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Quality Assurance for sensor based fenceline and near source monitoring

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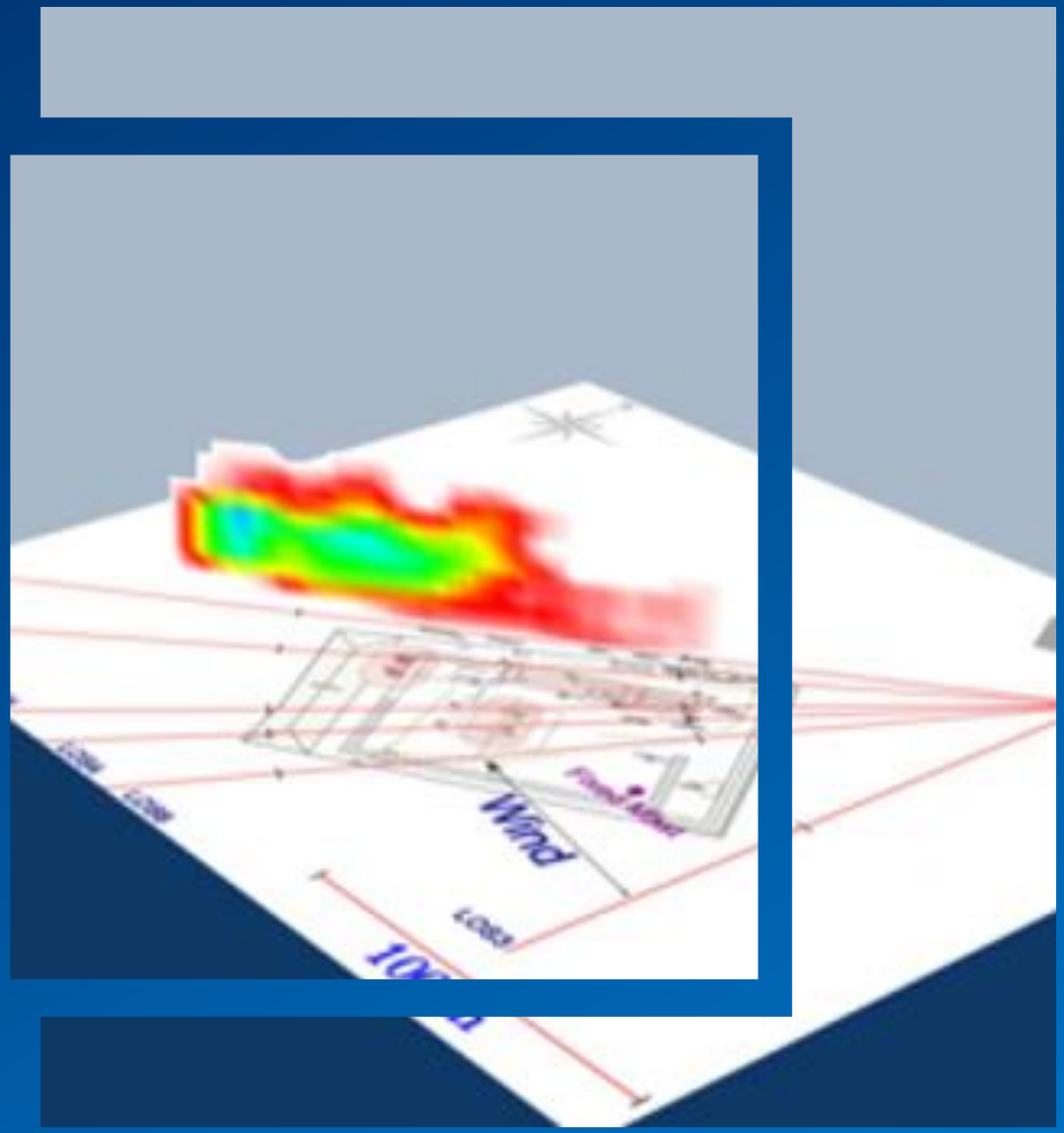
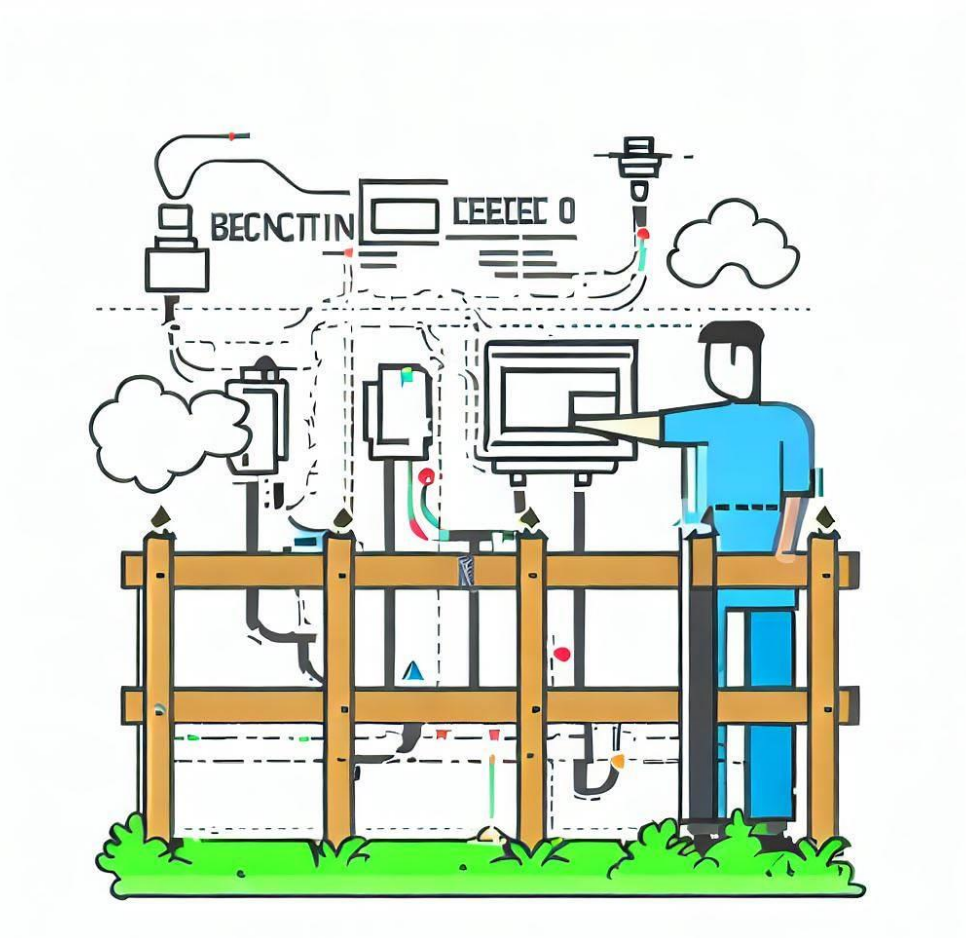


