IPACK2017-74191: Fugitive Methane Gas Emission Monitoring in oil and gas industry

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Technology developed in partnership with: arpa·e awardee

IBM

Princeton University Laser Sensing Laboratory

swn Southwestern Energy®

Harvard University Atmospheric Chemistry Modeling Group

Natural gas production

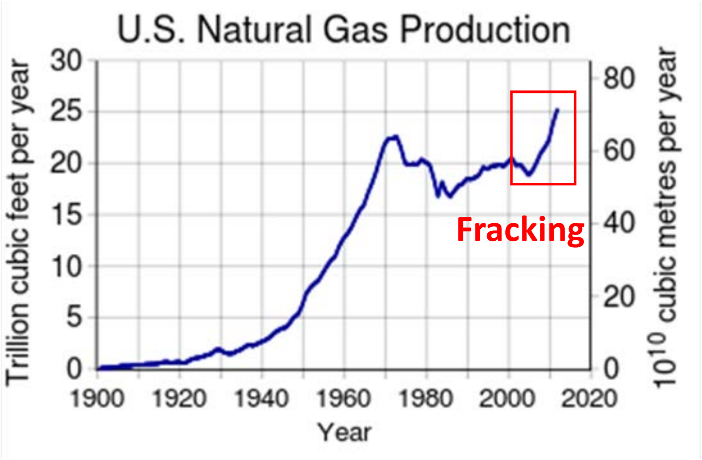
-85% of the natural gas composition is methane

-methane linger ~10 year in atmosphere before naturally decomposes

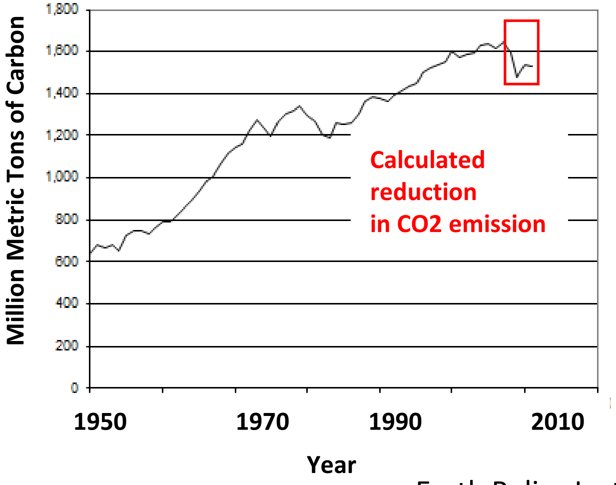
-methane's <u>green house warming potential </u>is 85 x larger than CO2

-burning methane produce 1/3 as much CO2 as burning coal

-a 3 % of the total explored gas escape as a fugitive gas leak; it would null out the benefit of using natural gas vs fossil fuel.

