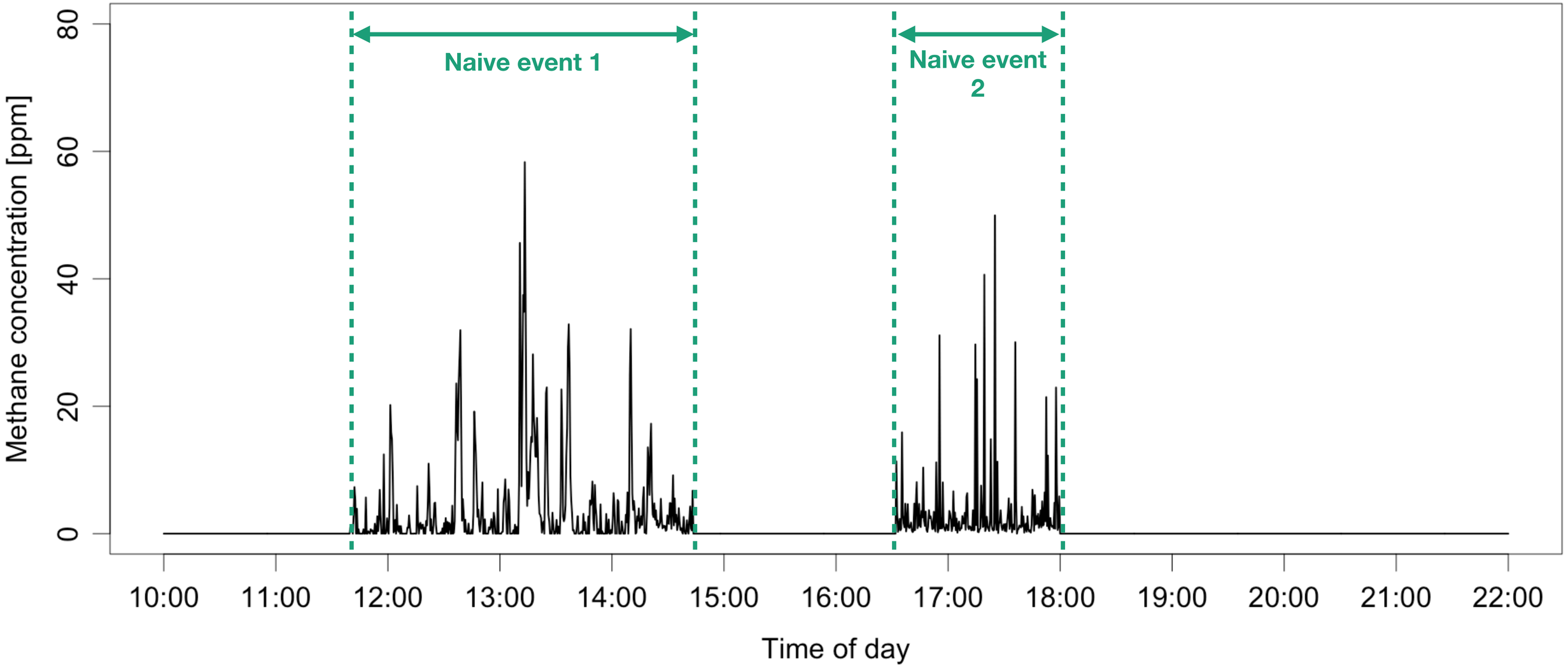
Wind direction



Downwind region **does** overlap with CMS sensors = period of “**information**”

