USING QUANTUM GAS LIDAR FOR CONTINUOUS METHANE EMISSIONS QUANTIFICATION OF GAS TO GRID PLANTS IN WATER SEWAGE TREATMENT WORKS

Alex Harrison[2], Gavin Lindsay[1],
Bharanitharan Srinamasivayam[2], Aaron Van Pelt[1],
Doug Millington-Smith[1]

[1] QLM Technology Ltd, Cardiff, UK
[2] Severn Trent Water, Coventry, UK

EGU General Assembly, Vienna, Austria, April 14-19, 2024
Oral: PICO spot 4, Monday, 15 April 2024, 09:03. PICO viewing: 09:11-10:15, PICO screen PICO4.11

QLM

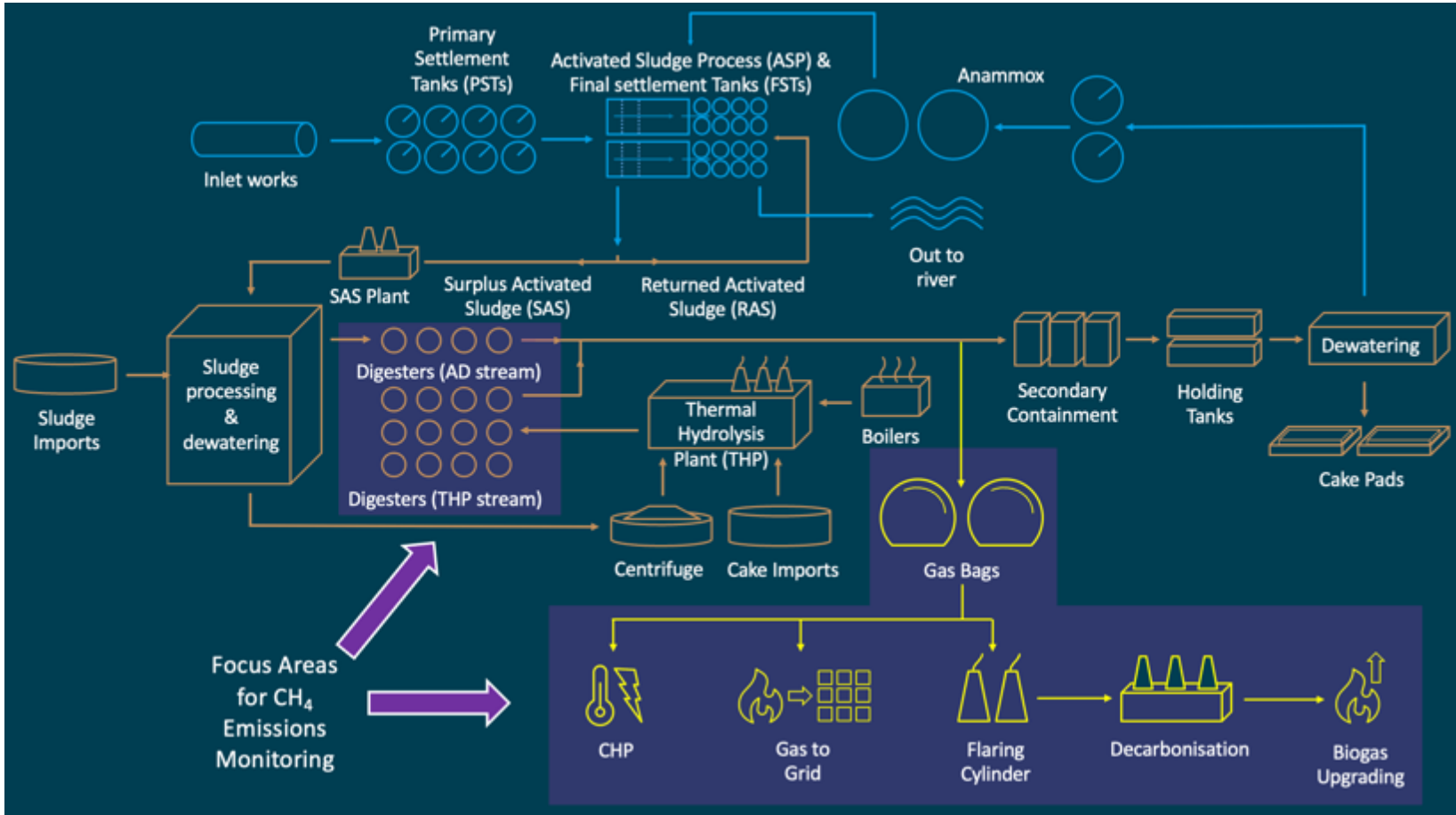
SEVERN TRENT
WONDERFUL ON TAP

ST Classification: OFFICIAL COMMERCIAL

BACKGROUND & INTRODUCTION

- One of UK's largest water companies, Severn Trent provide water and sewerage services to 8.5 million customers, 13% of UK
- Severn Trent have ambitious, industry-leading carbon targets; 100% renewable generation, EV's, and Net Zero by 2030
- 27 Sludge Treatment Facilities: methane-rich biogas produced from the anaerobic digestion of sewage sludge as a renewable energy source. We are aiming to minimise the carbon impact of these operations with the help of QLM.
- QLM Lidar for continuous CH_4 emissions monitoring - campaigns ongoing at 3 Severn Trent UK plants: 2 have full gas to grid infrastructure, 1 site uses combined heat & power engines to convert biogas into electricity for use on site and for export
- Monitor facility and use detected emissions for reporting and to inform further emissions reduction activities

Minworth STW Site & Process Schematic:



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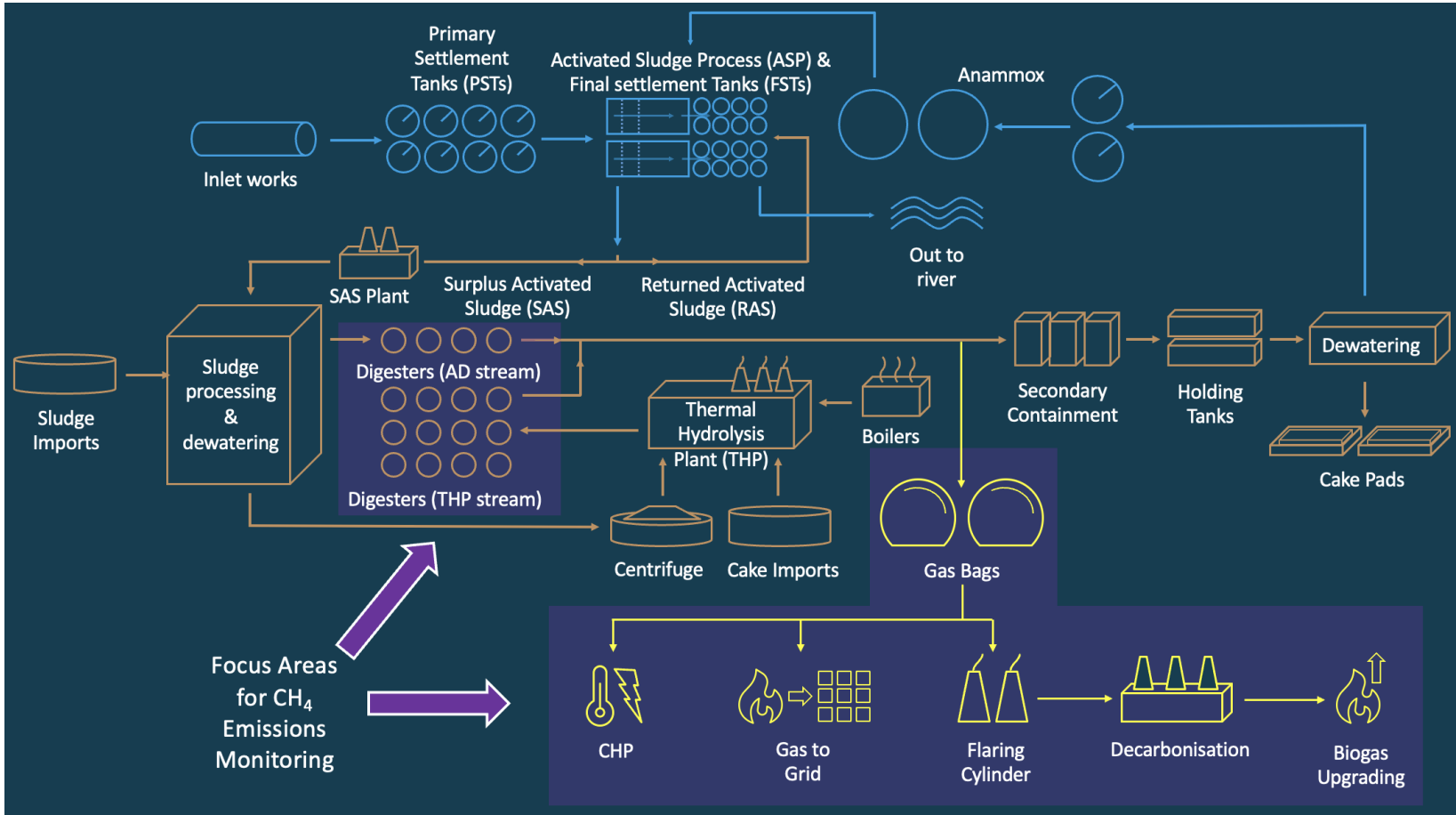
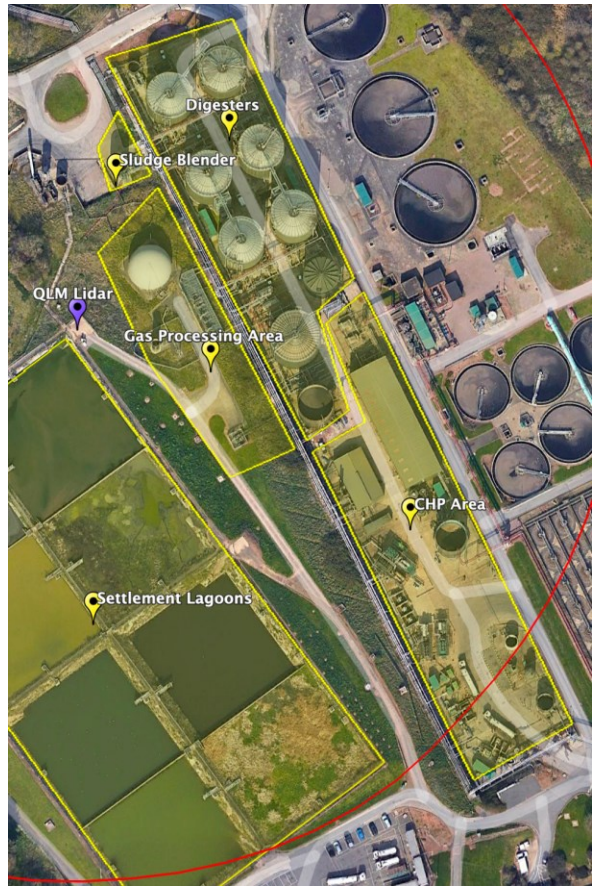


DEPLOYMENT DETAILS

- Minworth STW site: 2 QLM lidar systems. Wanlip STW site: 1 QLM lidar system
- Monitoring 24/7, targeting each area/equipment unit sequentially – 60-90 minutes to cover all site targets. 10-meter mast deployments
- 200m max lidar range, ~0.4 kg/h CH_4 typ. Sensitivity (weather/range dependent)
- Campaigns started at temporary locations: Minworth, Dec 22, 2023. Wanlip, Feb 23, 2024
- QLM systems have live 4G connection to QLM Cloud for data collection, analysis & reporting
- Data output from QLM system:
  - Emission location, start/end/duration, flow quantification
  - Lidar imagery: intensity, methane density, range & visible

— Wanlip Site —



— Minworth Site —

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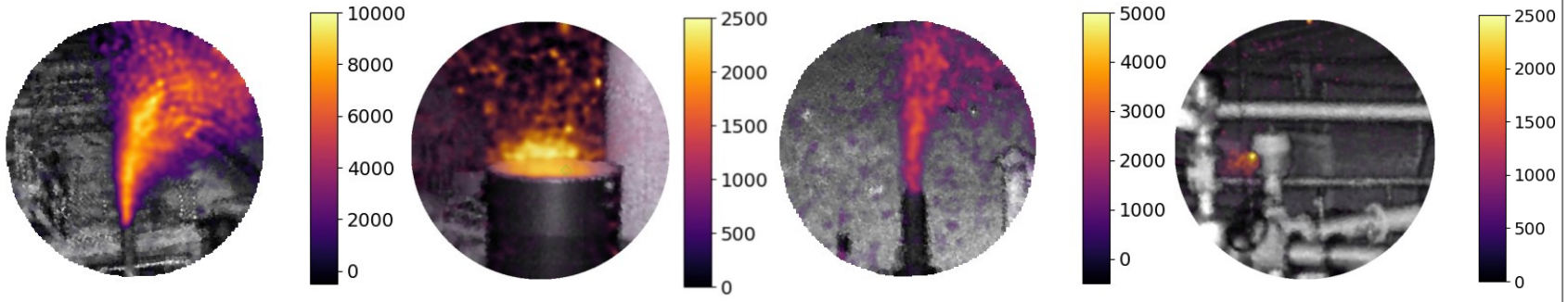
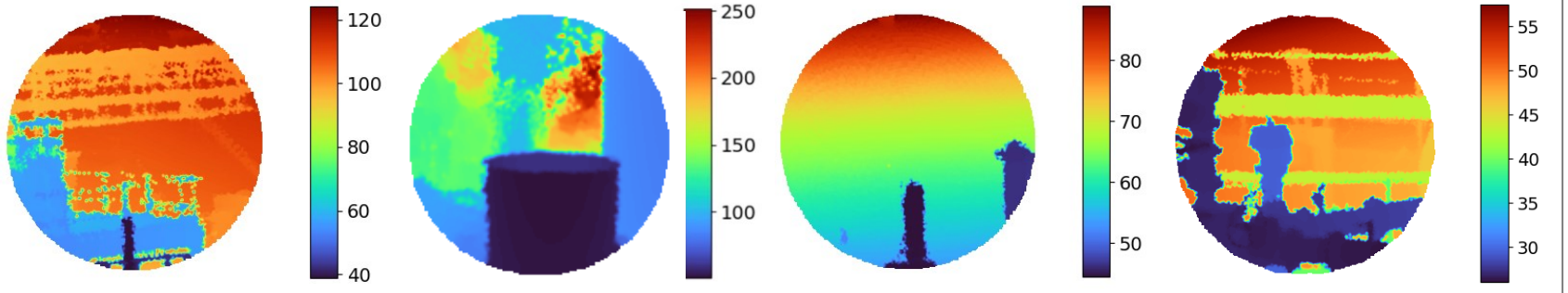
PRELIMINARY RESULTS

— Individual Emission Event Measurement Examples —

Lidar CH_4 (ppm*m) & Lidar Intensity Overlay →

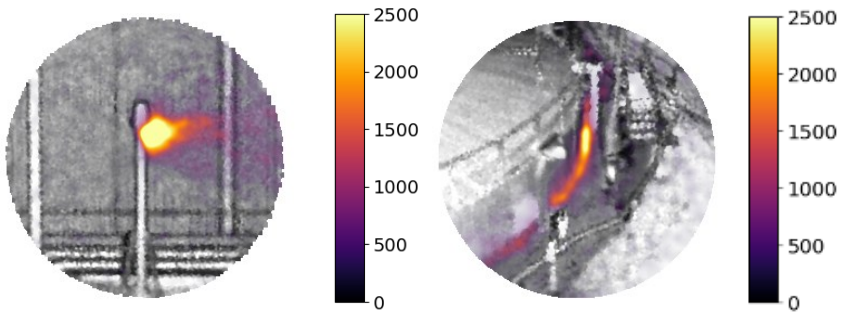


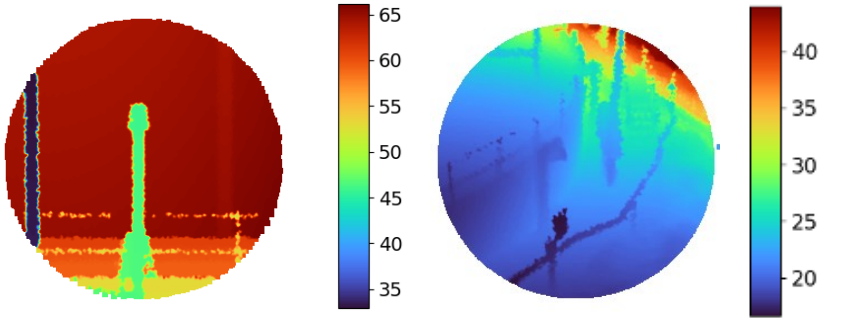
Range (m) →



Biogas Upgrading 11 kg/h | Flare Stack 8 kg/h | Decarboniser Chimney 0.5 kg/h | Digester 0.6 kg/h

— Intermittent Emission Sources —

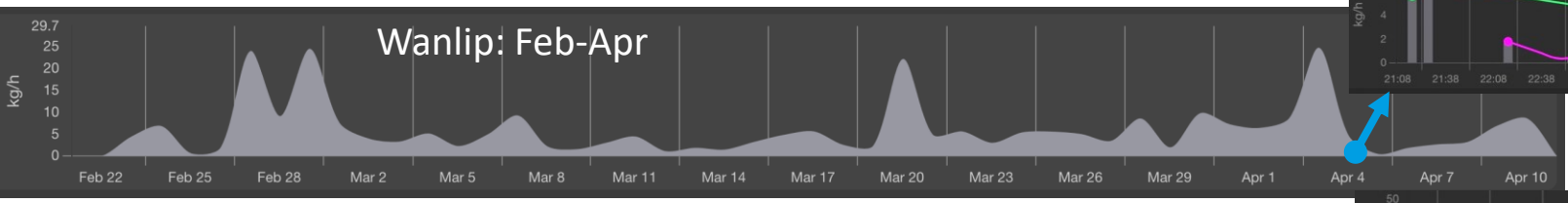


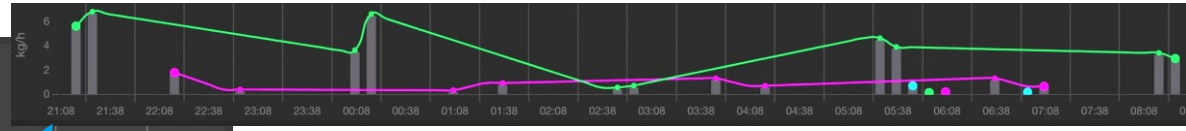


Pressure Relief Valve 0.9 kg/h | Digester Wall 2 kg/h

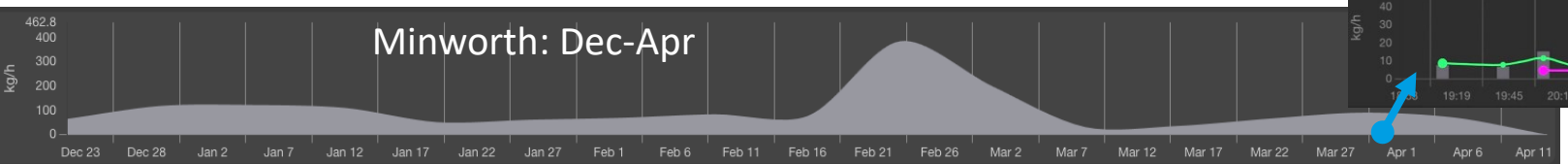
— Persistent / Continuous, Variable Rate Emission Sources —

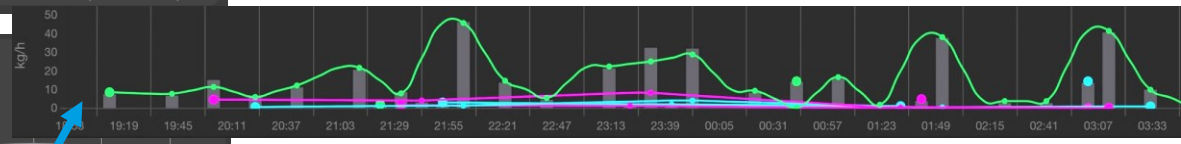
Emission Rate Trends





Example time series data over several hours – sites have a mixture of continuous and intermittent sources