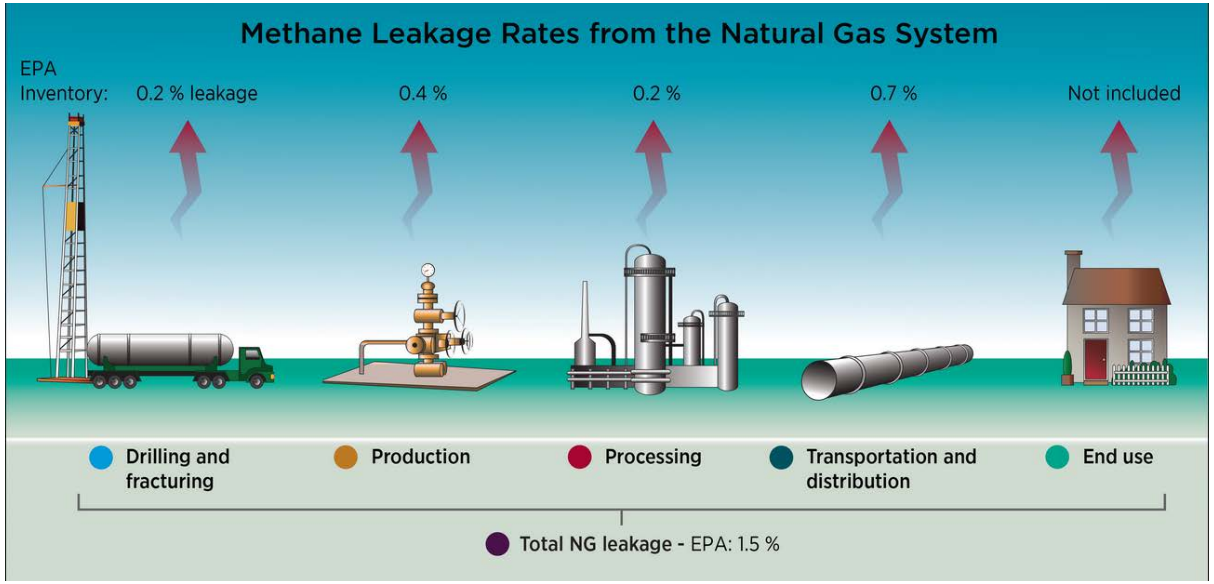


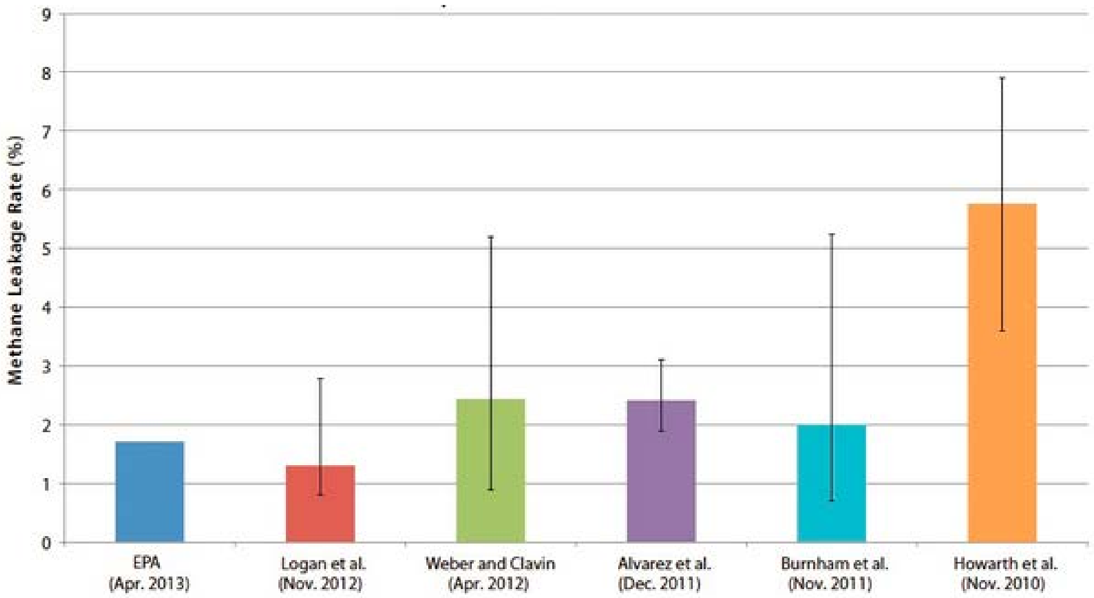
USA CO_2 emission



Earth Policy Institute

Methane emission estimates





Leaks between 1 to 10% commonly encounter in literature.


Well pads in Barnum Shell, Texas
Urban area
Gas pad
1 km

Technology specifications

Methane sensing

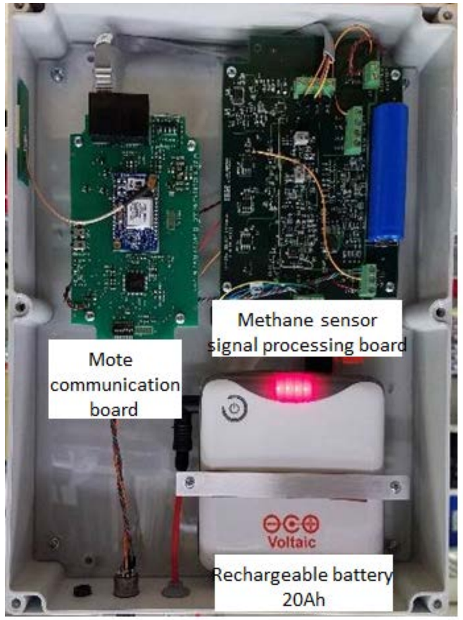
-1 ppm methane detection sensitivity
-robust sensor design for outdoor operations
-sensing optimized for 6 scfh to 200 scfm leak detection

Communications

-for multiple point monitoring sensors form a wireless network
-cellular link to send data from sensor to cloud

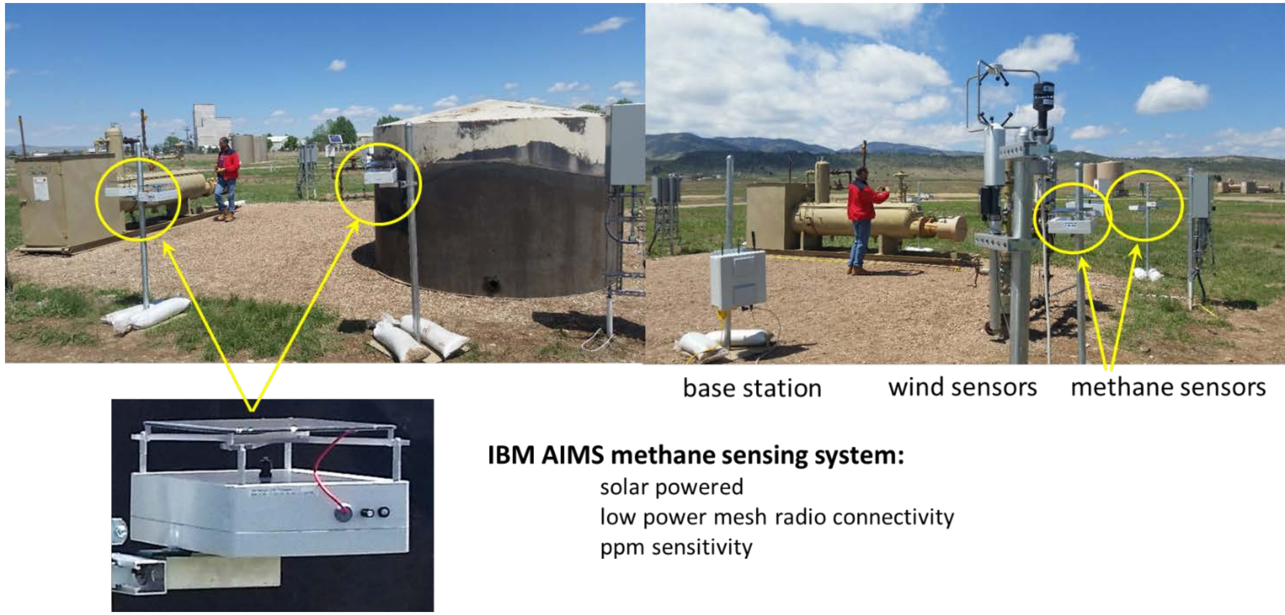
Intelligent sensors

-compensate sensor reading for environmental condition(temperature/RH)
-dynamic sampling driven by methane leak events
-extendable to other gases like H_2S