Probabilistic Duration Model

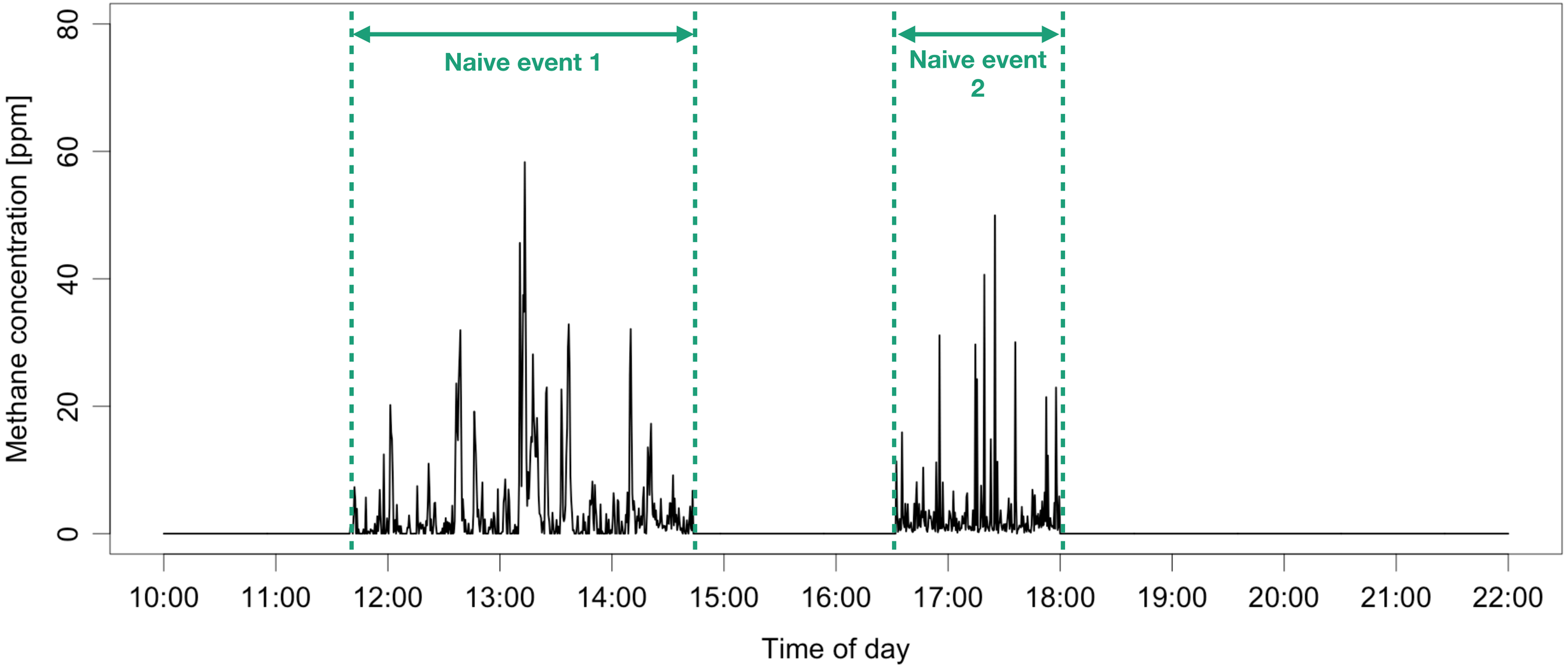
Step 1: Identify naive events



Probabilistic Duration Model

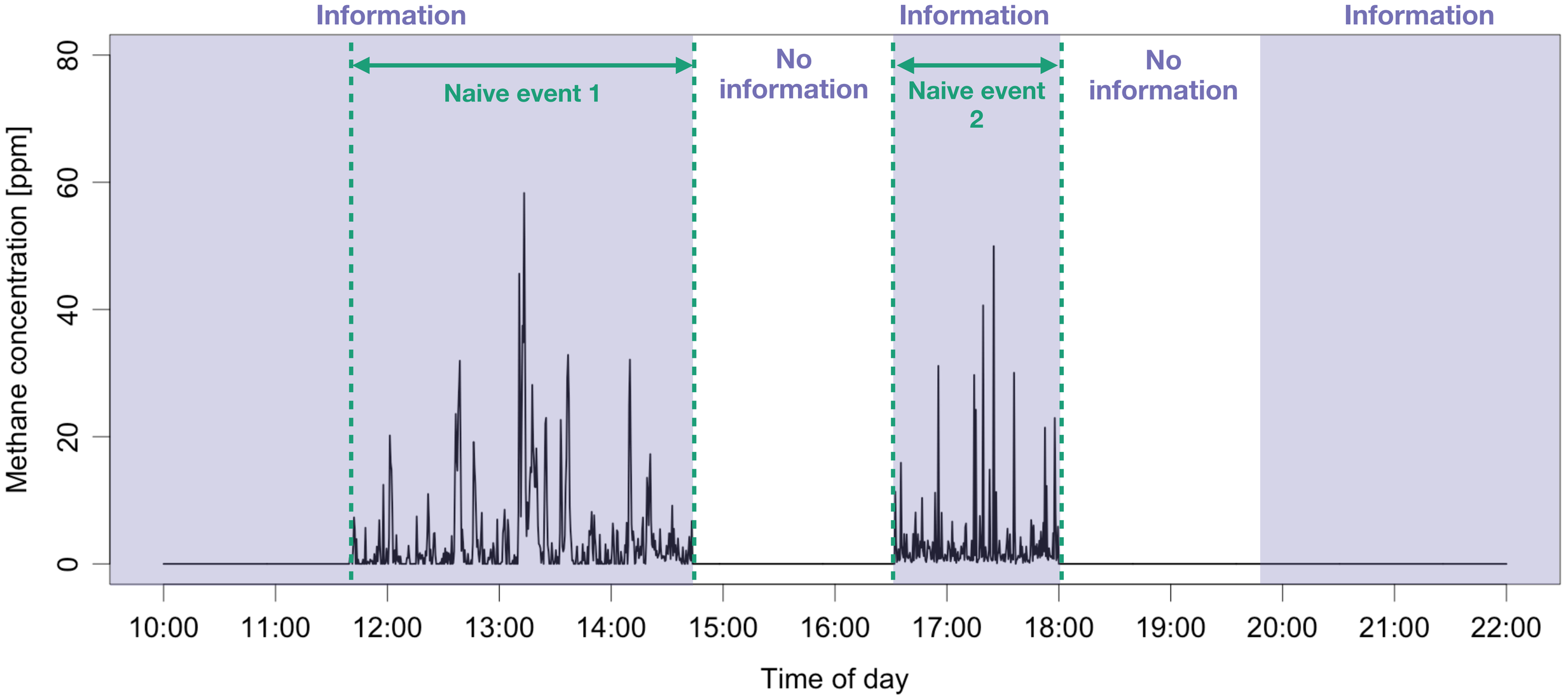
Step 1: Identify naive events

Example: we want a duration estimate for naive event 1