BACKUP MATERIALS – PICO VIEWING SLIDES

WONDERFUL ON TAP

SEVERN TRENT

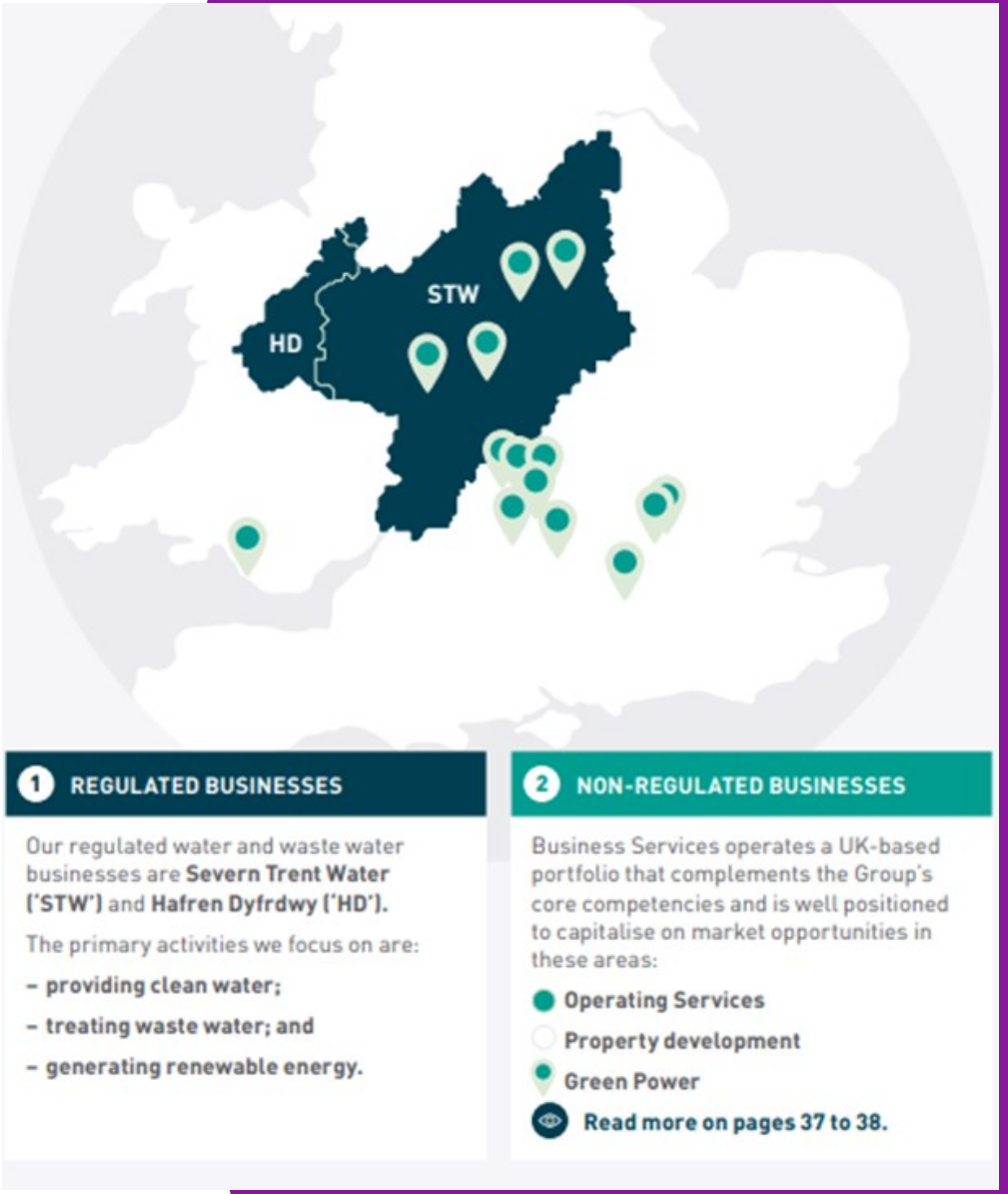
BACKGROUND ON SEVERN TRENT

- As one of the UK's largest water companies, we provide water and sewerage services to millions of people across the Midlands, from the outskirts of Sheffield, down to Bristol, and into north and mid-Wales.

- That includes providing fresh, clean drinking water every day. And when they've finished with it, we take it away again and clean and treat it before returning it safely to our environment.

- In addition to this we also make good use of our sewage sludge from the treatment process, in our anaerobic digestion facilities to produce biogas as a renewable energy source.

- We are aiming to minimise the carbon impact of this operations with the help of QLM Technology, a UK-based company specializing in quantum gas detection, quantification and monitoring.



OUR TRIPLE CARBON PLEDGE

Triple Carbon Pledge commitment to

Net zero operational emissions, including offsets, by 2030 from a 2019/20 baseline

100% energy from renewable sources by 2030

100% Electric Vehicles by 2030, where possible

SBT targets:
46% reduction in Scope 1 and 2 by 2031 from a 2019/20 baseline

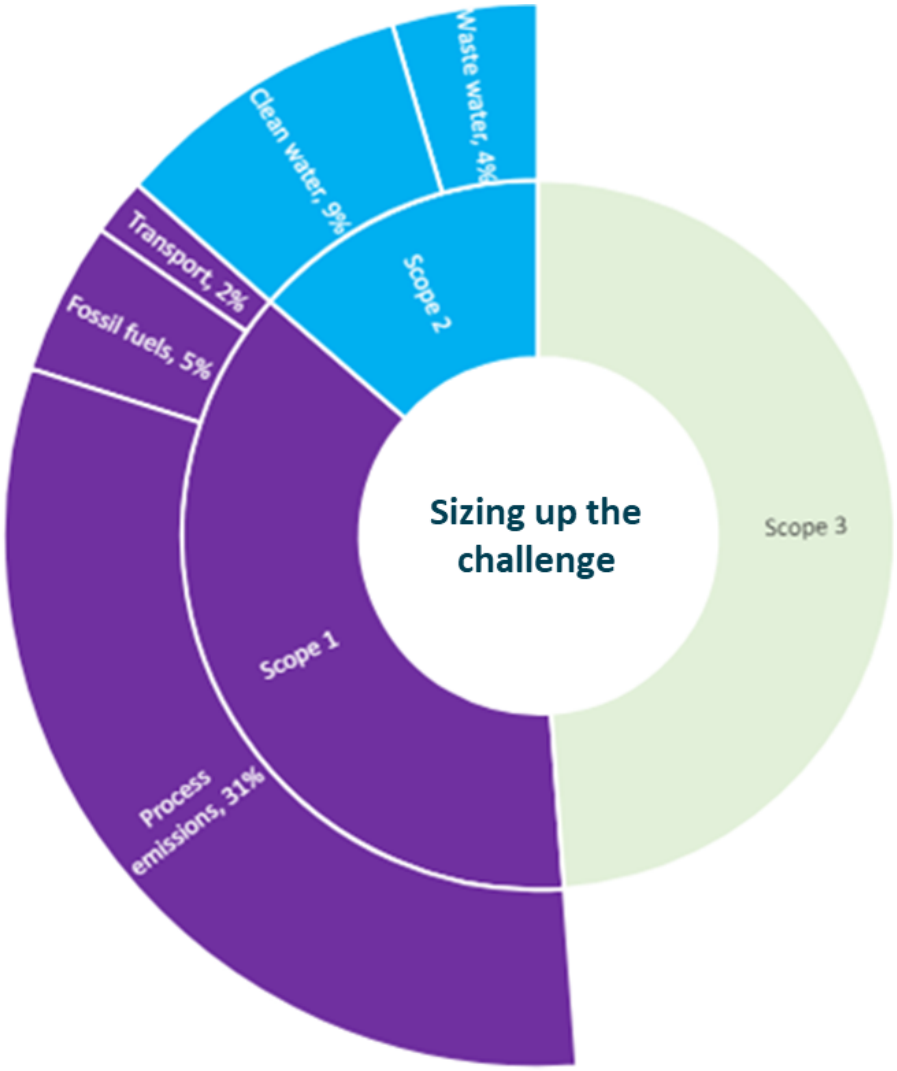
Protecting our environment

Launch of our Green Recovery programme in 2021
target of 58,000m³ of blue-green infrastructure for surface water storage

Launch of our Great Big Nature Boost
exceeding our 2020 targets to enhance the biodiversity of 5,000 ha of land, and restore 2,000 acres of peatland in England and Wales by 2025

River pledges
delivering against our pledges announced in March 2022, including support for farmers, better data and reduced CSO discharges, alongside nature-based solutions

Expansion of our catchment management programme
923 STEPS grants awarded to date



CARBON PLEDGES AND NET ZERO HUB

The following outlines performance against our existing targets and highlights of the last year's activities, see pages 60 to 62 and our dedicated Sustainability Report online for more information

OUR TRIPLE CARBON PLEDGE

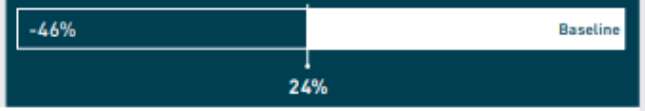
Net zero

operational carbon emissions Scope 1 and 2 across our business by 2030 **(offsets included)** from a 2019/20 baseline

OUR SCIENCE-BASED TARGETS

46% reduction

in Scope 1 and Scope 2 emissions by 2031 from a 2019/20 baseline



- Improving our data, particularly in monitoring actual process emissions
- Investing in national and international partnerships
- Working on a portfolio of innovations to test individual technologies and designing plans for a world's first Net Zero hub at a waste water treatment site to trial and test technologies that minimise our operational emissions
- Stepping up our operational focus on energy use, using energy more flexibly and promoting behavioural change to reduce wasted energy
- Building net zero into our business plans for the next regulatory cycle
- Investing further in peatland restoration and tree planting

NET ZERO HUB AT STRONGFORD

WATCH OUR VIDEO

Scan or click to read more

Process emissions contribute significantly to our reduction challenge, accounting for around 83% of operational emissions. We aim to convert a large number of our sites to low carbon works, necessitating scale deployment of new technologies and alternative processes to reduce our process emissions. Our first pilot project in this area is to deliver a Net Zero hub at Strongford, working in partnership with others in the UK and internationally. Proving the value of this concept now will provide the basis for wider roll-out across our region in coming years.

BACKGROUND ON SEVERN TRENT SITES

- Minworth has been generating renewable biogas from sewage sludge for 60 years and was first in the UK to upgrade biogas and inject into the natural gas network.

- Severn Trent currently generates and self supplies 53% of our energy consumption. Our climate change commitments specifically outline increasing energy from renewables and improving energy efficiency as priority activities. Finding and fixing leaks is part of this.

- Drone-based LDAR is helpful but doesn't quantify emissions, which is needed to make larger investment decisions (support business cases internally, or shape long term business plans with our regulator OFWAT). This is one of the key reasons this type of continuous monitoring is important.

- Deployment of QLM's emissions quantification solution is part of Severn Trent's Triple Pledge to achieve net zero carbon emissions by 2030


Minworth STW

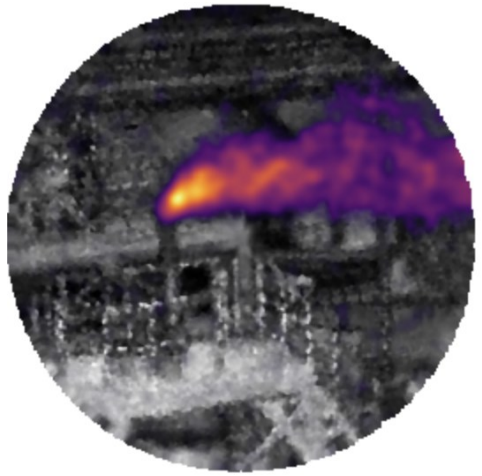

Wanlip STW

ST Classification: OFFICIAL COMMERCIAL

CASE STUDY: BIOGAS UPGRADING PLANT

- QLM's first deployment at Minworth quickly revealed significant emissions from the biogas upgrading plant.
- The biogas cleaning process involves:
  - Biogas passes through media, removing unwanted VOCs & H_2S before injection into the gas grid
  - 3 vessels containing adsorption media (2 on at a time while 3rd recharges)
  - Media used for this has proven less than optimal, so media must be recharged often (~every 10 mins)
  - Under normal operation, during the recharge process, biogas in the vessel is returned to the inlet of the upgrading plant before final blowdown to atmosphere
  - However, due to the frequency of recharges and short time window this process is disturbed and some of the trapped biogas is vented to atmosphere through the safety mechanism
- Current solution being worked on – the site team are working with the manufacturer to trial a different media type. If successful, then it would take more time before it gets saturated (30 vs. 10 min). This will help bring down emissions significantly by reducing venting whilst also increasing the amount of biogas returned to the front of the process.
- Whilst gathering data we noticed a period when the emissions stopped for several hours. This got us really excited but turns out the biogas upgrading plant was just turned off for some maintenance.
- Either way this shows the usefulness of QLM's continuous methane quantification. We now know that once leaks are fixed the QLM system will provide us evidence to bank the benefits.

Plume from biogas plant venting: ~20 kg/h



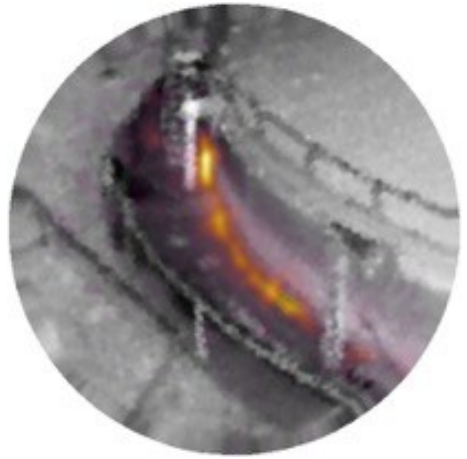
Biogas plant vessels

ST Classification: OFFICIAL COMMERCIAL

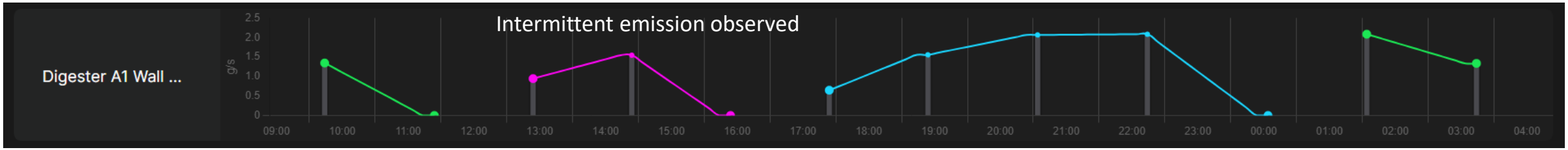
CASE STUDY: FLOATING ROOF DIGESTERS

- A short-duration trial at Finham STW (Coventry) and the deployment at Minworth STW, confirmed what was suspected about the methane emissions from the sludge seals on a legacy asset known as a floating roof digester.
- This has not been a standard digester design for decades, however we still have several of the assets within the business.
- The seal around the base of the anaerobic digester tank is supported by the sludge to be digested. This has benefits when it comes to the simplicity of design and balancing sludge levels, but has a downside in terms of emissions of methane.
- Continuous monitoring is able to:
  - Confirm methane emissions do occur from sludge seal
  - Quantify and track the continued nature of the emission
  - Build understanding of how any variation in emission rate may be affected by changes in the digester process
- At Minworth STW, a programme to replace the roofs is underway and we are able toalso monitor the newly fixed roofs and confirm the solution's emission benefits
- This allows Severn Trent to understand the benefits to emissions in upgrading our floating roof digesters to fixed roofs, support investment decisions across all these assets

Methane emission around sludge seal



Floating Roof Digester



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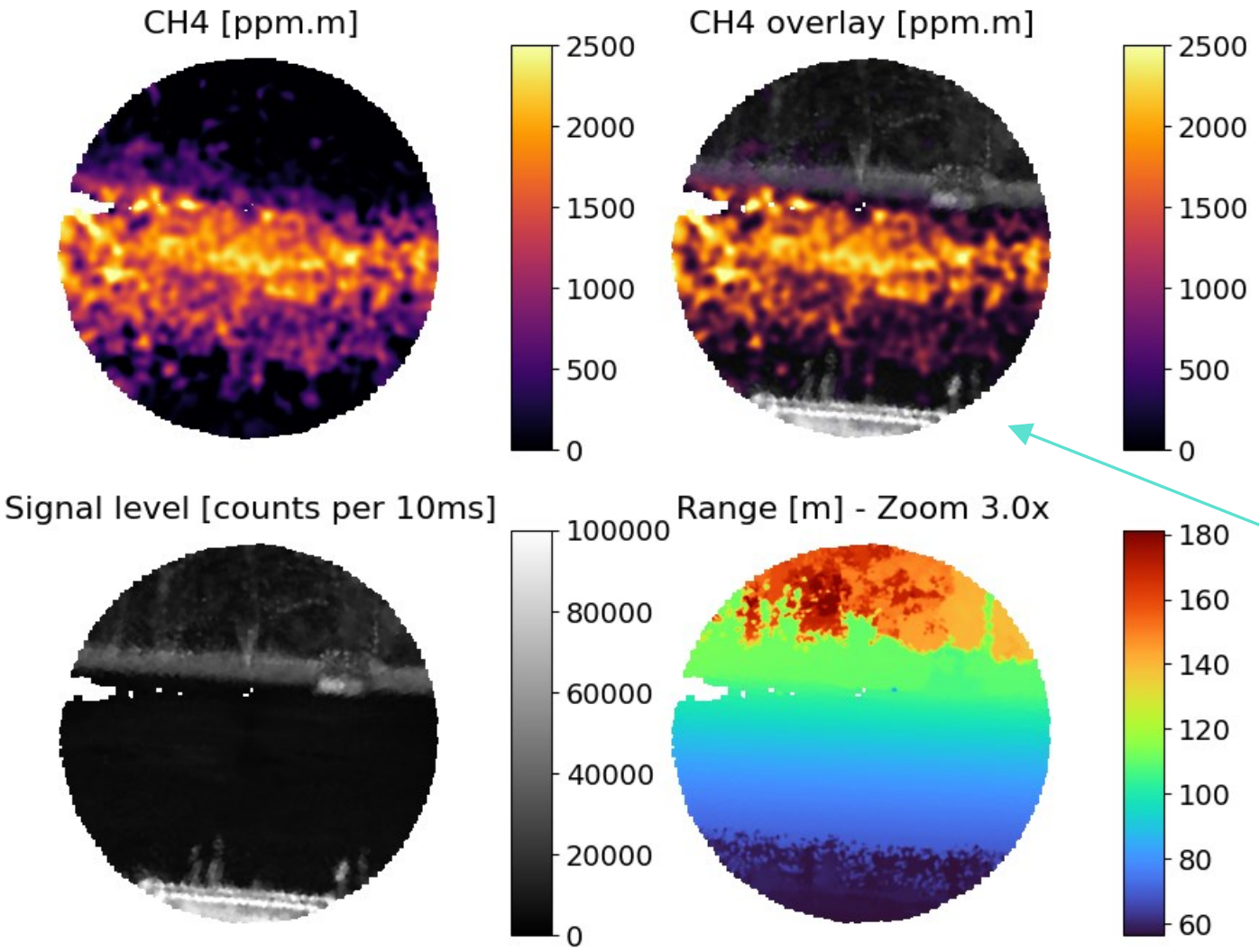
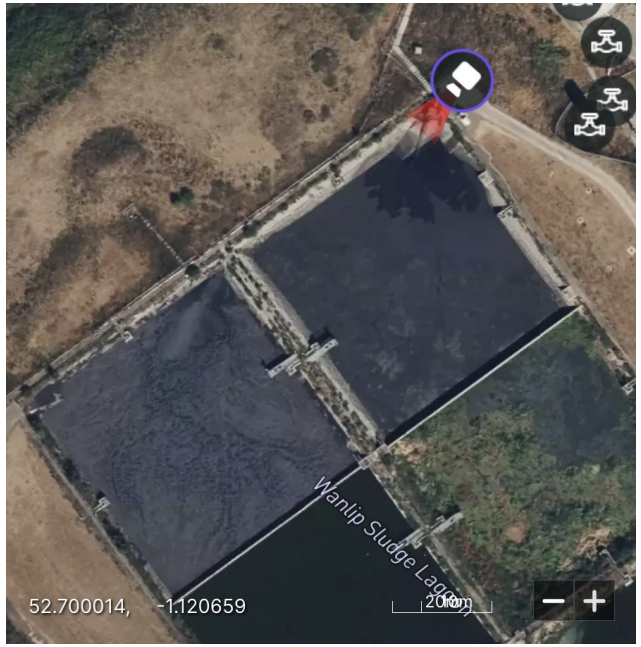
WANLIP SLUDGE LAGOON EMISSIONS

