

Lower-Cost Sensor Monitoring of $PM_{2.5}$ from Domestic Combustion

Monitoring in Greater Manchester

28th November 2024: Tim Bevington

Welsh Air Quality Seminar

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28/11/2024

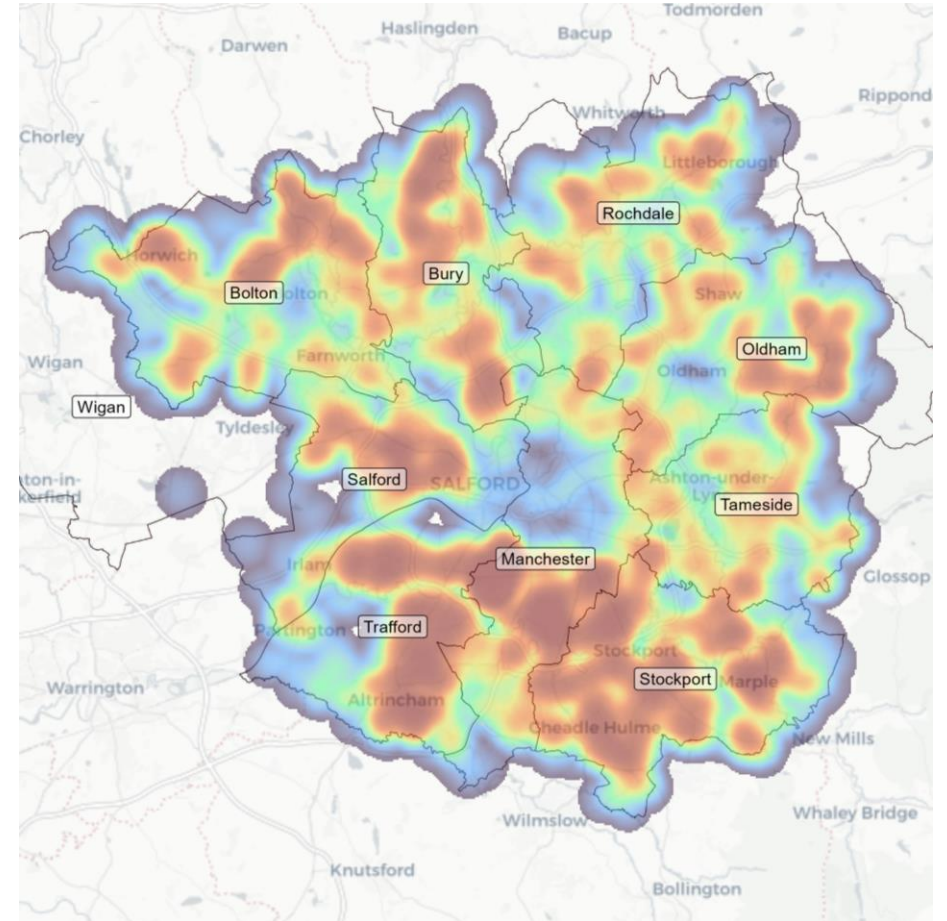
THE SENSOR NETWORK AND ITS OBJECTIVES

- DEFRA Air Quality Grant funded project to support Greater Manchester's aim to reduce PM_{2.5} concentrations through a reduction of domestic burning
- Sensor network to provide an evidence base for PM_{2.5} and to assess the impact of behavior change campaigns
- First behavior change campaign will be launched soon targeting the whole of Greater Manchester.
- We aim to improve the uncertainty of MCERTS indicative PM measurements to provide a strong evidence base to feed into research and public communications
- Ricardo have procured and deployed 43 indicative low-cost sensors (LCS) at 41 locations across Greater Manchester
- Along PM_{2.5} and PM₁₀ sensors also monitor NO, NO₂, CO, O₃ and 10 monitor CO₂
- On-going QA/QC regime for PM_{2.5} & PM₁₀ measurements. Other pollutants only scaled from co-location (greater measurement uncertainty)



NETWORK DESIGN

- Four sensors installed per borough and 3 sensor co-located with the Manchester Piccadilly AURN site
- Limited monitoring of PM2.5 from domestic burning to guide site selection
- Sites selected based on HETAS registration data: two background sites and two domestic burning sites per borough
- 10 CO₂ sensors installed at the five sites with the highest and lowest HETAS registrations within 200m
- Other site selection criteria:
 - Health & Safety
 - Site access
 - Power Supply
 - Local sources
 - Micro siting criteria – impact on air flow
 - Potential for public interference



DATA HUB AND REPORTING

- Data and reporting provided to the customer through a bespoke Data Hub
- The Data Hub includes:
 - Project details
 - Monitoring locations
 - Site types
 - Data explorer
 - Data download portal
 - Dynamic reports
- Password protected area due to sensitivity of the project
- Dynamic reports provide regular analysis of the data to increase understanding and accessibility