Industry compatible sensors

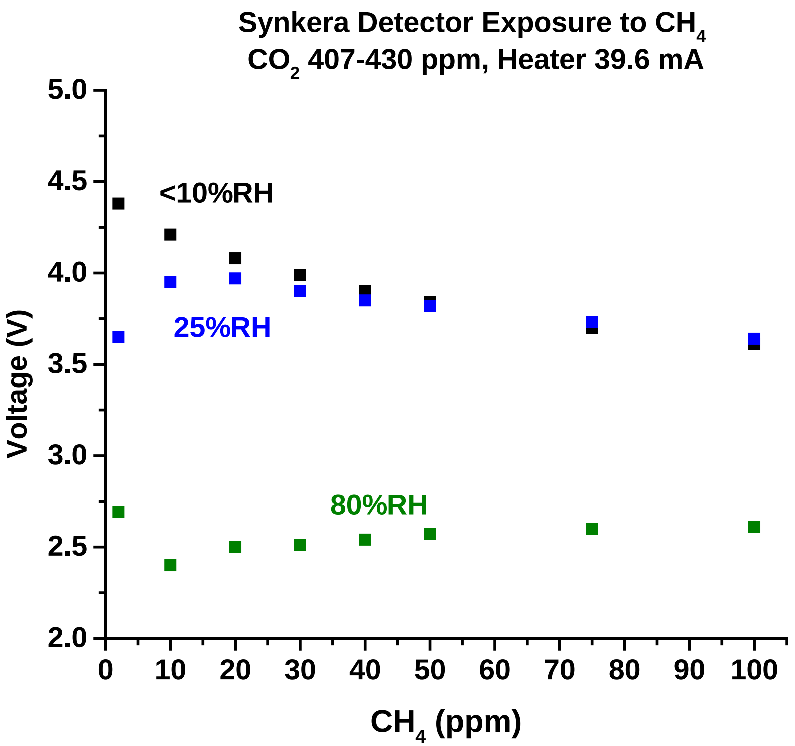
- Continuously monitor the environment and look for methane leaks
- System operates remotely with minimum maintenance
- System packaged for outdoor operation (-40 C to 40 C)
- Solar panel and battery sized for 5 consecutive cloudy days continuous operation

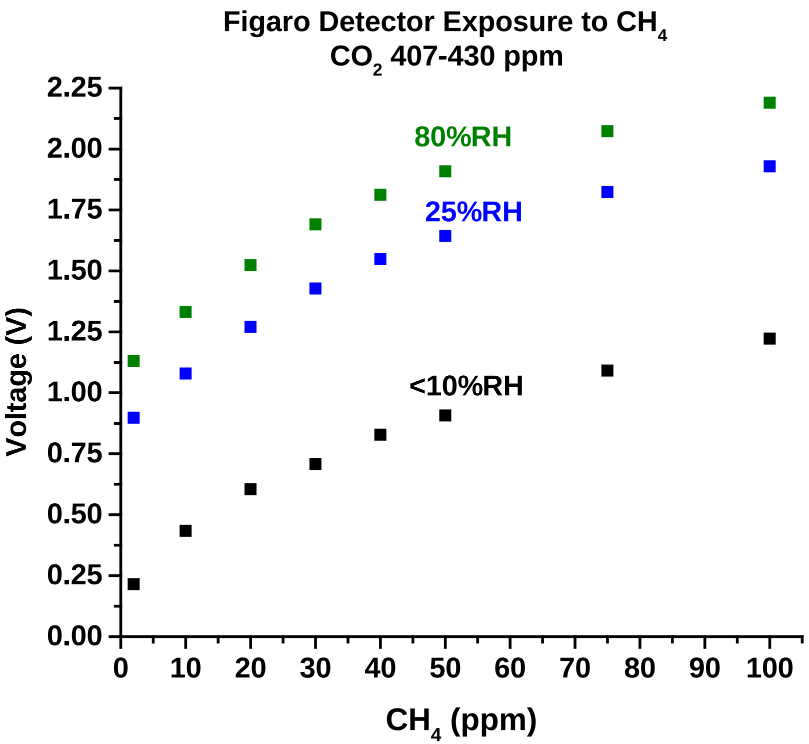


IBM AIMS methane sensing system:

solar powered
low power mesh radio connectivity
ppm sensitivity

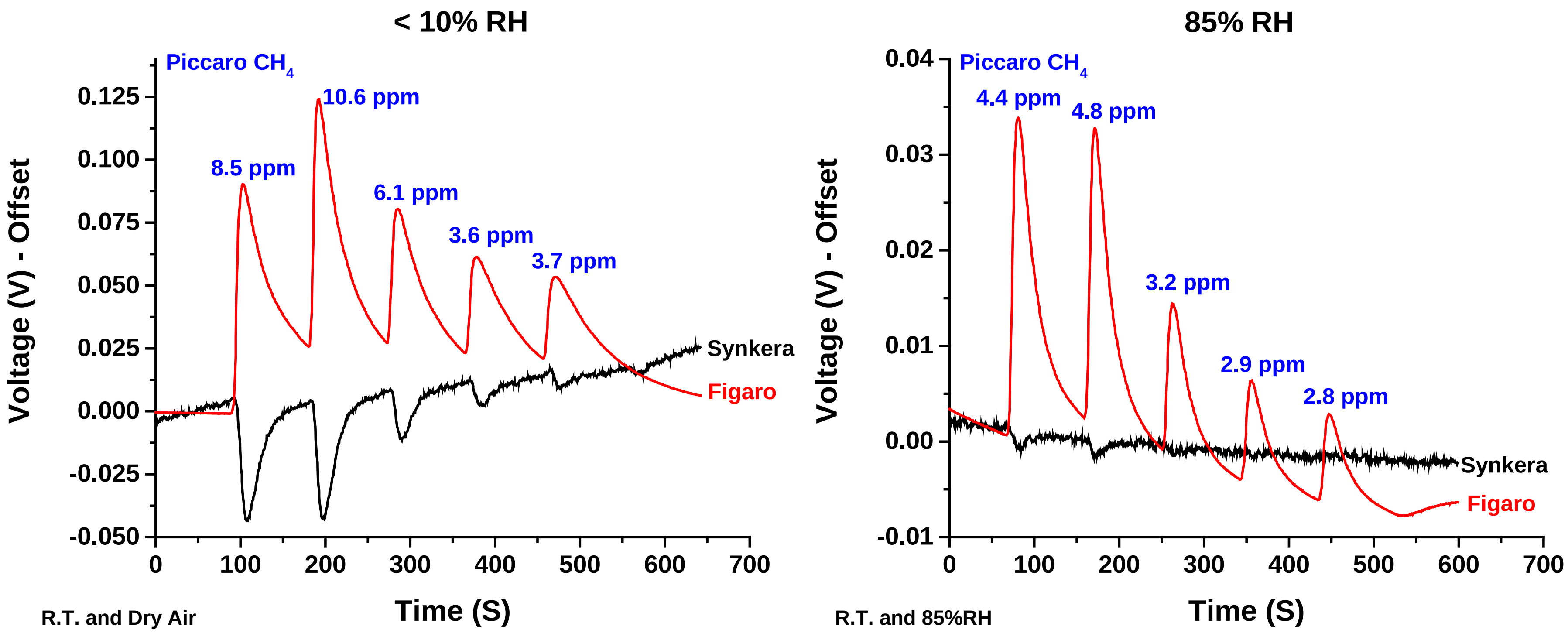
Detector Characterization (Steady State Conditions)