- Methane quantification over a section of one of the sludge lagoons
- Measured flow rate: 7 kg/h





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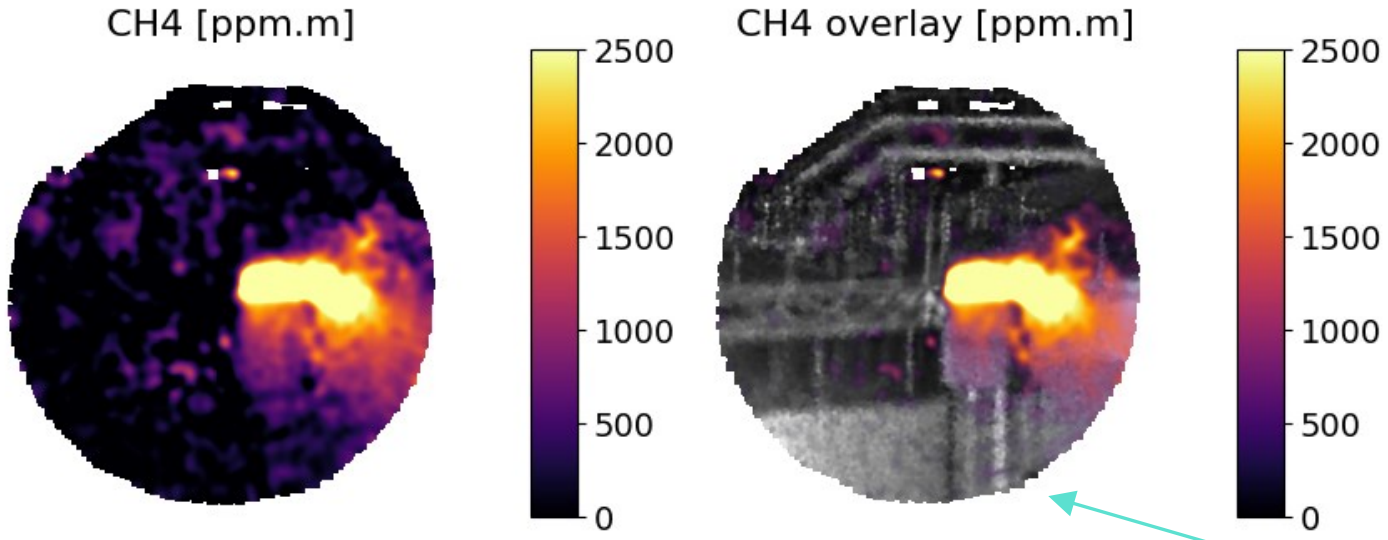
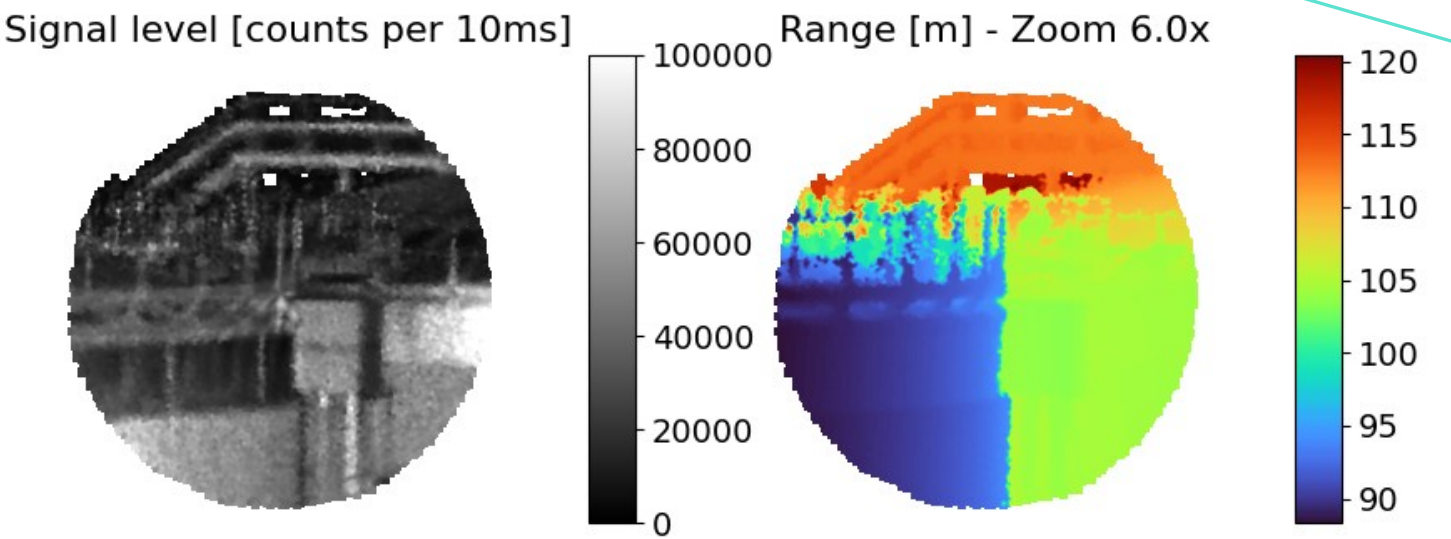
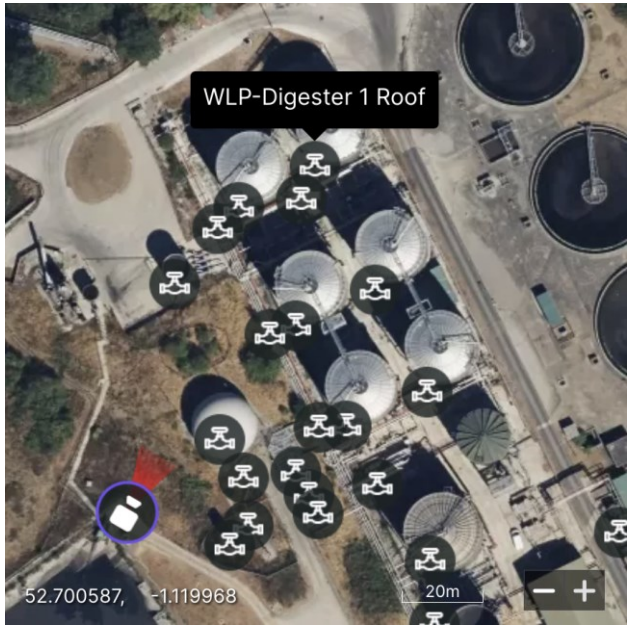
WANLIP DIGESTER EMISSIONS

- Emission detected and localized to roof of digester tank
- Measured flow rate: 0.4 kg/h







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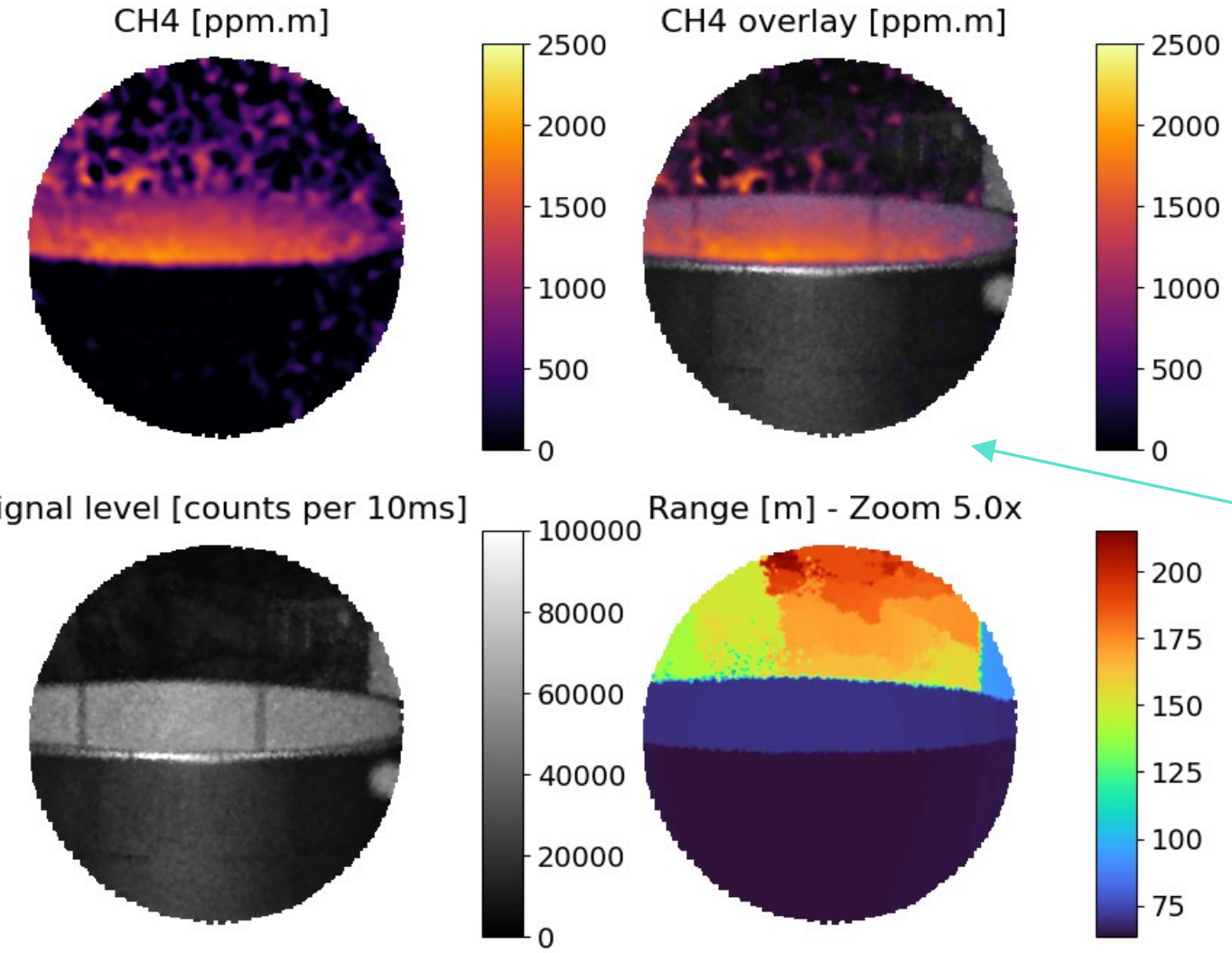
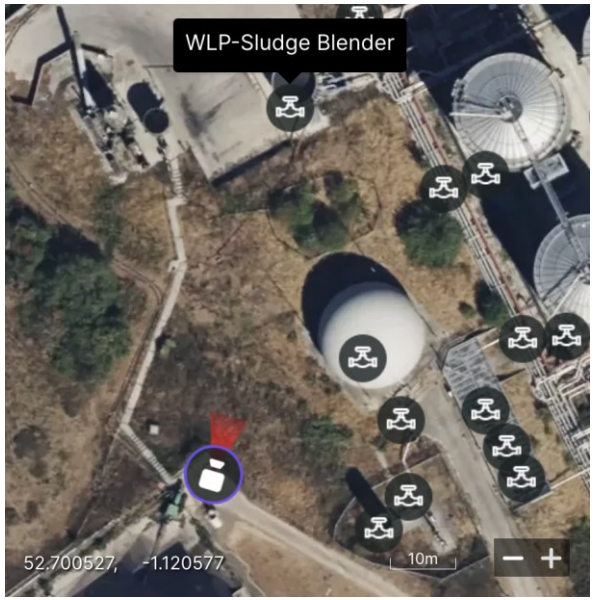
WANLIP SLUDGE PROCESS EMISSION

- Emission detected and localized to sludge holding tank
- Measured flow rate: 2 kg/h





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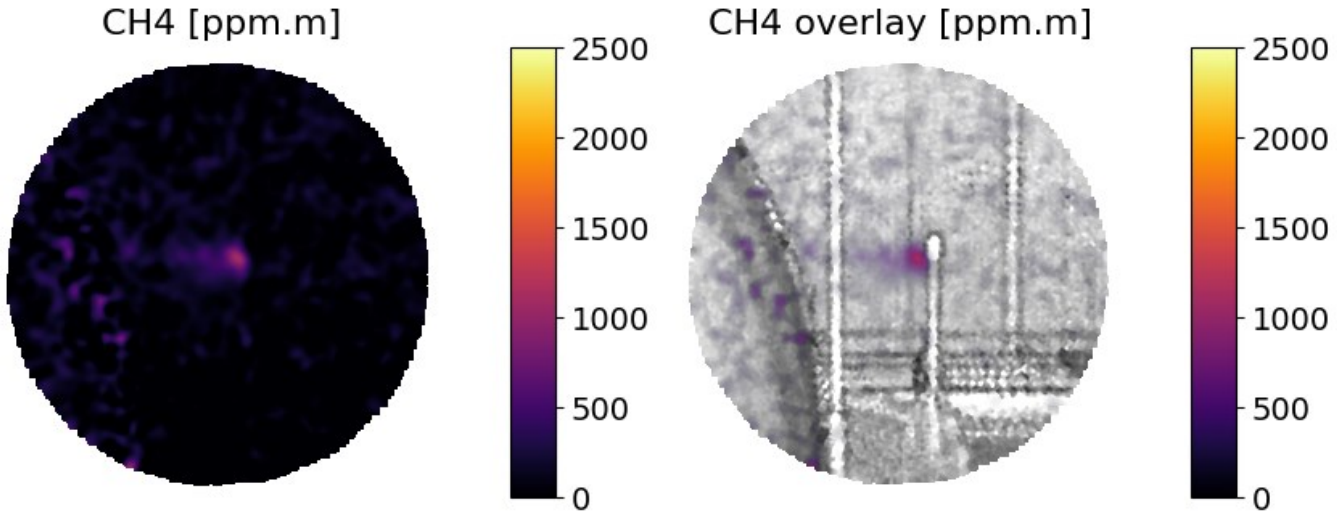
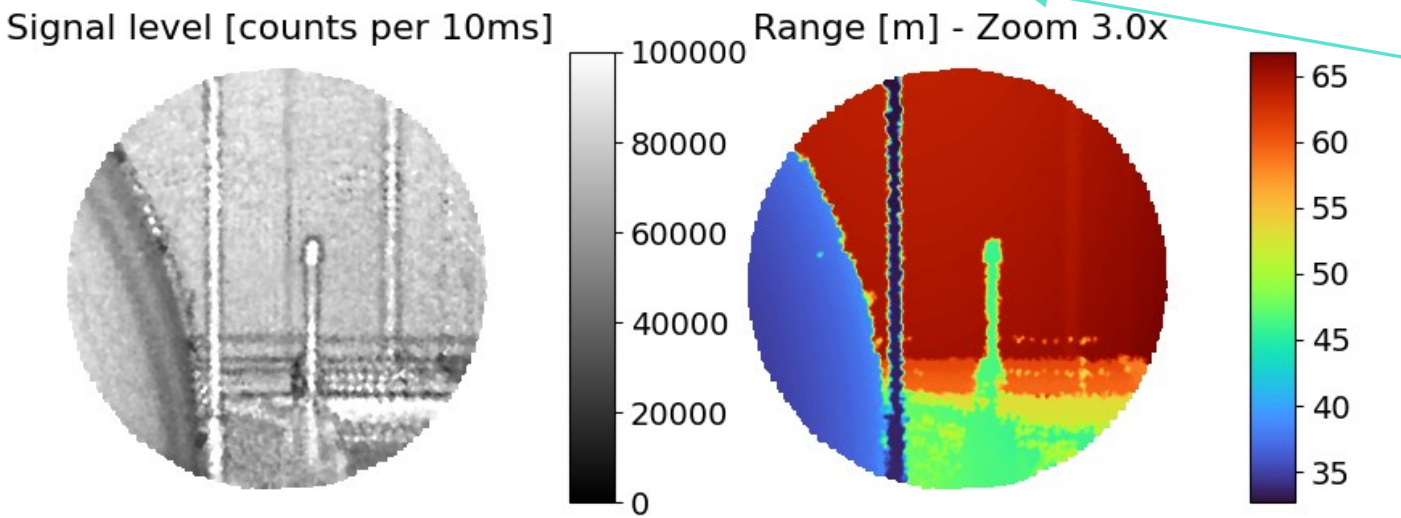
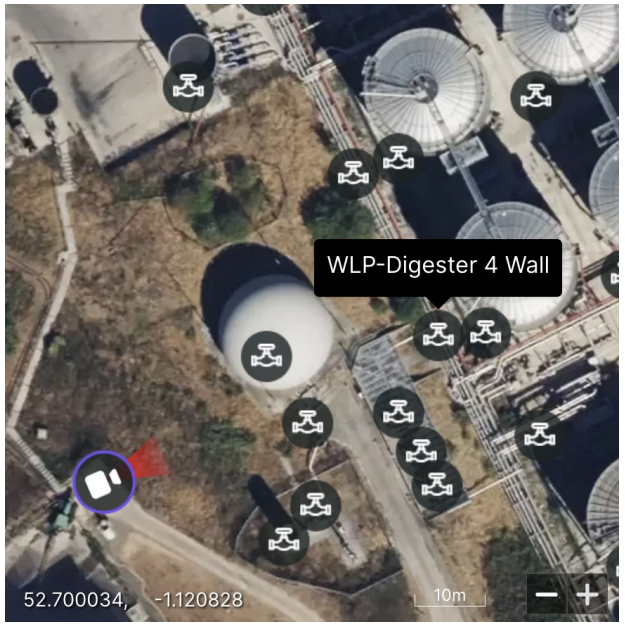
WANLIP PRV EMISSION

- Emission detected and localized to a pressure relief valve in the gas processing area
- Measured flow rate: 0.3 kg/h