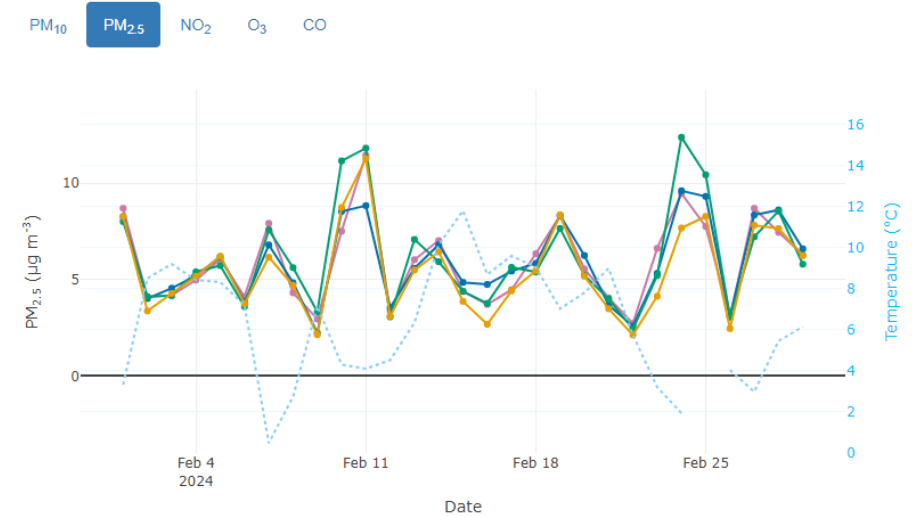


Figure 16: Time series plot of daily average PM_{2.5} concentration.

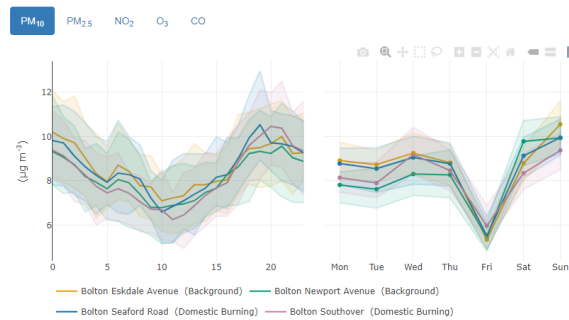
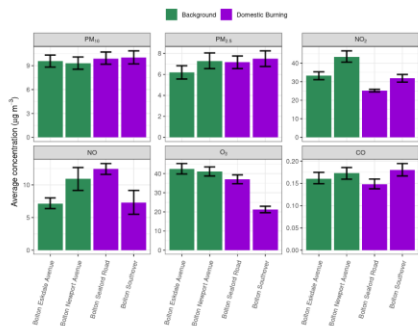


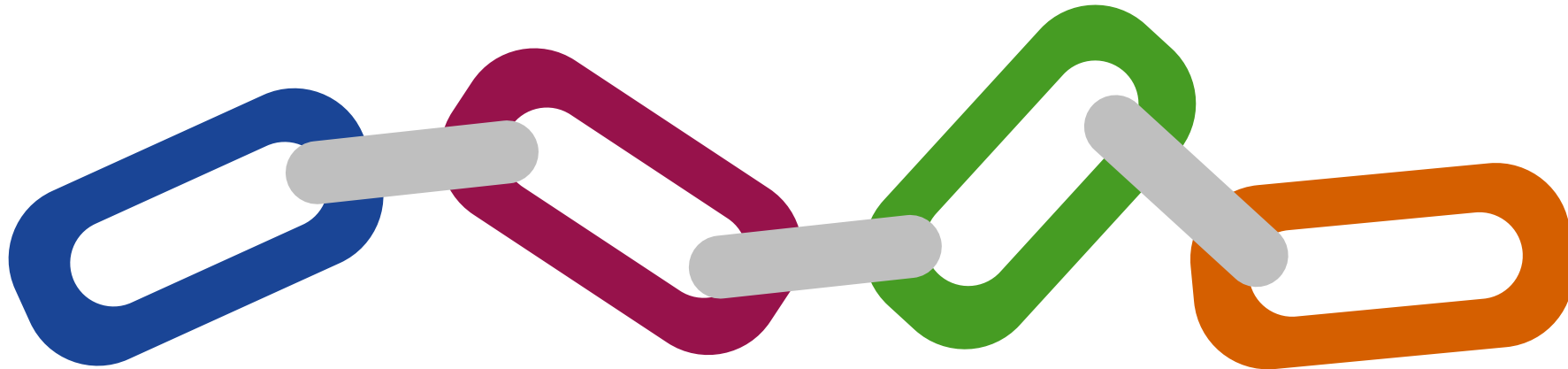
Figure 25: PM₁₀ time variation plot.



Figure 3: Polar plots for PM_{2.5} on map

QAQC – WHY?

- Need some way of linking lower cost sensor (LCS) measurements to more accurate reference measurements.
- **BUT** also need to know that reference measurements are of the required quality.