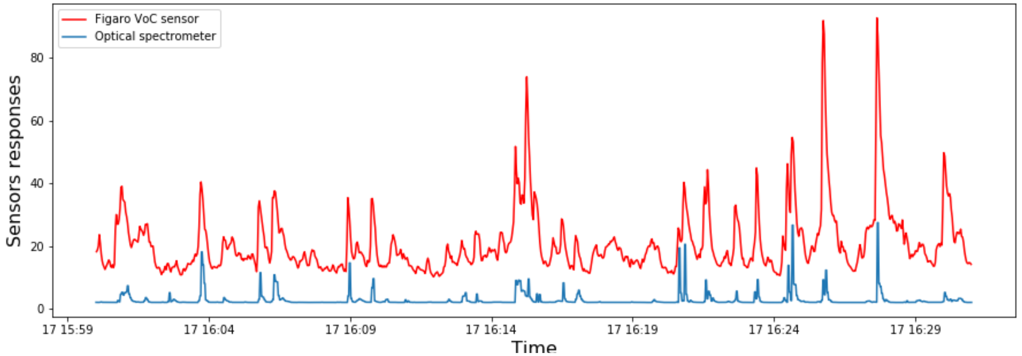
-- Voltage vs. CH_4 concentration at various RH%'s show the same trends for a second set of Synkera and Figaro sensors.

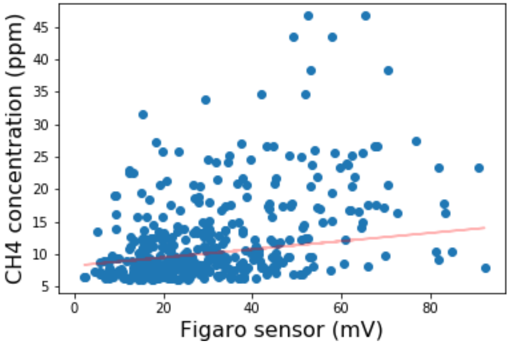
Synkera / Figaro Responses to 3 s Pulses of Methane



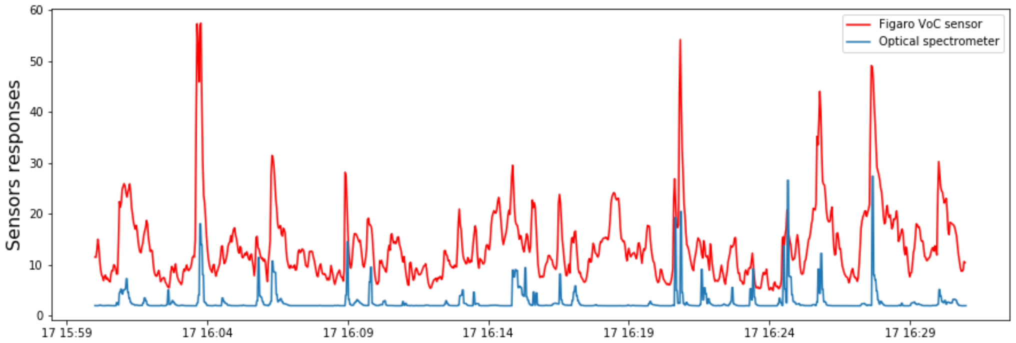
-- The response times for a Synkera and Figaro sensors are similar, with the Figaro slightly faster.
-- The sensitivity of the Figaro sensor is many times better, especially in humid conditions.