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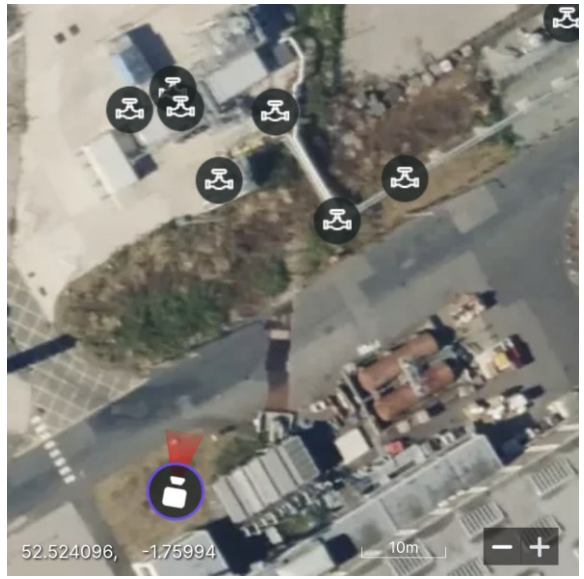
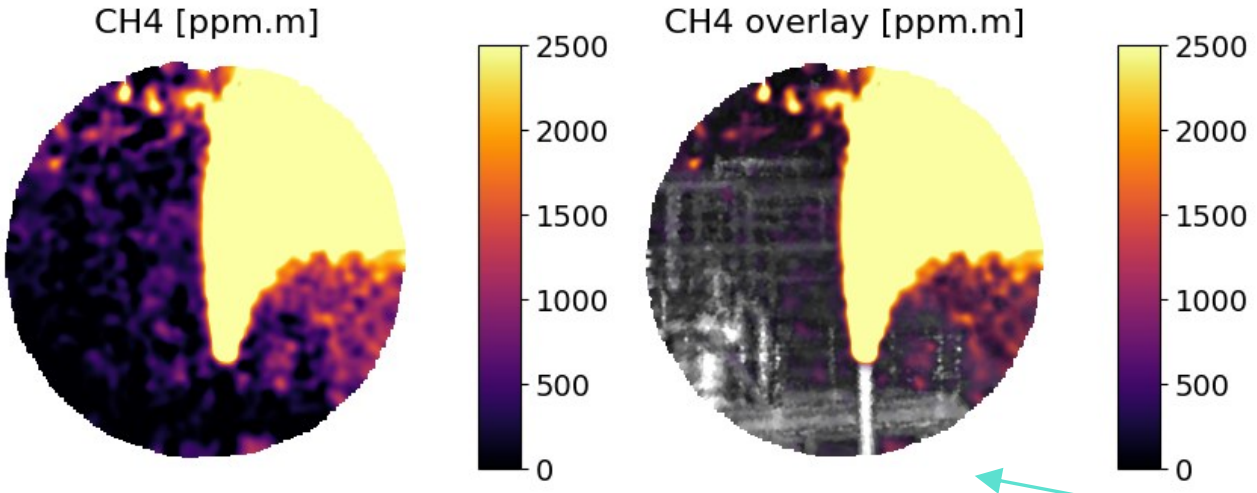
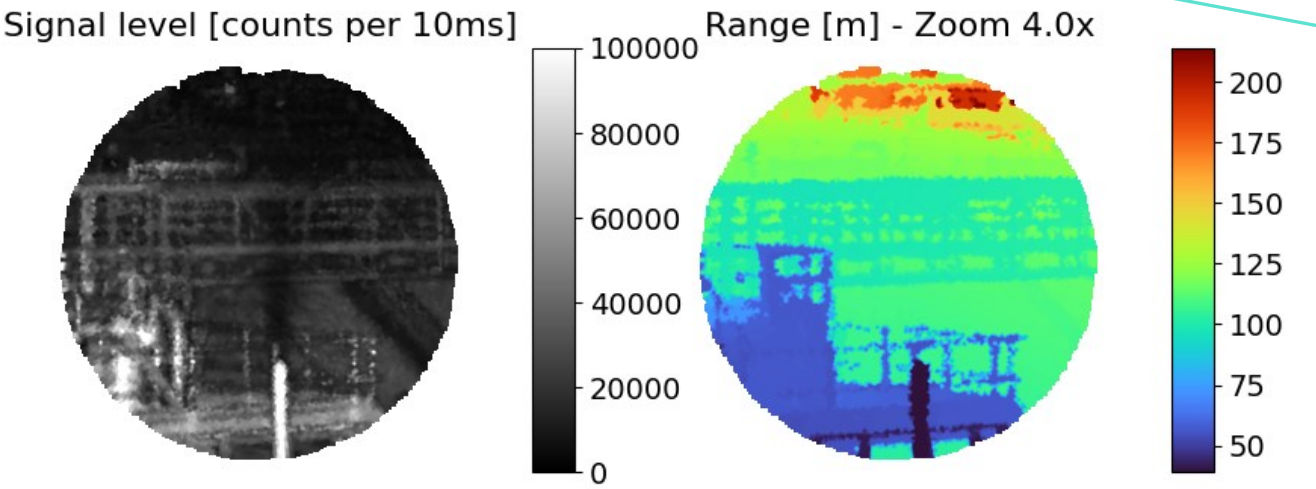
MINWORTH BIOGAS VENT EMISSION

- Emission detected and localized to a venting from the biogas upgrading process
- Measured flow rate: 245 kg/h







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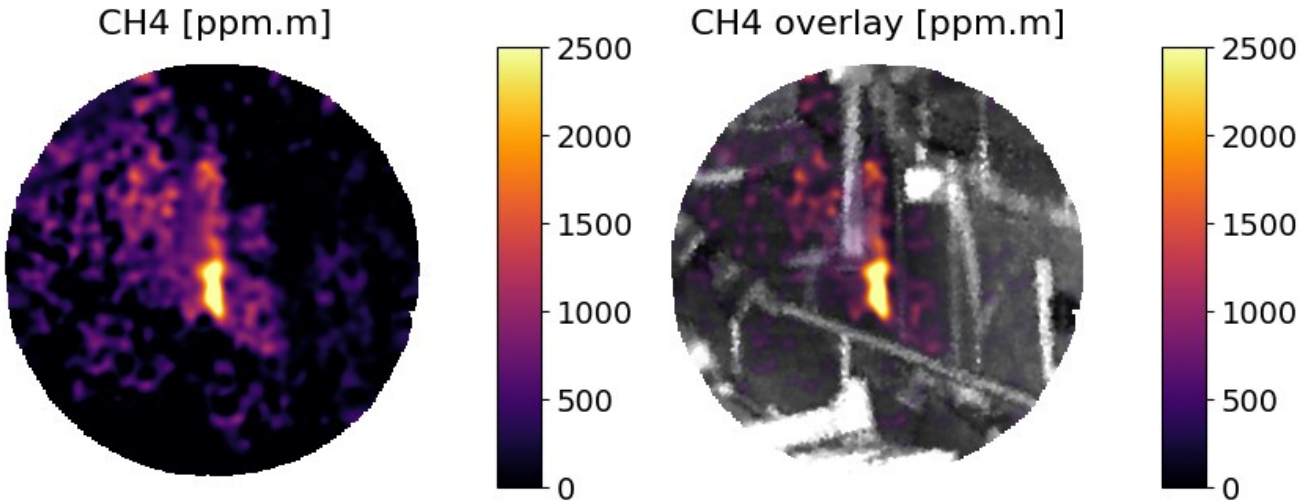
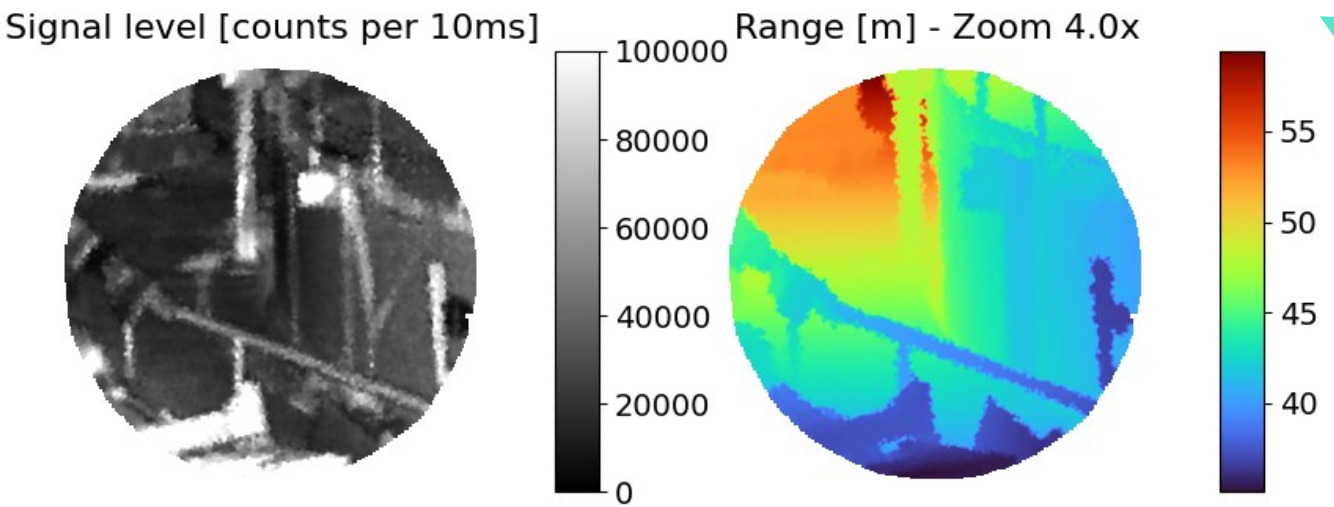
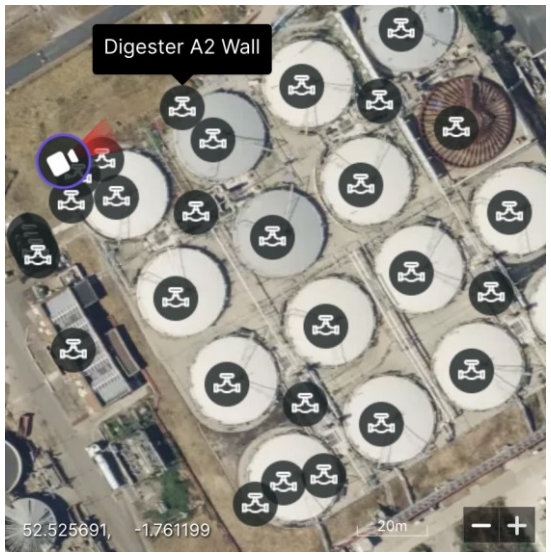
MINWORTH EMISSION

- Emission detected and localized to
- Measured flow rate: 11.5 kg/h







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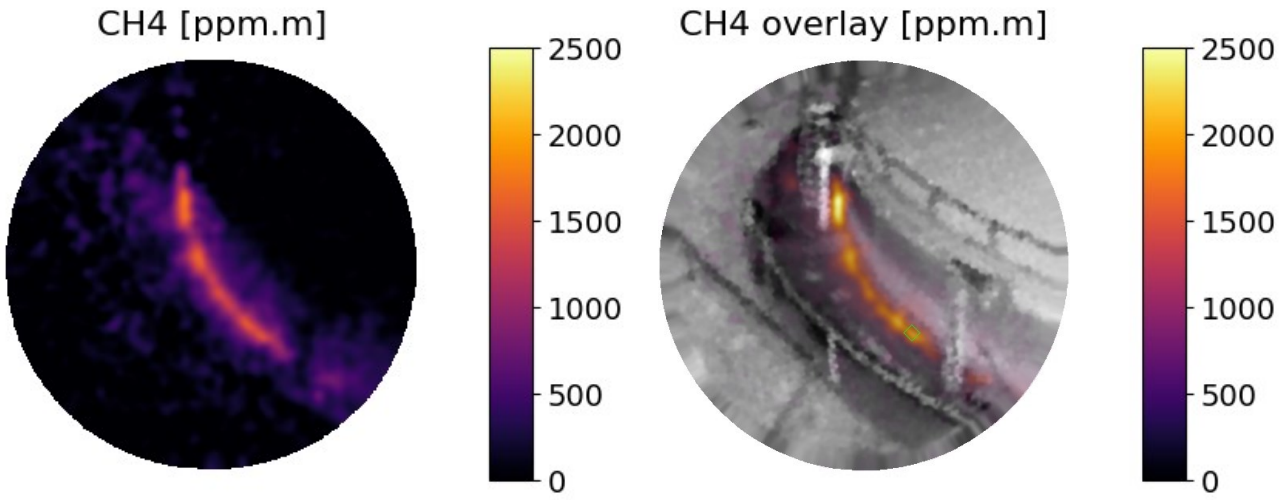
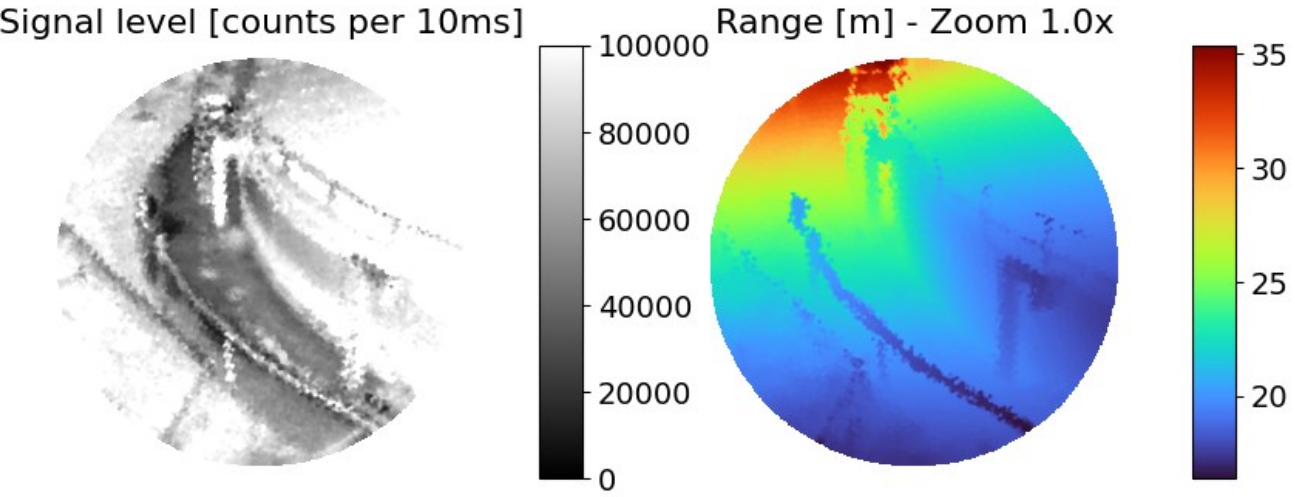
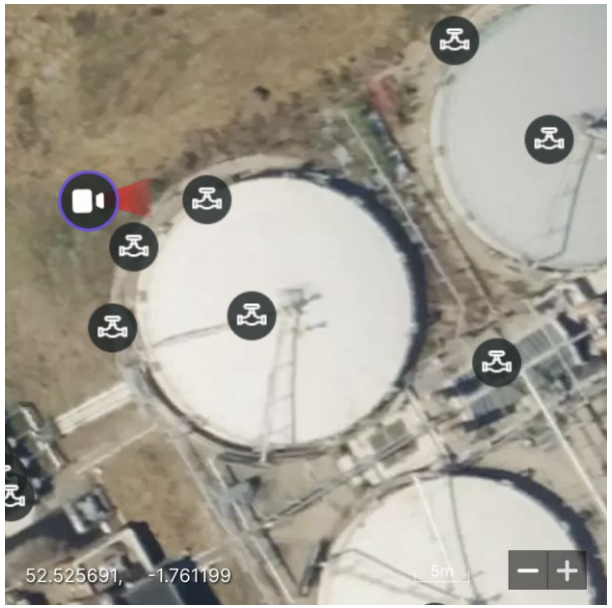
MINWORTH DIGESTER EMISSION

- Emission detected and localized to sludge digester wall
- Measured flow rate: 18.6 kg/h







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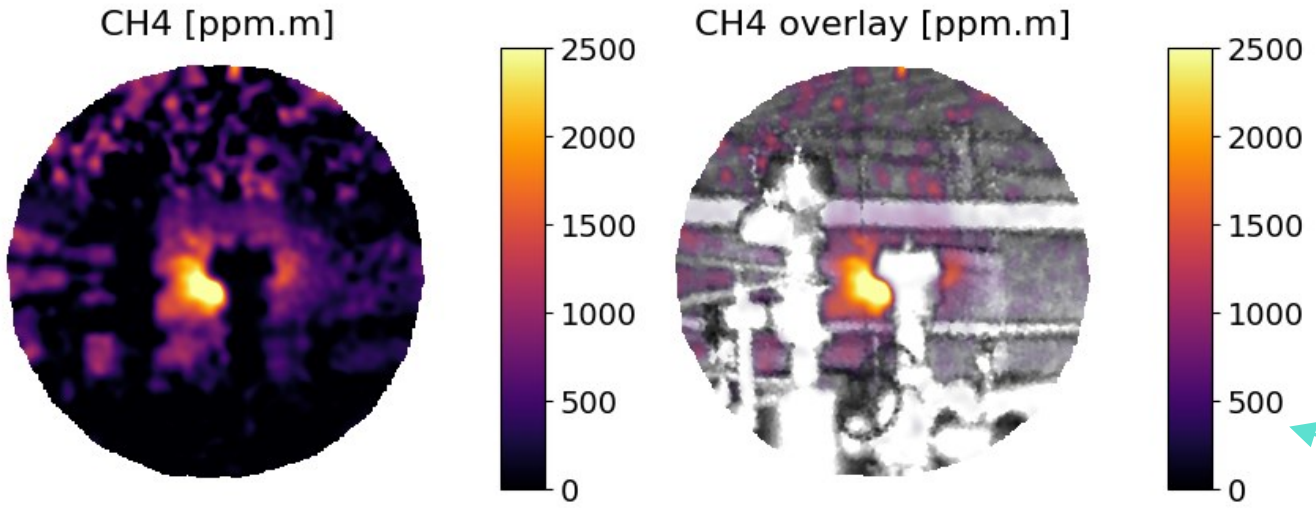
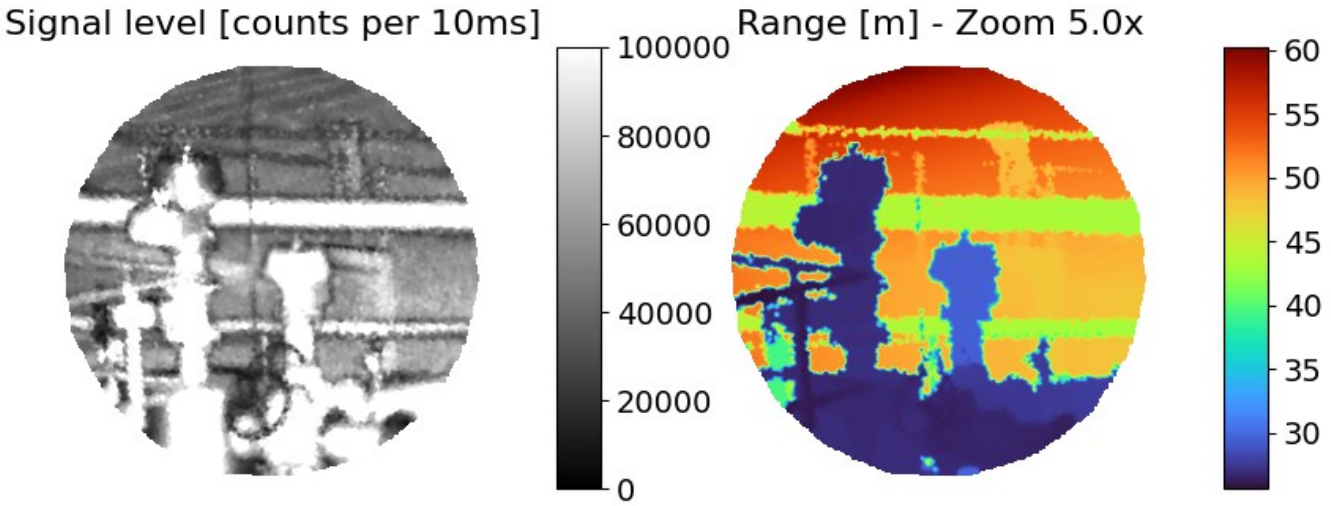
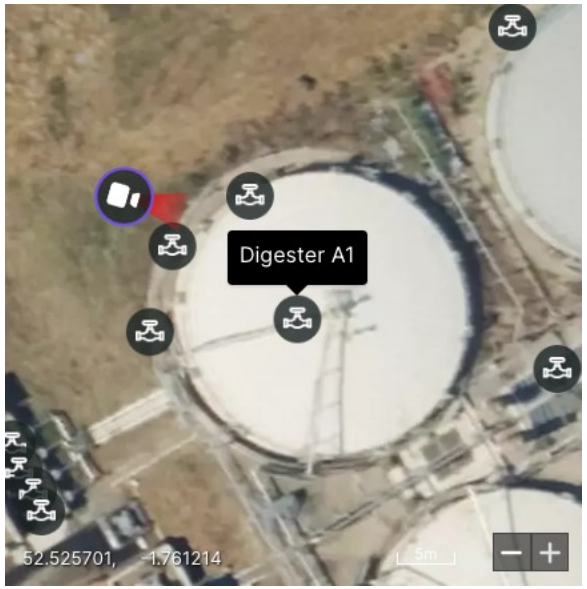
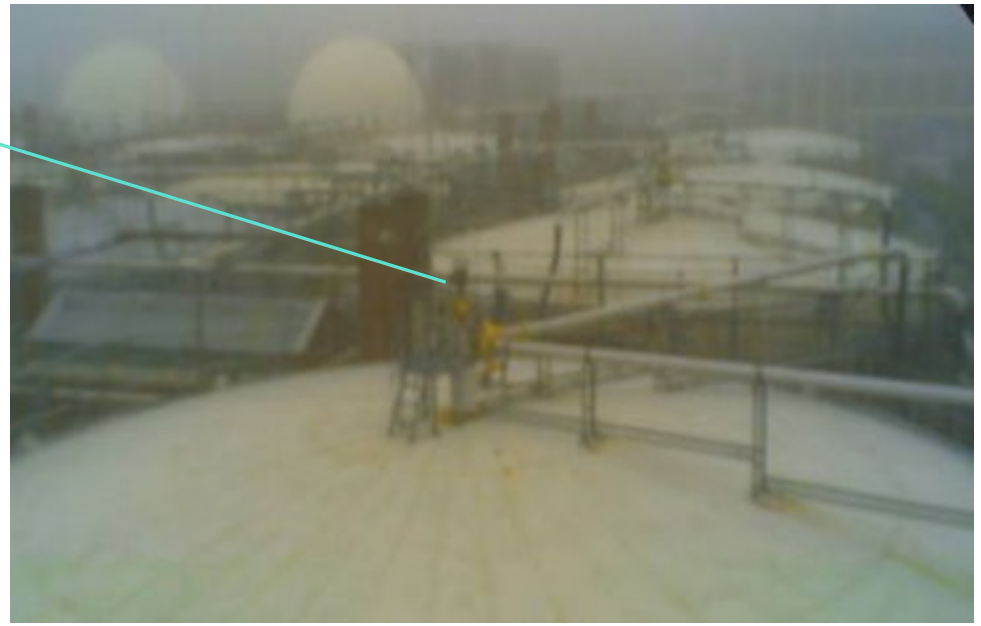
MINWORTH DIGESTER EMISSION

