



# “Low-Cost” Air Quality Sensor Systems

Opportunities and Challenges

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Introduction

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What is a “Low Cost” Sensor System?

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How can we make the most of the data?

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What are the potential applications?

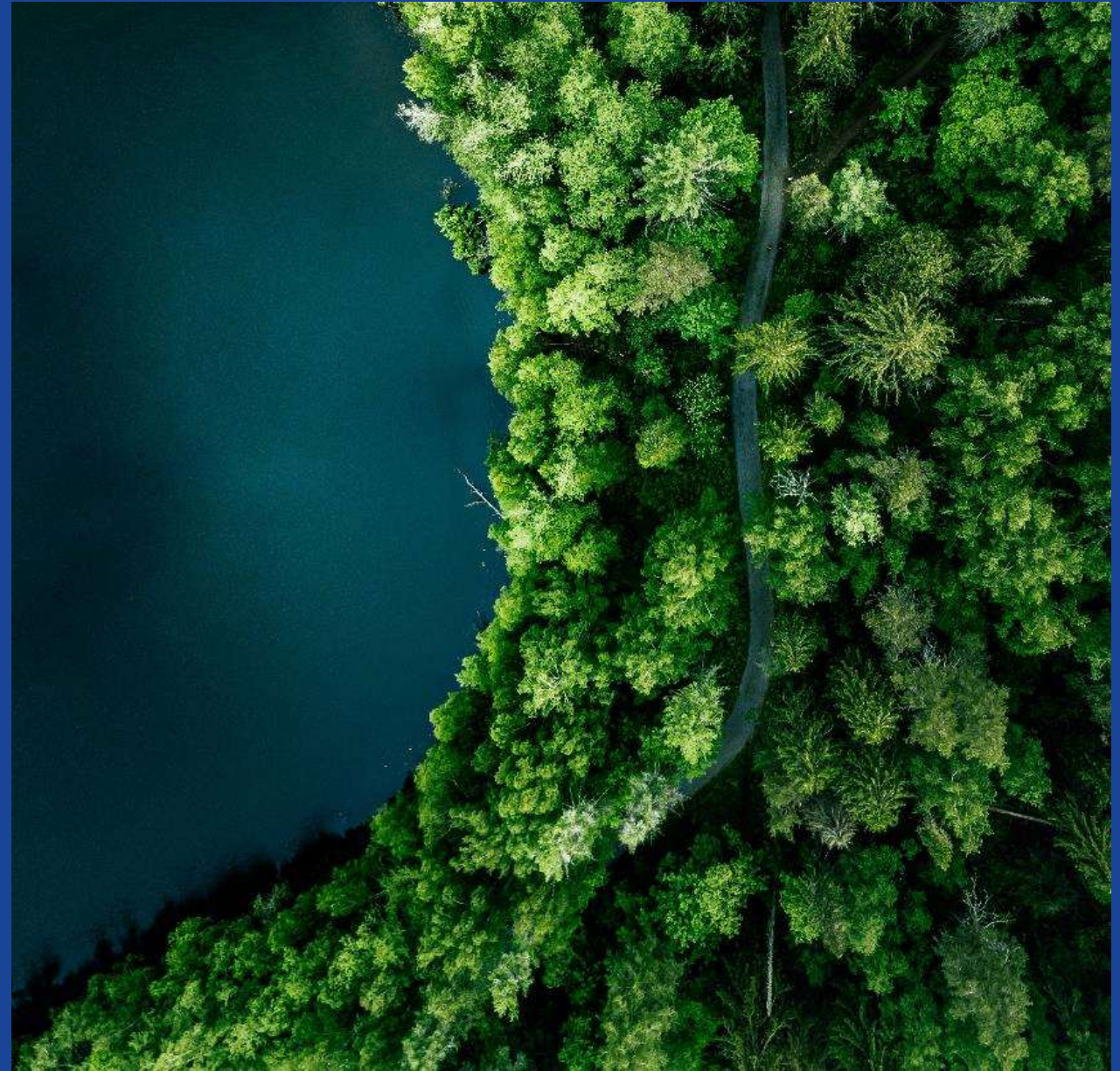
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Conclusions

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# WE'VE COVERED THIS TOPIC BEFORE, SO WHY ARE WE TALKING ABOUT IT AGAIN?!

- Things are changing rapidly.
- There is lots of lots high-quality, glossy marketing out there.
- New products are appearing all the time.
- Every project and proposal seems to be suited to a low-cost sensor deployment.
- What's the true story?



## Definitions

- Sensor – a component that responds to a pollutant in some way
- Sensor system (or device) – a product built with sensors, with controlling firmware / hardware
- Reference analyser – an instrument with tested and quantified performance



# A quick history...

- Personal samplers (now known as AQ sensor systems) have been around since the late 1980s
- Battery powered (for short periods) but bulky!
- It's always been the case that QC is essential to get fit for purpose data (but still not as good as a reference analyser)
- Latest devices are compact, often lightweight, autonomous for longer, and measure more pollutants.



# “Low Cost” Air Quality Sensor Systems & Networks

- Ricardo is independently involved in many research projects, development evaluation and implementation of sensor systems.
- We regularly publish updates on our findings in blogs [here](#).