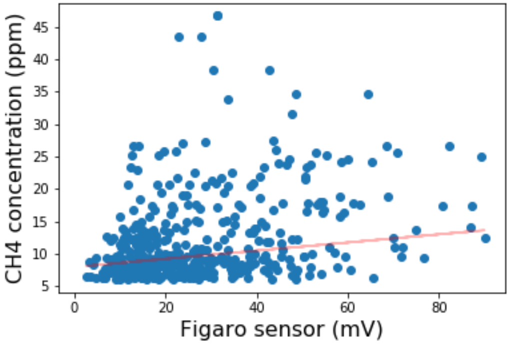
Sensitivity study on sensors



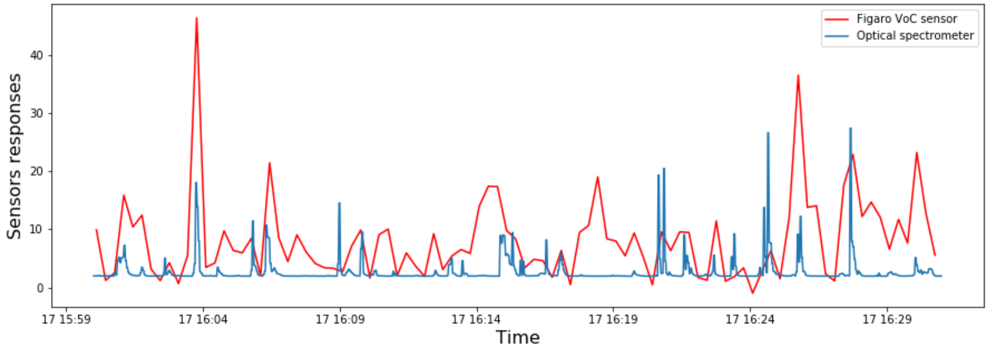


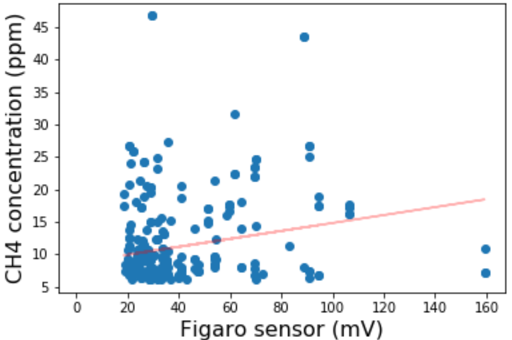
1.98 mv/ppm





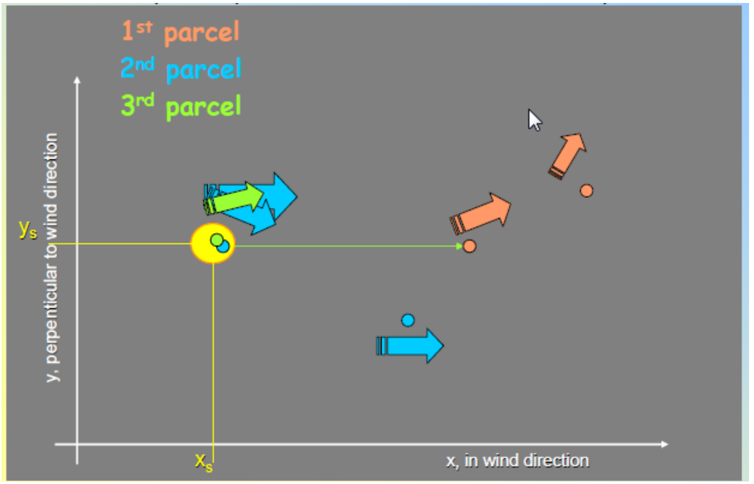
2.21 mv/ppm





2.51 mv/ppm

Lagrangian dispersion model

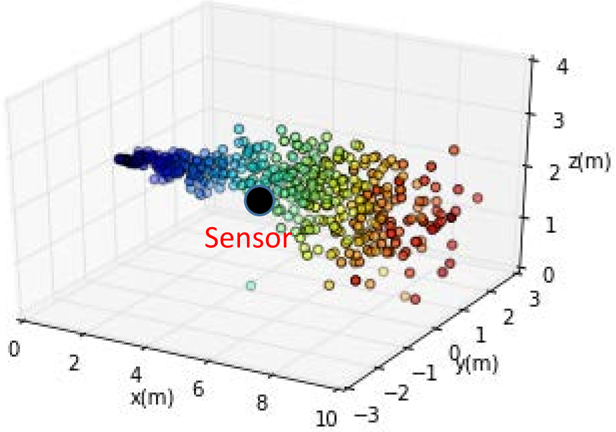


Small parcels/puffs emitted every 0.1 sec and carried by the wind

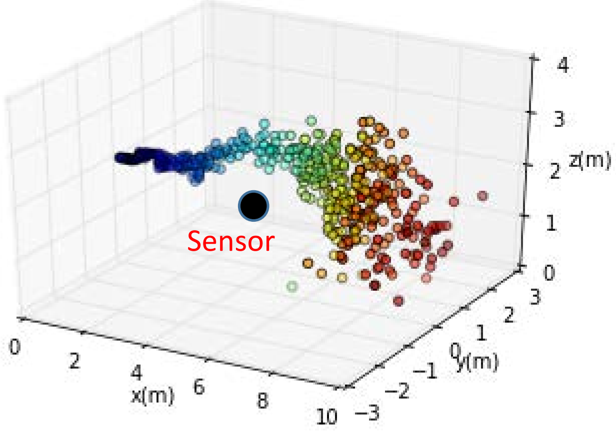
$$dx_p = (u + u')dt, \quad dy_p = v'dt, \quad dz_p = w'dt$$

