Quantification of methane emissions from the natural gas gathering system using distributed sensors

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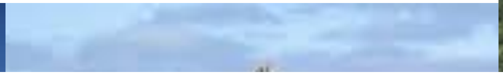
Project objectives

- Demonstrate the ability of a distributed, low-cost sensor network to quantify temporally varying methane emissions from natural gas gathering infrastructure
- Apply this approach to measure emissions from gathering pipelines and pig launchers

Emissions occur at all stages of the gas life cycle

Temporal variability largely explains top-down/bottom-up difference in methane emission estimates from a natural gas production region

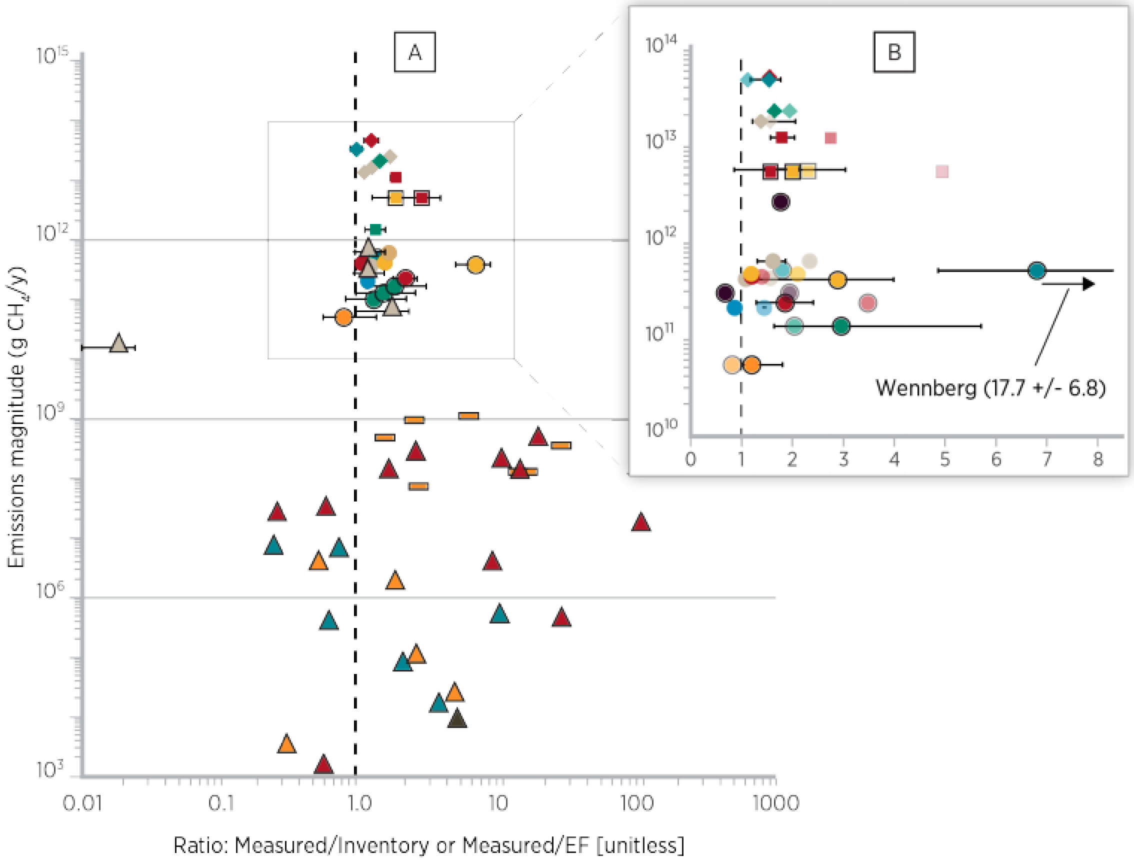
Timothy L. Vaughn, Clay S. Bell, Cody K. Pickering, Stefan Schwietzke, Garvin A. Heath, Gabrielle Pétron, Daniel J. Zimmerle, Russell C. Schnell, and Dag Nummedal

PNAS published ahead of print October 29, 2018 https://doi.org/10.1073/pnas.1805687115




Knowledge gaps

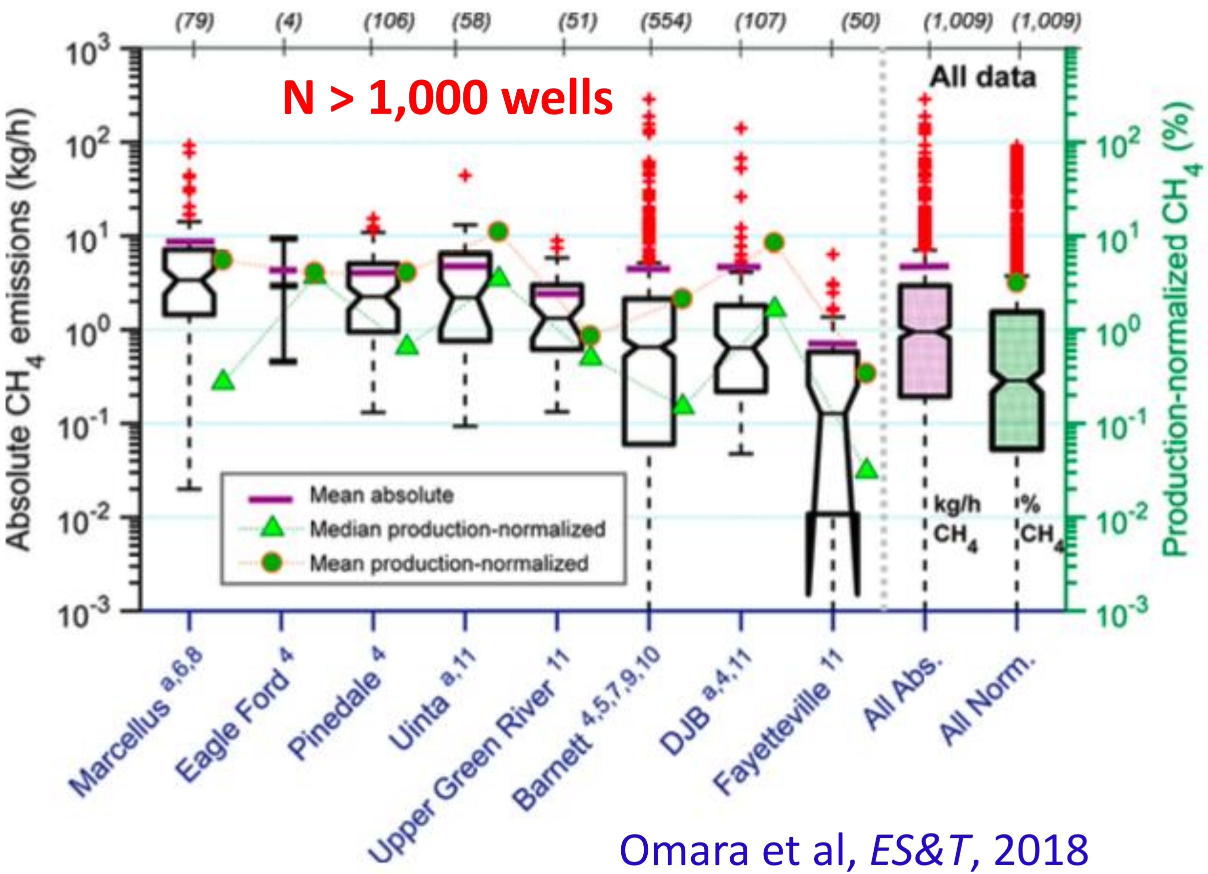
- ***Mass Closure:*** Inventories under predict actual emissions.



Brandt et al, *Science*, 2014

Knowledge gaps

- ***Incomplete emissions information across sectors:*** Skewed towards production



Omara et al, *ES&T*, 2018

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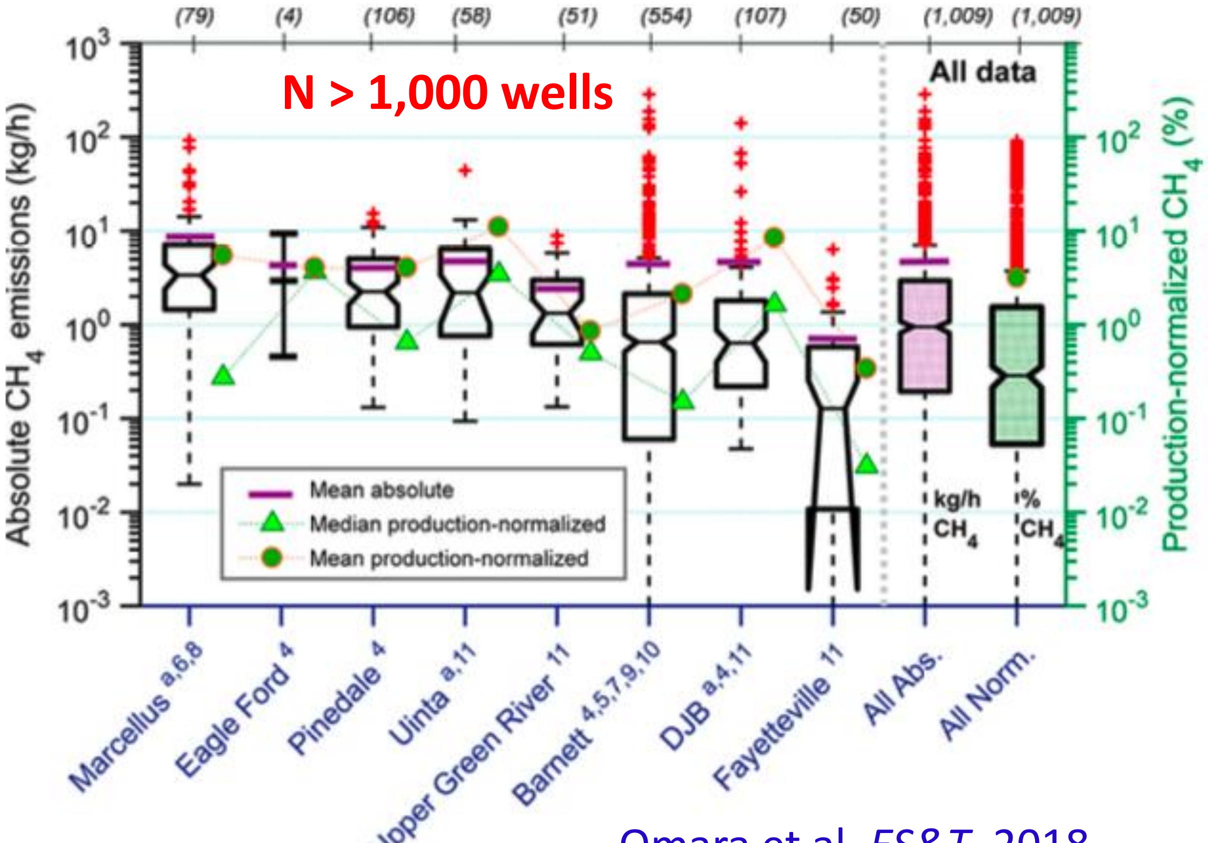


Omara et al, *ES&T*, 2018

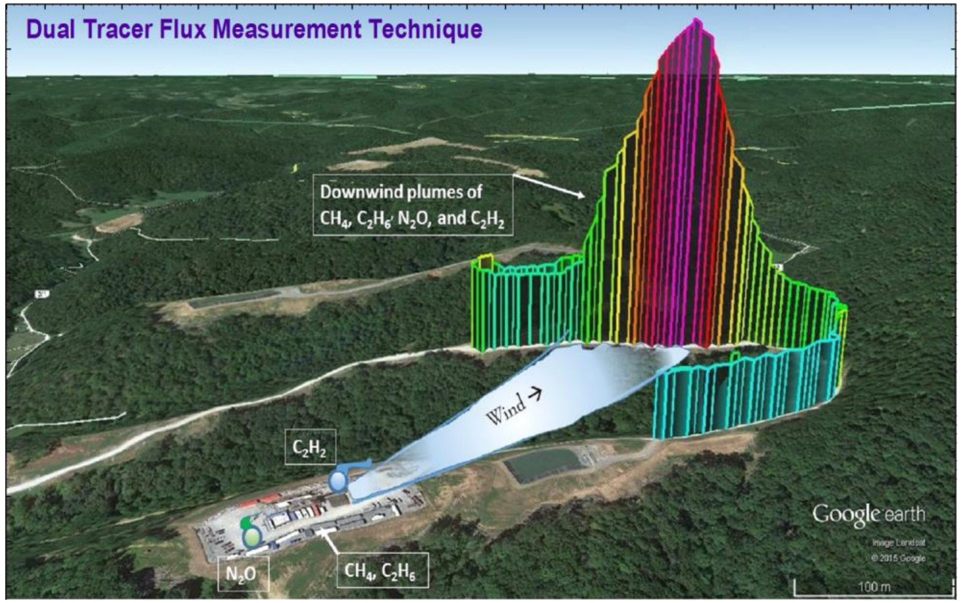
Gathering pipelines: 1 paper

Gathering pipeline methane emissions in Fayetteville shale pipelines and scoping guidelines for future pipeline measurement campaigns

Authors: Daniel J. Zimmerle, Cody K. Pickering, Clay S. Bell, Garvin A. Heath, Dag Nummedal, Gabrielle Pétron, Timothy L. Vaughn

Knowledge gaps

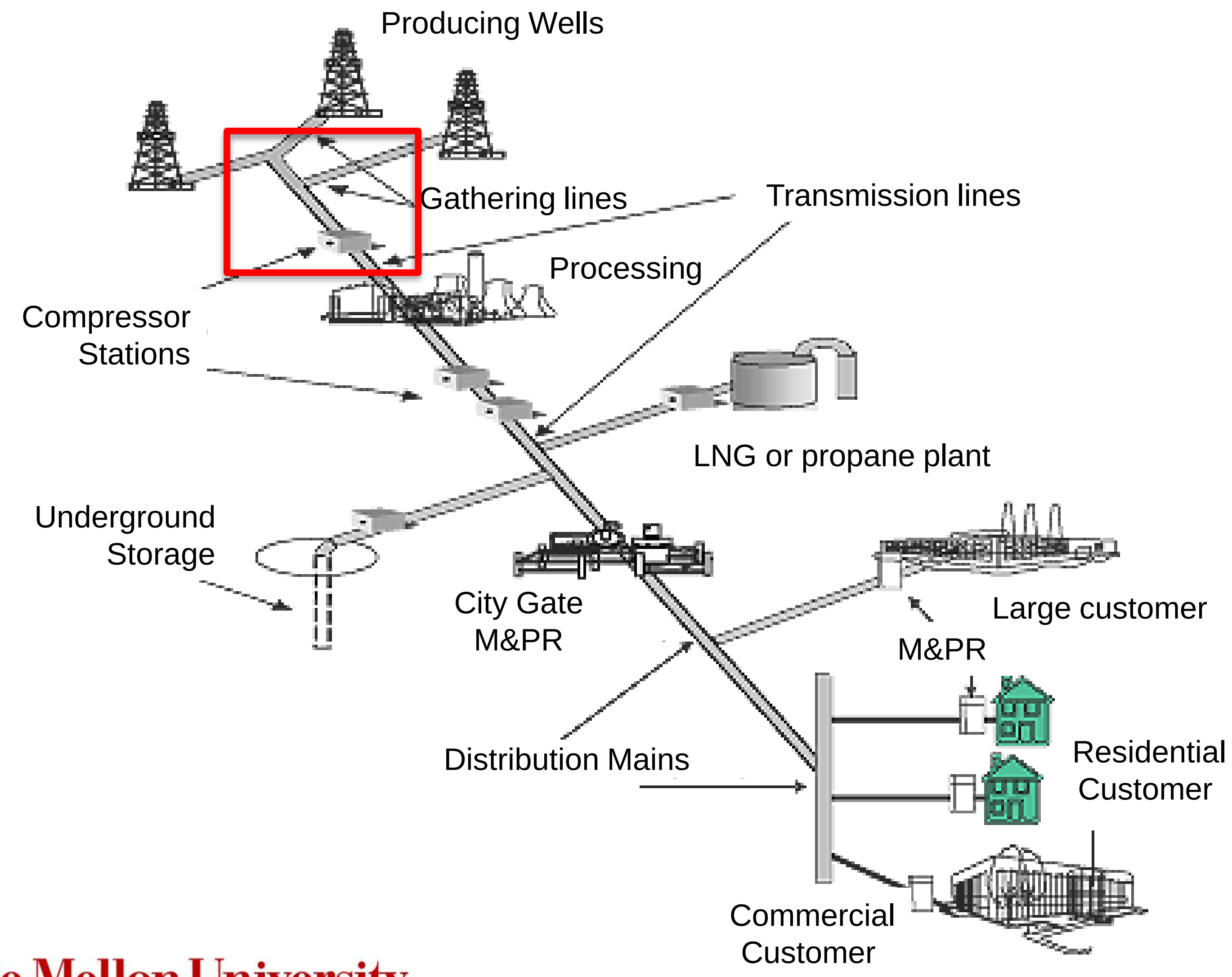
- ***Incomplete emissions information across time:*** Most previous emissions measurement studies collected snapshots of emissions.