Outline

- Intro – where are we going?
- Sensor QA – stages of quality
  - Sensor performance
  - Network performance/ configuration
  - Operational QA
  - Output quality
- European and UK update
- Fenceline monitoring
- Are we there yet?



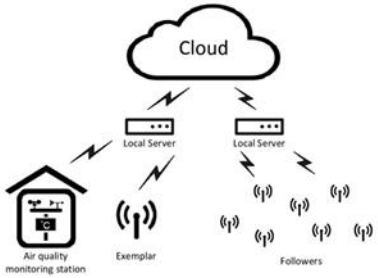
An AI generated illustration of "a sensor based fenceline pollution monitoring system". Perhaps the robots haven't taken over just yet.

Sensors -> networks

- For the purposes of this presentation
- Sensor –
  - lower-cost continuous concentration measuring device
  - Generally an integrated system adding data collection, sampling power
  - Time resolution – active / passive sampling

Integrated systems

Sensor unit, database and dataportal, calibration factors visualisation

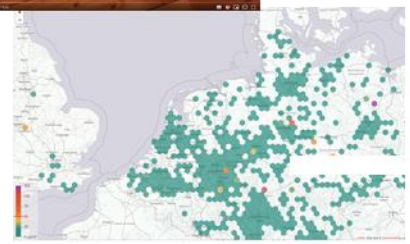


Hybrid systems

Sensor network using also additional data (a.o. AQMN, models)

Sensors

Different types Measuring unit

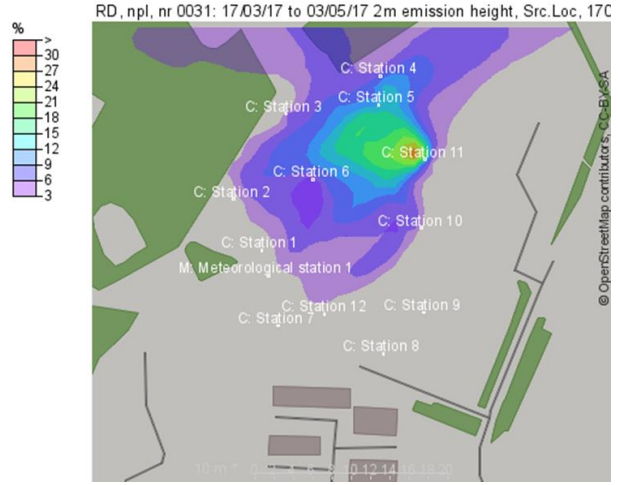


DIY building blocks

sensor, Arduino, dataportal

Purpose of fenceline monitoring

- Level and approach for QA will depend on the purpose of the fenceline network
- Safety alert – long history
- Receptor monitoring (concentration)
- Emission detection – location of source
  - Activate / focus leak detection
- Long term average emission reporting
- Time series mass emission
  - Time series –relate to



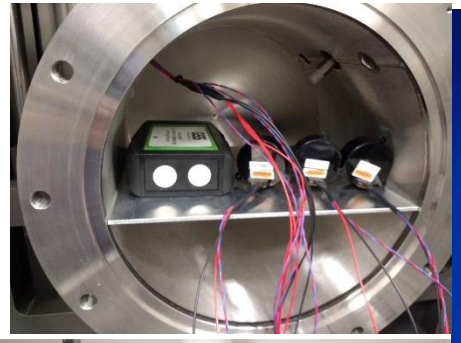
Elements of a sensor based fenceline system

- Fenceline monitoring systems will include
  - Sensing elements
  - Concentration and additional (meteorological) measurements
  - Sampling configuration
  - Data collection
  - Analysis, modelling
  - QA STEP
  - Data output, visualisation
- Purpose
  - Event detection
  - Leak identification
  - Reporting

- Not only ‘sensor’ networks
- Fenceline systems can include
  - Sensor based networks
  - Distributed sampling
  - Open path optical systems
  - Camera based
  - Automated drone
  - Hybrid systems

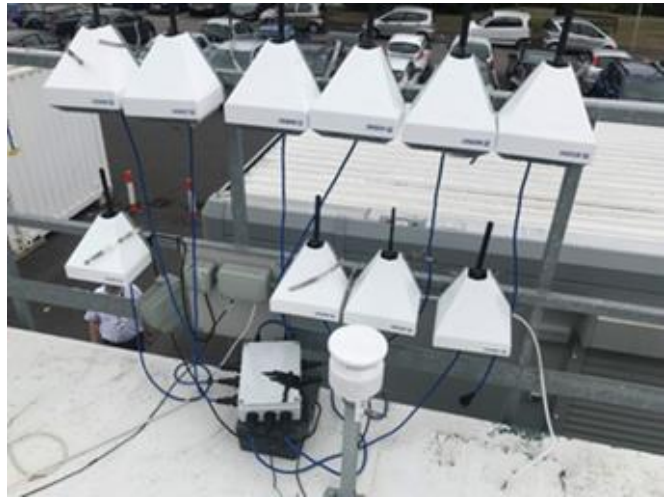
Elements and aspects of quality assurance/control for fenceline systems

- Defined performance requirements
  - DQOs
- Equipment qualification
  - Sensors
  - System performance assessment
  - Analysis / data product generation (emission rate, leak location)
- Site specific quality plan
  - Operating procedures
- In operandi performance evaluation (internal)
  - Configuration and installation checks
  - Calibration
  - Ongoing data checks
    - Data assessment
  - Ratification / expert judgement
- External QA/QC
  - Audits
  - Reference measurements
  - Validation of outputs (leak/emissions source confirmation)
  - Assessment of external data processing steps (cloud based)