International:
European
Intercomparisons –
reference instruments
(BS EN 12341)

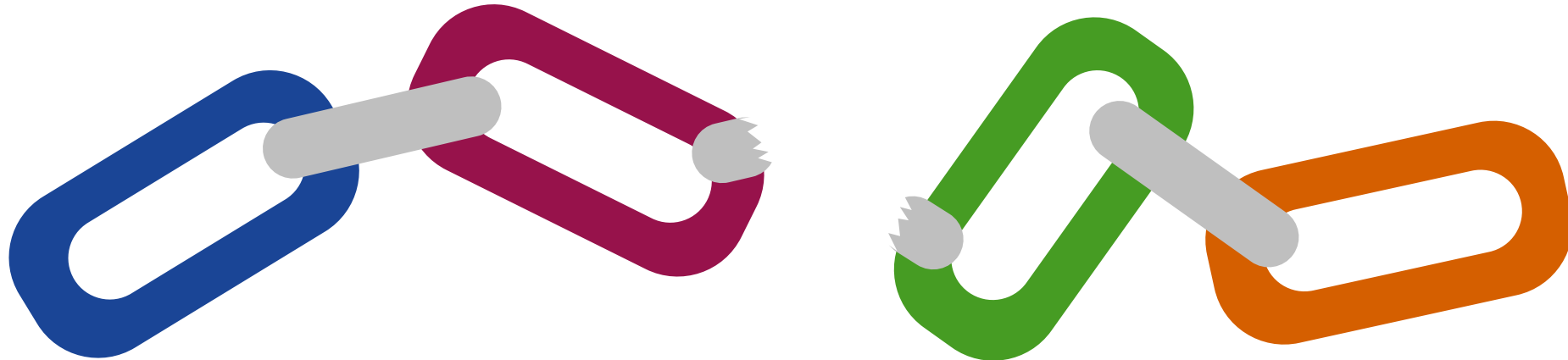
UK Certification:
BS EN 16450
(MCERTS)
TS 17660-2 (due late
2024 for PM LCS)

Local “calibrations”:
Co-locations of LCS with
reference-equivalent
instruments or other method
(PAS 4023)

**LCS measurements of
known accuracy:**
Indicative?
 $\leq 50\%$ uncertainty
relevant PM Limit Value

QAQC – WHY?

- Any break in this **traceability chain** and you lose the link to more accurate measurements
- ...**AND** as a result, the ability to assess the accuracy of the LCS measurements, which has direct implications on how you can use the data!



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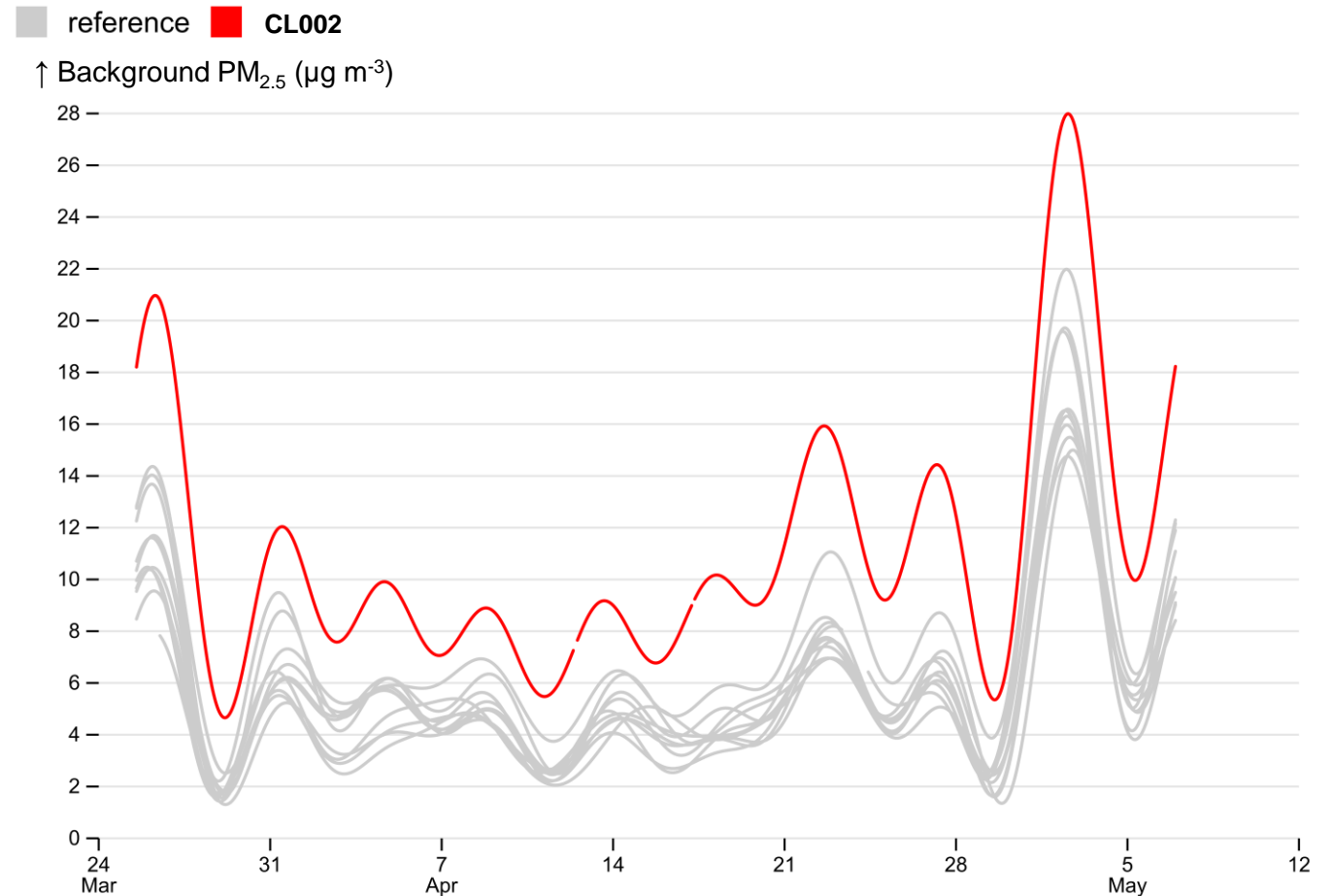
QAQC AND NETWORK PERFORMANCE