Knowledge gaps

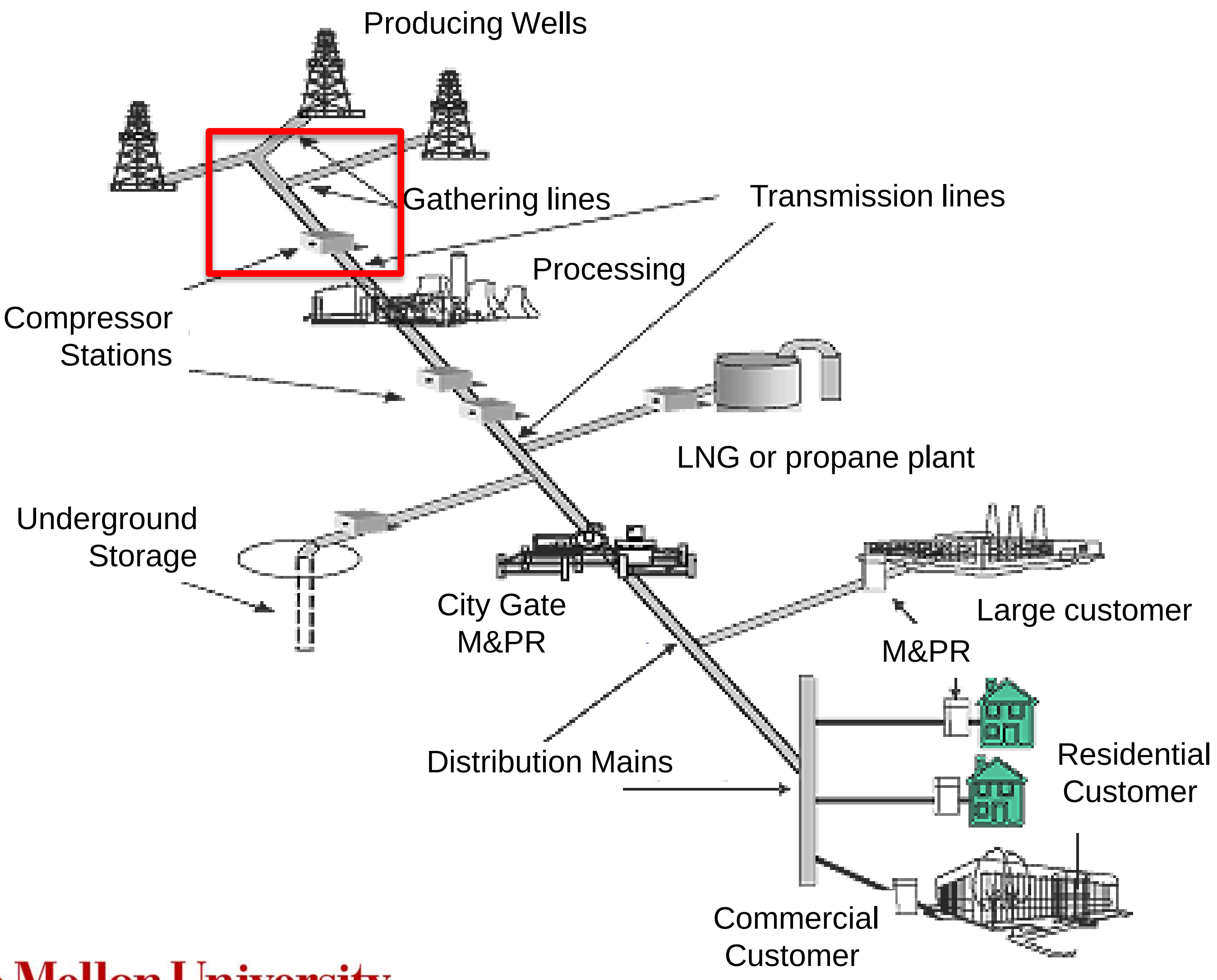
- ***Leak detection strategies:*** There is uncertainty in how to best identify leaks from widely distributed infrastructure (like pipelines) and how to design efficient maintenance and repair schemes

Three main emissions sources for gathering system



Three main emissions sources for gathering system

- Pipeline leaks



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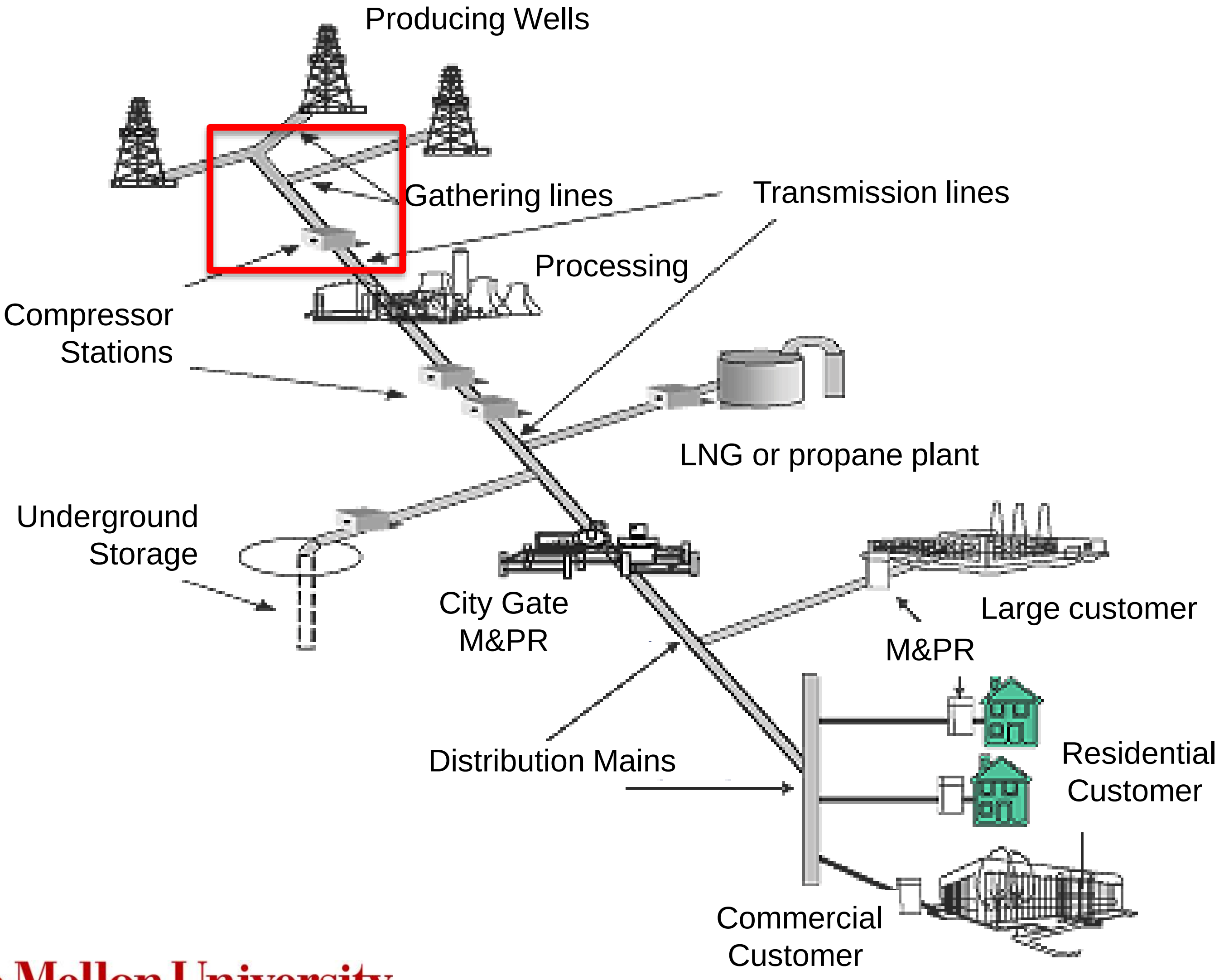
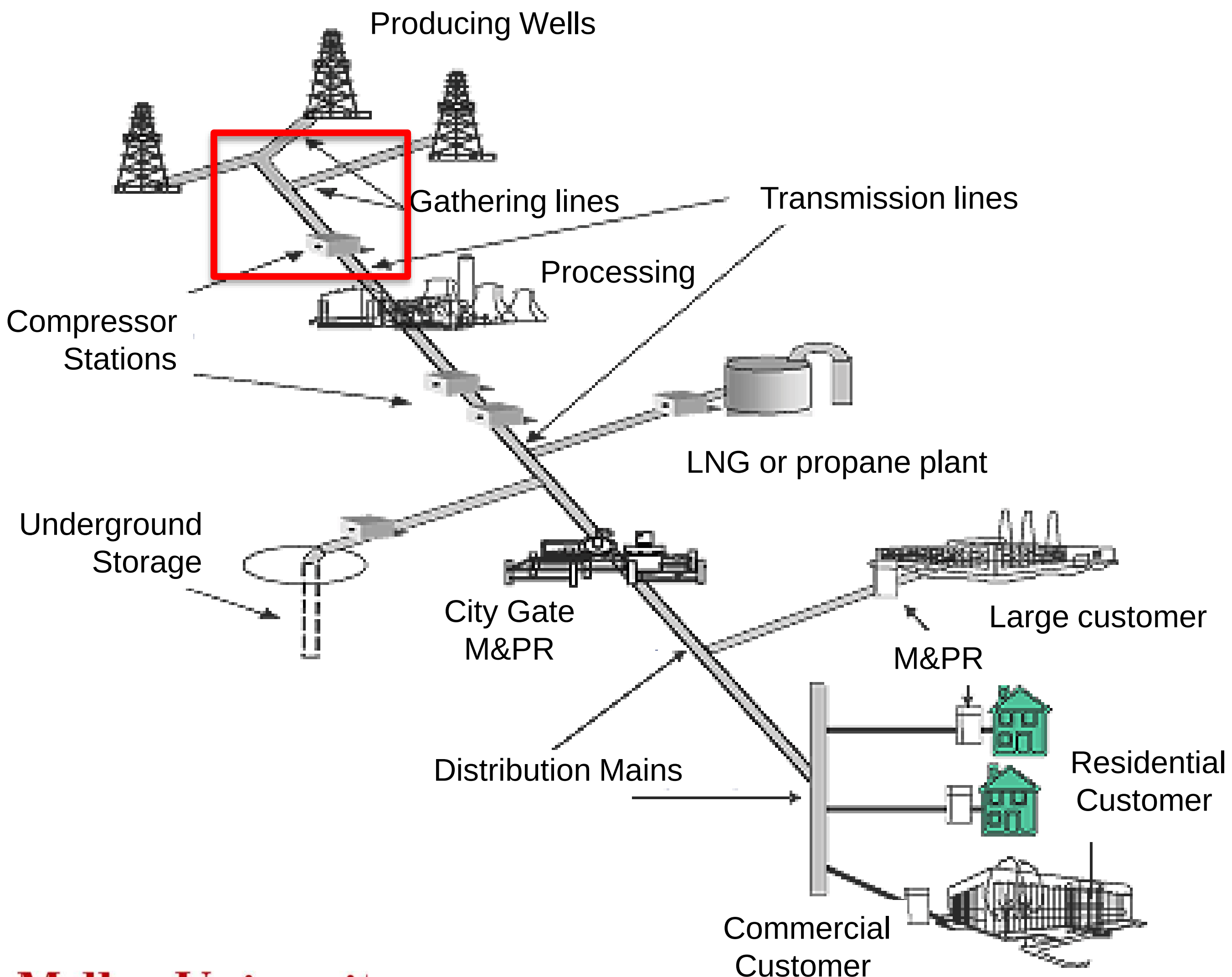
Three main emissions sources for gathering system

- Pipeline leaks
- Emissions from process equipment



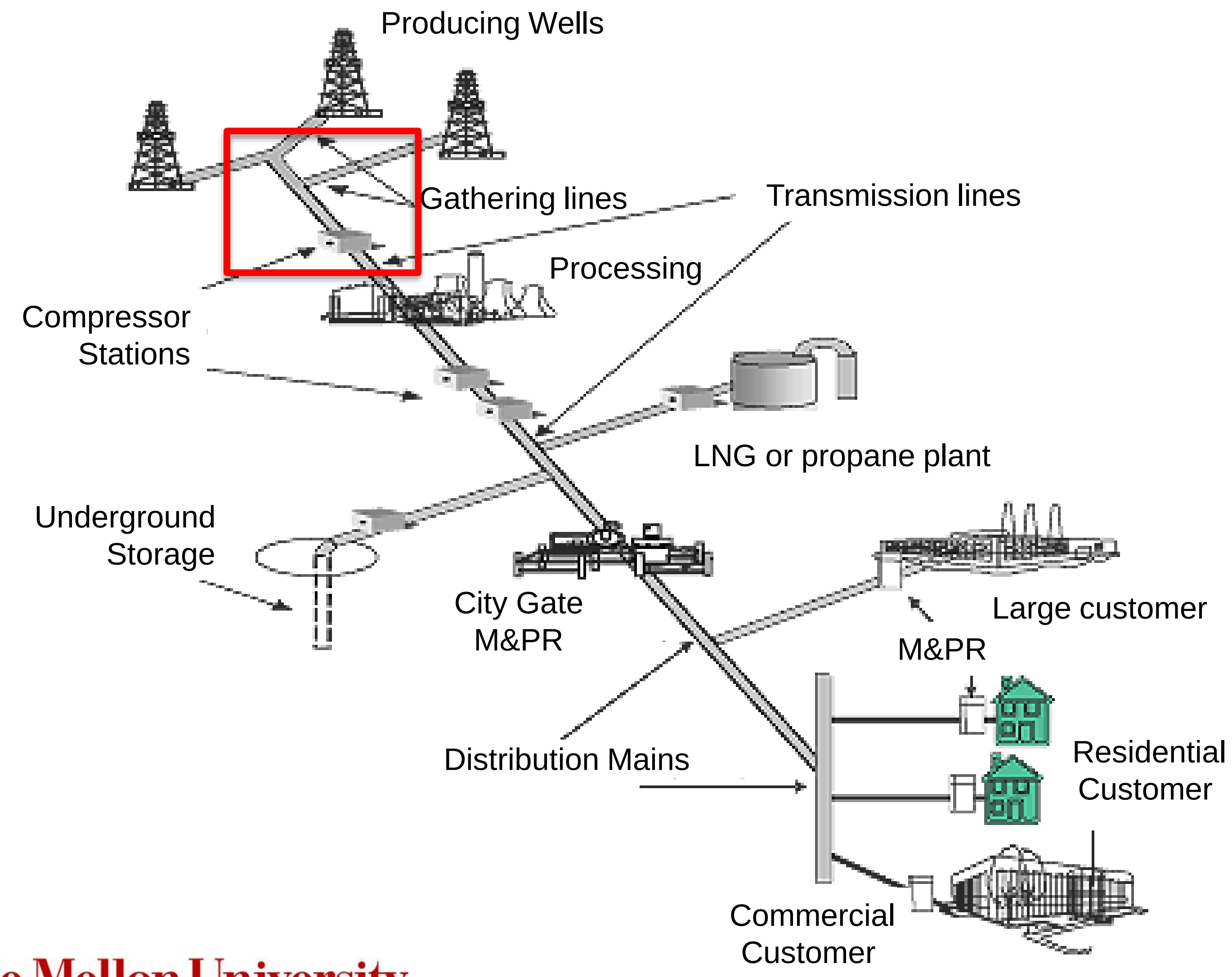
Three main emissions sources for gathering system