- Emission detected and localized to Whessoe valve on digester roof
- Measured flow rate: 0.8 kg/h





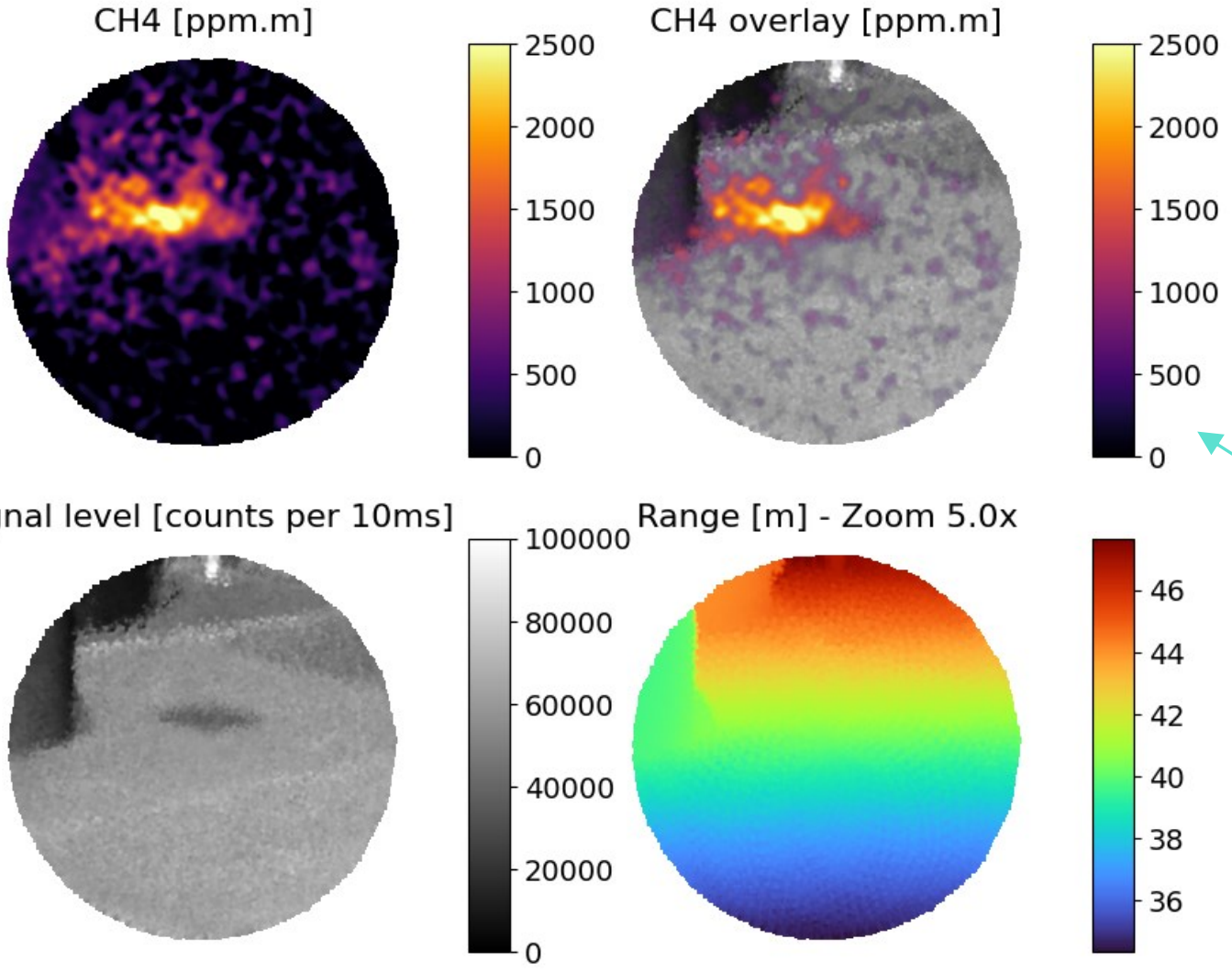


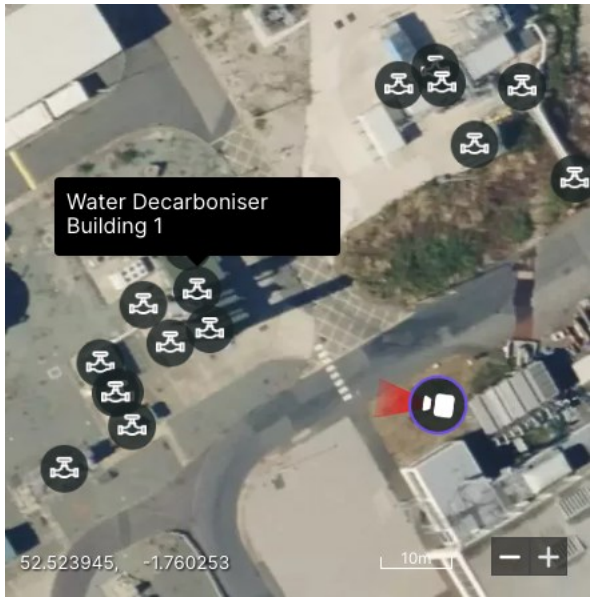


ST Classification: OFFICIAL COMMERCIAL

MINWORTH PIPEWORK EMISSION

- Emission detected and localized to subsurface pipework near decarbonizer
- Measured flow rate: 0.7 kg/h

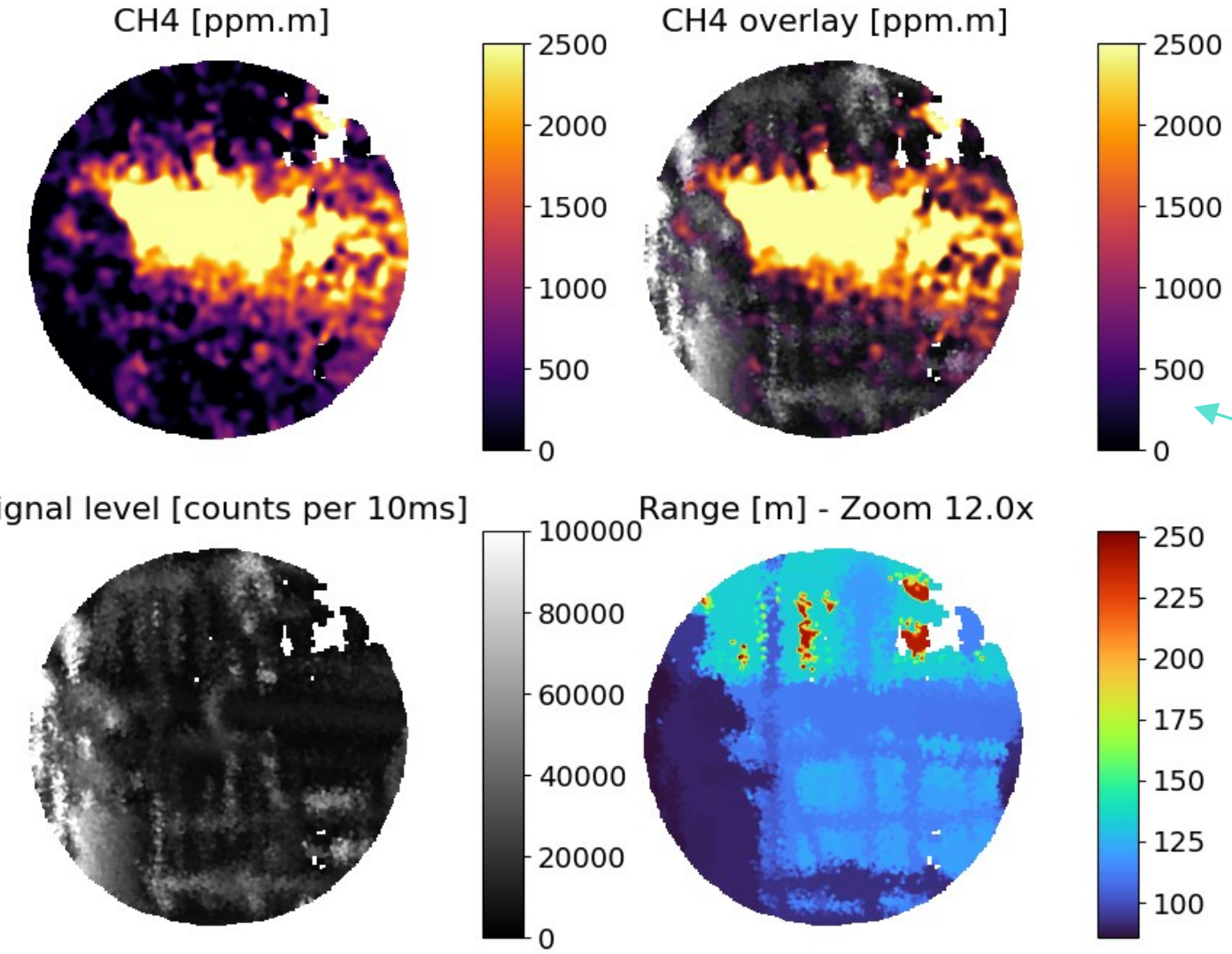


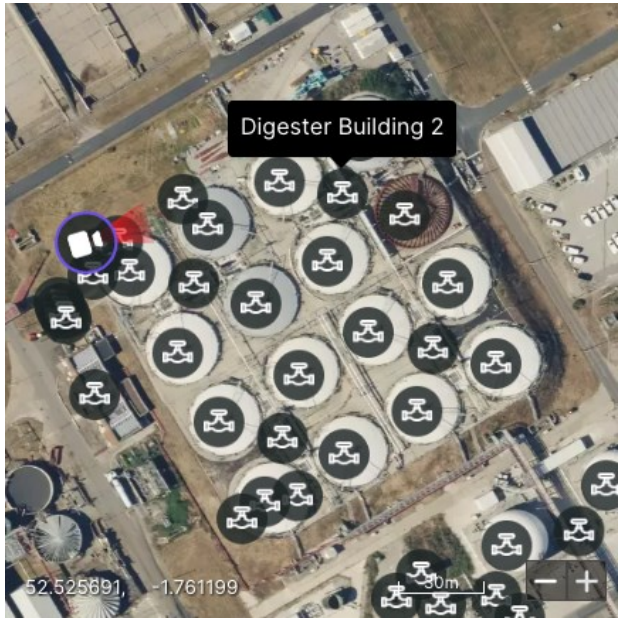


ST Classification: OFFICIAL COMMERCIAL

MINWORTH DIGESTER EMISSION

- Emission detected and localized to sludge digester
- Measured flow rate: 5.7 kg/h

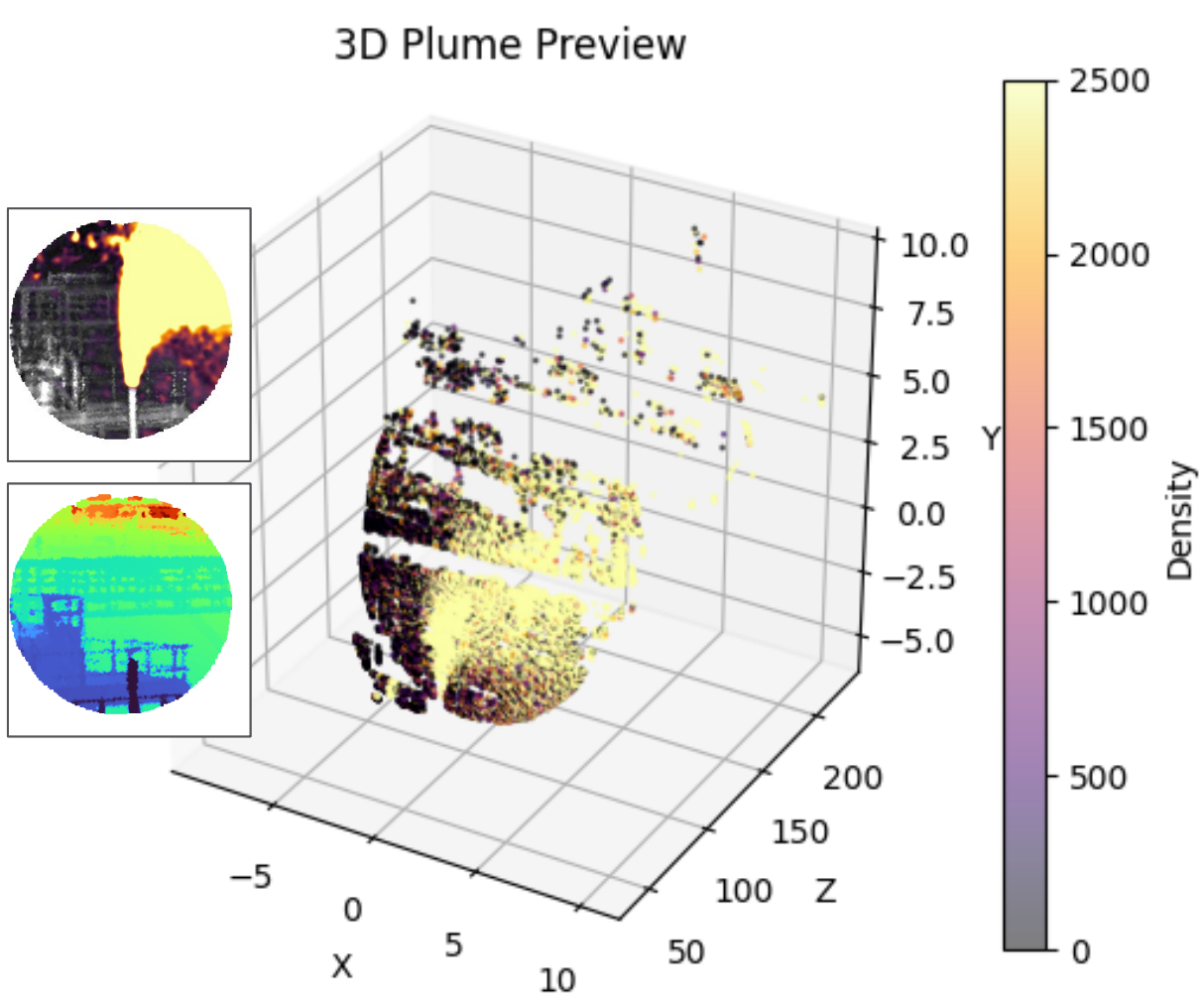


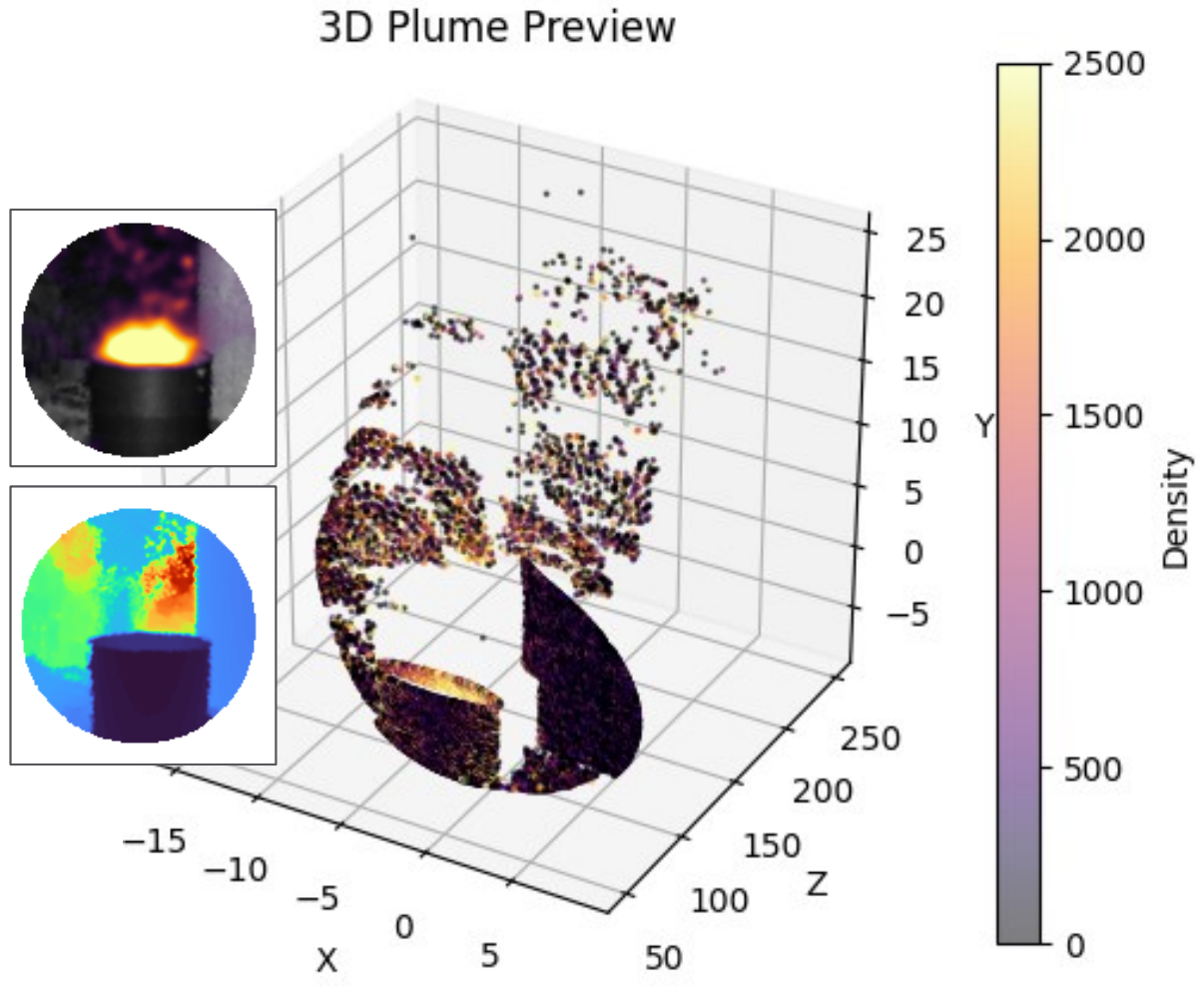


ST Classification: OFFICIAL COMMERCIAL

3D LIDAR POINT CLOUD EXAMPLE

- QLM lidar measures in 3 dimensions
- 3D capability of lidar enables extremely accurate plume size measurement and therefore high quantification accuracy