AQMesh



South Coast  
Science  
Praxis Urban



Airly



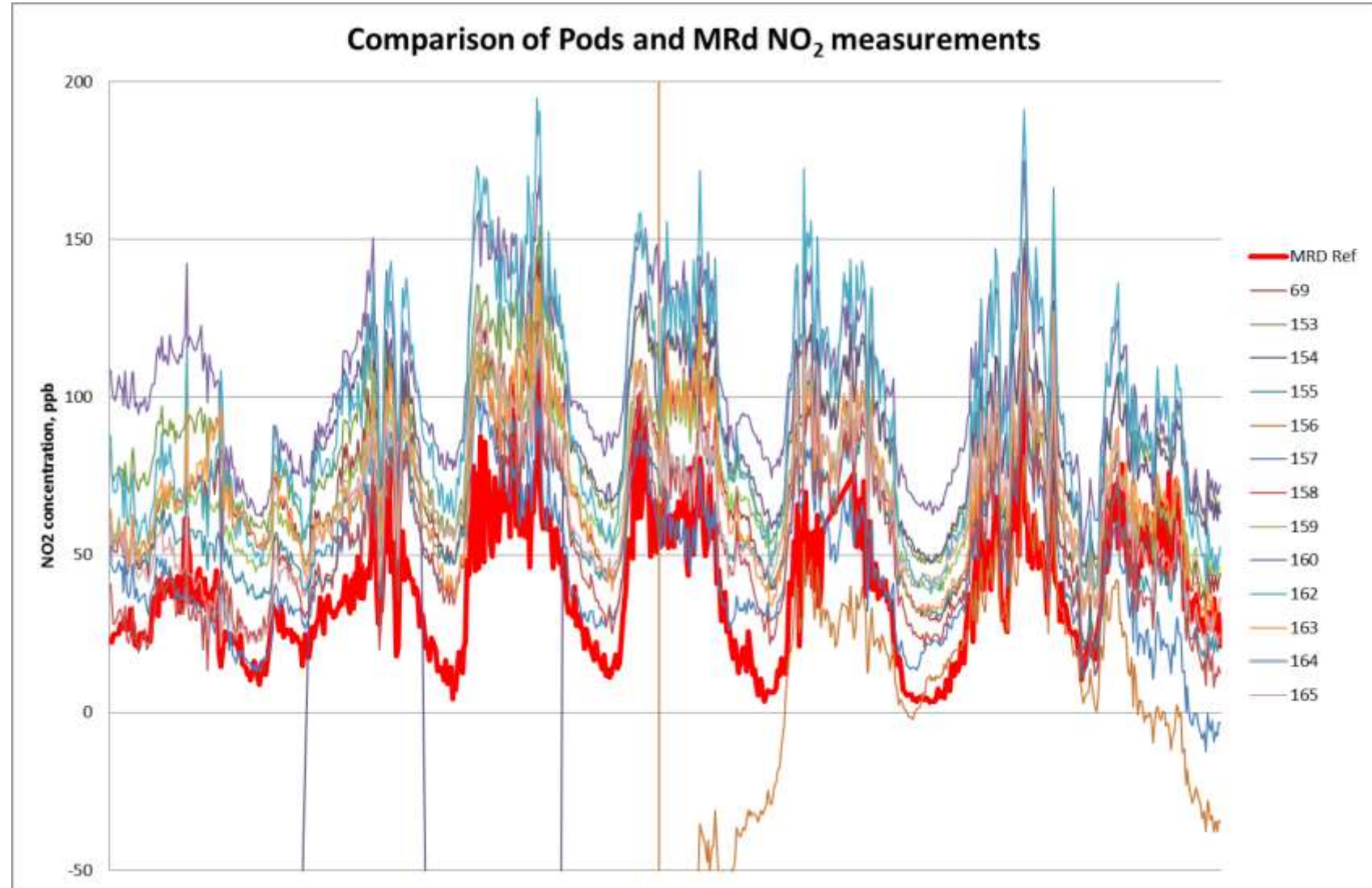
## Sensors Systems - Pros and Cons

There are many factors to consider:

| Pros                     | Cons               |
|--------------------------|--------------------|
| Low cost                 | Data Quality       |
| Low power                | Drift              |
| Portable                 | Noise              |
| Deployability            | Limit of detection |
| High time resolution     | Repeatability      |
| Microenvironment mapping | Uncertainty        |
| Ease of use?             | Ease of use?       |

# Example of the challenge – NO<sub>2</sub> measured by co-located sensors

- Trends look good, but wide scatter
- Mostly higher than the reference instrument
- Ratios between 1.2 and 2.7 (Averaged 1.9)
- Some rogues
- QA/QC - Baseline and scaling critical



# Sensor Certification / Approval

- MCERTS, gives some confidence in performance.
  - Must be operated in the same configuration.
- CEN WG42 also investigating how to test sensor systems
- Main challenges:
  - Cost of testing vs price of systems
  - Test sensors? Test end products?
  - Time required for test programme
  - Speed of sensor development
  - Where / when to test?  
Hot/Cold/Wet/Dry/UB/Traffic/Industrial
  - Software or algorithm updates