- Pipeline leaks
- Emissions from process equipment
- Emissions from pipeline operation (e.g., blowdowns)



Two major challenges in emissions quantification

- Accessibility – underground infrastructure
- Temporal variability

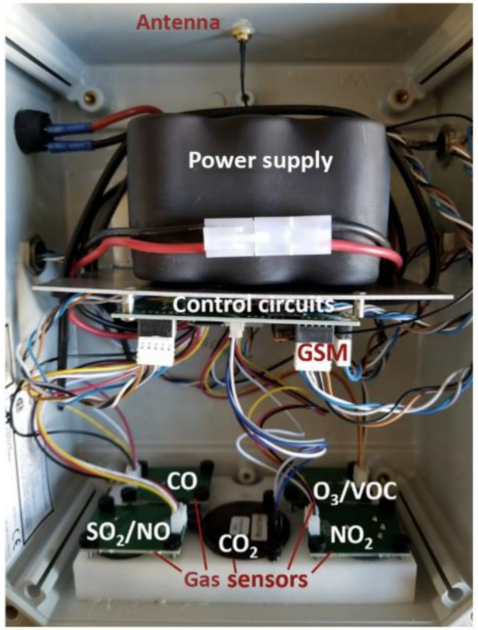


Approach: Use distributed sensors to detect leaks

“RAMP”

(a)

(b)

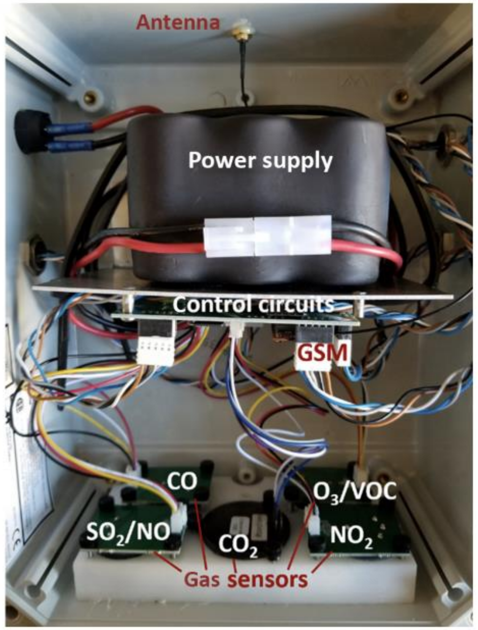


We already run a large network of low-cost sensors

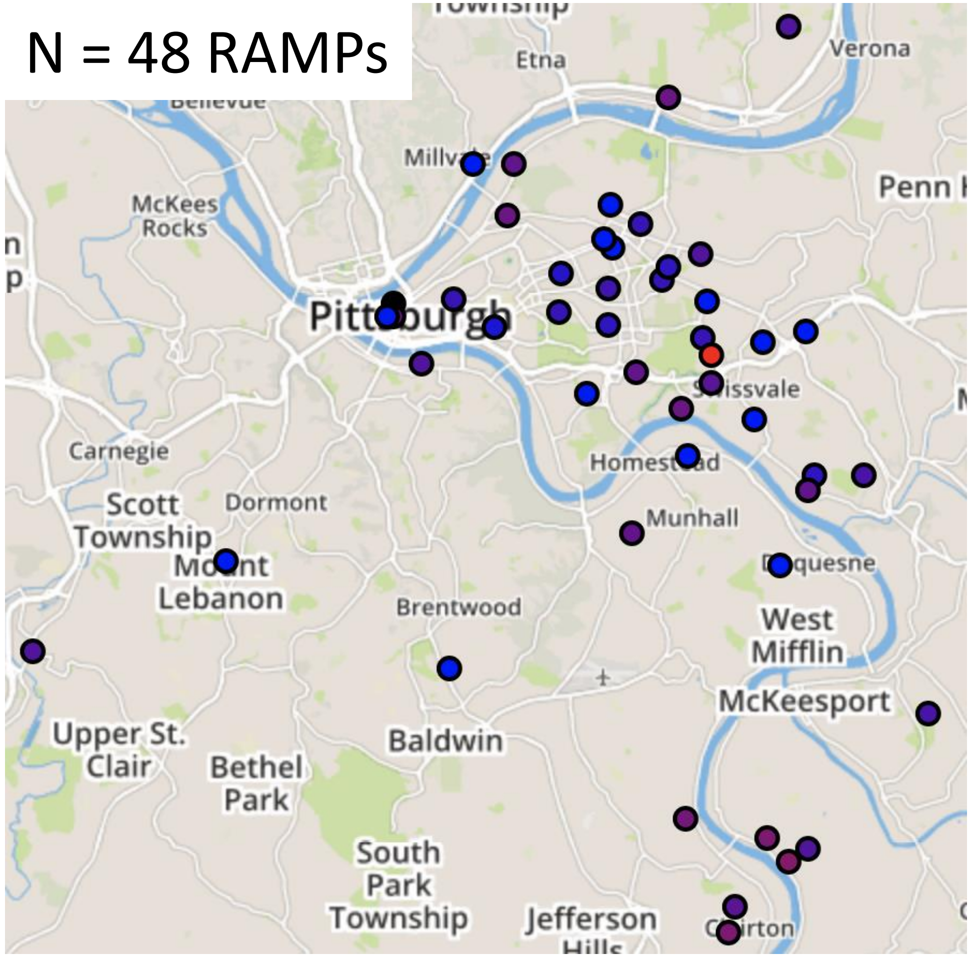
“RAMP”

(a)

(b)



N = 48 RAMPs



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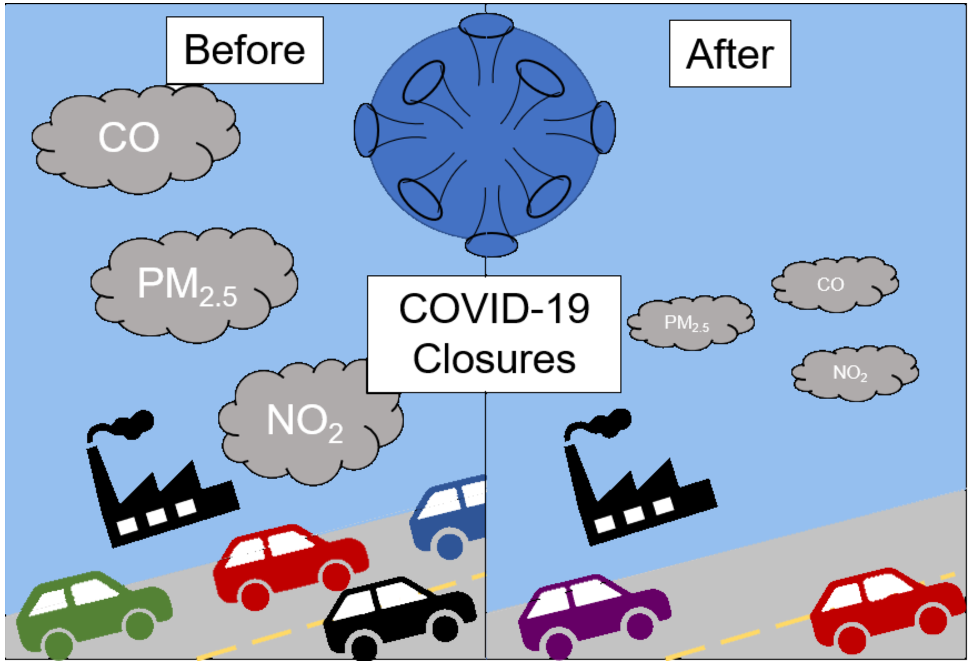
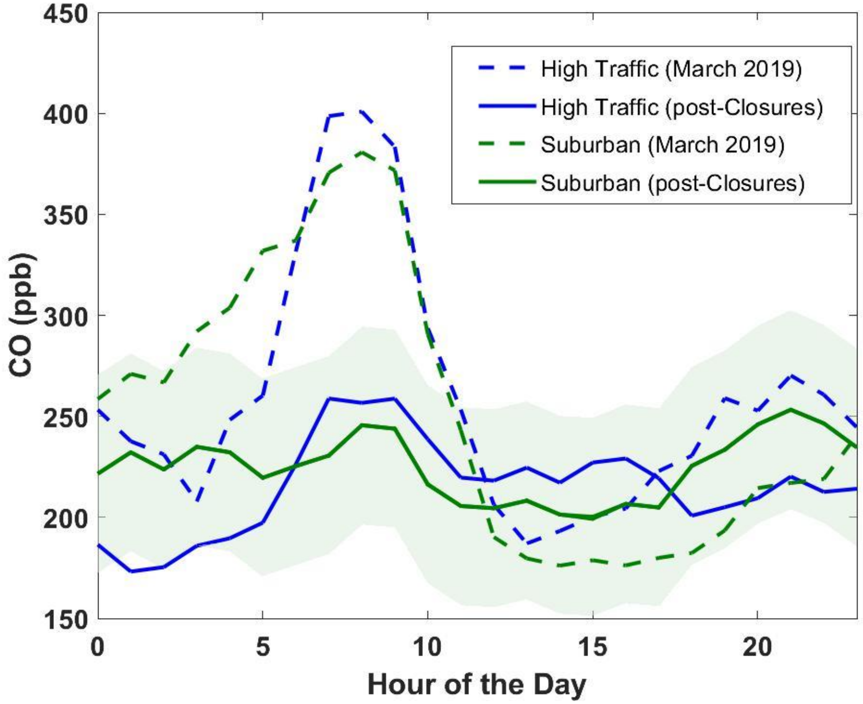
Example outcome: Impact of COVID on air quality





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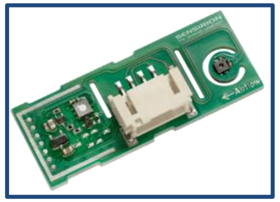
Tanzer-Gruener et al, *ES&T Letters*, 2020

We tested sensors using different operating principles

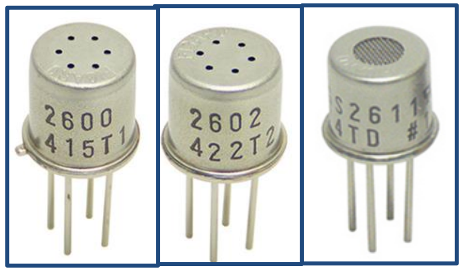
Metal oxide semiconductor

MQ-4



Sensirion SVM30

SGX IR12GJ, VQ549ZD



TGS 2600, 2602, 2611

Alphasense MOX

Photo ionization

Alphasense PID (10.6 & 9.6eV)

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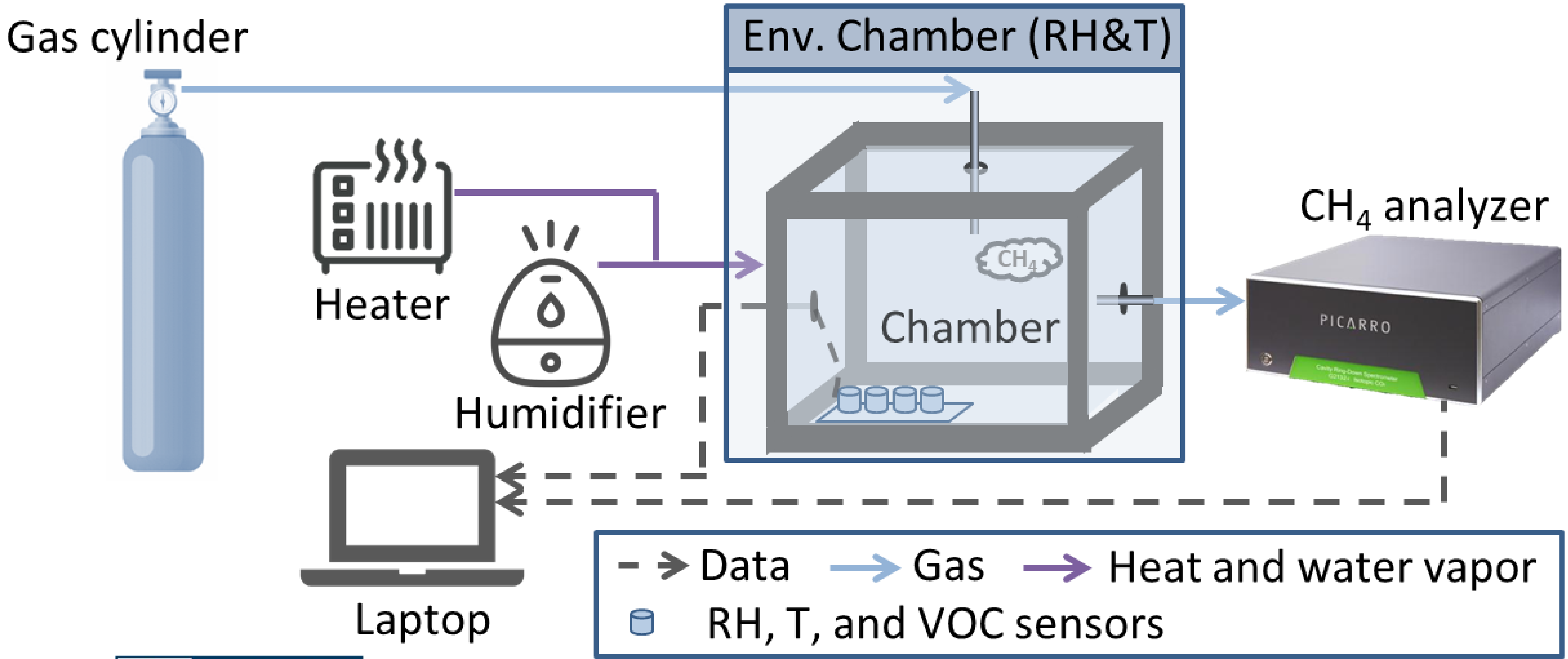
We conducted laboratory tests to identify candidate sensors