- Sensor holds MCERTS indicative certification for PM measurements (50% Data Quality Objective for PM at relevant Limit Value)
- On-going QA/QC required to maintain MCERTS standard
- Project aims to improve measurement uncertainty through proven QAQC methodology
- Initial Co-location at reference station before project commenced
- Co-location of any sensors following repair
- Ongoing co-location of three sensors at Manchester Piccadilly to monitor performance and provide regional adjustment if required
- Sensor datasets scaled automatically based on co-location factor
- Continuous QAQC with sensor data corrected in near real time and ratified quarterly
- Existing reference network will be used to further scale the sensor network based on assumption that background PM measurements are relatively consistent across a large area
- Understanding of regional background allows direct comparison of the underlying trend between sensors and reference sites
- Understanding of sensor performance from the initial co-location, regional background analysis and from triplicate co-location



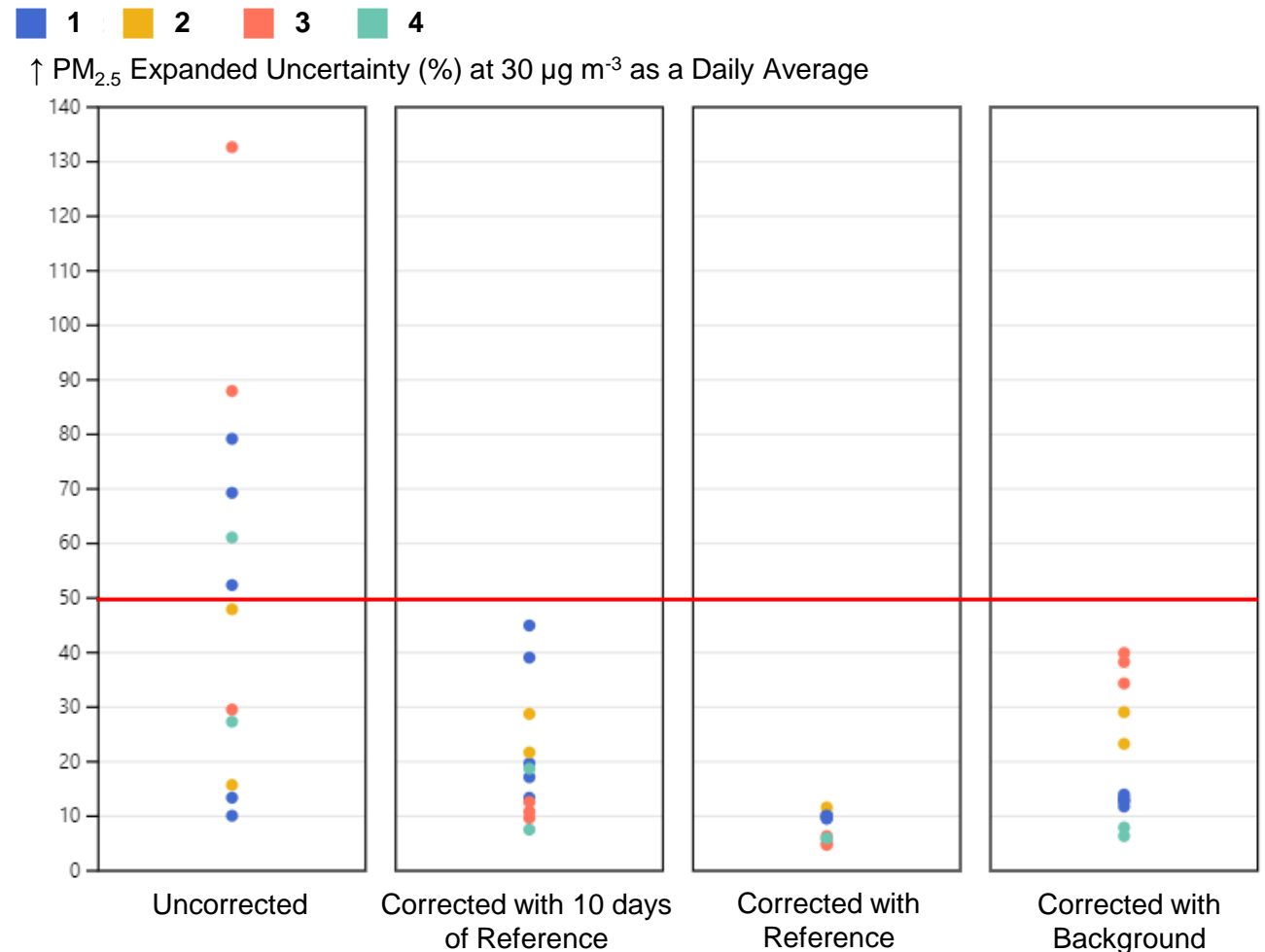
REGIONAL ADJUSTMENT – EXTRACTING THE “BACKGROUND SIGNAL”