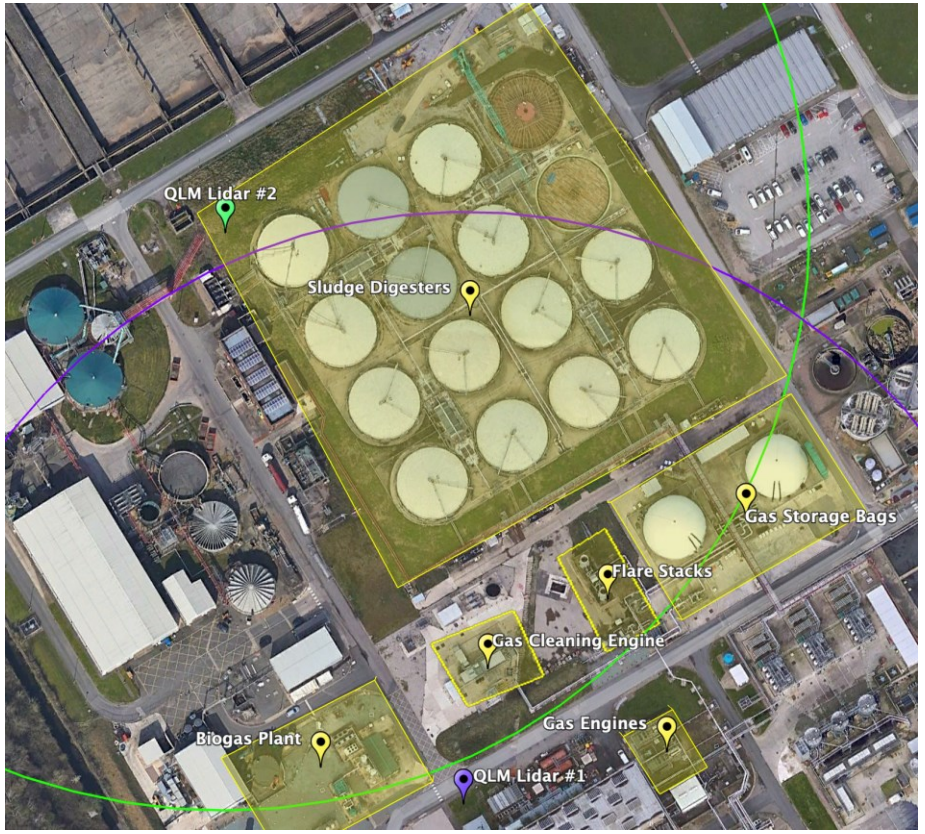


ST Classification: OFFICIAL COMMERCIAL

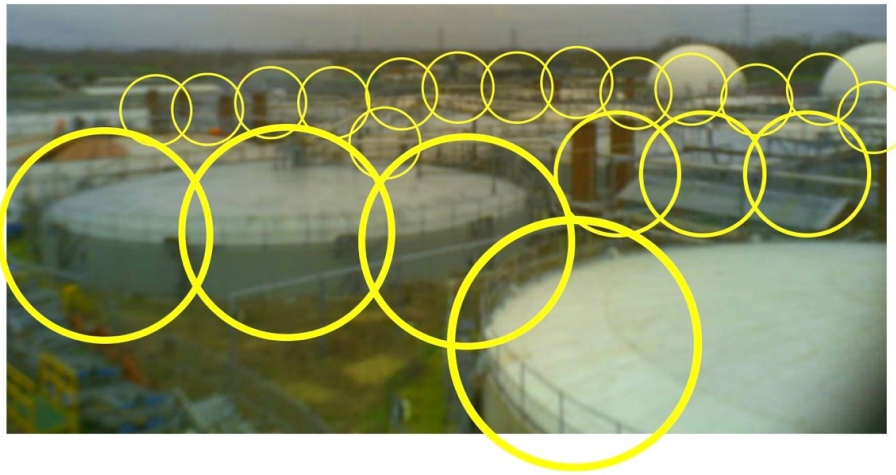
SITE COVERAGE DETAILS

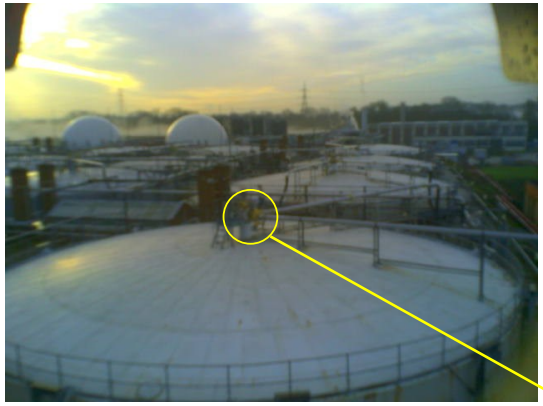
Visible images from QLM 1 & QLM 2 lidars as deployed showing views of the infrastructure being monitored.

Locations of two QLM deployments at Minworth STW. Maximum coverage radius shown for each system (purple, green circles). Key areas of interest shown shaded in yellow.

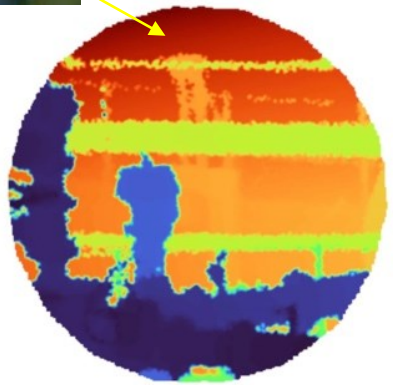


Conceptual tiling of lidar frames with different zoom levels across a scene to build up coverage.





Lidar range image of a frame with particularly high zoom and long distance showing the liar's ability to spatially resolve small features of ~10cm in such cases.



ST Classification: OFFICIAL COMMERCIAL

KEY INFORMATION

SEVERN TRENT - MINWORTH SEWAGE AND SLUDGE TREATMENT FACILITY

Key information	Severn Trent - Minworth Sewage and sludge treatment facility
Size of facilities	PE: 1,852,391 TDS: 78861
WWTP loading	15:25:3 BOD:SS:NH_3-N 1 mg/l total phosphorous DWF: 450,000 FFT: 12,400
Wastewater treatment process (WWTP)	
Type of process	Wastewater ASP – P removal achieved by EBPR using University of Cape Town configuration.
Number of lines/ zones/ zone size	7 ASPs lanes. Operates at BOD and ammonia F:M ratios of 0.083 kgBOD/kgMLSS/d and 0.023 kgNH_3-N/kgMLSS/d respectively with a sludge age >12 days. Nominal total hydraulic retention time through ASPs is 15.4 hours and 8.1 hours at average and maximum flow respectively.
Sludge treatment centers (STCs)	
Sludge treatment – process	Advanced anaerobic digestion (12 digesters using THP) and 4 digesters AD.
Biogas treatment and utilization	Combined heat and power Upgrading and biomethane to grid.
Sludge tanks – covering and arrangement	All 16 tanks have floating roofs (currently being replaced)
Liquors management	Sludge liquors treated through Annamox liquor treatment plant (LTP) before being returned to settled sewage

QLM SOLUTION – BACKGROUND INFORMATION

What is Quantum Gas Lidar?

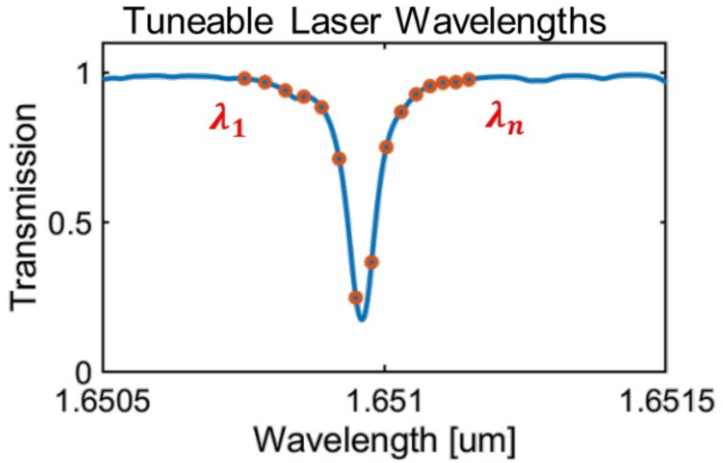
- It is *not* an OGI or passive gas imaging camera
- QLM's technology uses quantum technology & Lidar to detect, localize & quantify GHG emissions
- Developed a new type of Lidar which combines:
  1. Tunable Diode Laser Absorption Spectroscopy (TDLAS)
  2. Differential Absorption Lidar (DIAL)
  3. Time Correlated Single Photon Counting (TCSPC)
- Uses eye-safe infrared semiconductor lasers & single-photon detection ("Geiger counter for light") to count gas molecules in a plume from >200m distance
- Scanning the laser around builds a 3D picture (Lidar point cloud) of objects and gas showing the exact plume location & size

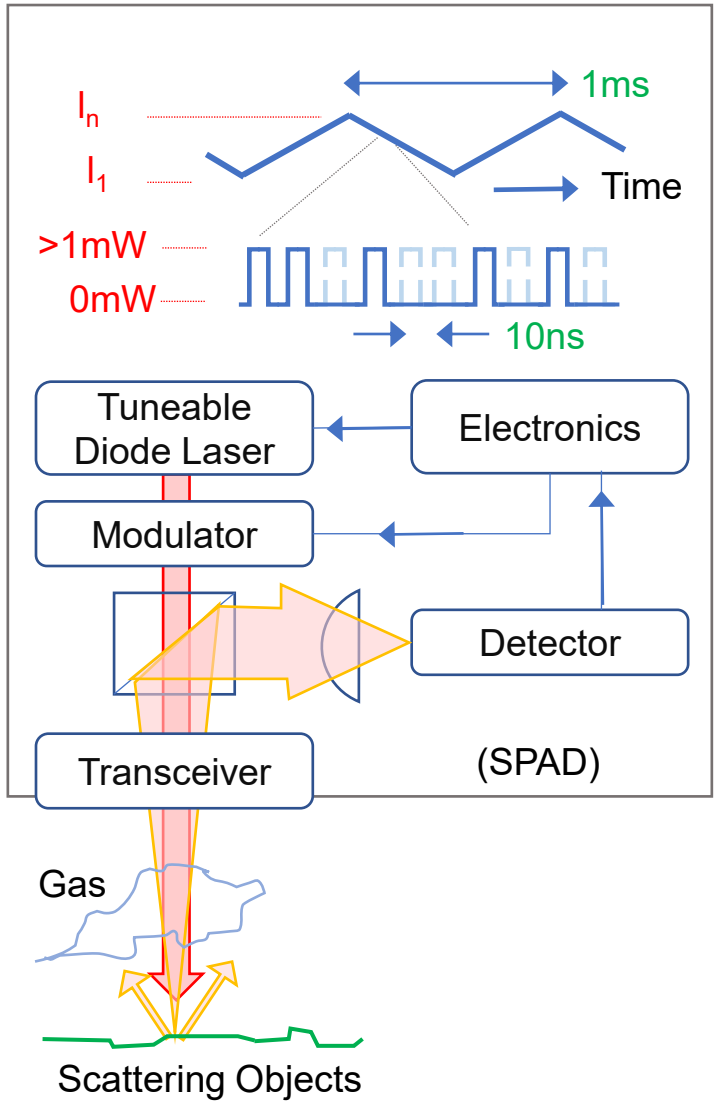
Quantum Gas Lidar – How It Works

Low-power, DFB laser
- continuously tuned in wavelength around 1651nm methane absorption
- rapidly modulated in random code

Projected to remote surface, scattered return detected by SPAD (Single-Photon Avalanche Diode)

Time-correlated signal gives
- distance to scattering surface (m)
- gas concentration pathlength (ppm*m)



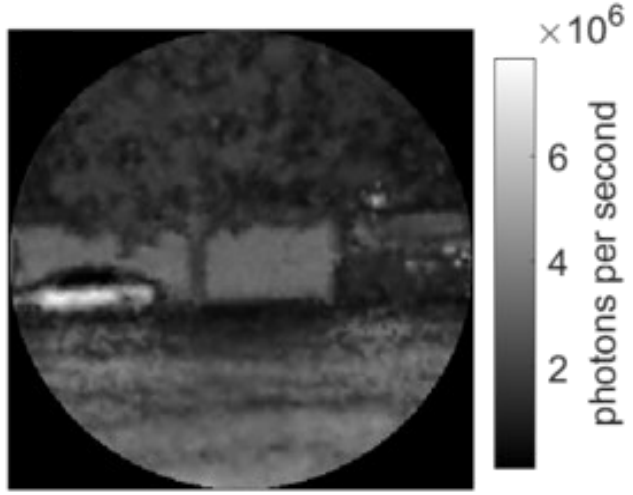


For a detailed description of QLM's Quantum Gas Lidar technology please see:

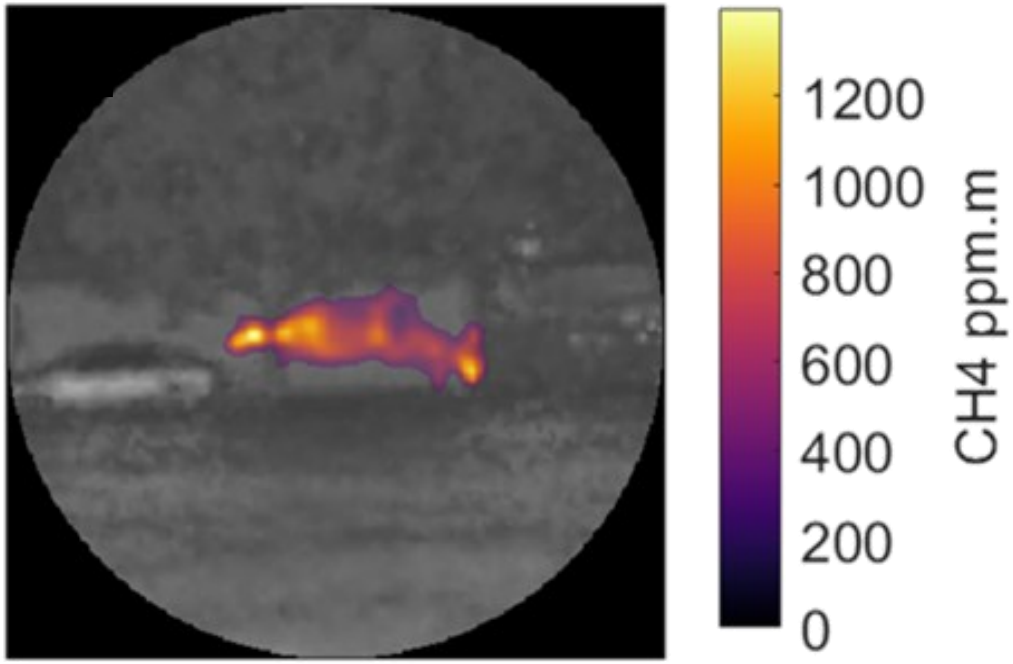
James Titchener, Doug Millington-Smith, Chris Goldsack, George Harrison, Alexander Dunning, Xiao Ai, Murray Reed, "Single photon Lidar gas imagers for practical and widespread continuous methane monitoring," Applied Energy, Volume 306, Part B,2022, 118086, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2021.118086

Lidar Gas Imagery

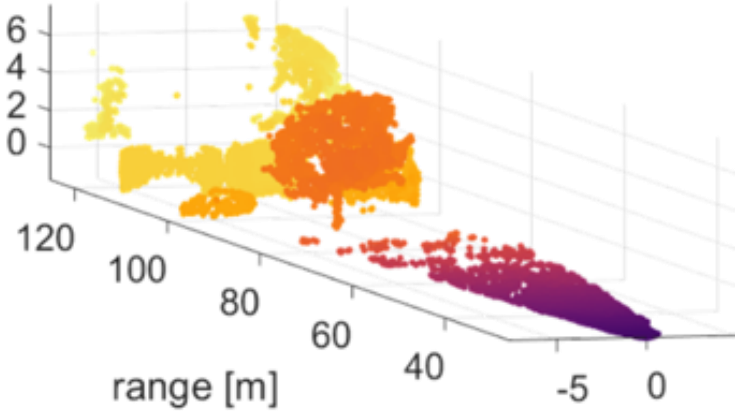
CH_4 concentration path length with background level subtracted & overlaid on the signal level image (90m range)

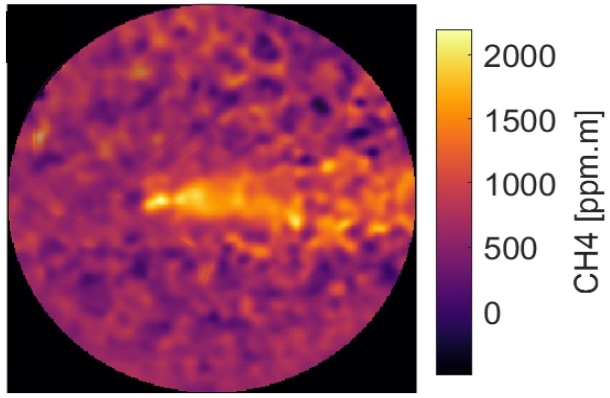


1650nm signal intensity



Lidar distance point cloud

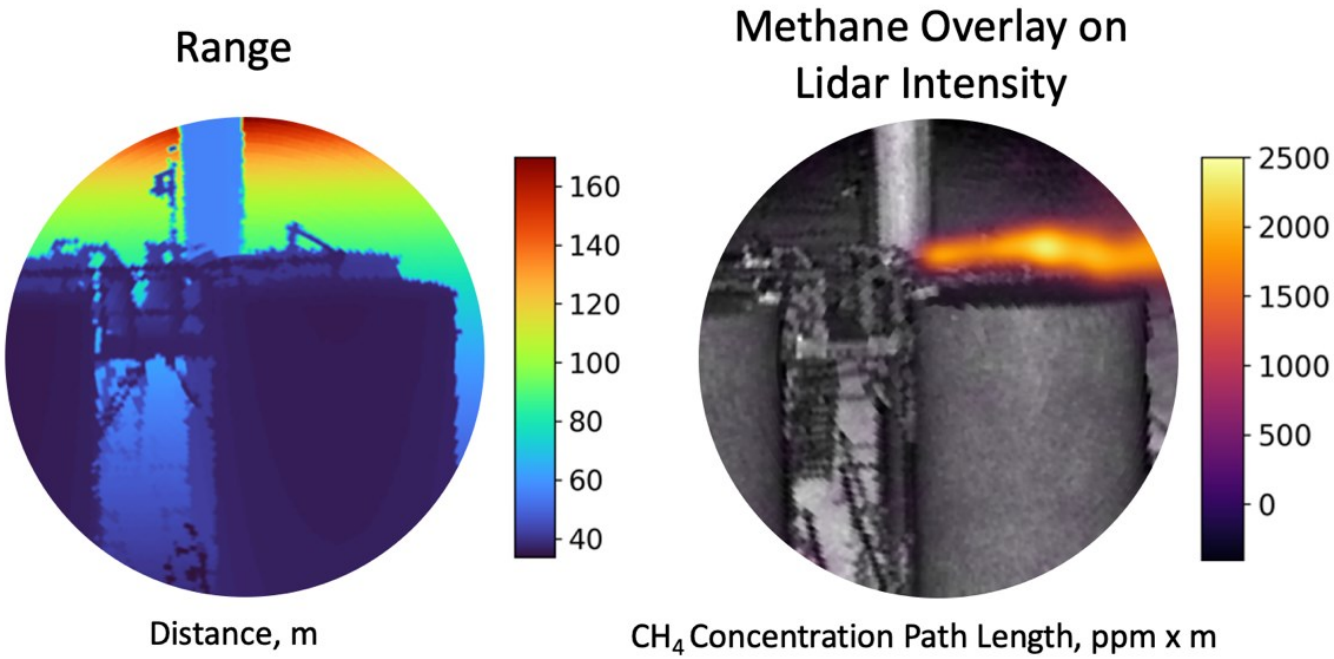




CH_4 concentration path length with internal 600 ppm.m reference gas cell

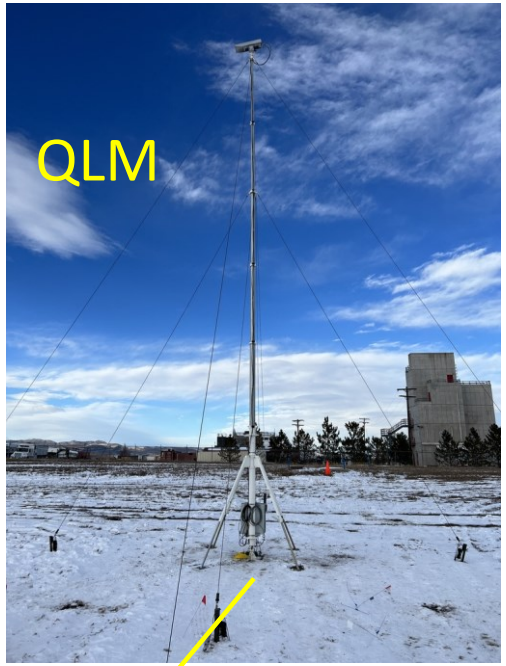
Quantum Gas Lidar vs. Legacy Passive Optical Gas Imaging