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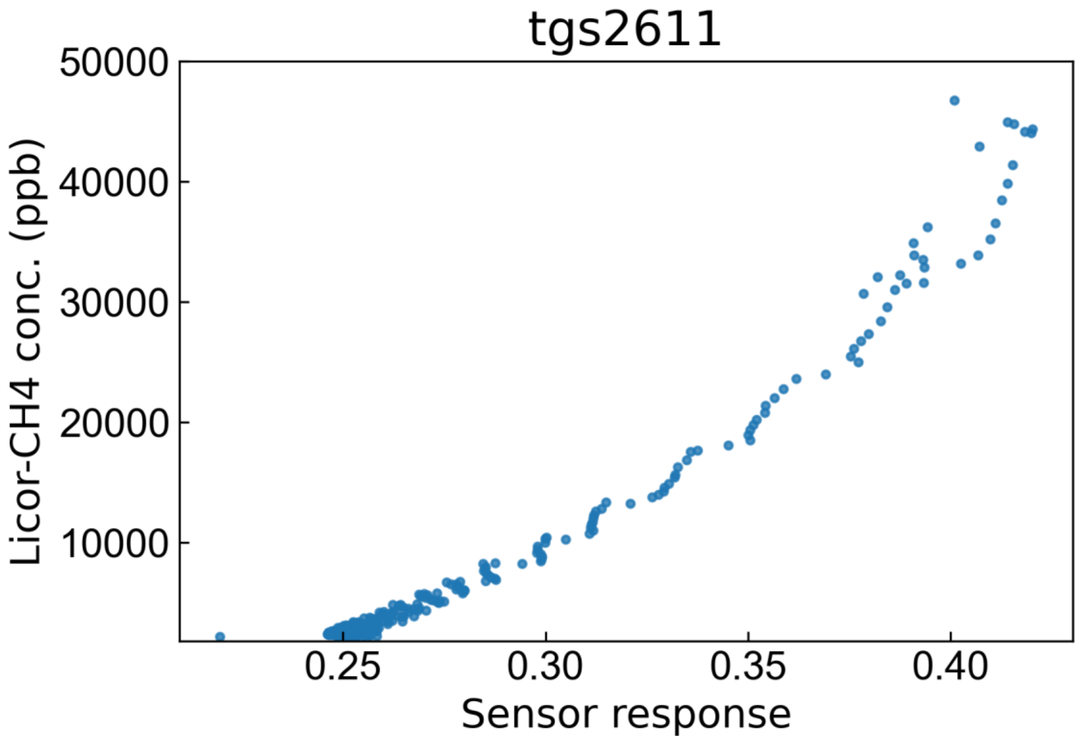
Some sensors performed well



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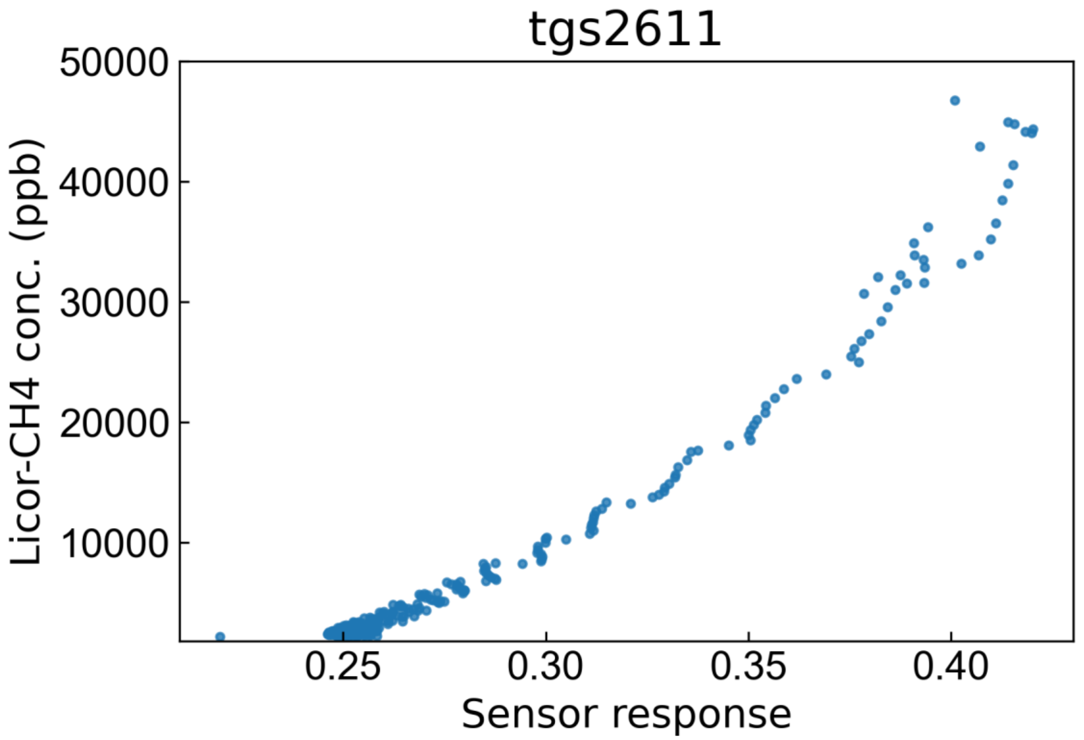
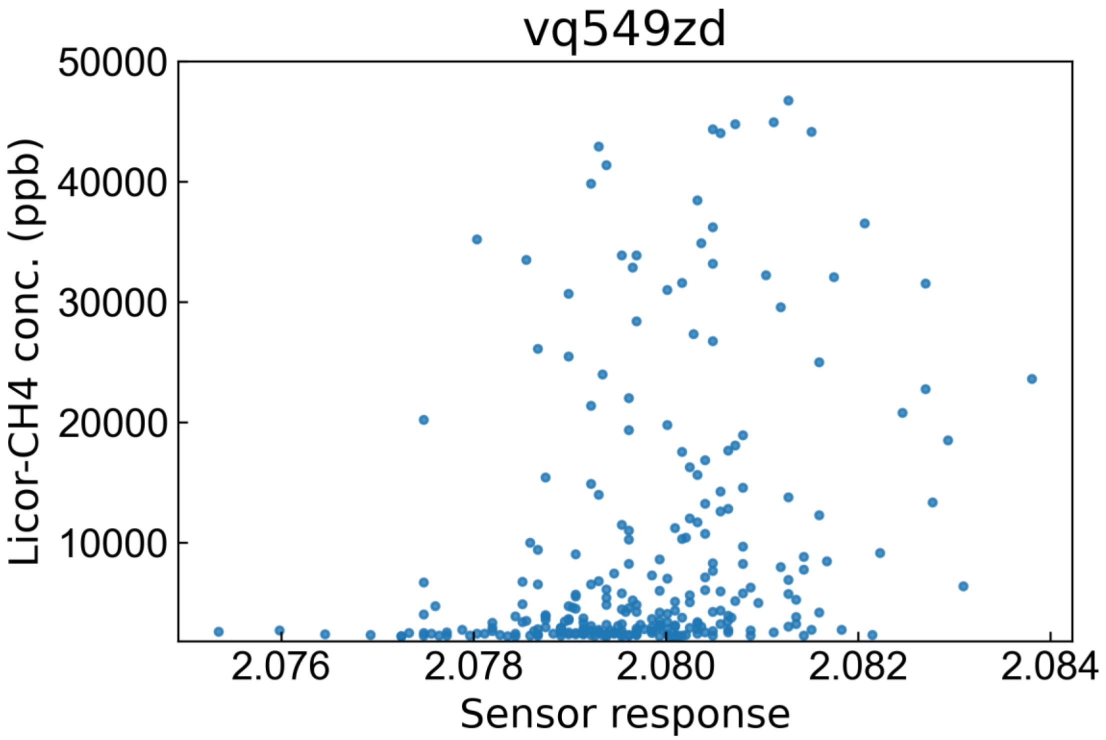
Others did not





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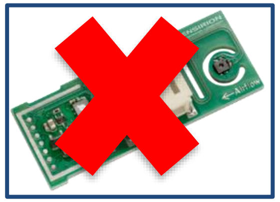

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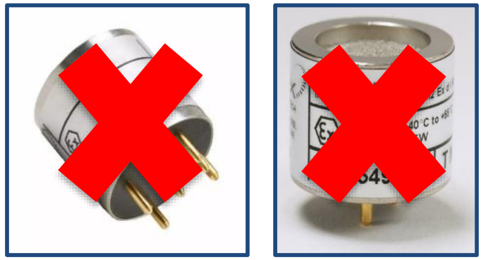

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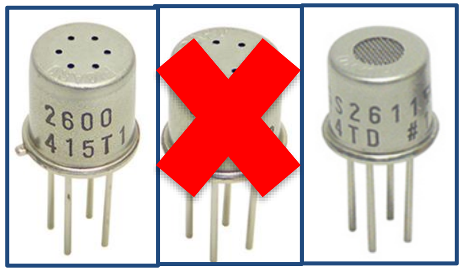

TGS 2600, 2602, 2611

Alphasense MOX

Photo ionization

Alphasense PID (10.6 & 9.6eV)

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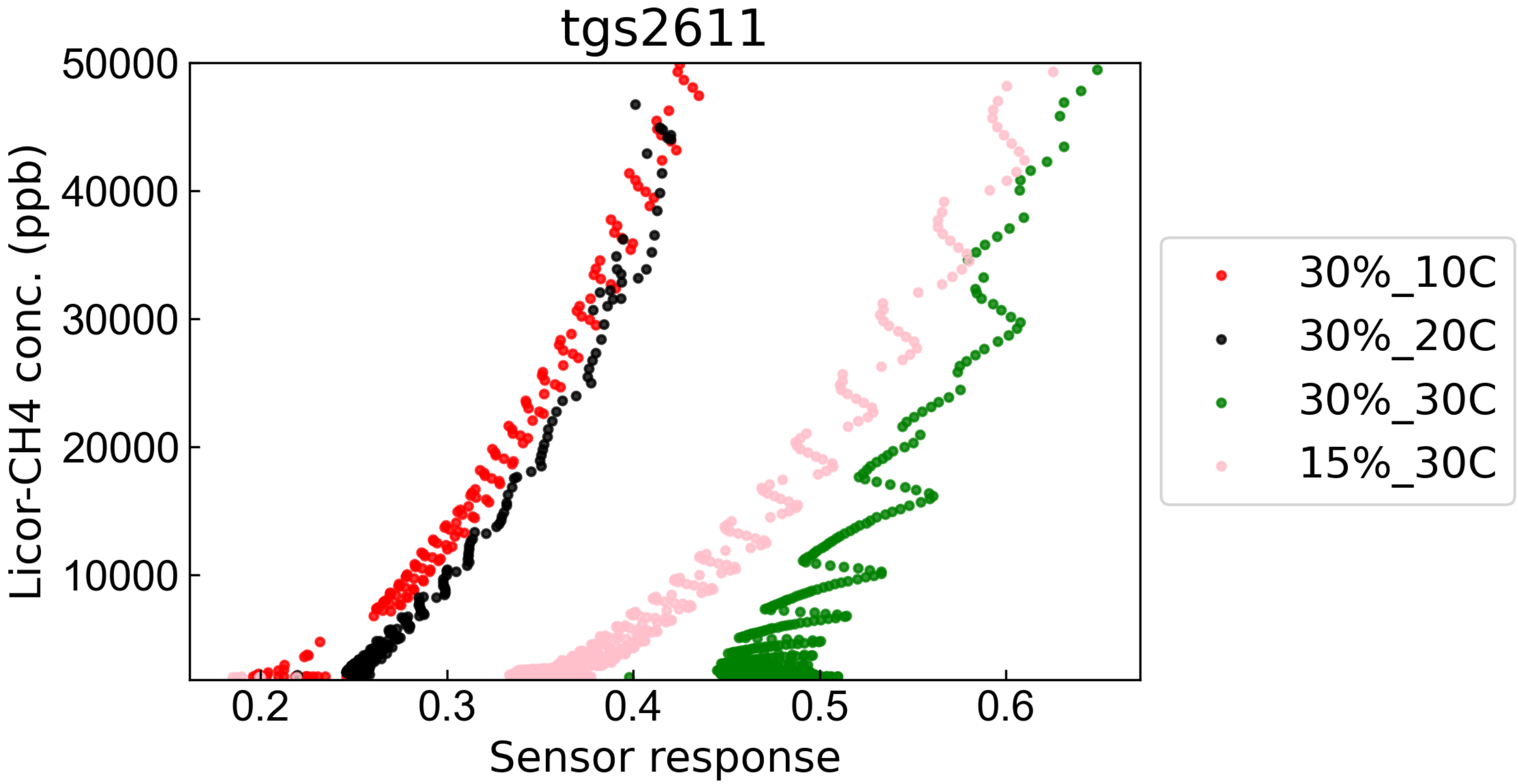
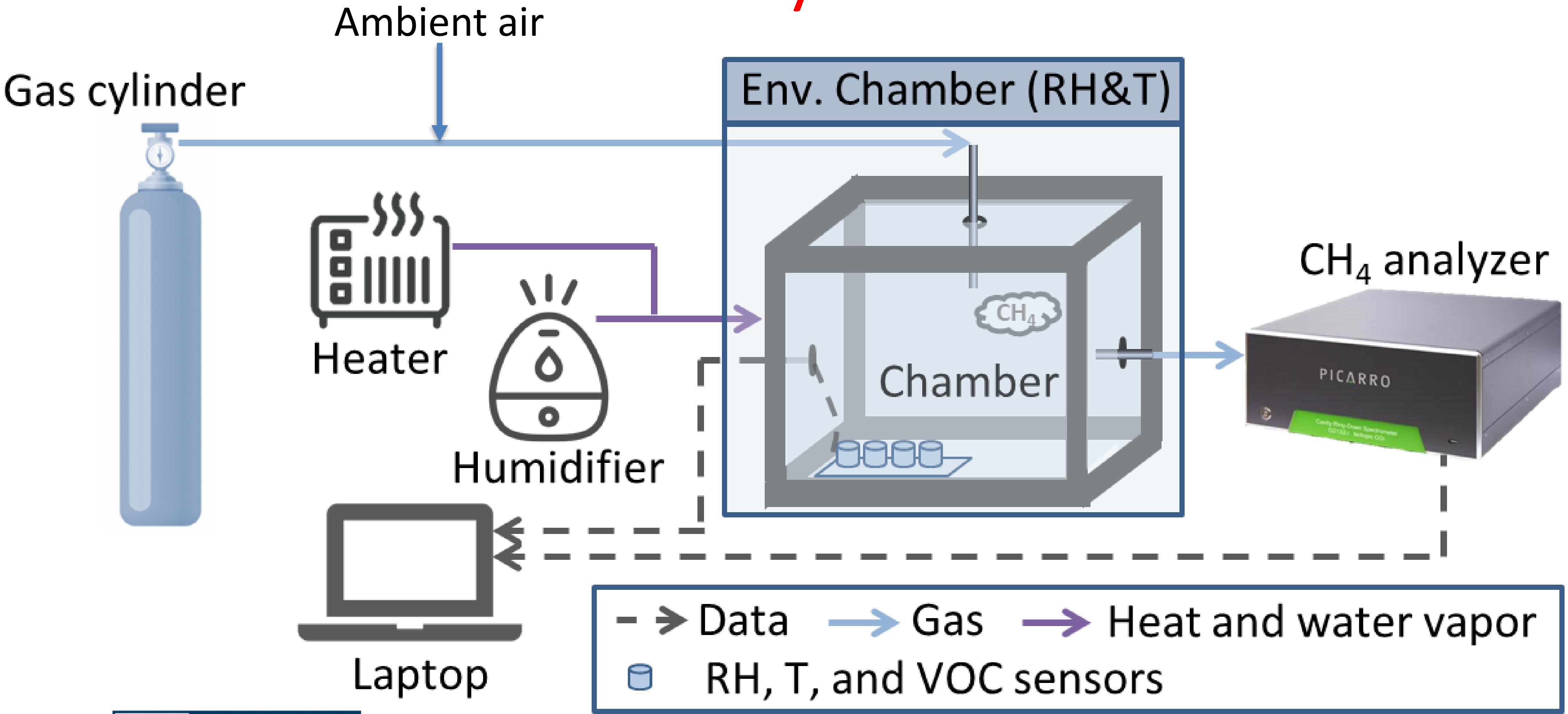
“Good” sensors showed humidity and T dependence