Sensor performance validation

- The elements of a fenceline monitoring system can be evaluated
  - traditionally this has been the approach used
- This will provide information on the individual sensor ability to measure concentration
- The challenge is to extend this to the performance of the network

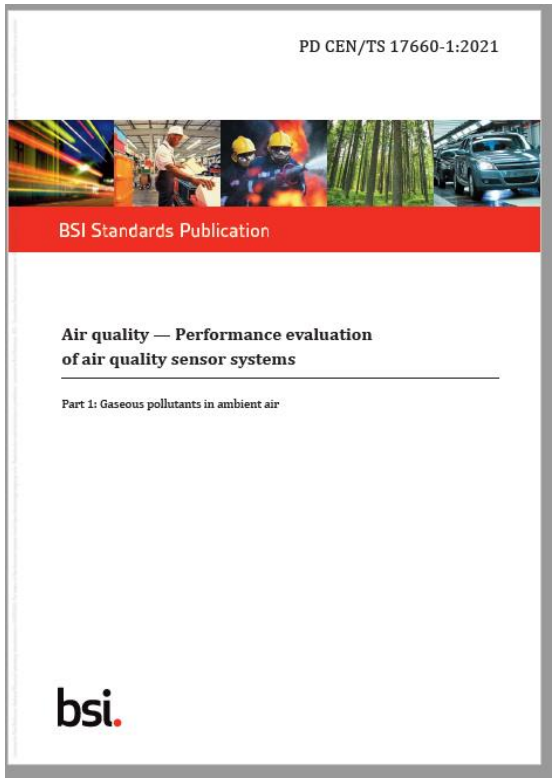


European standardisation of air quality sensors

- TC264/ WG42 Air quality - Performance evaluation of air quality sensors

- Part 1 Gaseous pollutants in ambient air (NO2, NO, CO, SO, O3, benzene, CO2)
- TS ready and available: CEN/TS 17660-1
- Waiting validation funding

- Part 2 Particulate Matter in ambient air (PM10, PM2.5)
- In preparation
- Expected to be ready for vote June 2023