- Rural background concentrations consistent across >100 km
- Urban background concentrations consistent across areas of a city
- How can we extract the “background signal” from measurements:
 - Find commonality across the reference network
 - Frequency analysis - extract low frequency trends e.g. 1-min to hourly peaks due to local sources; background concentrations will vary over several days.



REGIONAL ADJUSTMENT – TESTING PM_{2.5}

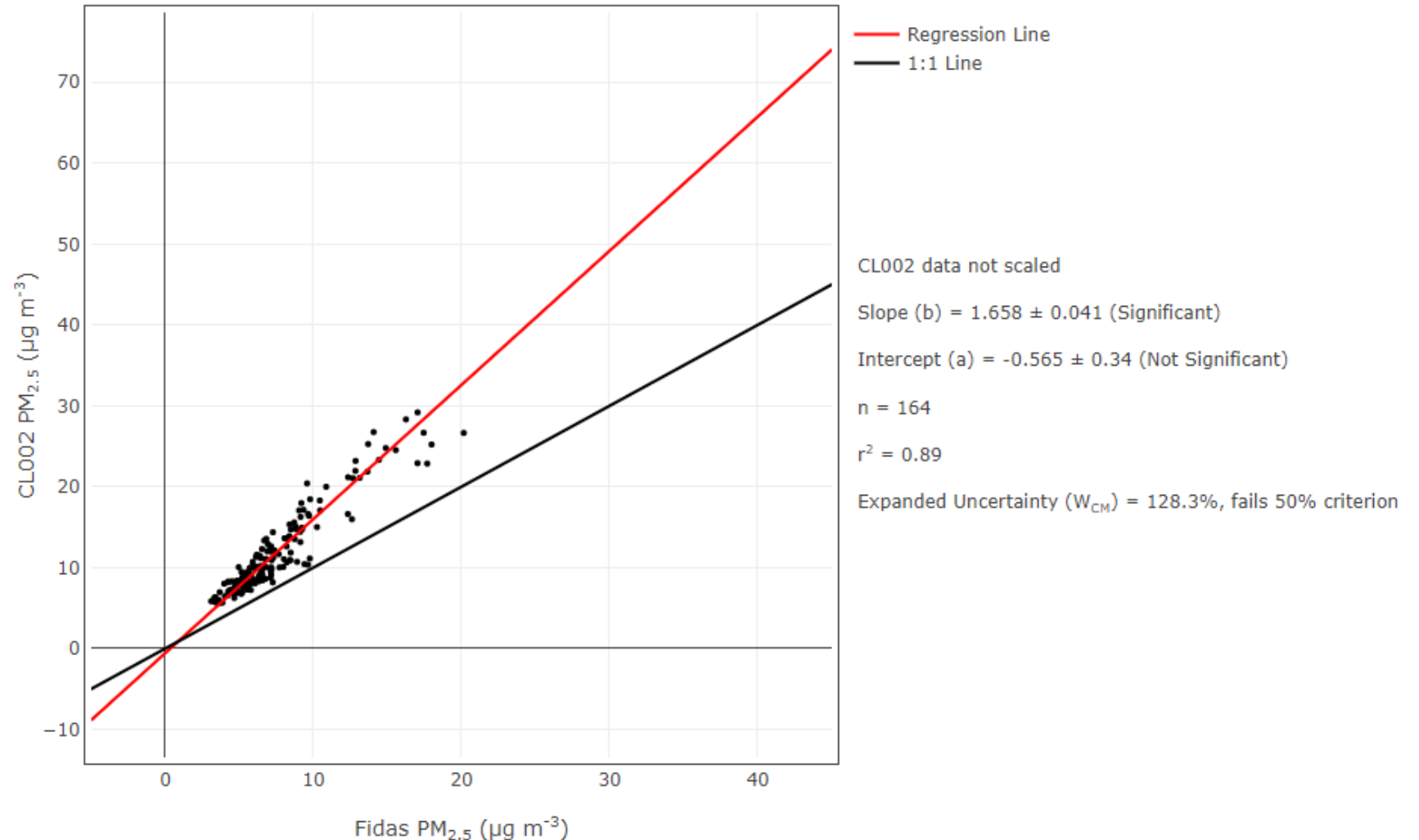
- Four co-location sites throughout the UK (mixture of roadside and background)
- **Uncorrected:** wide range of performance!
- **Corrected with 10-day co-location:** Improvement, all LCS pass 50% target, but co-locations are required, and results are not guaranteed on an ongoing basis.
- **Corrected with ongoing co-location:** All perform well as expected but not real life!
- **Corrected with “background” (regional):** All achieve < 50% uncertainty providing confidence that indicative measurements can be achieved using a regional correction.