We doped ambient air with methane to explore a wider variety of conditions



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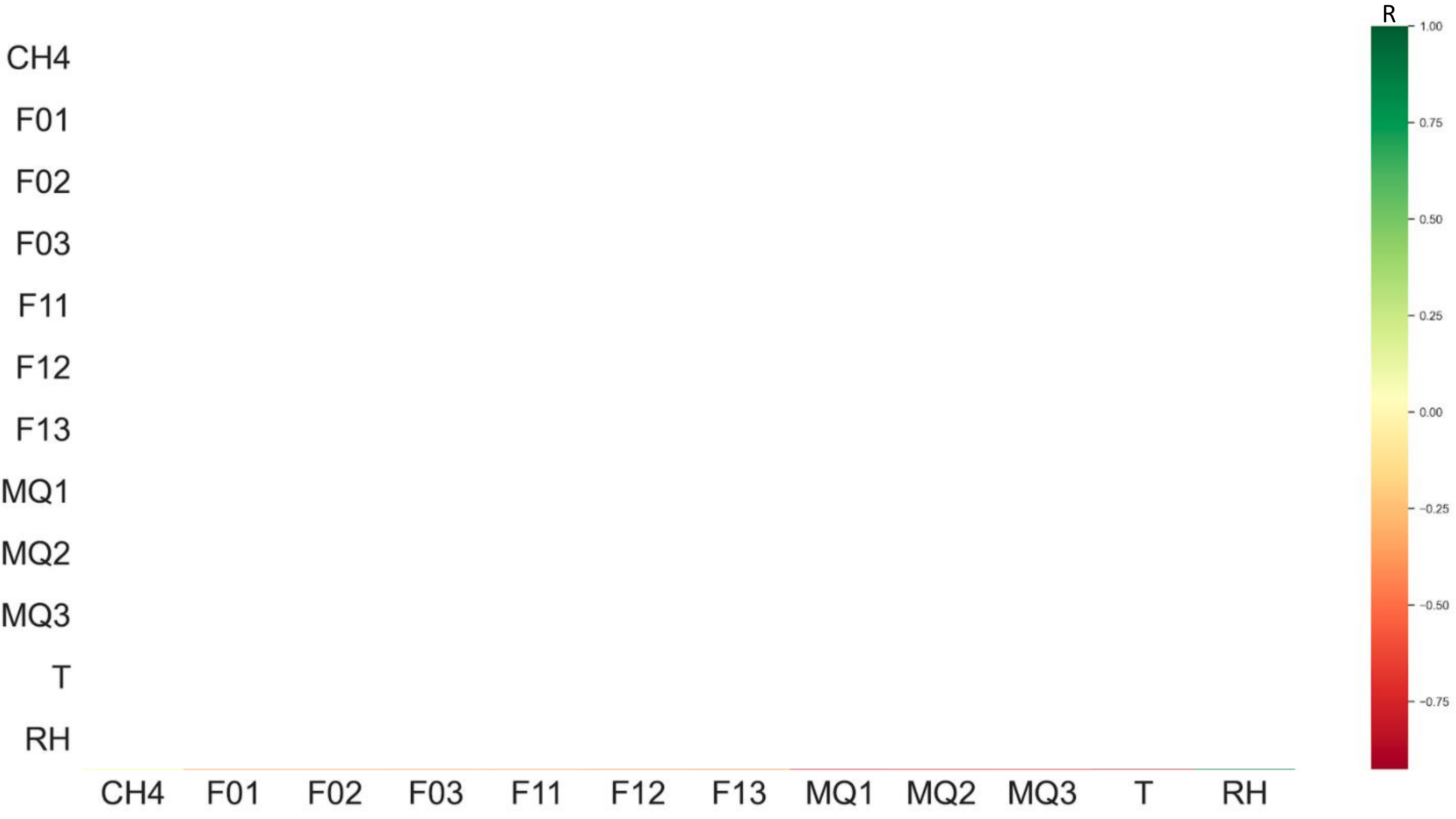
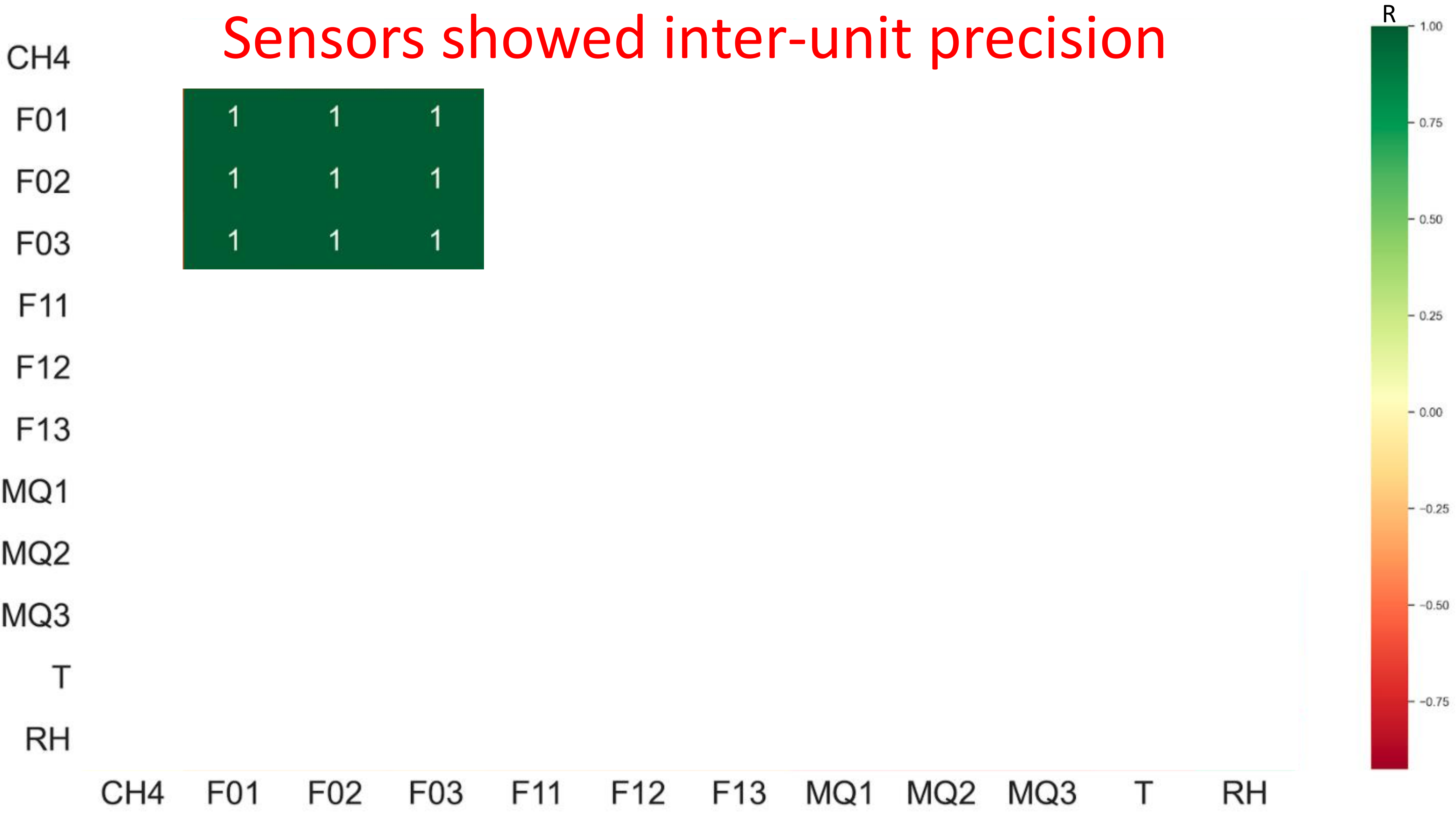

R
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
CH4
F01
F02
F03
F11
F12
F13
MQ1
MQ2
MQ3
T
RH

Sensors showed inter-unit precision



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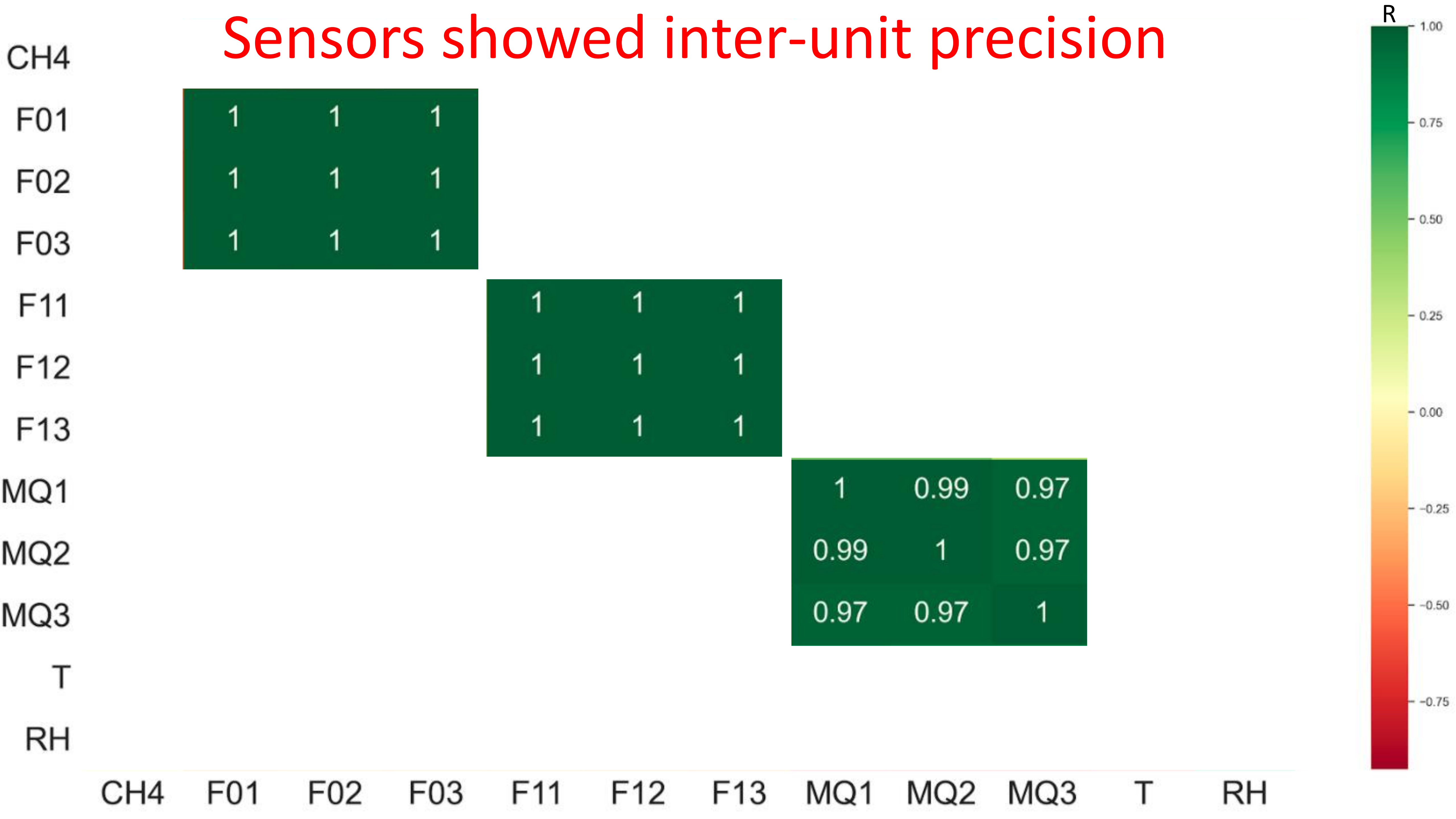
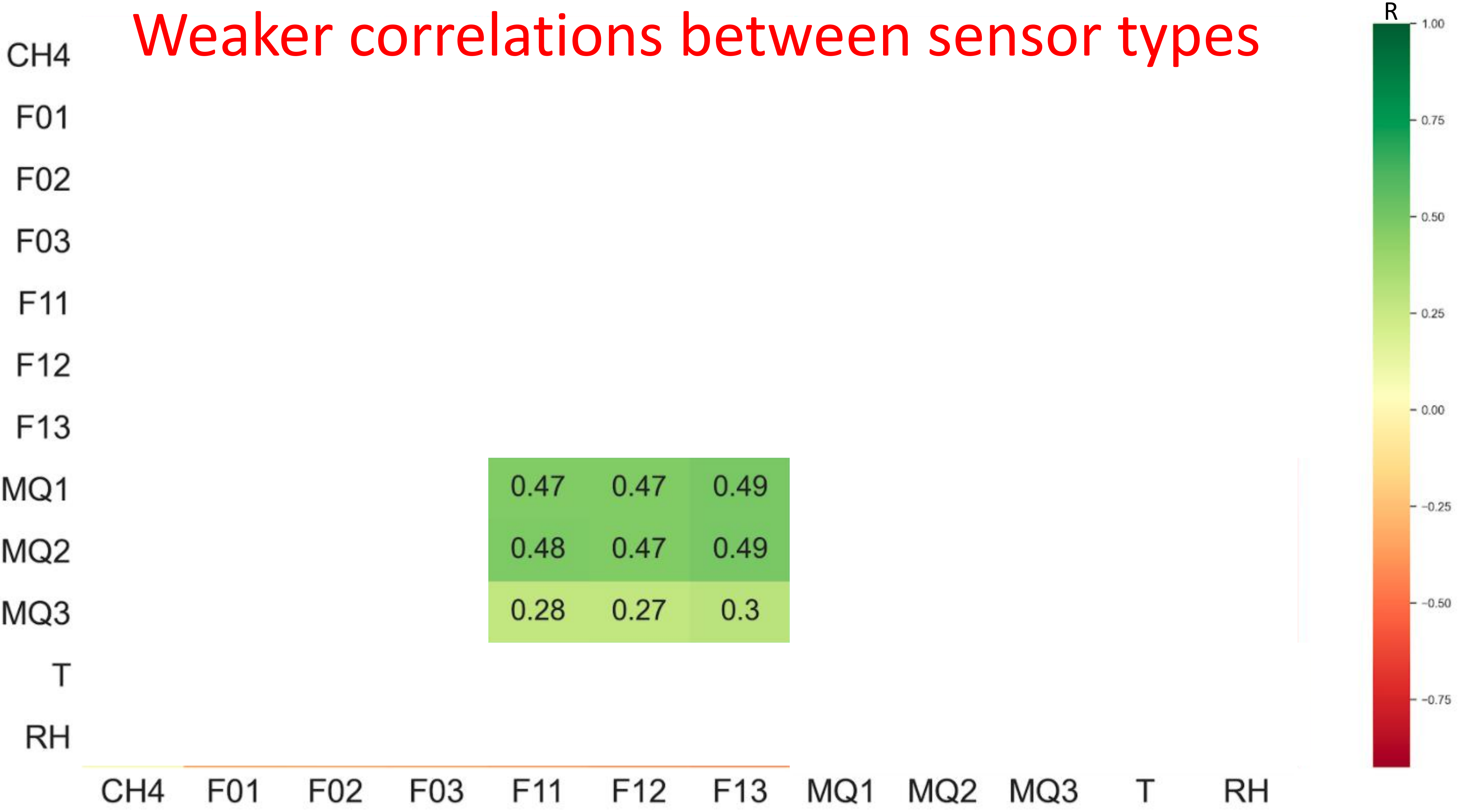
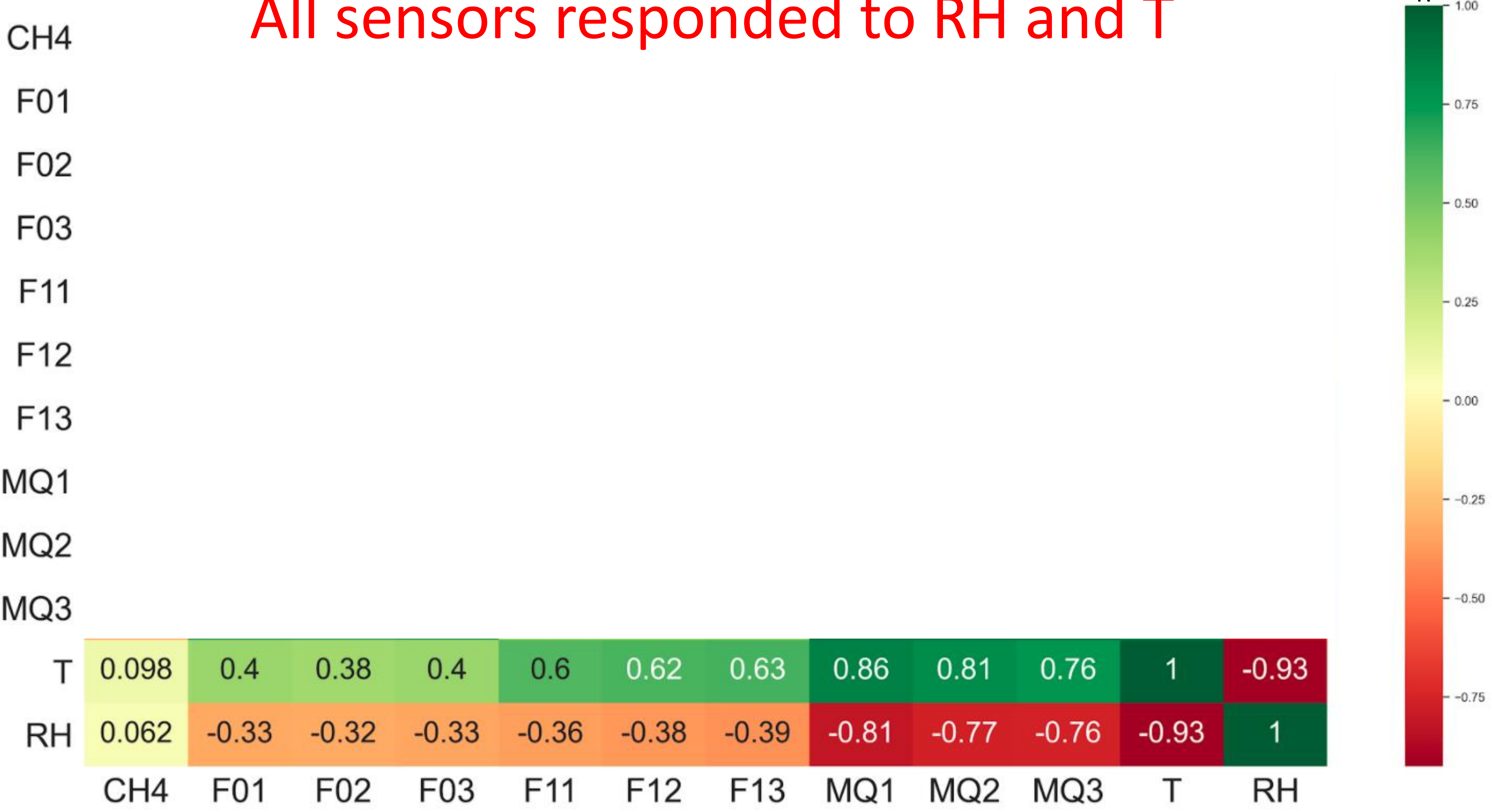