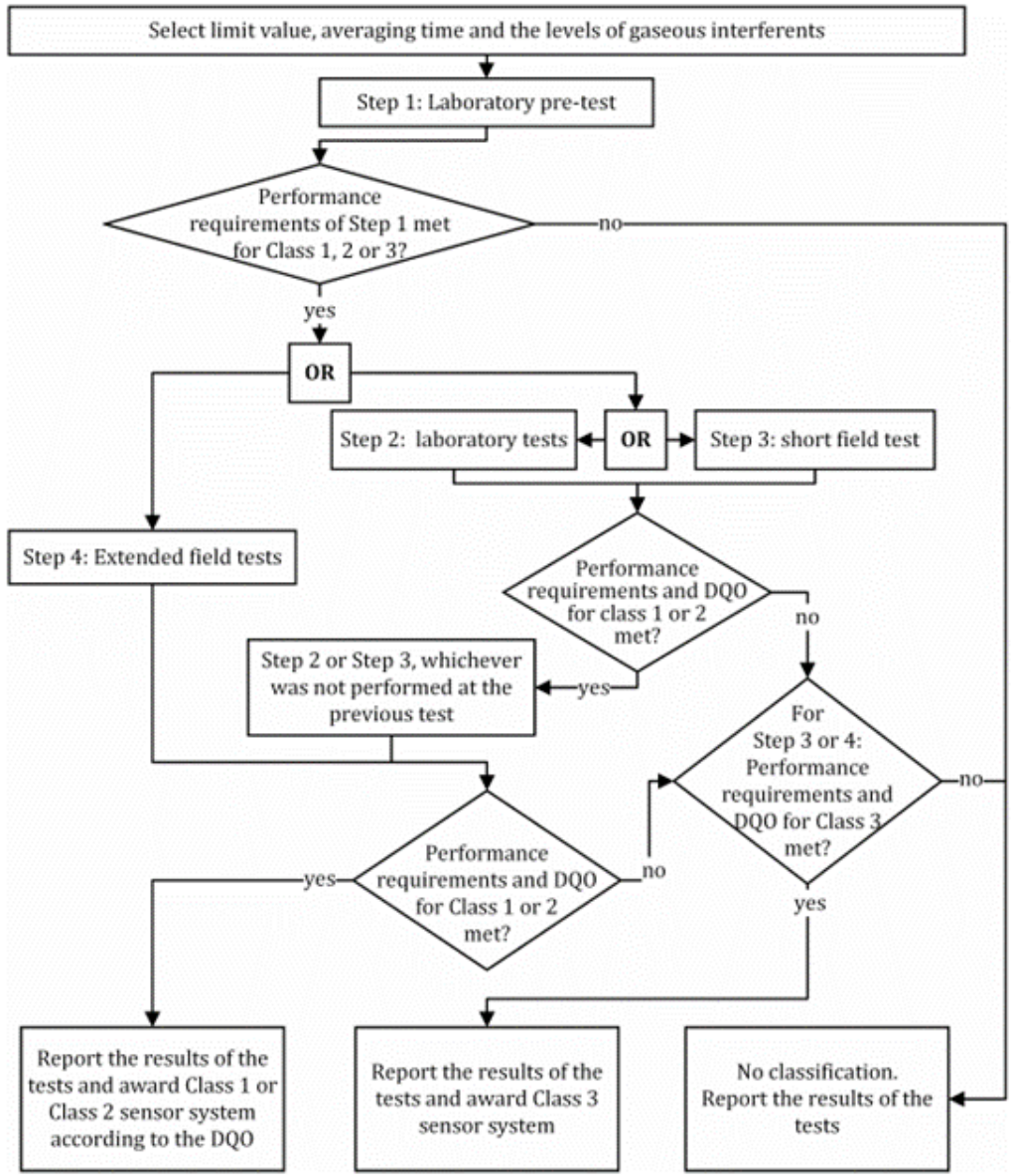


- Also a UK PAS (Publicly Available Specification) being developed
  - *PAS 4023, Air quality monitors – Selection, deployment, and quality control of mountable, static air quality monitors in ambient air – Code of practice*
  - *Currently at draft stage*

HAGLER, G et al. Air Quality Sensors and Data Adjustment Algorithms: When is it no longer a measurement? Environ Sci Technol 2018 52 10 pp 5530-5531
SCHNEIDER,P. et al. Toward a Unified Terminology of Processing Levels for Low Cost Air Quality Sensors Environ Sci Technol 2019.53 pp 8485-8487

WG42 sensor testing

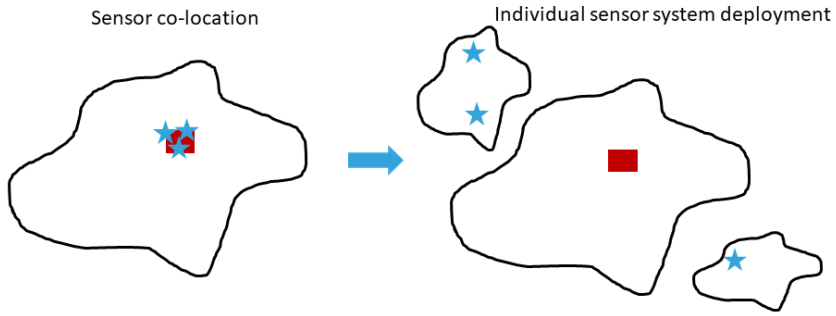
- Sensors are classified as
  - Class 1,2,3 or unclassified
  - Depending on pre-tests
  - Performance tests are then related to the classification (DQOs)



Sensor networks

Informative Annex A – co-location, deployment and management of a network of sensor systems

- TS 176601 is applicable to '**individual sensor systems**'
- Future work
  - There is a need for guidelines and a common approach of calibration methods for sensor networks and how the data can be applied/used
  - and/or techniques combining sensor data and modelled data, such as data fusion



- Annex to TS :
- Informative annex with guidance on network performance
- Intention is to prepare separate document covering this