ONGOING CO-LOCATION AT MANCHESTER PICCADILLY – RAW DATA

LCS CL002 – PM_{2.5}:

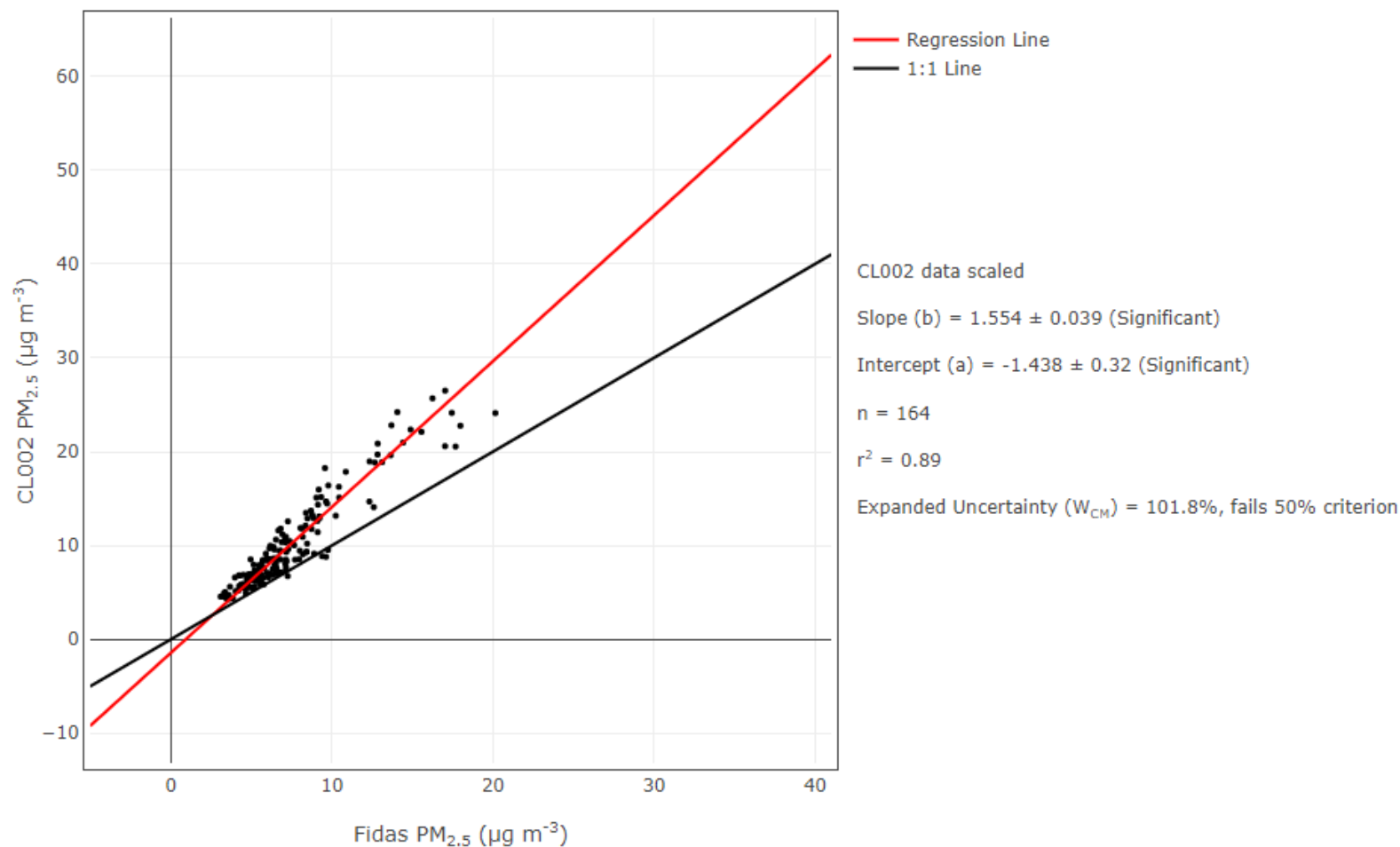
- Jan-24 to Aug-24 data
- Unscaled PM_{2.5} fails the 50% uncertainty requirement at 30 $\mu\text{g m}^{-3}$ as a daily average (128.3%).
- n - the number of valid daily averages
- r^2 - 0 indicates no linear relationship and 1 indicates a perfect linear relationship