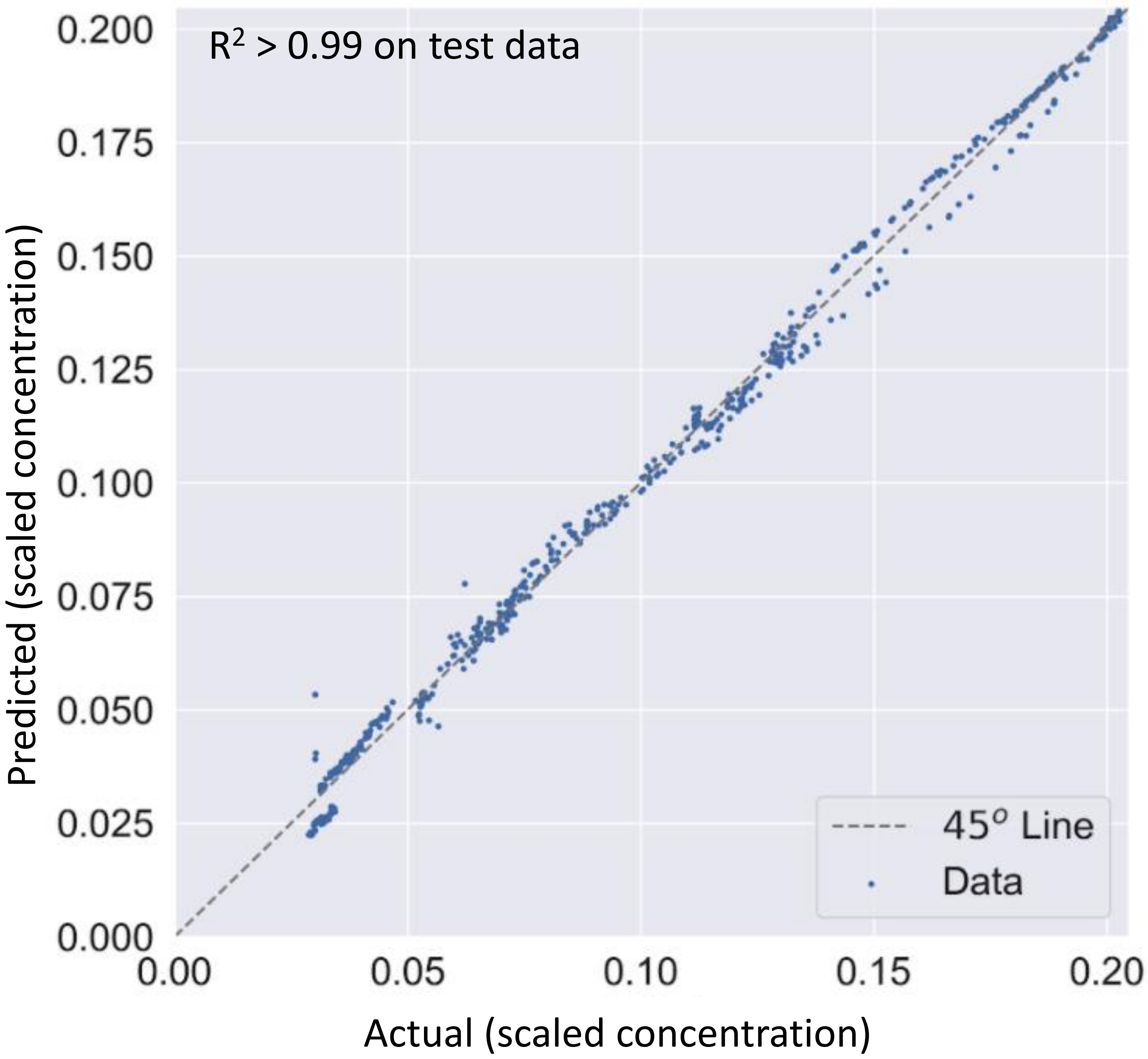
Weaker correlations between sensor types



All sensors responded to RH and T



We built calibration models with all available data



70:30 Train:Test split

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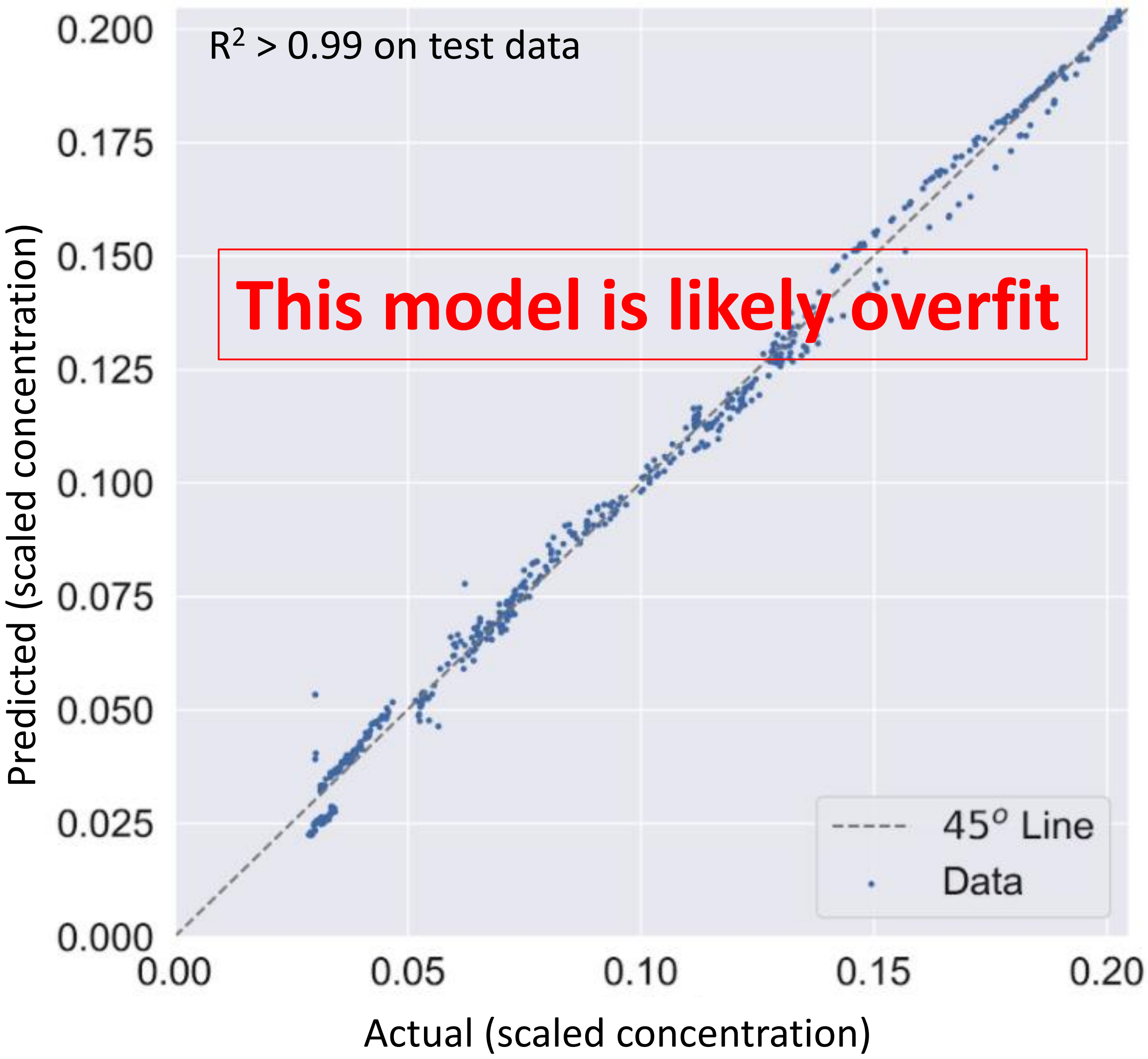
70:30 Train:Test split



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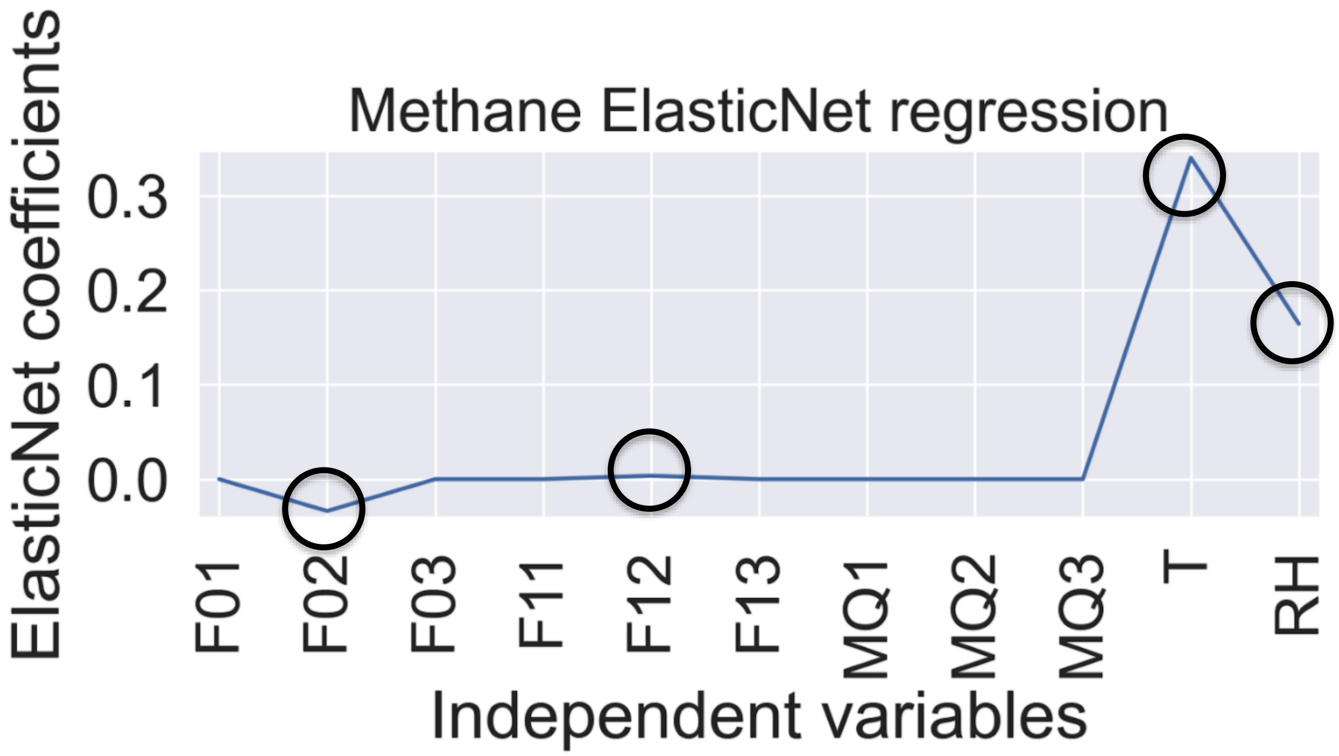
We used Elastic Net regression to perform variable selection