Probabilistic Duration Model

Step 2: Identify periods of information

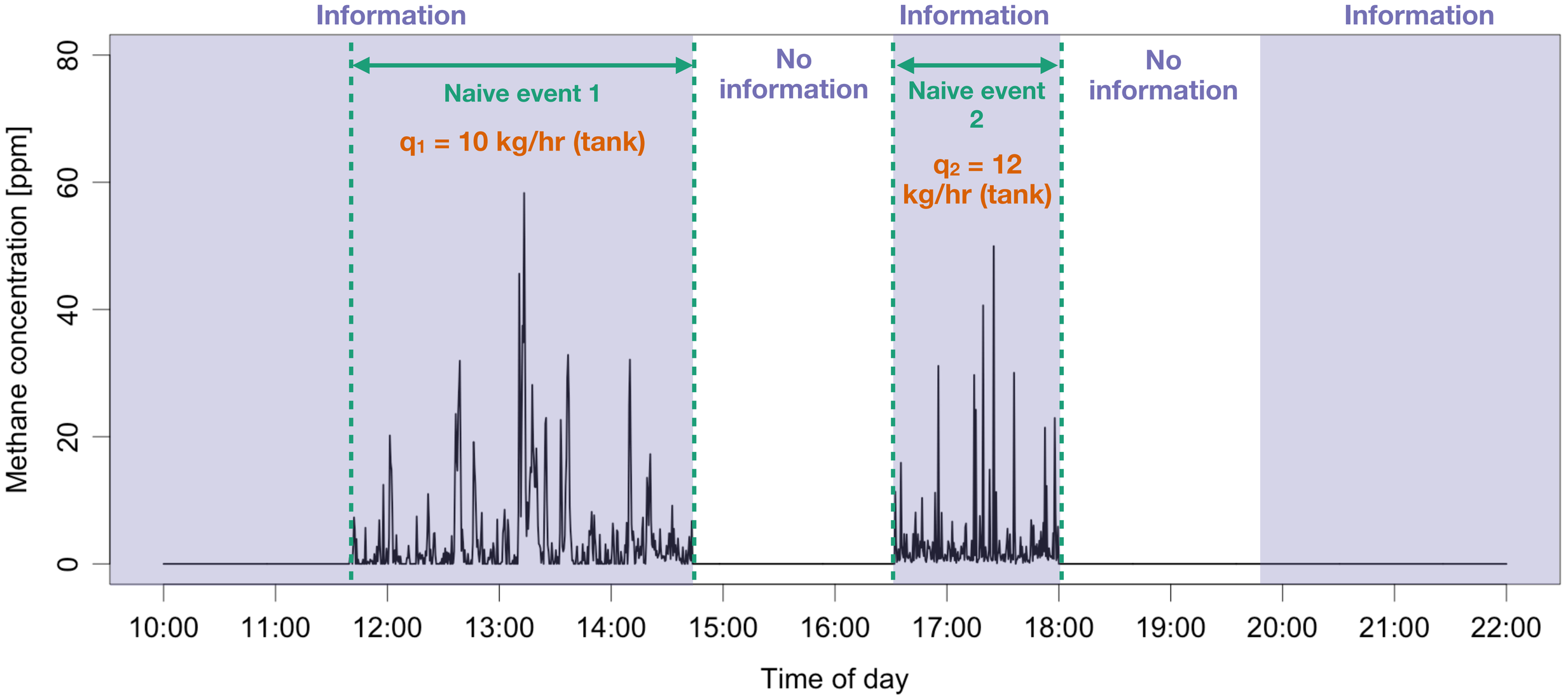


Probabilistic Duration Model

Step 3: Compute probability of combining events

$$\mathbb{P}_{i,j} = 1 - \frac{|q_i - q_j|}{P_{95}(\boldsymbol{q}) - P_5(\boldsymbol{q})}$$