Other European work standards

- BS EN 17628:2022
- Fugitive and diffuse emissions of common concern to industry sectors. Standard method to determine diffuse emissions of volatile organic compounds into the atmosphere
- Recent standard for VOC emissions – campaign based but does include performance requirements for RDM
- Intention is to cover continuous monitoring in future standard

- BS EN 15445:2008 - Fugitive and diffuse emissions of common concern to industry sectors. Qualification of fugitive dust sources by reverse dispersion modelling
- Older standard but does cover network deployment
- Reverse dispersion modelling – based on EPA method

Performance standard for systems

- The challenge is to evaluate the performance of a system
  - Data inputs sensor and other data sources
  - Data processing step
  - Procedures
  - Configuration
  - Site specific issues
  - Changes to system over time
  - Expert input
- Sensor specific issues
  - Inter sensor issues
  - Sensor aging
  - Sensor recovery/poisoning
- Machine Learning / AI
  - What is the ‘system’
  - What is being validated

- NPL are working on a performance standard for continuous monitoring systems – not specific to sensor based systems but – it does address many of these network/configuration issues
- Functional element model of sites
  - Allows sub site monitoring
  - Characterisation of emission sources
  - Spatial and temporal characteristics
  - Tailored emission measurement to source types
- Performance characteristics generalised for different system types
- Defined operating methods
- Configuration
- Definition of outputs

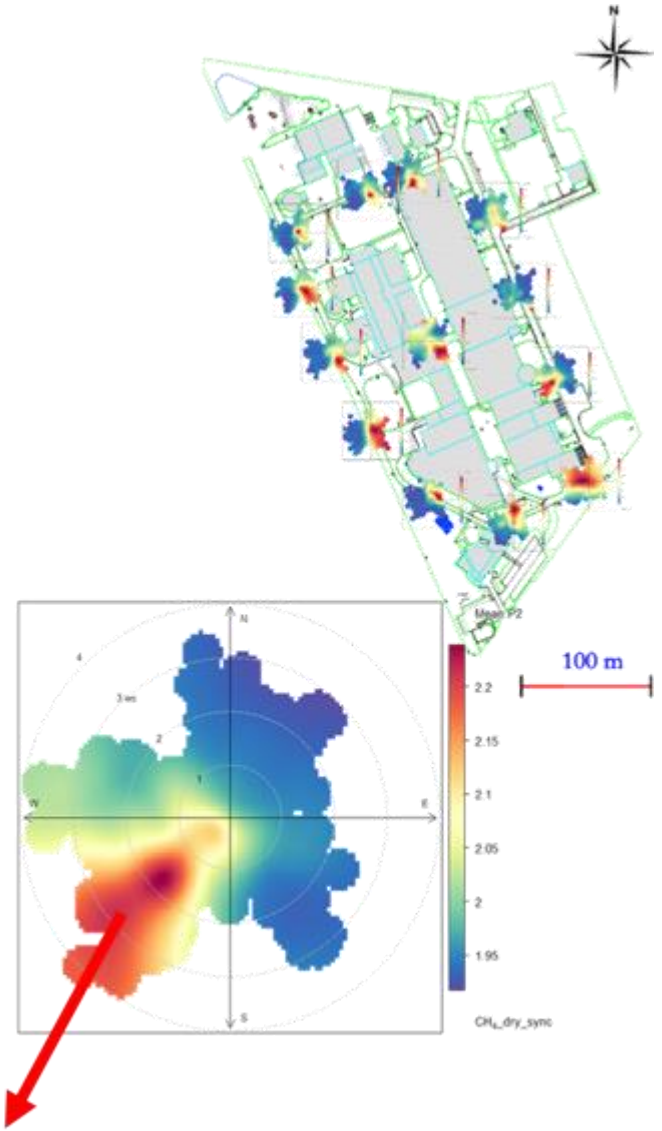
In operandi QA of networks

- Installation checks
- Internal audit checks
  - Reference measurements
  - Calibration
  - Data reviews / ratification
- External audits
  - Equipment audits
  - Data audits
- Reference measurements
  - Periodic assessment – c.f continuous emission monitoring
- Verification of emissions
  - Source identification and emission quantification