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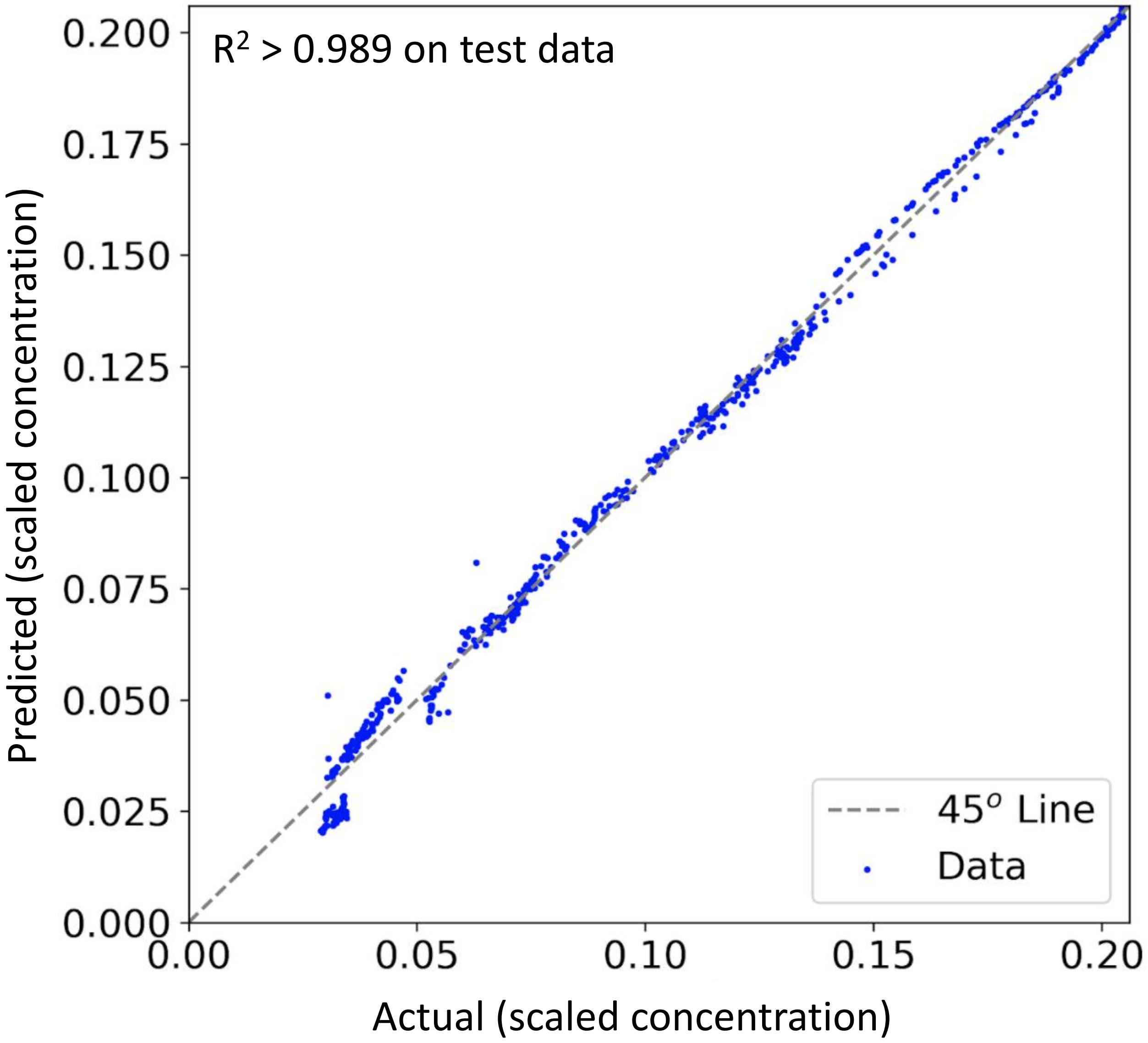
The final model shows strong performance on holdout data



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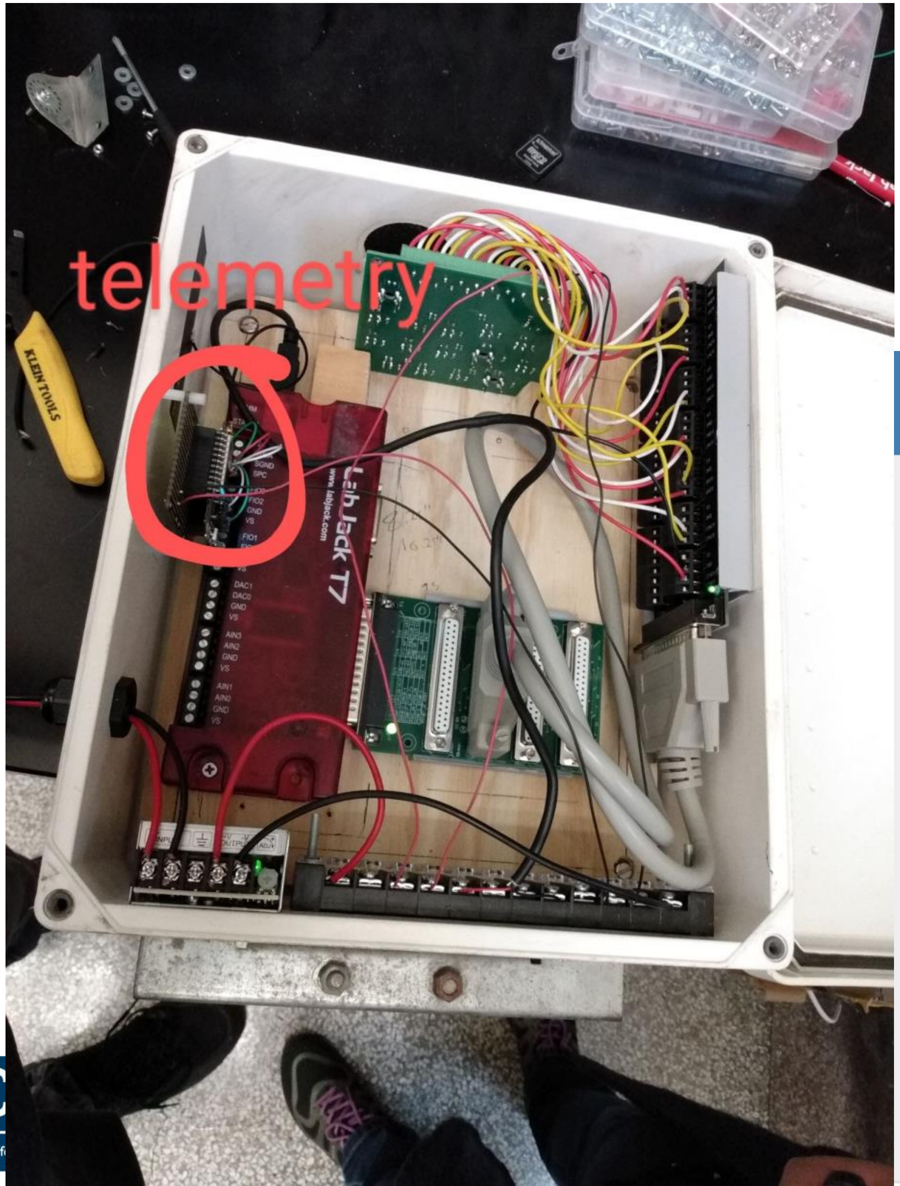
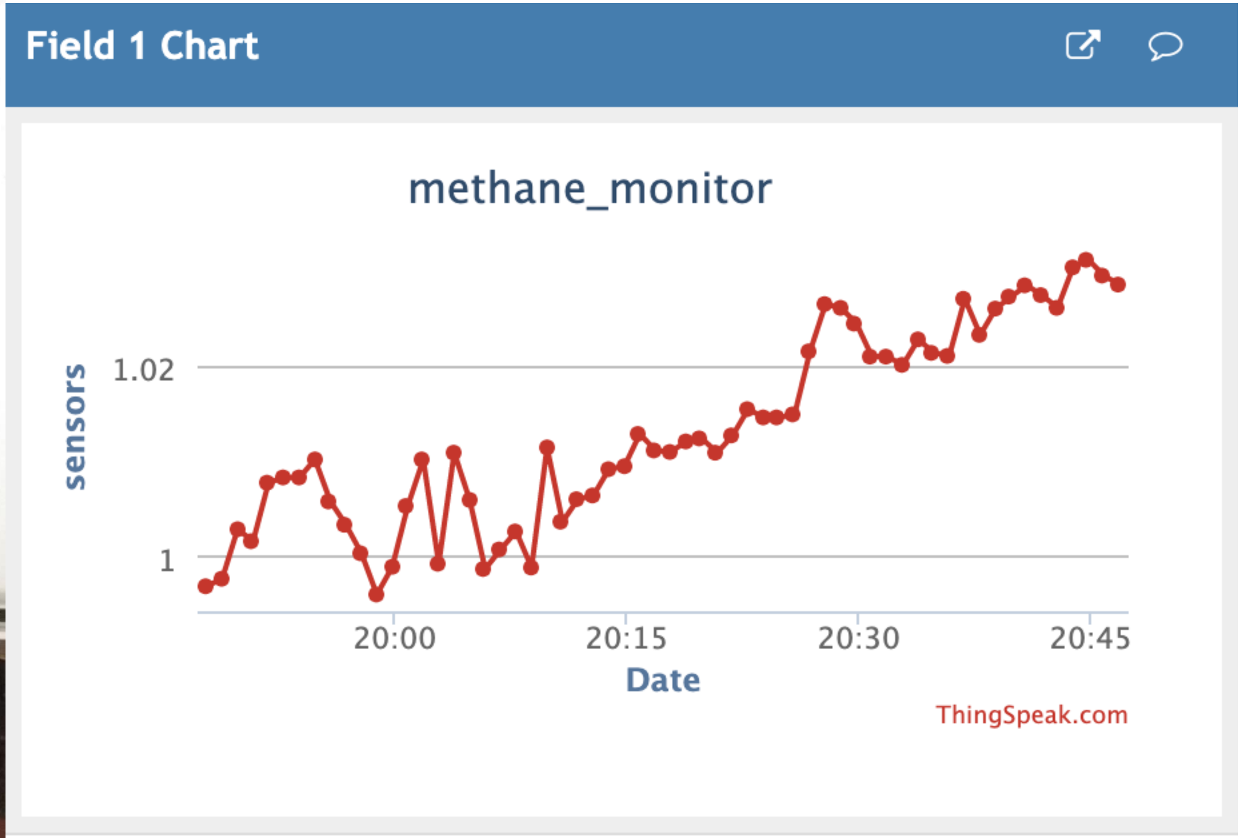
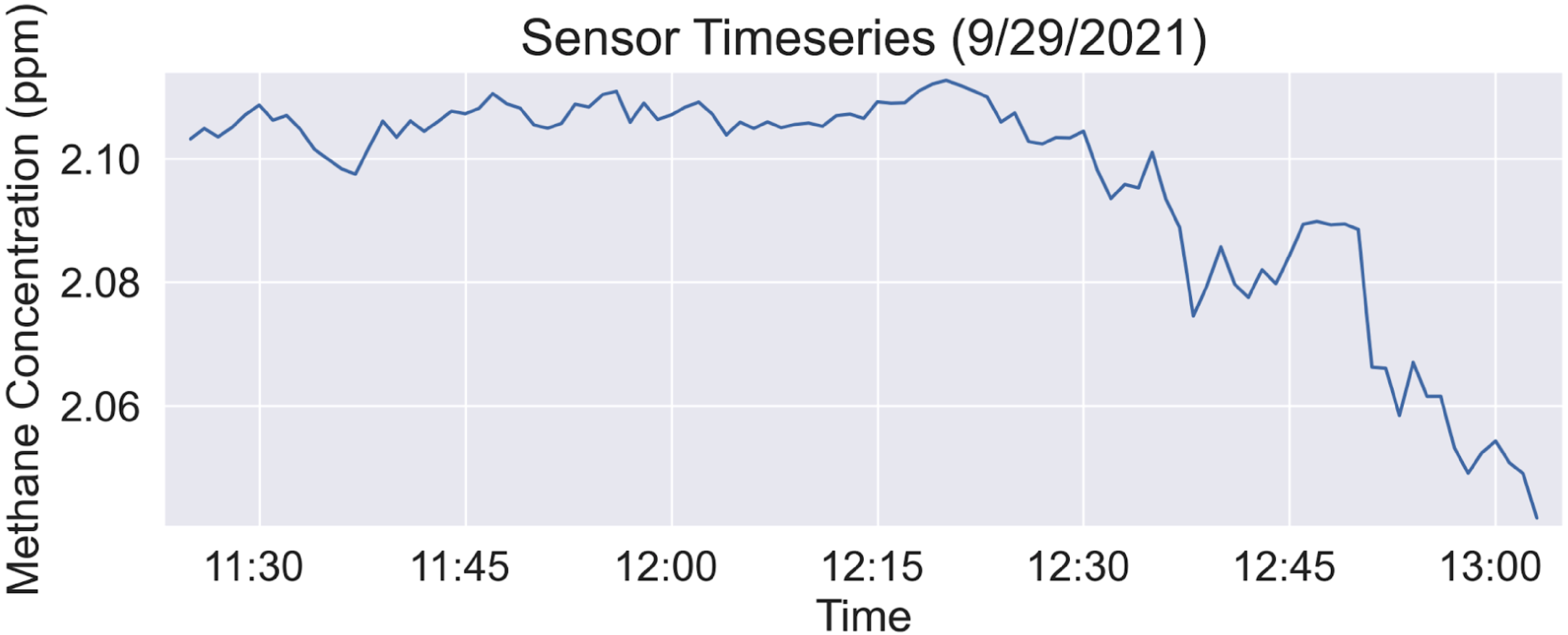
Next step: Field deployments