$$dv'(t) = -\frac{1}{T_{IL,y}}dt + \sigma_v \sqrt{\frac{2}{T_{IL,y}}} dW_y(t)$$

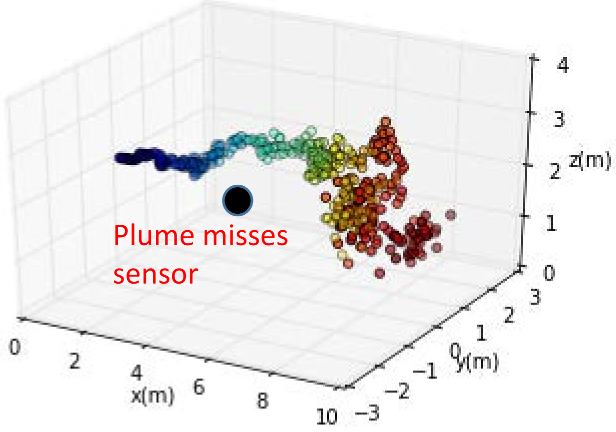
T_{iL}=1 sec



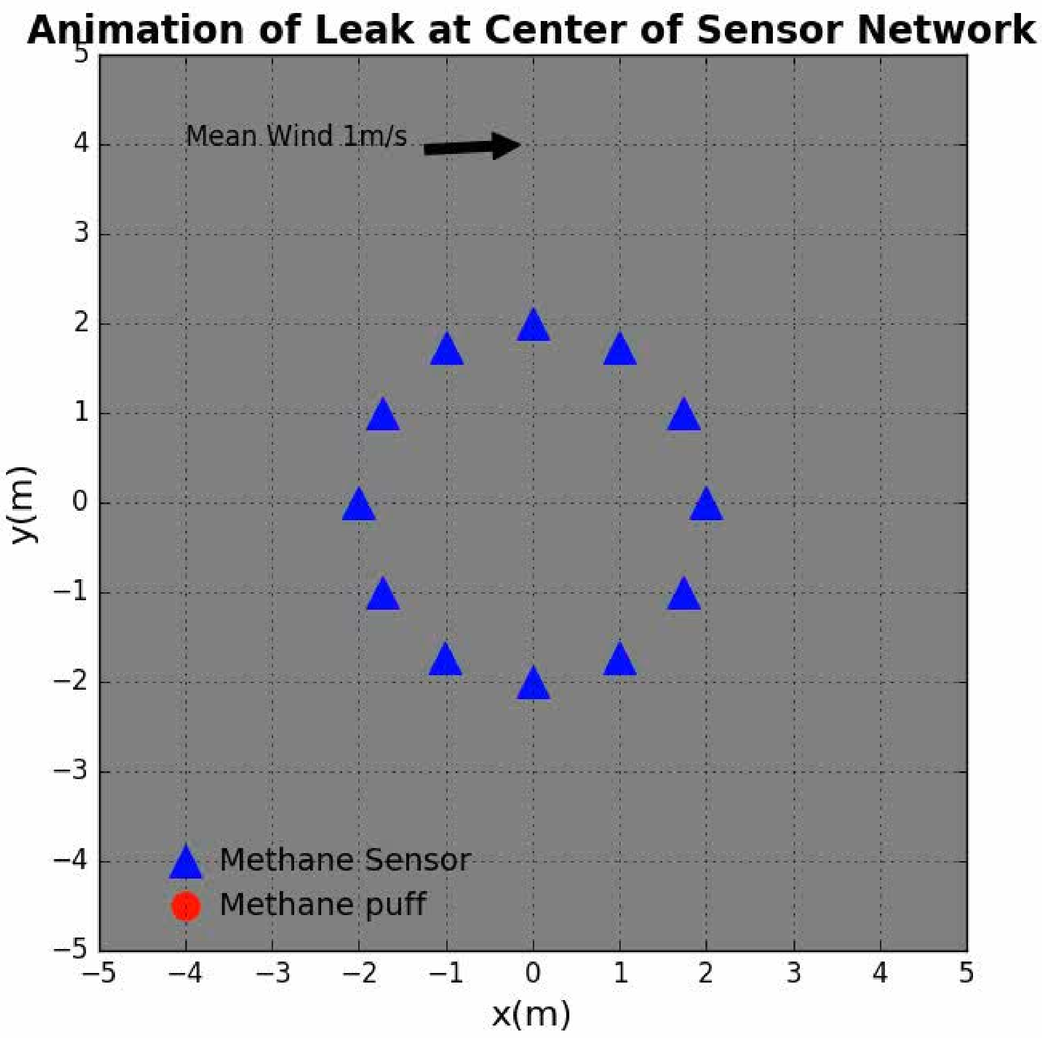
T_{iL}=10 sec



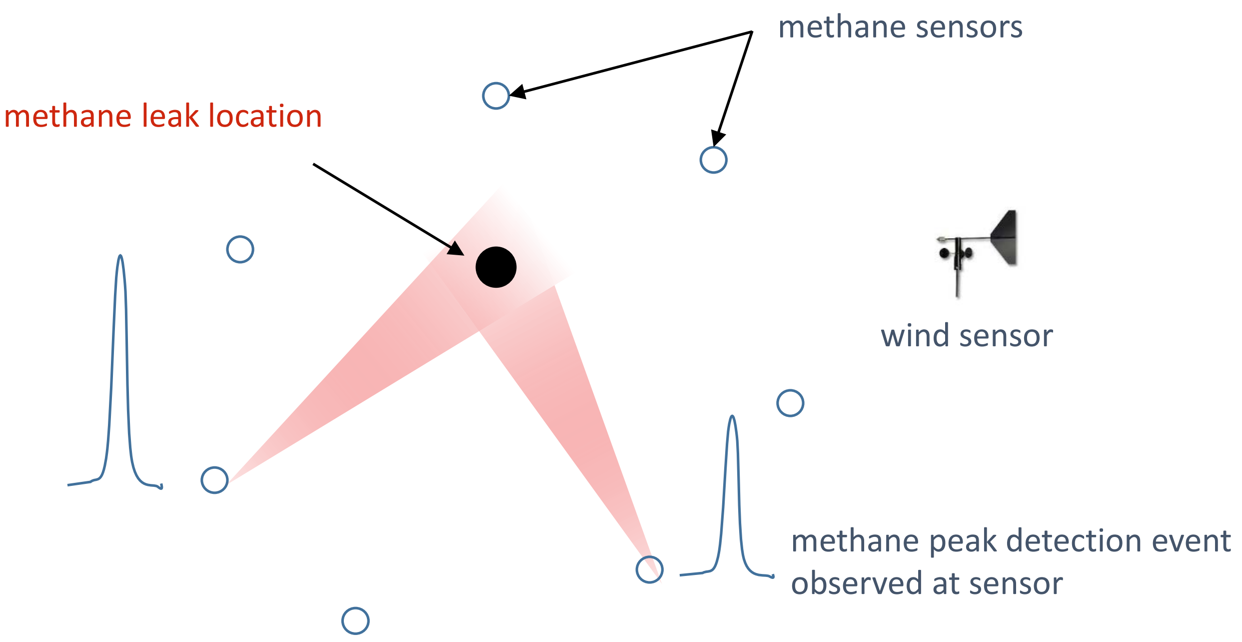
T_{iL}=100 sec

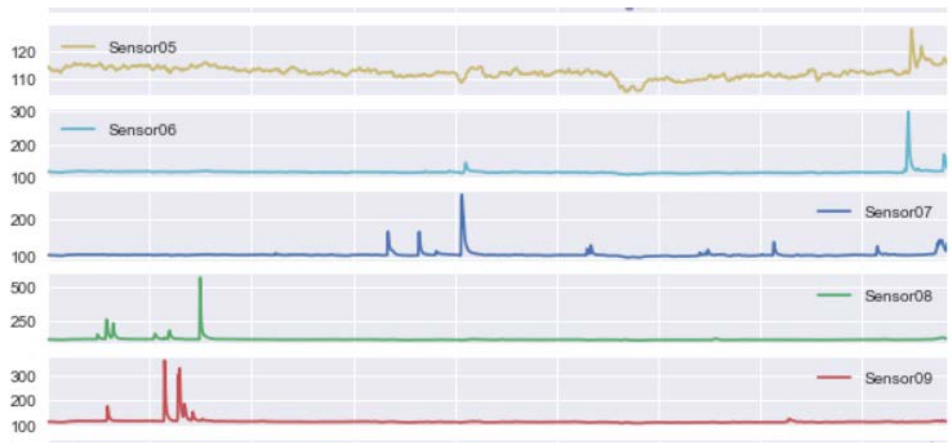


Plume dispersion



Methane Leak Location Estimation

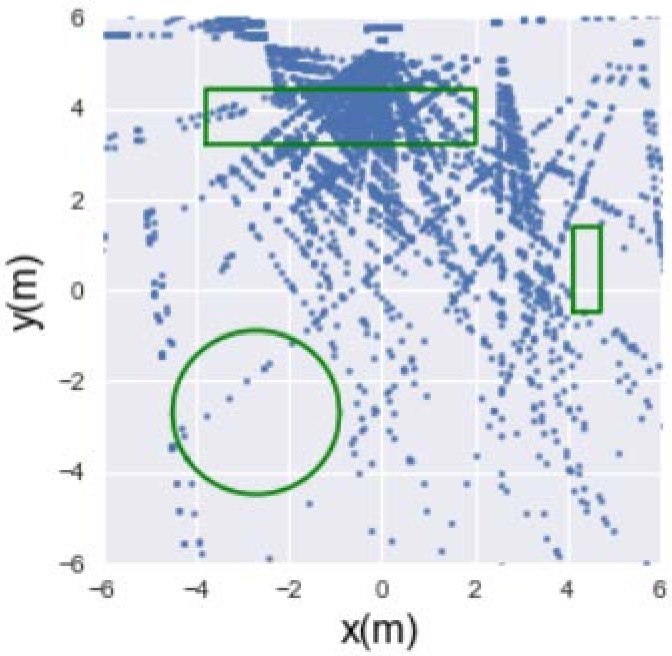




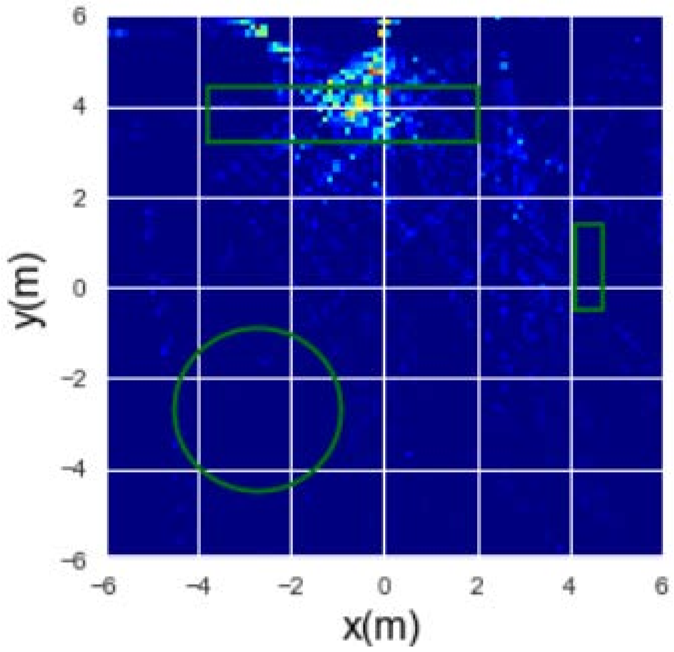