- Gas leak visualization & leak localization day or night & in precipitation
- Insensitive to temperatures of objects or interference from sunlight
- Methane specific (no interferences from other gases or water vapor)
- 3D imaging, range, & context imagery using Lidar intensity
- Single-photon sensitivity: long range, low power
- Scalable to very low cost
- Accurate leak quantification



Methods – METEC ADED

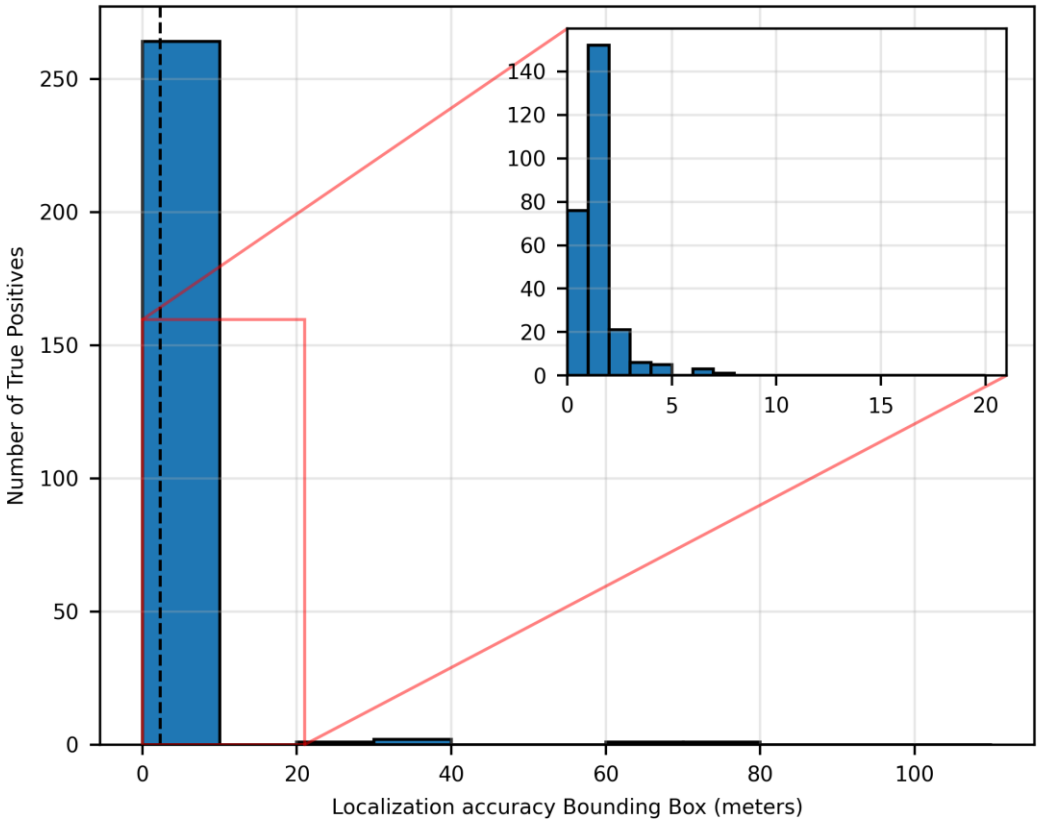
- Test campaign Feb-April 2023
- Performance metrics on blind, controlled-release testing of automated detectors: report where, when & how much is leaking from from 18 different pieces of O&G equipment
- QLM lidar system deployed on a mast
- 577 controlled releases, ranging from 0.175 to 344.0 slpm whole gas of <1 to >10 h in duration
- Meteorology: temperatures from -27° to +27° C, winds 11 km/h avg., gusts >100 km/h, rain, fog, snow



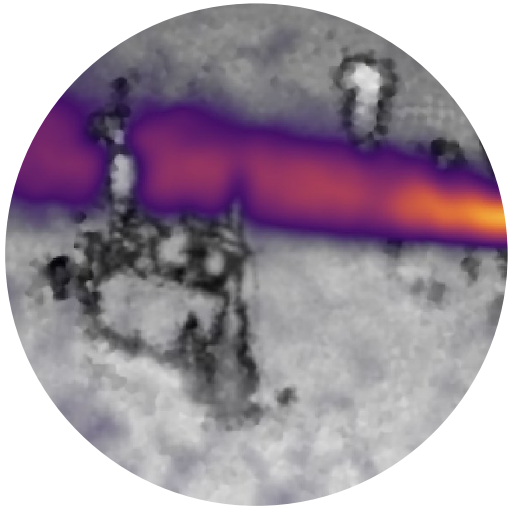
QLM is participant "B" in this study:
Ilonze C, Emerson E, Duggan A, Zimmerle D. "Assessing the progress of the performance of continuous monitoring solutions under single-blind controlled testing protocol." ChemRxiv. 2024; https://doi.org/10.26434/chemrxiv-2023-8bfgm-v2

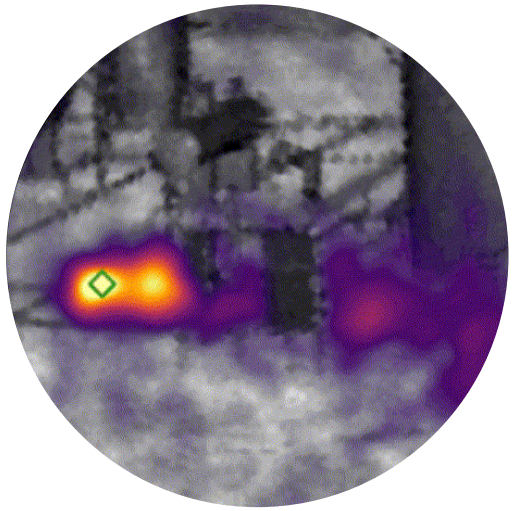
What & Where? – Location Accuracy

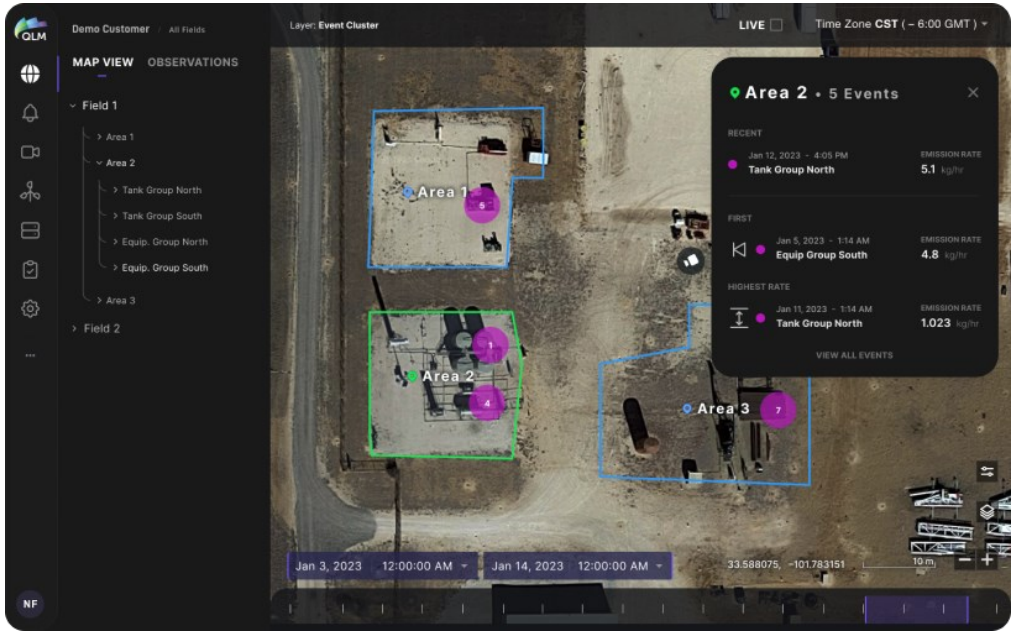
- METEC mean localization accuracy (bounding box) of 2.34 m (QLM)
- Highly accurate location determination due to 3D lidar pinpointing of leak origin



3D context – can see plume behind some objects, in front of others

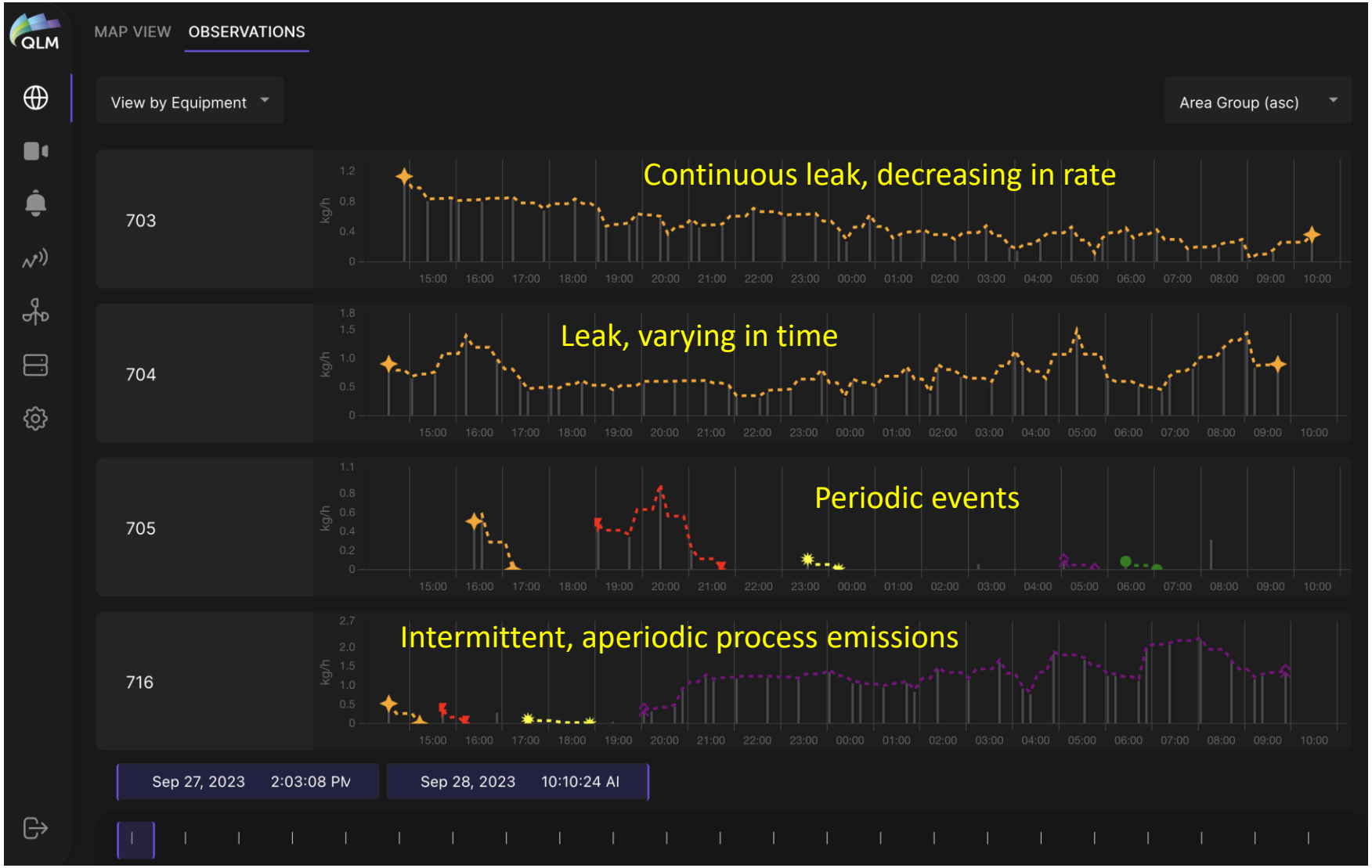






When? (and Why?!) – Time-Series Analysis

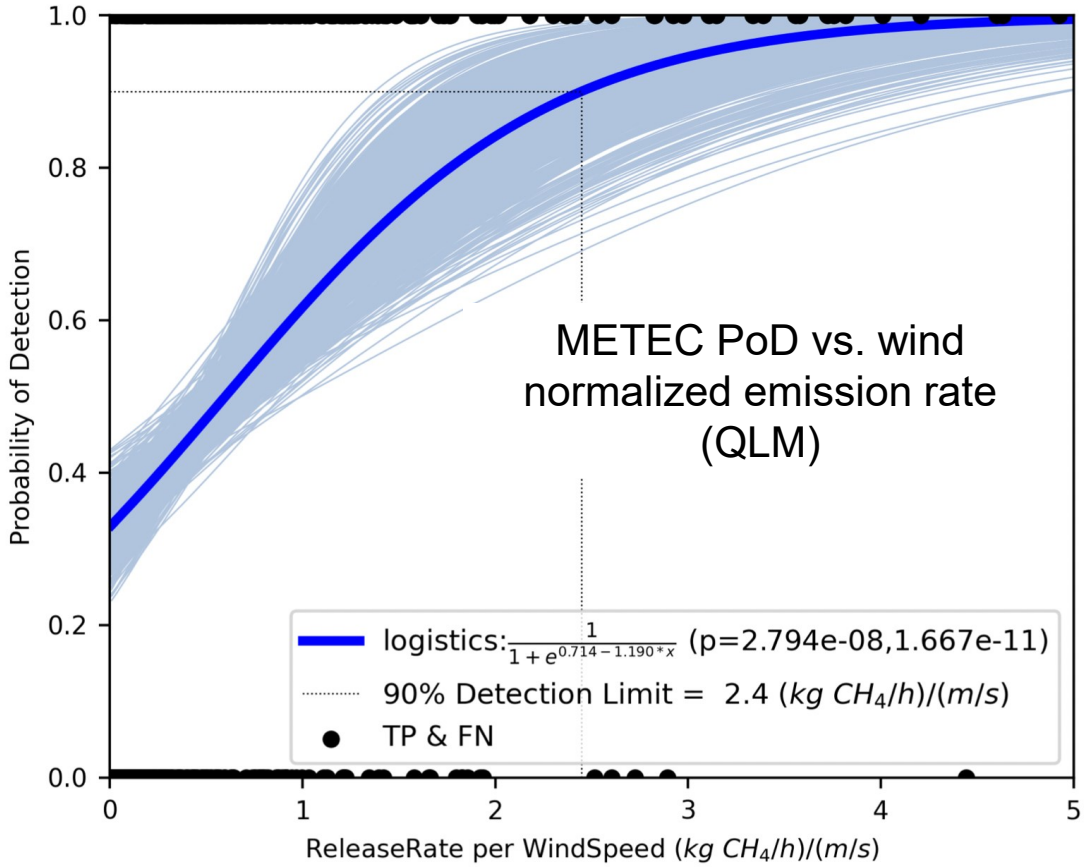
- Continuous monitoring enables frequent measurements of individual emission sources so patterns in time can be revealed:
  - Continuous fugitive leak or intermittent process emission?
  - Variation in flow rate
  - One-time or repeating events?
  - Periodic or aperiodic?

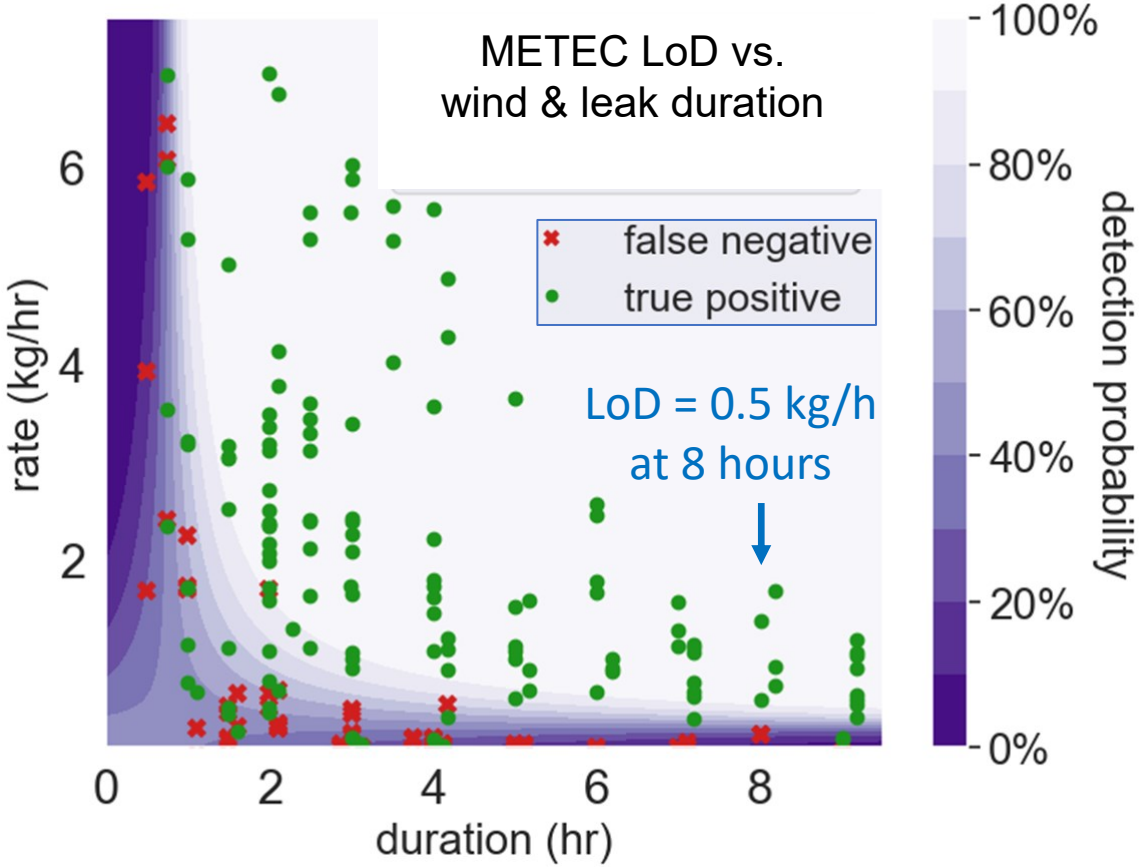


When? – Probability of Detection

- Quantum Gas Lidar detection probability depends on:
  - Leak rate
  - Wind speed
  - Distance
  - Optical zoom level
  - Duration of emission event

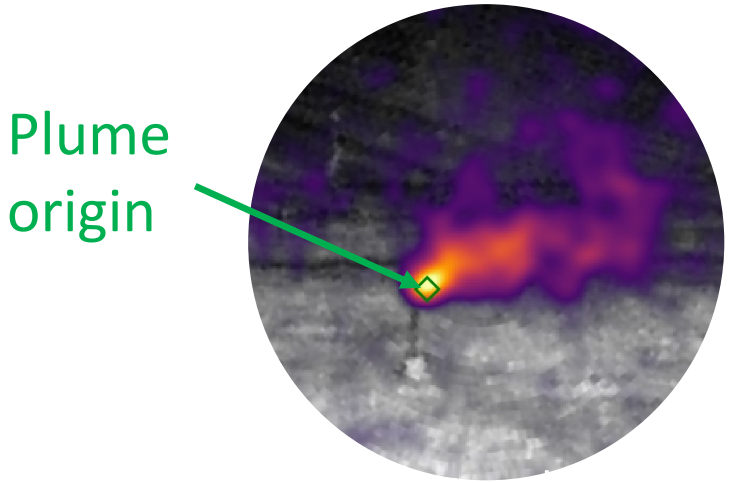
QLM Limits of Detection Specifications (typical, 90% PoD, continuous emissions)			
Distance	Wind Speed		
	<1 m/s	<5 m/s	<10 m/s
<100-m (<328-ft)	0.2 kg/h	1.0 kg/h	2.0 kg/h
<200-m (<656-ft)	0.4 kg/h	2.0 kg/h	4.0 kg/h