The sensor suite shows good performance under ambient conditions



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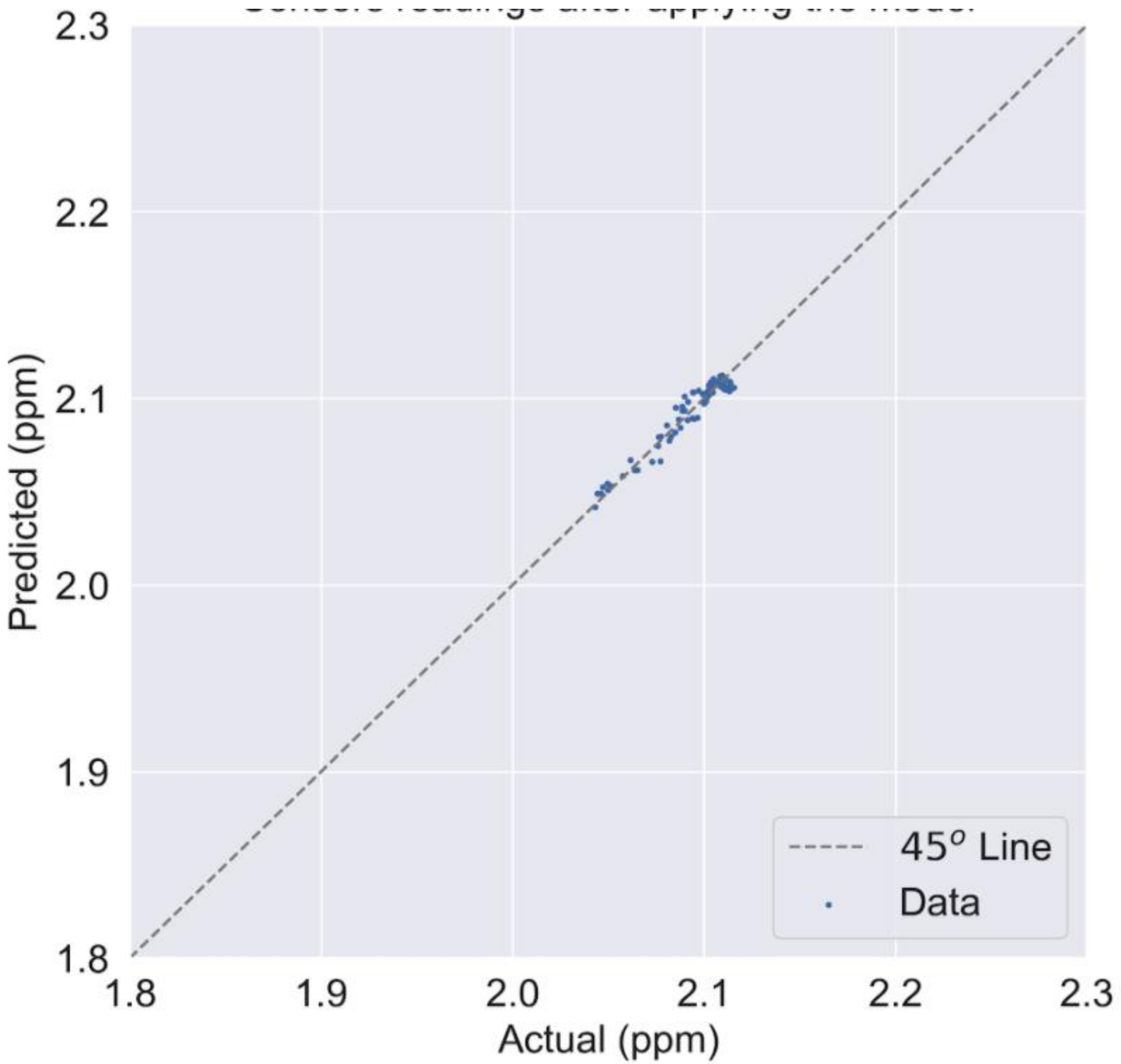

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We proposed to measure emissions along pipelines and near pig launchers

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- Our NETL partners (Dr. Natalie Pekney) have not found any significant leaks along gathering pipelines

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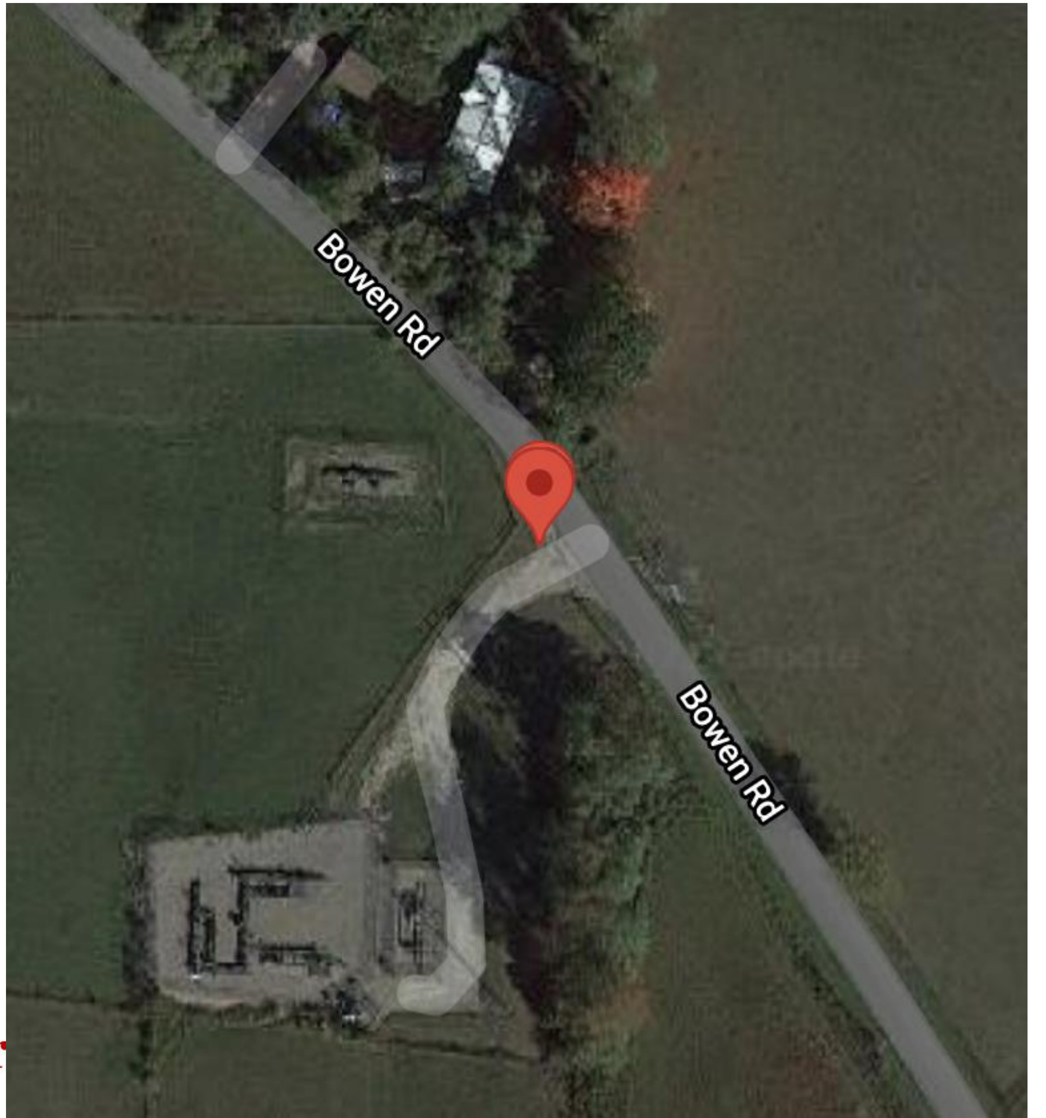
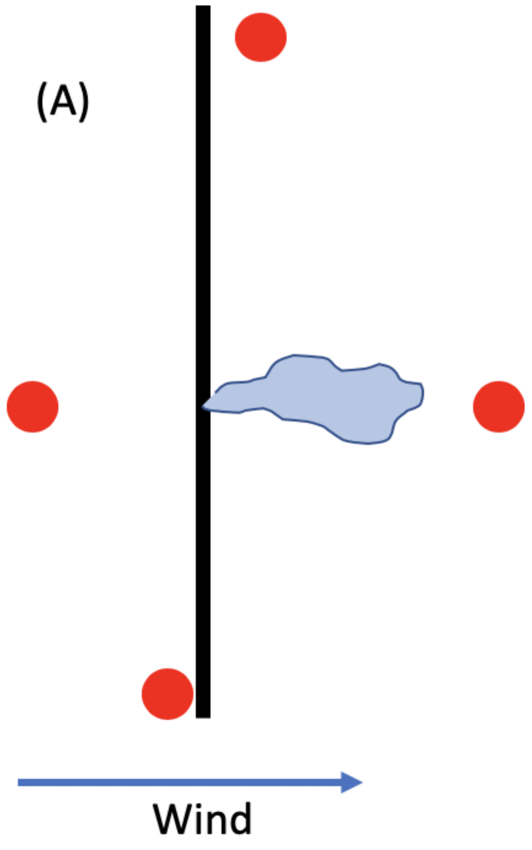
- Our NETL partners (Dr. Natalie Pekney) have not found any significant leaks along gathering pipelines
- We are working to identify locations near pig launchers



Summary and Next Steps

- Identified a suite of sensors capable of measuring ambient methane concentrations
- Developed calibration models to invert raw signal to methane concentration
- We will soon deploy near pig launchers to quantify emissions

Tasks 3 and 5: Detect leaks along pipelines and from pig launchers



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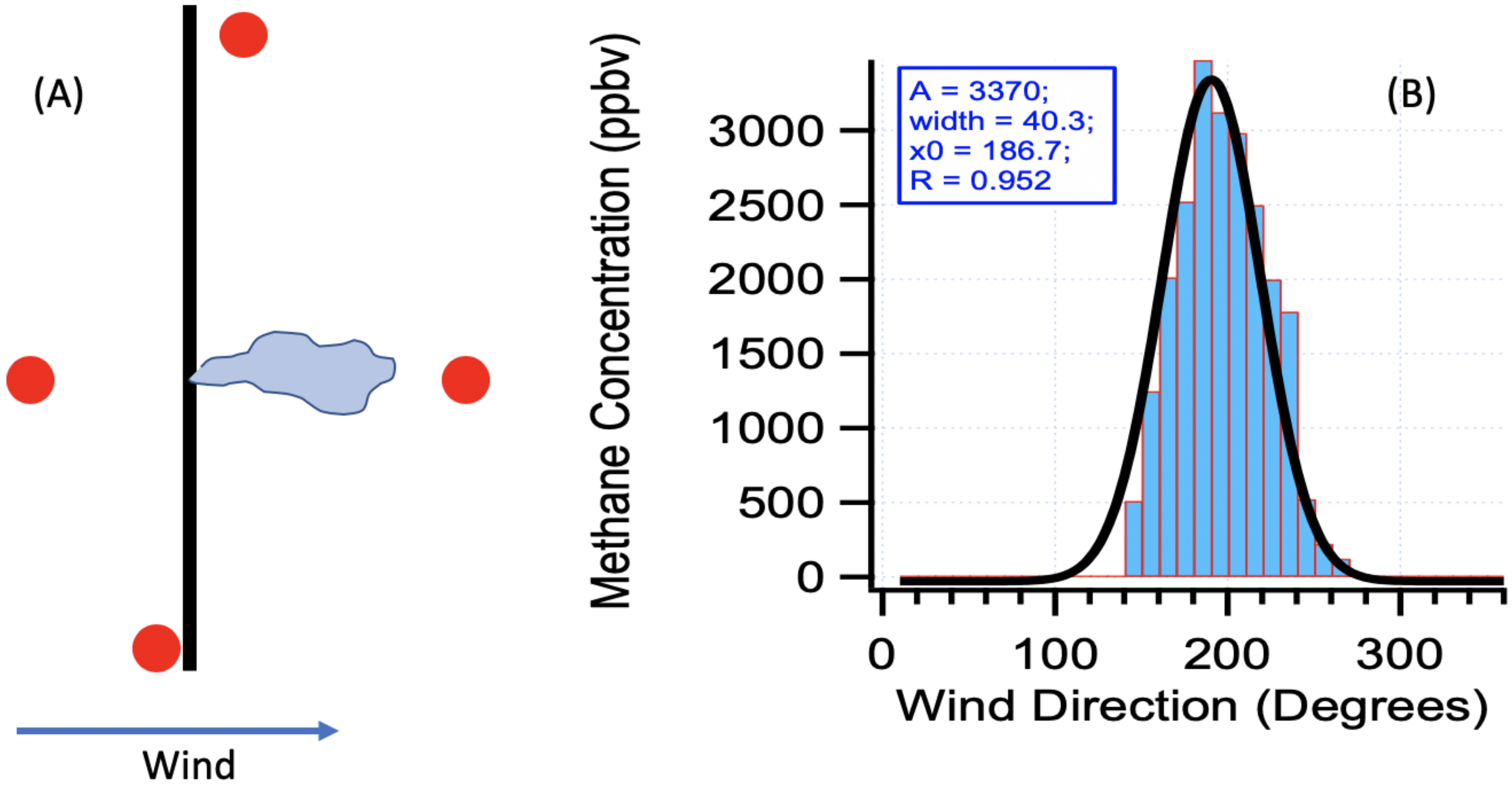

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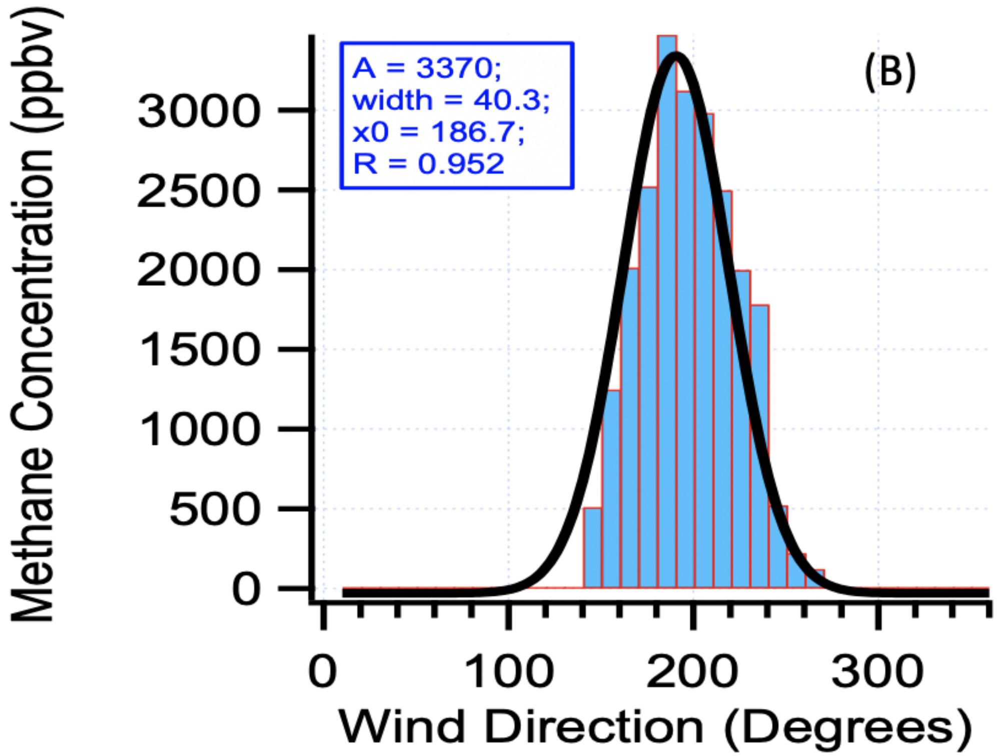
Task 4: Quantify emission rates based on Gaussian dispersion

$$Q = 2\pi \cdot C \cdot u \cdot \sigma_z \cdot \sigma_y$$



Anticipated results and significance

- ***Method Demonstration:*** We will show that that the RAMP+CH4, as well as similar sensor networks, can be used for robust long-term monitoring and quantification of methane leaks. Developing robust leak detection systems that are capable of unattended operation is critical for monitoring NG emissions, especially for infrastructure that is difficult to access (e.g., underground pipelines far from roadways).
- ***Leak quantification – gathering system:*** This project will quantify emissions from the natural gas gathering system, which has been understudied relative to other portions of the NG infrastructure.
- ***Leak quantification – temporal variations:*** RAMP+CH4 sensors will operate continuously. This will enable us to quantify temporal variations in emissions over several months.
- ***Improved methane mass closure:*** This project will provide emissions data for the NG gathering system, which has been previously understudied relative to other parts of the NG infrastructure. The new data provided by this project will be available for incorporation into inventories (e.g., Greenhouse Gas Inventory) and to improve methane mass closure estimates.