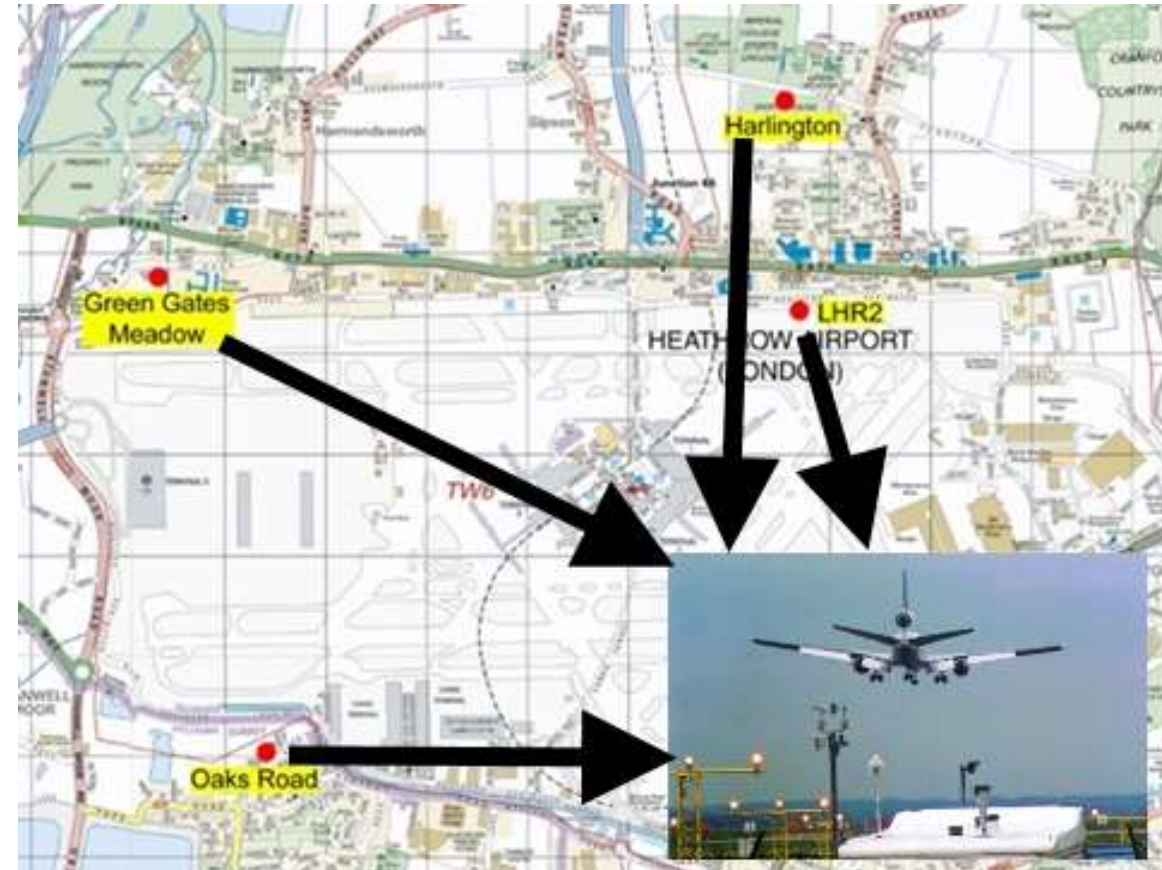


# Initial and Ongoing Field characterisation of sensor systems in a network

Ongoing assessment probably more important than certification...

Methods include:

- All sensor systems regularly assessed against a true reference station

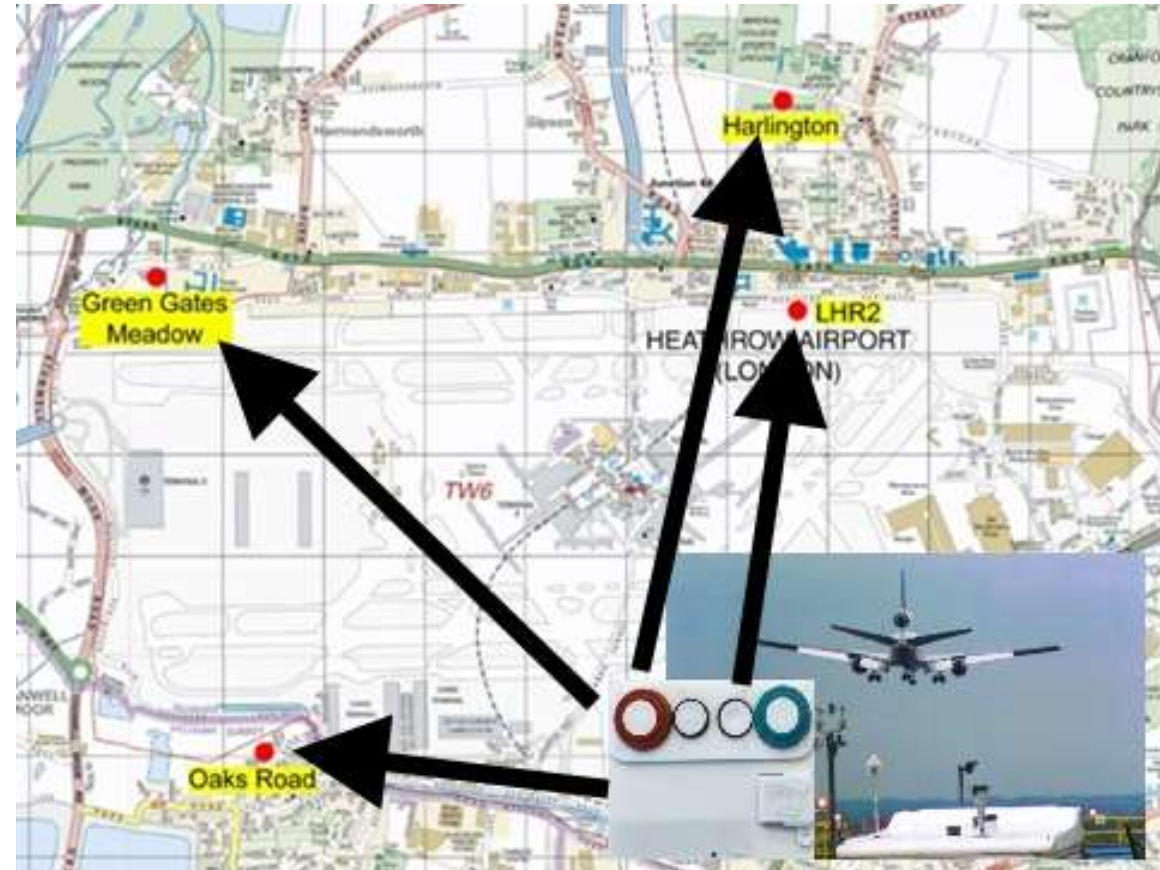


# Initial and Ongoing Field characterisation of sensor systems in a network

Ongoing assessment probably more important than certification...

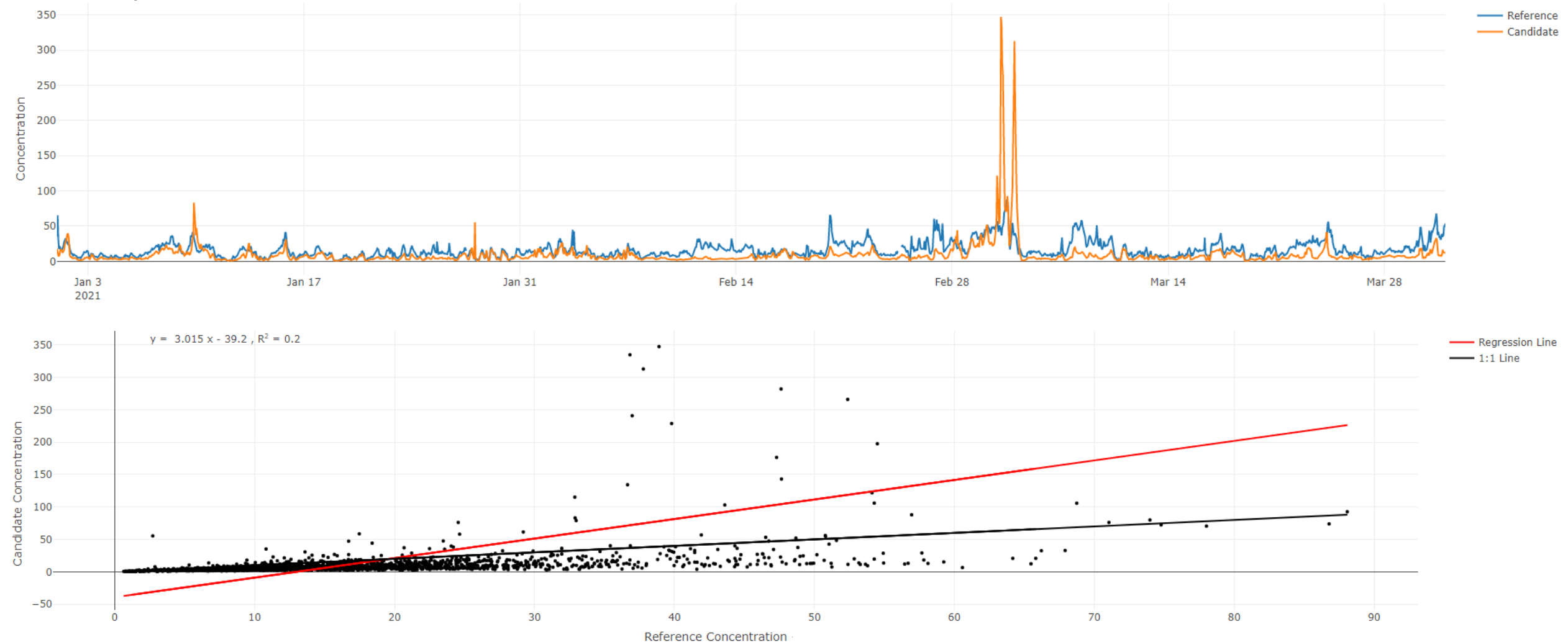
Methods include:

- All sensor systems regularly assessed against a true reference station
- One system regularly assessed against a reference station, then used as a transfer standard at other system locations
  - Either physically or virtually...