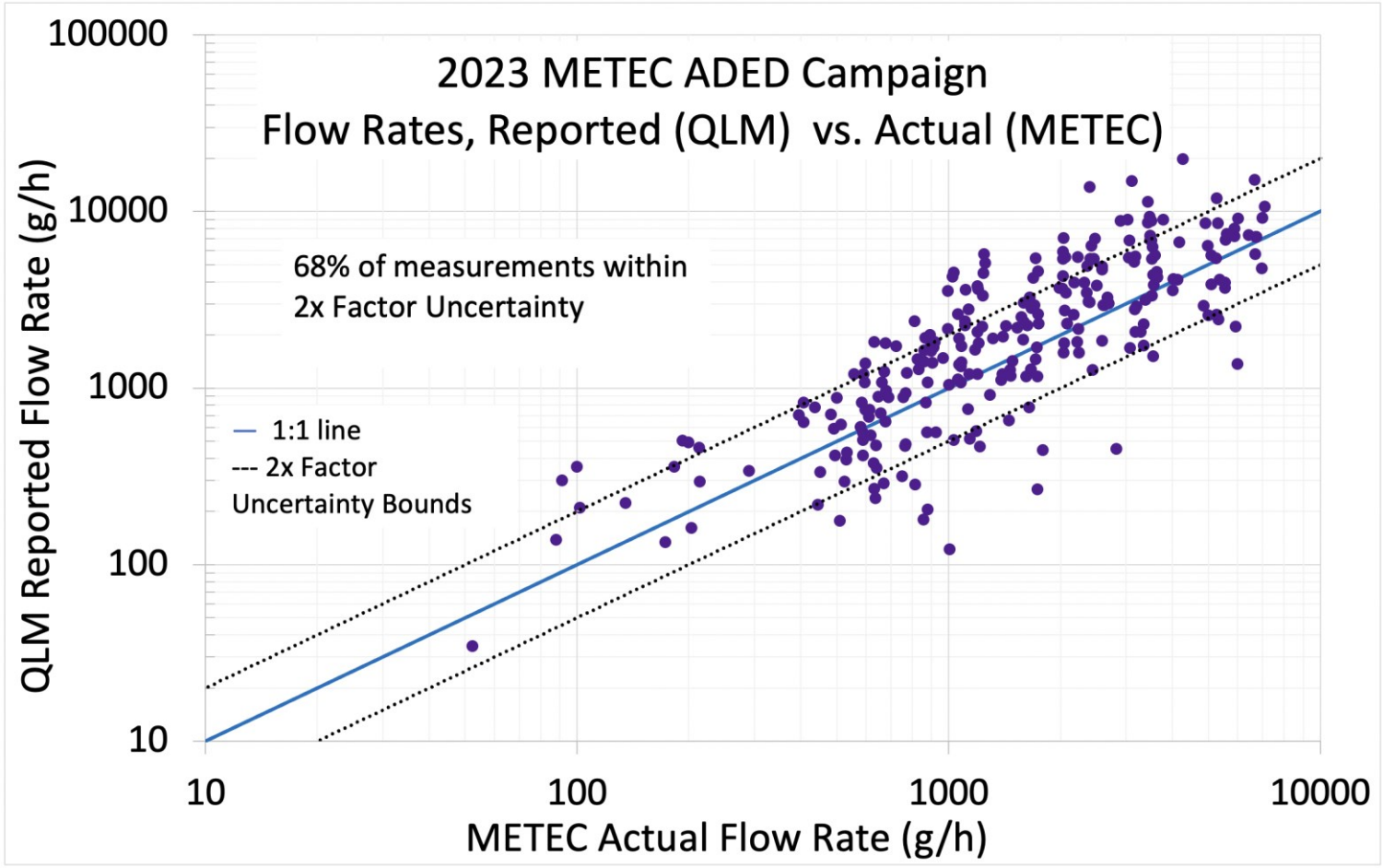




How Much? – Quantification Accuracy

- Very accurate leak flow rate quantification due to Lidar's ability to measure *exact* distance to plume origin and accurately scale the physical size of the 2D plume image
- Proven at METEC as the highest-accuracy method for remote quantification of methane emissions



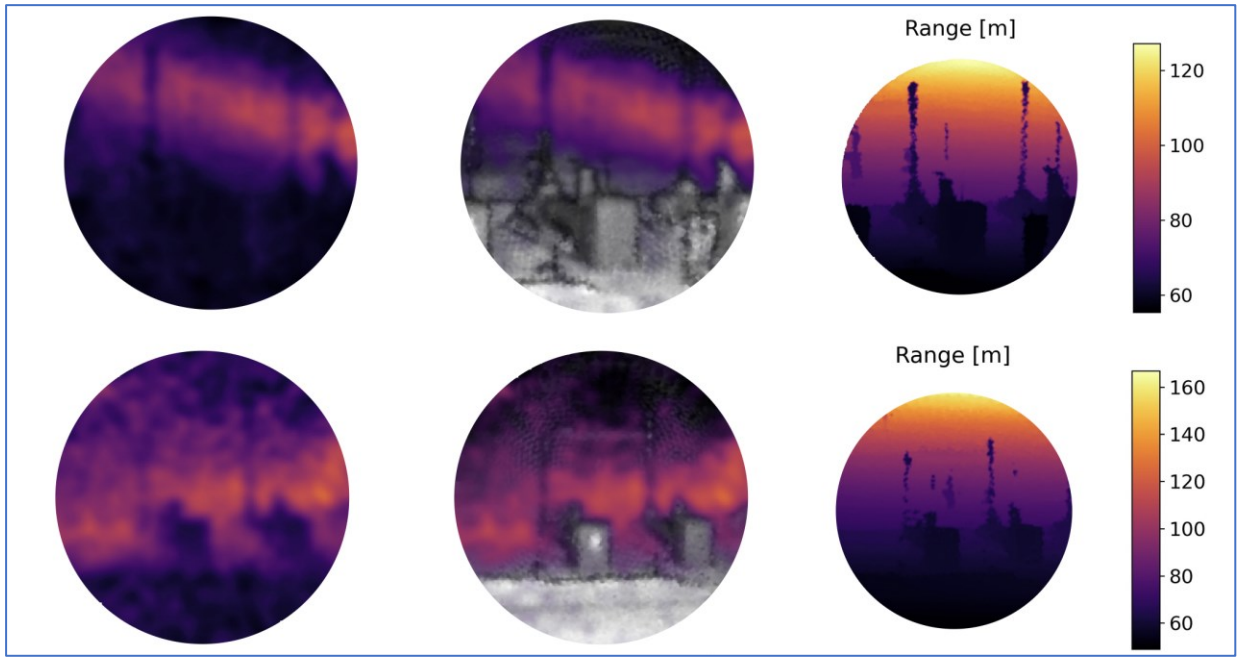


Examples

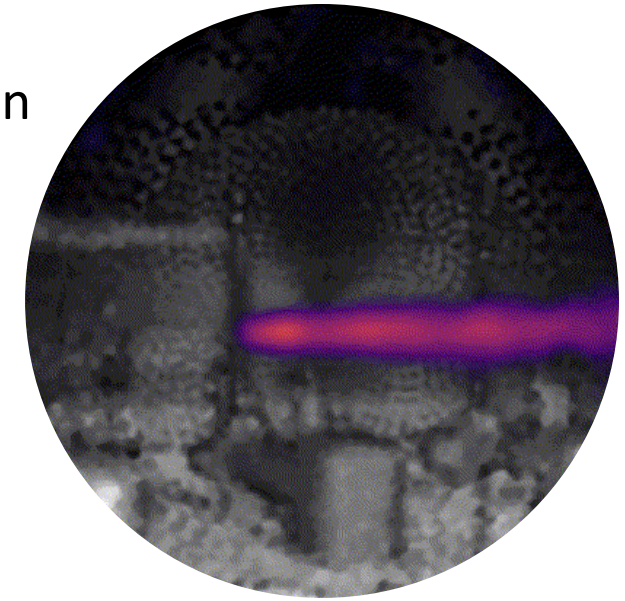
- Accurate & consistent quantification in different imaging and wind conditions

METEC True Flow Rate: 6.4 kg/h
QLM measured Flow Rate: 6.8 kg/h

Imaging only plume tails →

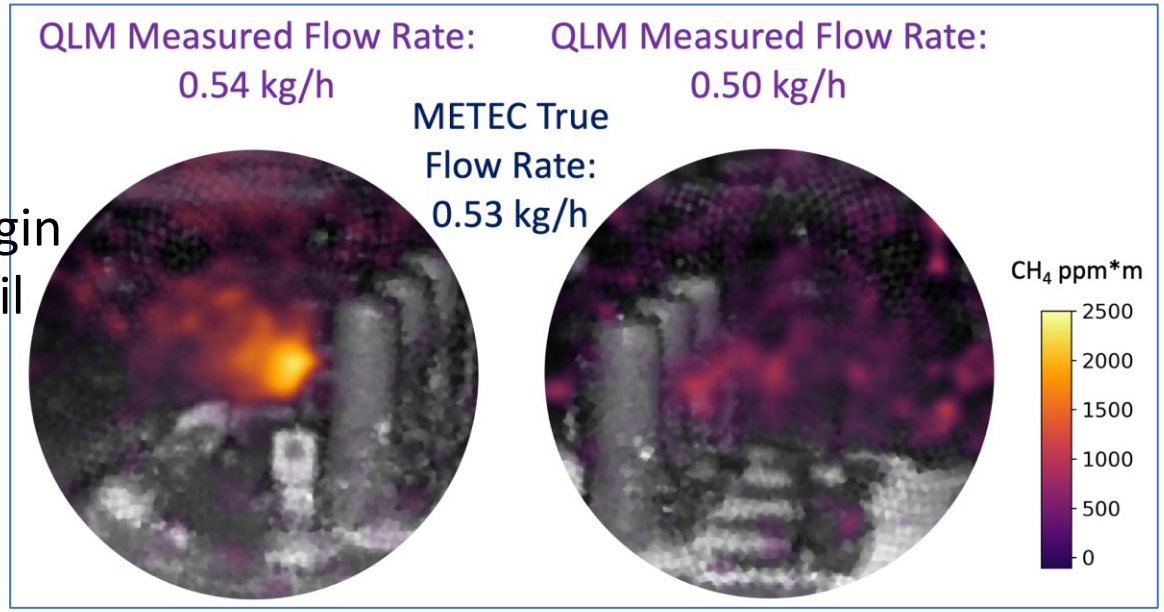


Quantification in different local wind fields →



METEC True Flow Rate: 12.3 kg/h
QLM Measured Flow Rate: 6.1 kg/h
(within 2x Factor Uncertainty Specification)

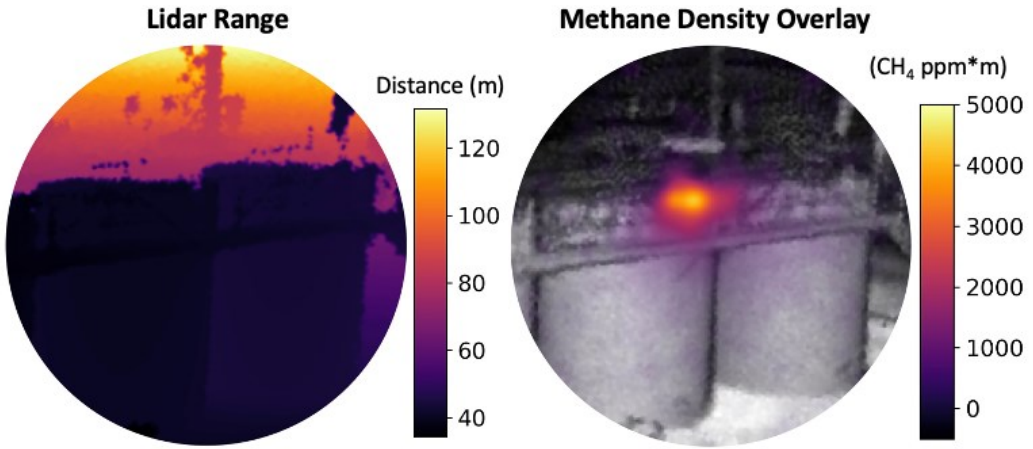
Imaging full plume including origin vs. diffuse tail excluding origin →



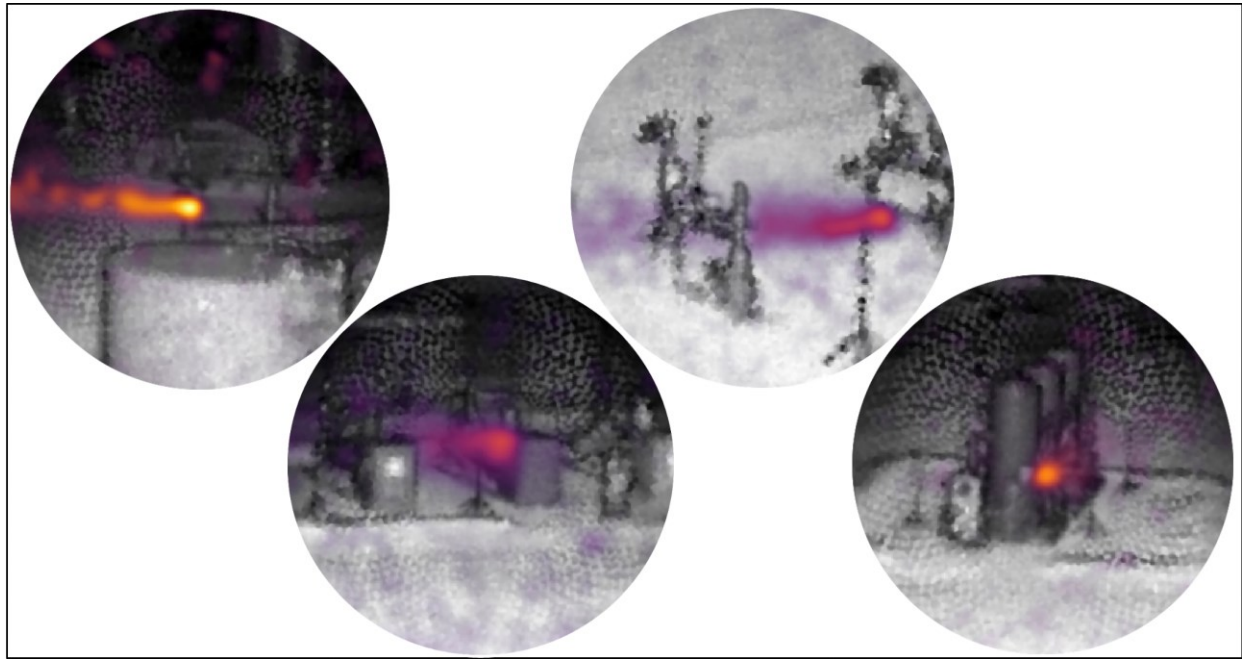
Discussion & Examples

- During METEC ADED, QLM successfully detected and accurately located & quantified:
  - 269 individual emissions
  - ranging in size from 0.05 to 7 kg/h
  - identifying 1.39 (75%) of the 1.85 tonnes of total trial emissions
  - at ranges from 10-80 m

Typical METEC ADED Plume Imagery



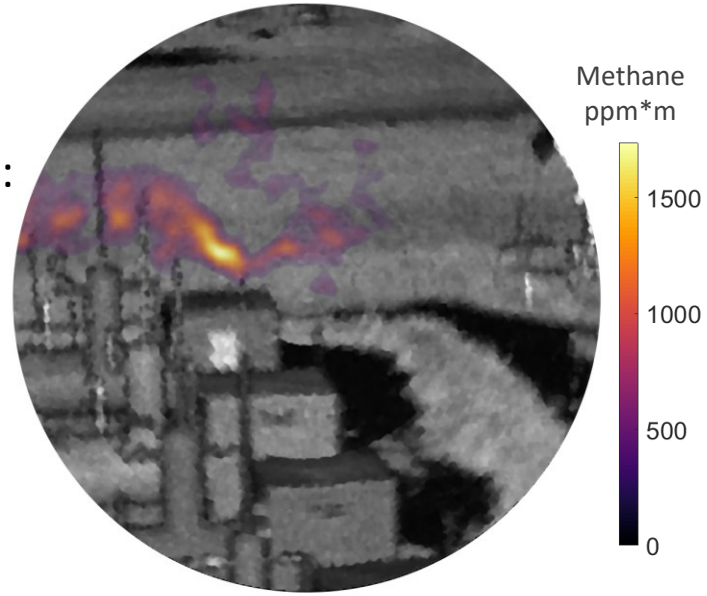
Example of 4 simultaneous emission points during METEC ADED



QLM Methane Emissions Quantification Examples

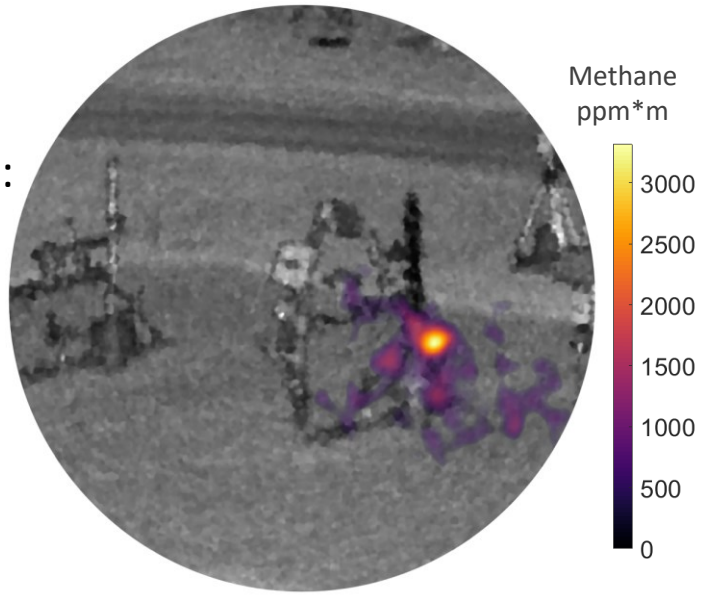
Leak Rate:
0.01 kg/h

Distance:
40 m



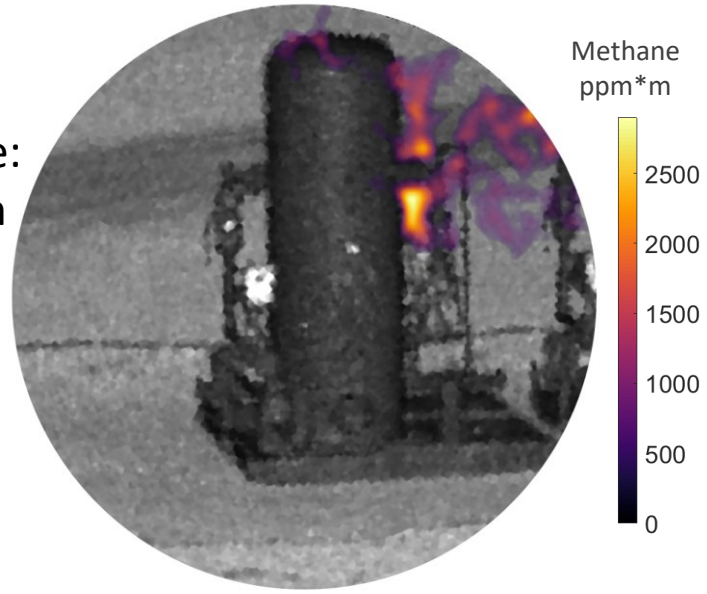
Leak Rate:
0.14 kg/h

Distance:
50 m



Leak Rate:
0.42 kg/h

Distance:
60 m



METEC
METHANE EMISSIONS TECHNOLOGY EVALUATION CENTER