$$\mathbb{P}_{1,2} = 0.85$$

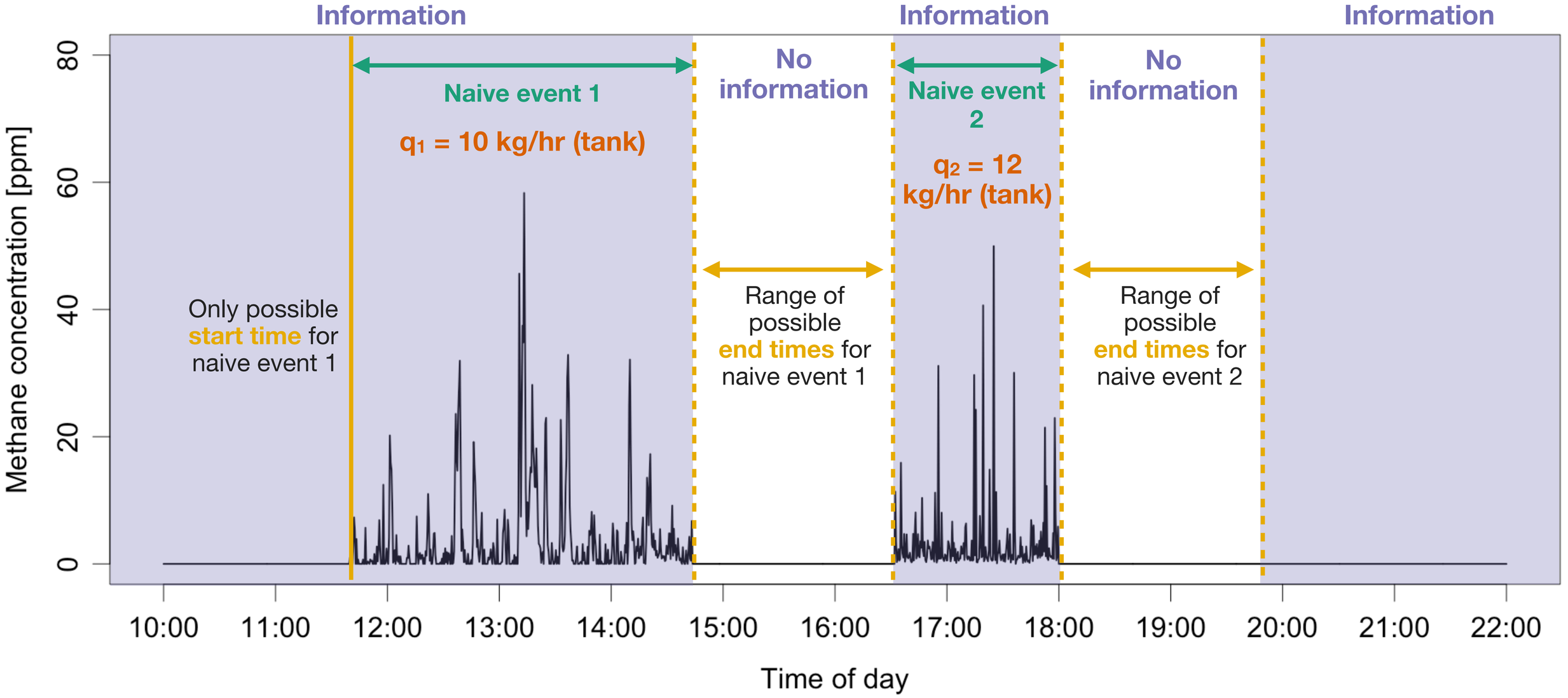


Probabilistic Duration Model

Step 4: Sample start and end times

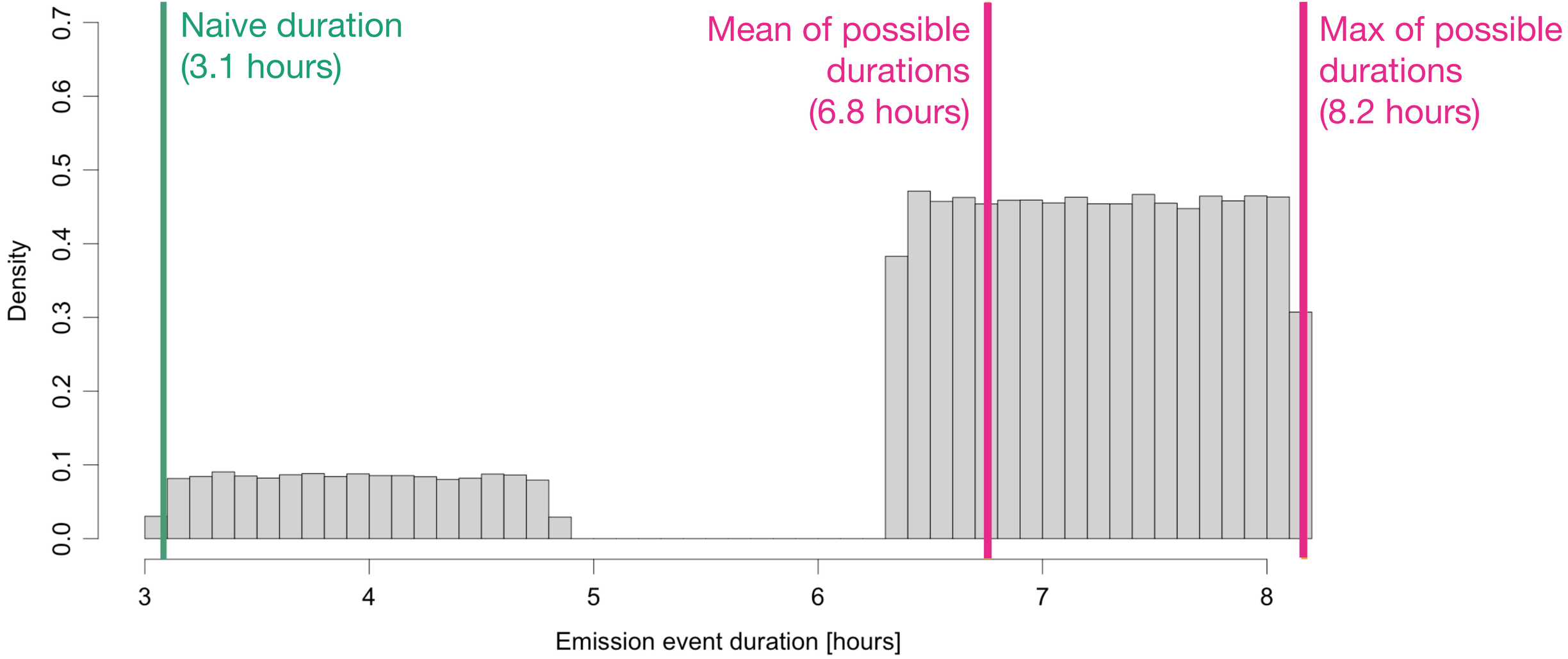
$$\mathbb{P}_{i,j} = 1 - \frac{|q_i - q_j|}{P_{95}(\boldsymbol{q}) - P_5(\boldsymbol{q})}$$

$$\mathbb{P}_{1,2} = 0.85$$



Probabilistic Duration Model

Step 5: Compute distribution of durations



Probabilistic Duration Model

Mixture model of uniform distributions

We want the distribution of durations for naive event k.