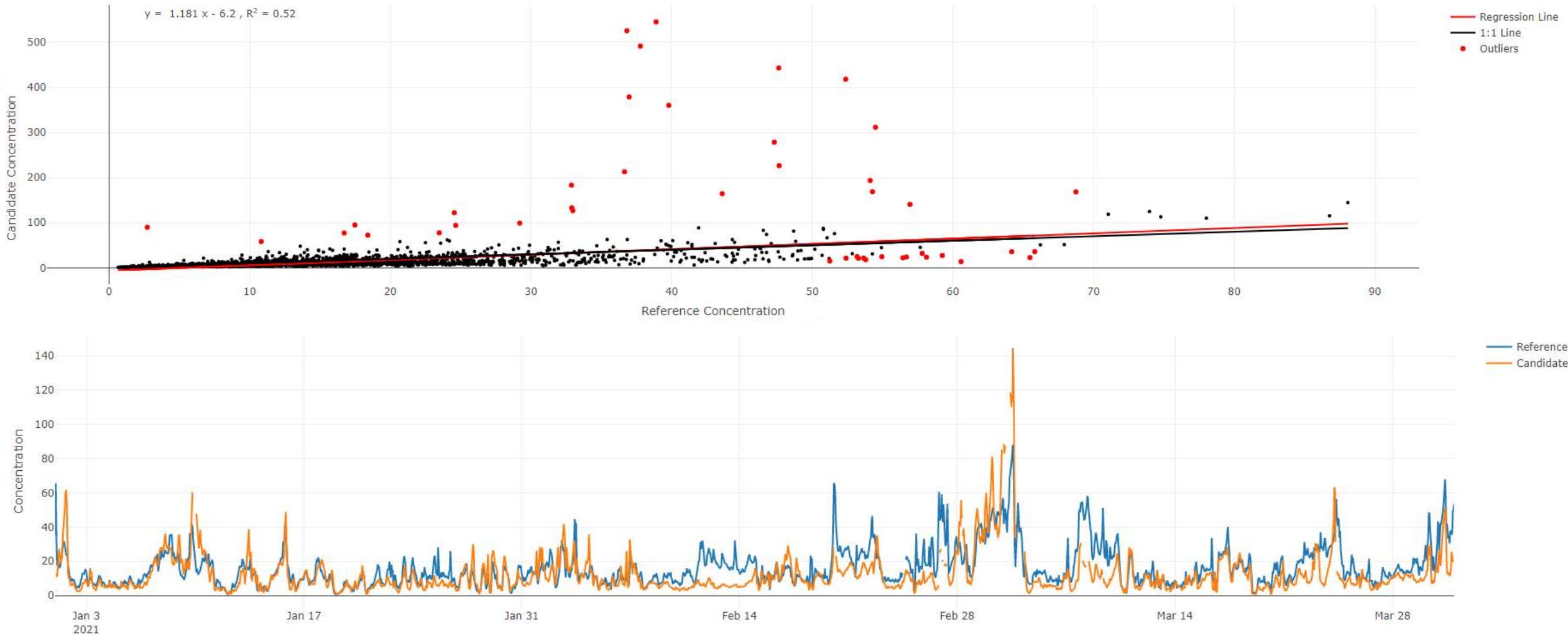
## Data Correction - example PM<sub>10</sub> sensor system data

- Sensor data trends well with the reference analyse in some places but there are obvious outliers.
- Makes it difficult to derive a correction factor from linear regression analysis (poor correlation,  $R^2 = 0.2$ ).
- PM<sub>10</sub> peaks likely due to high relative humidity, not real PM.