ONGOING CO-LOCATION AT MANCHESTER PICCADILLY – SCALED DATA

LCS CL002 – PM_{2.5} (provisional):

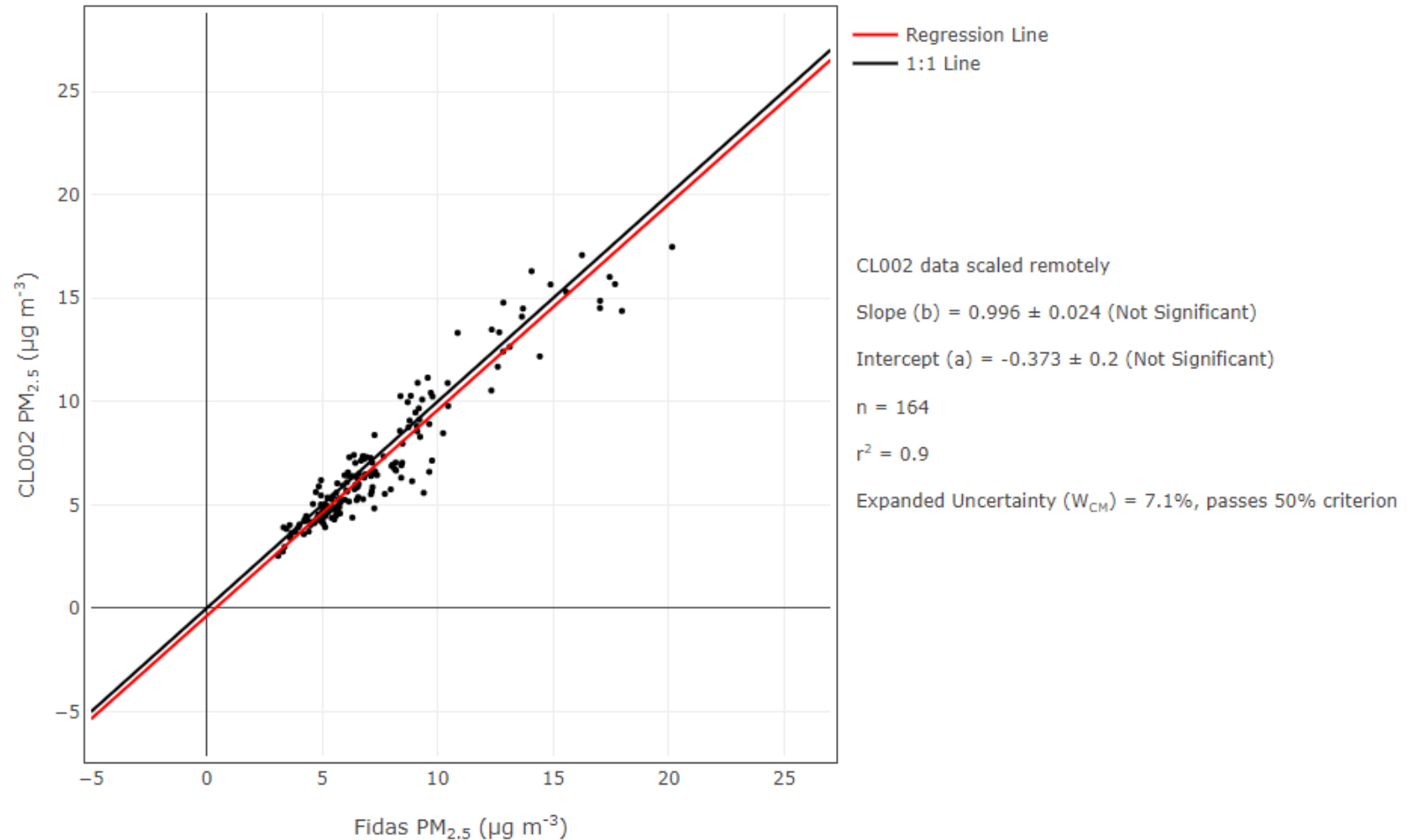
- Jan-24 to Aug-24 data
- When scaling the data using the initial co-location, the PM_{2.5} fails the 50% uncertainty requirement at 30 $\mu\text{g m}^{-3}$ as a daily average (101.8%).