Probabilistic Duration Model

Mixture model of uniform distributions

We want the distribution of durations for naive event k.

First, consider the simplest case where there is zero probability of combining with neighboring events.

$$S_k \sim \text{Unif}(\cdot,\cdot) \quad \text{and} \quad E_k \sim \text{Unif}(\cdot,\cdot)$$

Here the durations are simply: $D_k = E_k - S_k \sim \text{Trap}(\cdot,\cdot,\cdot,\cdot)$.

Probabilistic Duration Model

Mixture model of uniform distributions

We want the distribution of durations for naive event k.

First, consider the simplest case where there is zero probability of combining with neighboring events.

$$S_k \sim \text{Unif}(\cdot,\cdot) \quad \text{and} \quad E_k \sim \text{Unif}(\cdot,\cdot)$$

Here the durations are simply: $D_k = E_k - S_k \sim \text{Trap}(\cdot,\cdot,\cdot,\cdot)$.

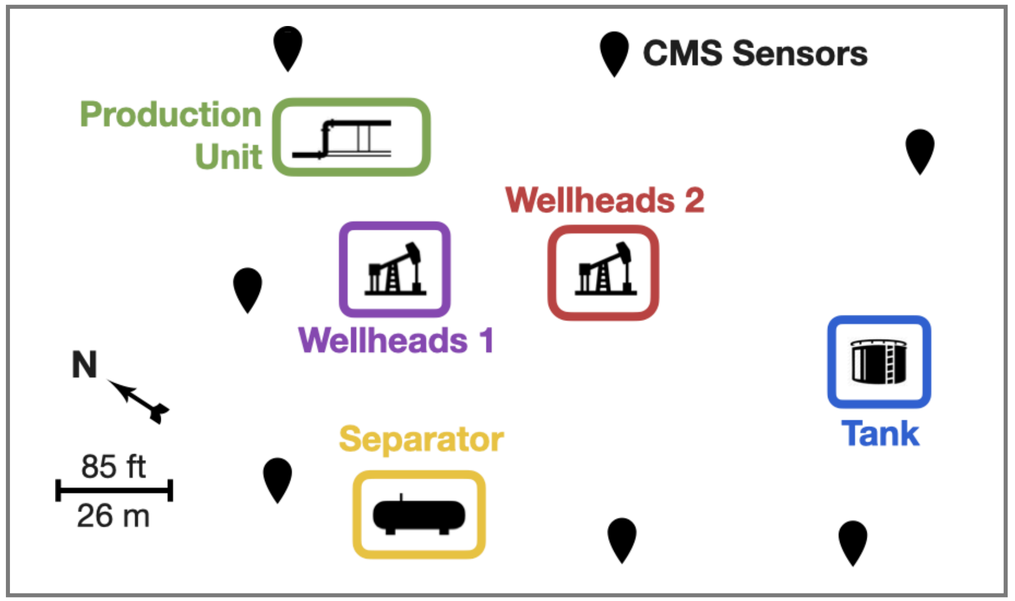
Next, consider the situation with n preceding events and m subsequent events:

$$S_k \sim \sum_{i=1}^{n} \mathbb{P}_{k,i} S_i \quad \text{and} \quad E_k \sim \sum_{j=1}^{m} \mathbb{P}_{k,j} E_j$$

Again the durations are: $D_k = E_k - S_k \sim ?$

Case study:

Bounding the duration of an aerial measurement



Aerial technology detects separator emission of 9.6 kg/hr

9.6 kg/hr	X	naive duration: 1.78 hours	=	17.1 kg
		mean of possible durations: 10.2 hours		97.9 kg
		max of possible durations: 18.8 hours		180.5 kg
9.6 kg/hr	X	time since previous aerial survey: 3 months	=	21,024 kg
Detected emission rate		Potential duration estimates		Total emitted methane

CMS Series #4:

Estimating methane emission durations on oil and gas sites

Estimating methane emission durations using continuous monitoring systems.

William Daniels, Meng Jia, Dorit Hammerling.

Environmental Science and Technology Letters, 11(11), 1187-1192 (2024).

Thank you!

COLORADO SCHOOL OF MINES

EEMDL
Energy Emissions Modeling and Data Lab

U.S. DEPARTMENT OF ENERGY