## Example PM<sub>10</sub> sensor system – corrected

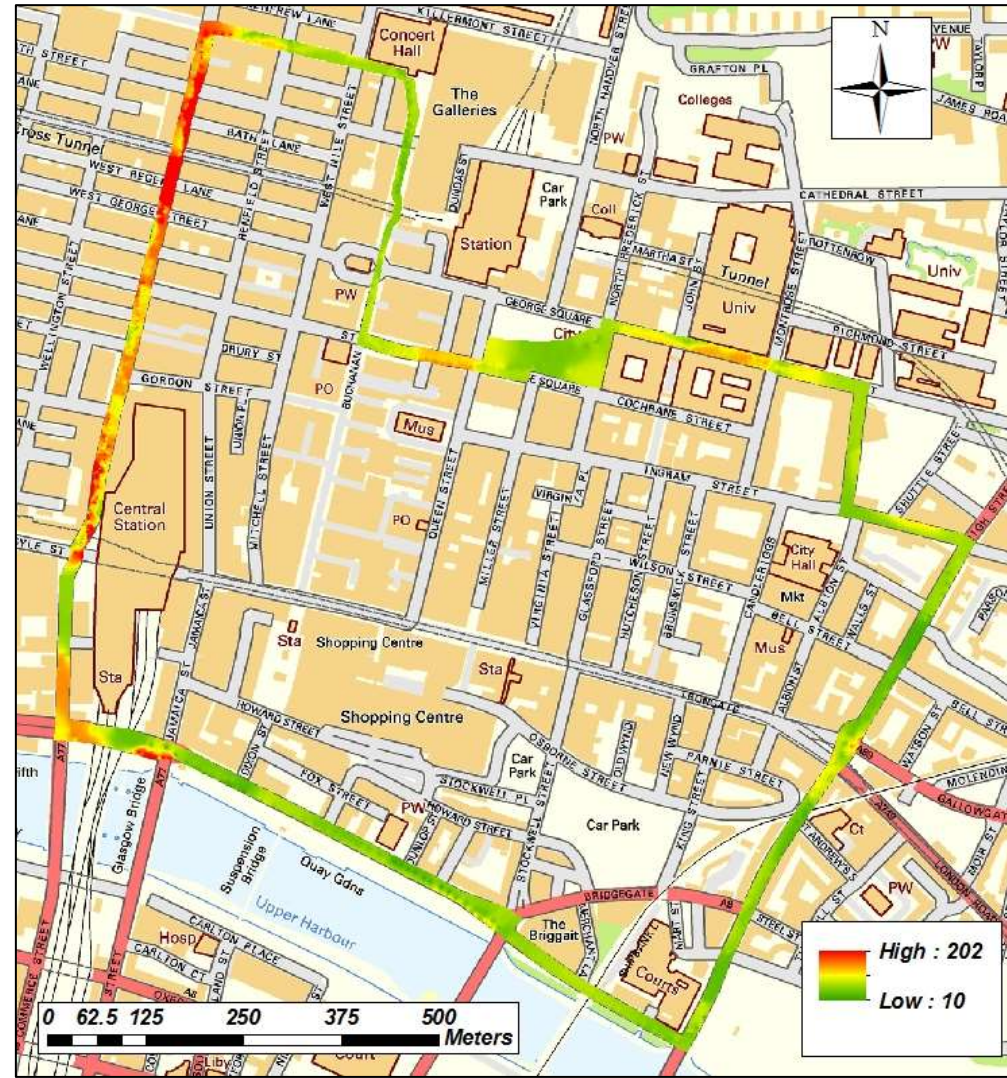
- Remove outliers through statistical analysis.
- Improved  $R^2 = 0.52$ .
- Correct data using factors from linear regression.



# Mobile Monitoring Video



NO<sub>2</sub> (µg m<sup>-3</sup>)



Contains Ordnance Survey data © Crown copyright and database right 2014.

# Sensors Data Visualisation and Research

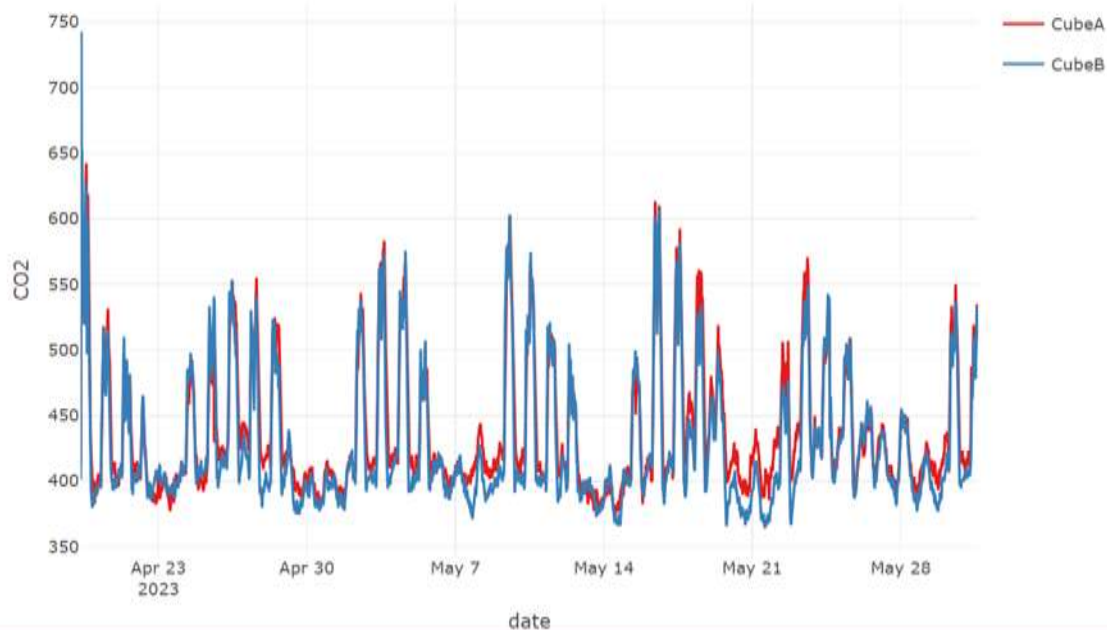


## Analysis of indoor measurements in Ock Wing

The data was analysed for both sensors when they were located in the Ock wing at Harwell, between 19/04/2023 and 31/05/2023.

| CO <sub>2</sub> | NO <sub>2</sub> | PM <sub>10</sub> | PM <sub>2.5</sub> |
|-----------------|-----------------|------------------|-------------------|
|-----------------|-----------------|------------------|-------------------|