ONGOING CO-LOCATION AT MANCHESTER PICCADILLY – REGIONALLY SCALED DATA

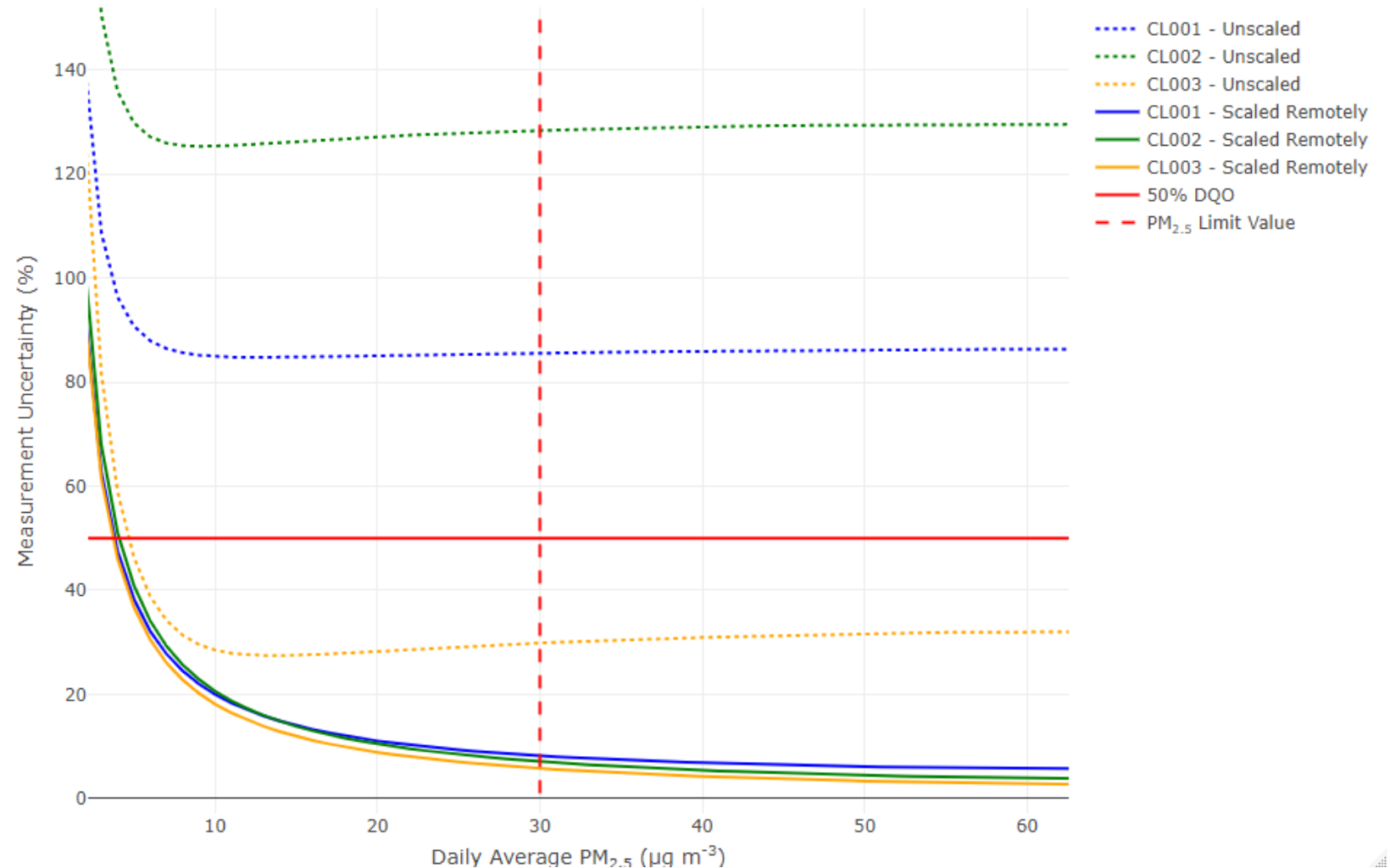
LCS CL002 - PM_{2.5} (provisional):

- Jan-24 to Aug-24 data
- When scaling the data using “extracted background”, the PM_{2.5} passes the 50% uncertainty requirement at 30 $\mu\text{g m}^{-3}$ as a daily average (7.1%).



QA/QC AND NETWORK PERFORMANCE – PM_{2.5}

- Chart summarises the PM_{2.5} measurement uncertainty across a measurement range for each of the three co-located LCS (CL001, CL002, CL003)
- Regional scaling of PM_{2.5} from the three co-located LCS also improves the between-sensor variance



CHALLENGES AND NEXT STEPS

Challenges

- Ensuring sites were all set-up as required across Boroughs
- Resolving faults quickly to maintain data capture
- Risk of vandalism but only seen at one site
- Management of multiple site power suppliers
- The networks target is to achieve at least 90% data capture
- To help achieve this there is a dedicated sensor checking team, automatic notifications of sensor status change, two spare floating sensors, site attendance within 24 hrs, supplier support to fix faults within 10 working days

Next Steps

- Baseline monitoring complete, we're entering the first full winter period
- Maintain network, regular review of performance
- Analysis following the winter period to compare background and burning sites
- Provide guidance on analysis and message content for public communications
- Use of other networks for greater understanding of elevated PM



ANY QUESTIONS?





THANK YOU!

Tim Bevington

Principal Air Quality Consultant

tim.bevington@ricardo.com

01235 753 125