Peaks observed at methane sensors are used with wind data to estimate <u>the likely direction the plume took</u> to arrive at the sensor,

the superposition of data of many such peaks allows the estimation of the leak position.

Source Location Estimate Using Tomographic Method



Well pad with controlled release of methane

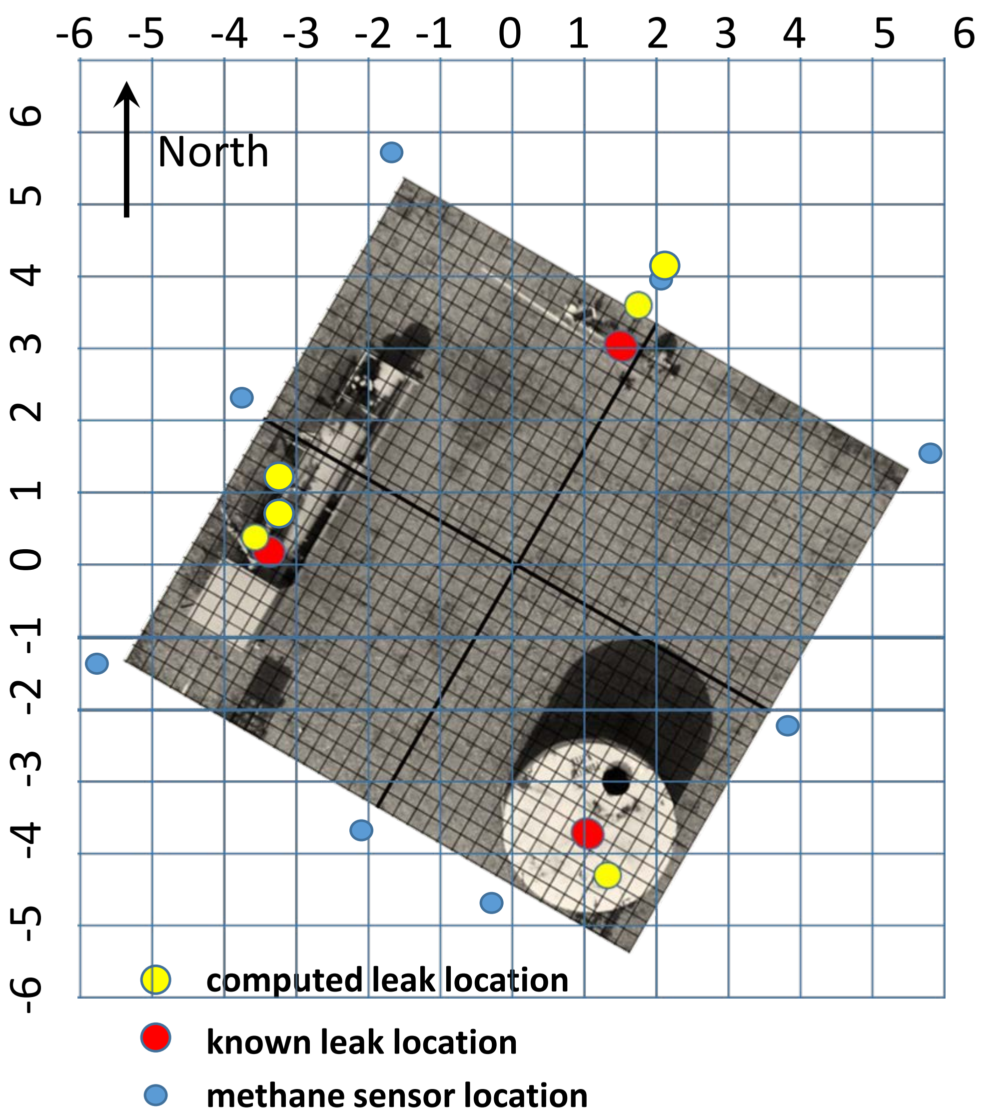


Heat map of leak localization

Methane Leak Estimates

Location of Leak:

Feature	Known			Estimated			Error, m
	Leak Position, m			Leak Position, m			
	X	Y		X	Y		
tank center	1.1	-3.8		1.27	-4.25		0.48
GPU center	-3.5	0.25		-3.64	0.42		0.22
tree center	1.5	3		1.95	3.76		0.88
GPU center	-3.5	0.25		-3.09	1.06		0.91
tree center	1.5	3		2.27	4.05		1.30
GPU center	-3.5	0.25		-3.32	0.83		0.61



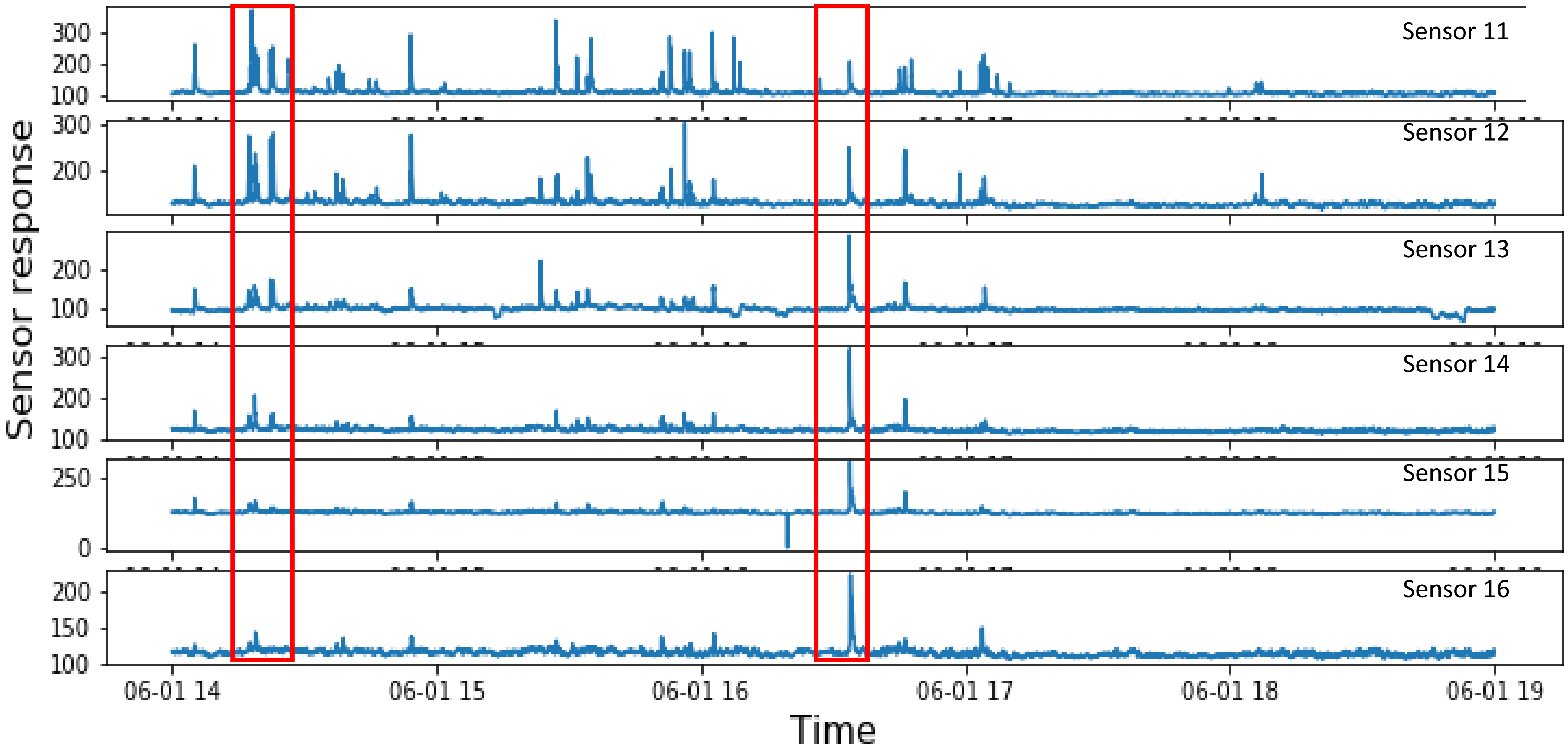
Magnitude of Leak:

Feature		Known Flow, SCFH		Computed Flow, SCFH		Error, SCFH		Error, %
tank center		32		34		2		7
GPU center		32		29		-3		-8
tree center		32		33		1		4
GPU center		17		19		2		10
tree center		21		17		-4		-18
GPU center		10		12		2		24

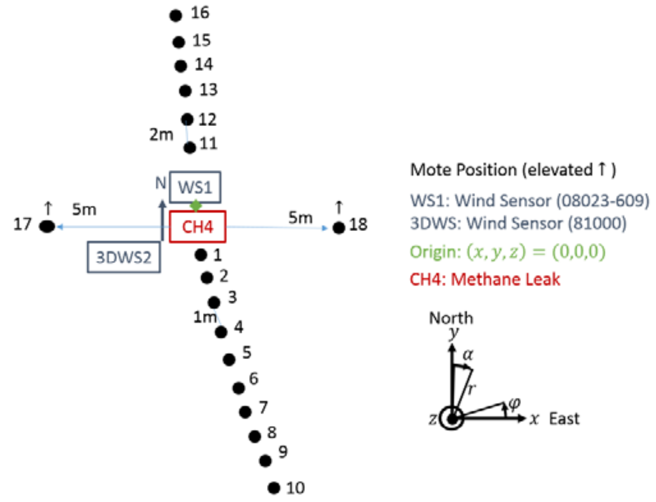
Conclusions

- Outdoor sensor network design needs to be optimized for power, communication bandwidth and cost perspective
- Sensors needs to be packaged to withstand extreme environments and sensor reading needs to be compensated for environmental fluctuations
- Data compression and analytics needs to be adapted to data acquisition strategy.
- Developing and end to end solution gives the flexibility to adjust sensor reading and analytics to be combined seamlessly.

Methane detection along a line direction



Experimental setup



Methane propagation along a line of sight direction