- QA Plans
  - Critical to design QA into the methods for fenceline monitoring
  - Specific DQOs
  - QA not a retrofit
  - Cover all aspects not just sensor performance
  - Data products not just concentration
  - Uncertainty determined quantified result

Hybrid system

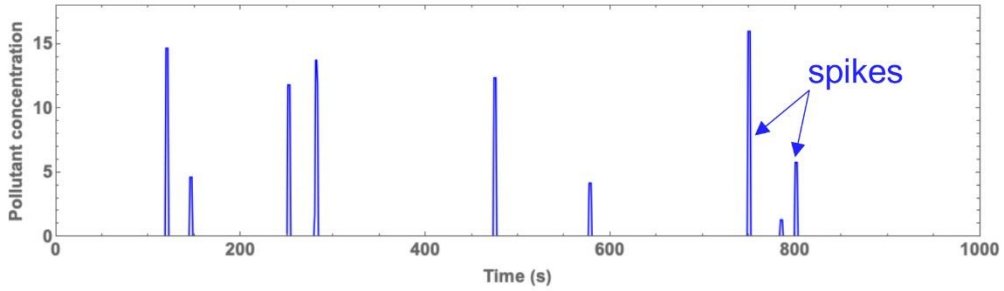
- Use of low cost sensors to enhance continuous monitoring system
  - Distributed sampling
- Co-located sensors can be periodically calibrated
  - Removes drift and effect of interferences/ambient conditions
- Increase temporal resolution
- Spatial resolution (infilling)
- Extend coverage



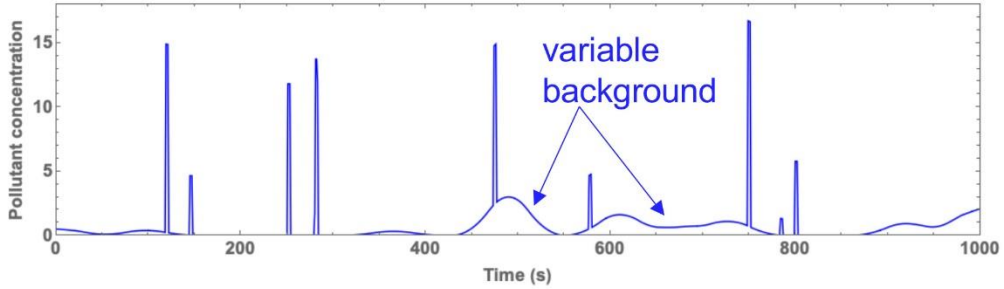
Red indicates elevated methane levels

Low cost sensors: cloud based calibration

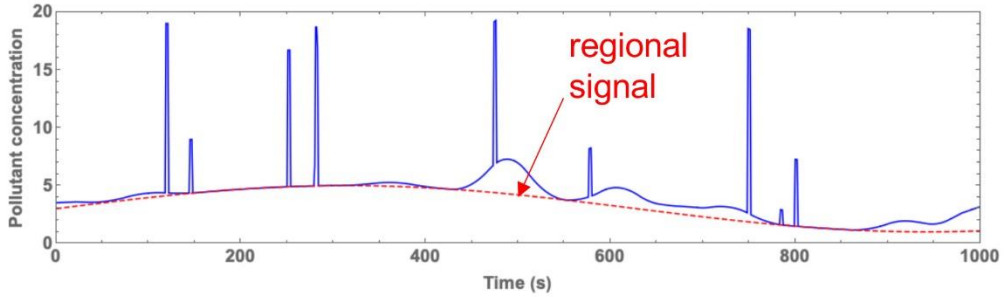
- Combined response is composed of different source signatures



Sources (e.g. vehicles)
local to sensor
- ‘spikes’



Dispersed sources
~local to sensor
- ‘variable background’



Regional signal

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Conclusions and next steps

- There is a recognition of the role of sensor based systems
- Commercial and research systems are being developed and deployed
- There is a need for
  - Harmonised approach to describing the performance of such systems
    Terminology, performance characteristics
  - Approaches to specify and describe network configuration, internal QA and data handling – machine learning, AI, data fusion, role of experts
  - Standards/protocols for sensor network/system QA
- Challenges
  - AI based systems

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