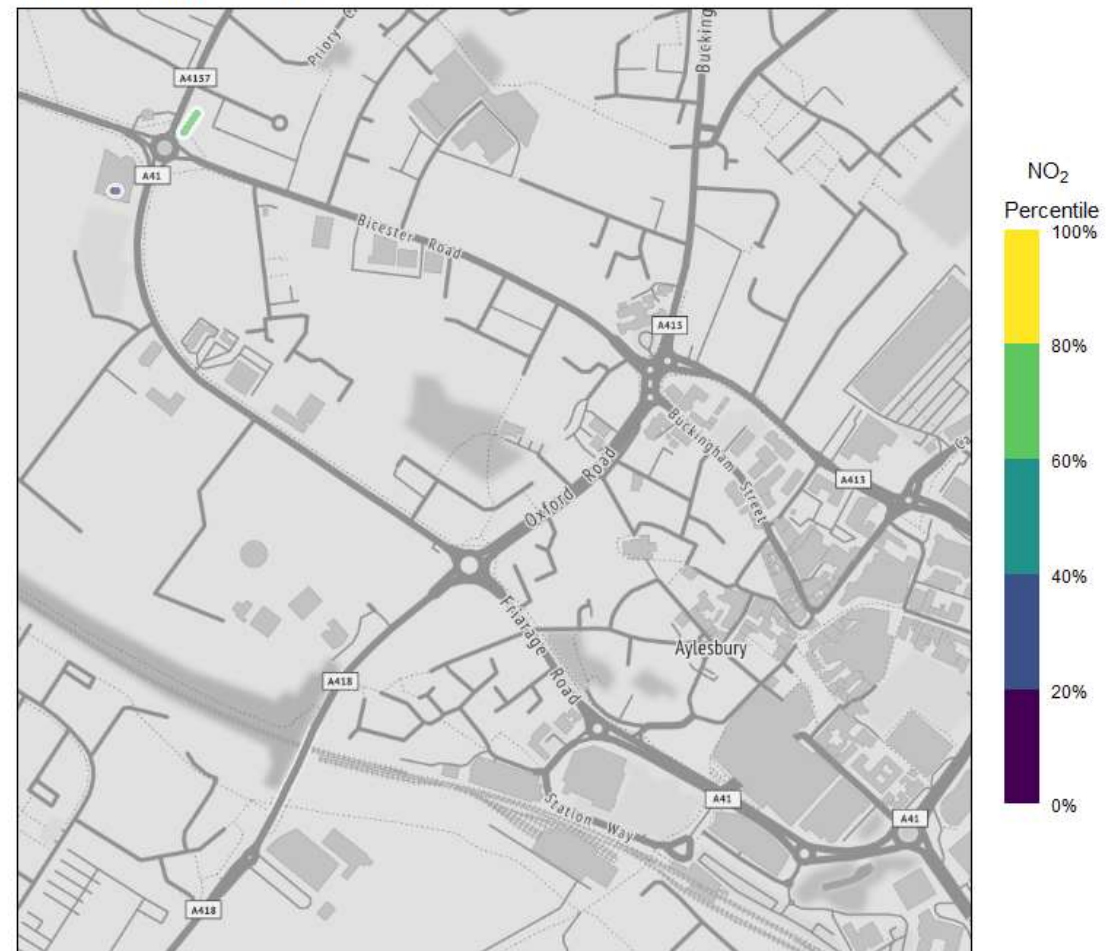
**Timeseries** Time variation



Ricardo Air Quality

@RicardoAirQ

Time: 2023-06-15 10:10:10



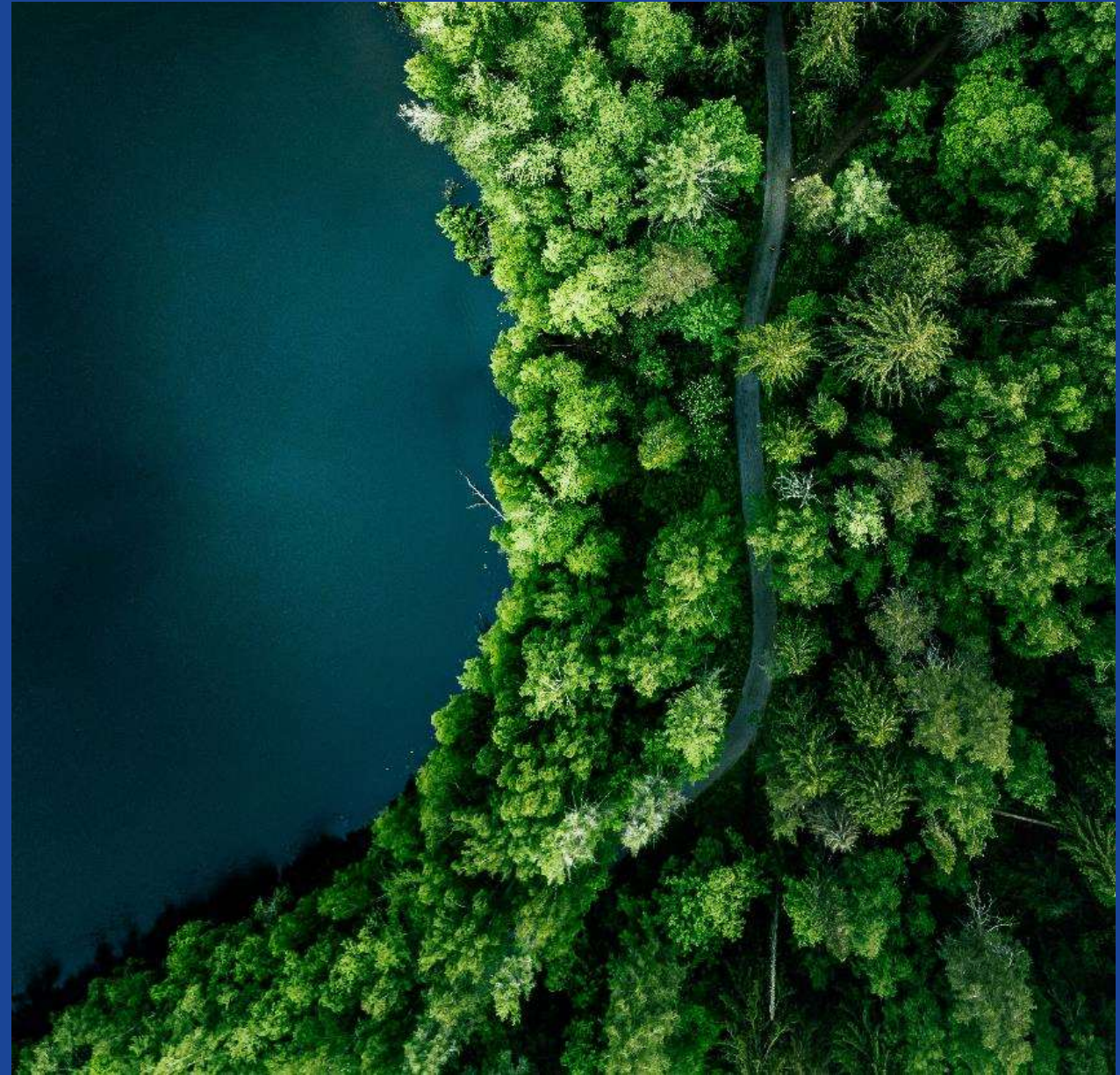
## Further Applications – awareness raising / education

- Wearable technology is not really a “sensor system” as we’ve discussed here.
- Potentially can be used to indicate hotspots but will have higher uncertainty associated with it.



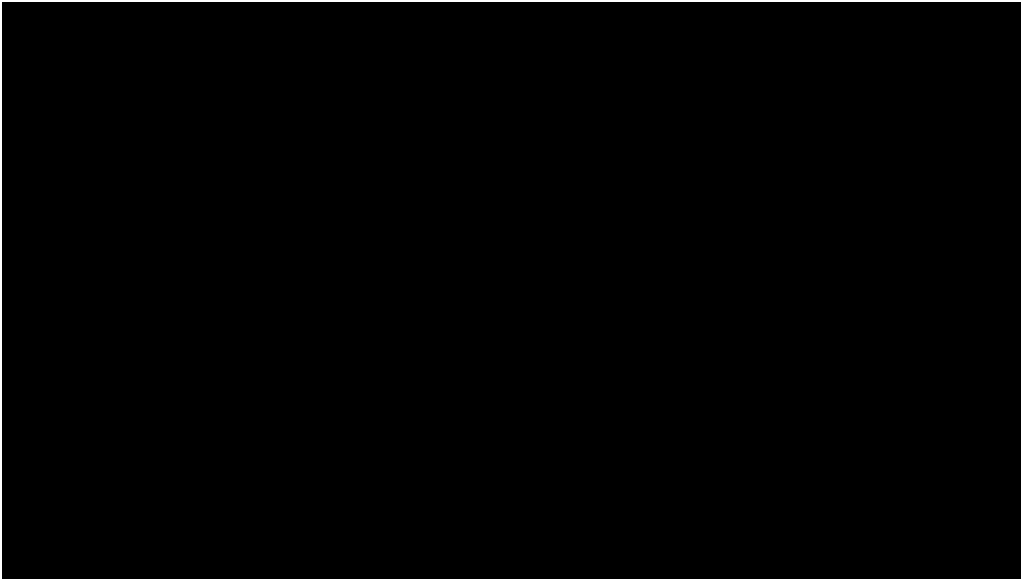
## CONCLUSIONS

- Many sensors and systems are now available.
- Look for certification and results of independent testing and assessment to provide more confidence in results.
- Some ongoing QC is essential, especially for operating networks of sensors to supplement reference monitoring.
- There are lots of exciting opportunities for mobile monitoring and educational programmes using sensors but be cautious about interpreting results.
- <https://ee.ricardo.com/air-quality/air-quality-measurements/independent-qa-qc-of-air-quality-sensor-data/blog-series>



# Plume Chasing

- On-road rapid-response measurements of NO<sub>2</sub> with an iCAD instrument
- Other instruments can be deployed for PM, particle counts, black carbon.



## Plume Chase- Preliminary Data

2023-06-14

### Maps

The maps below show the concentration of NO<sub>2</sub> measured by the iCAD every 2 seconds during the route in and around Oxford. The maximum value on the colour scale is the 99<sup>th</sup> percentile of all NO<sub>2</sub> measurements. However, some individual measurements were measured above this upper limit.

