

Findings from the QUANT study: Key considerations when setting up a sensor network

Dr Pete Edwards
University of York / NCAS
pete.edwards@york.ac.uk

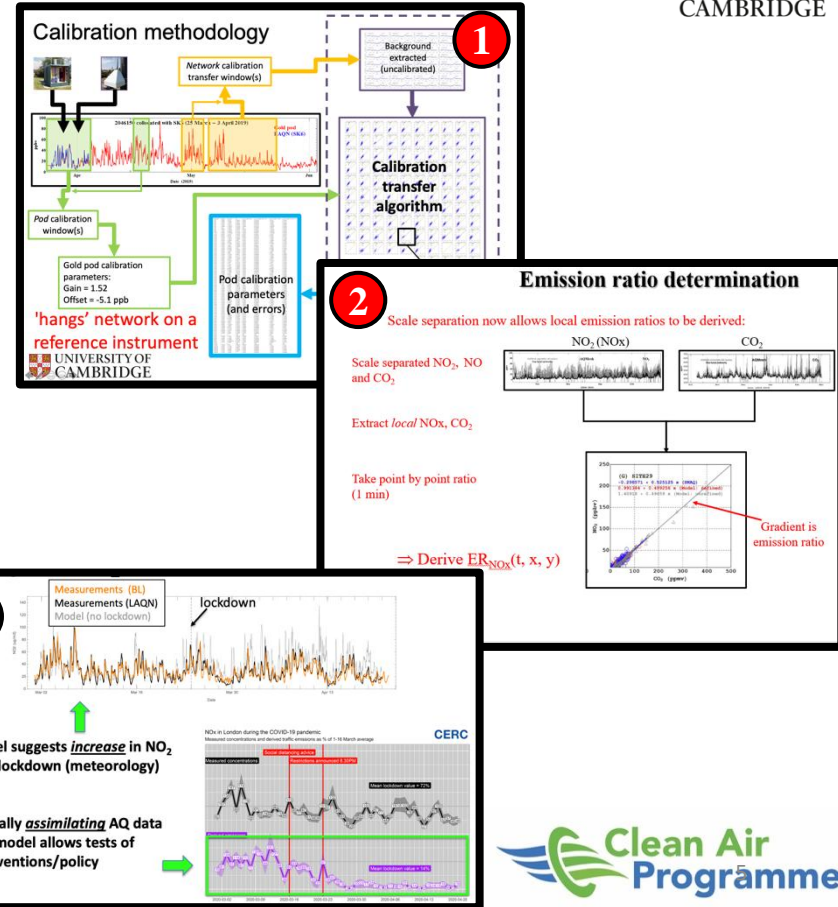
Assessing and enabling the use of low-cost air pollution sensors in UK urban environments

1. Delivery of a real-world open and fully-traceable assessment of the application of low-cost air pollution sensors and sensor networks in UK urban environments.
2. Enhance the value of low-cost sensor data for UK air quality challenges through the development of novel methods that use the unique strengths of these devices.

- Devices cover a range of technologies and calibration approaches.
- Deployment for > 2 years allows study of seasonal variations and long-term performance.
- Sites include urban background and road-side locations.
- Data analysis approaches being developed to enhance value of low cost sensor data, whilst acknowledging limitations.



- Tested and validated method for cloud-based calibration of sensor network (gases and PM)- low cost sensors and reference instruments
- New diagnostic approaches using fast-temporal data: source attribution and emission indices (relative to ΔCO_2)
- Assimilation of AQ data to quantify sources and trends (e.g. NO_2 sources due to Covid lockdown in the UK)





- Can low cost sensors provide pollutant source information?
- Separated and identified the sources and conditions that affected the air quality at a site using data from an Optical Particle Counter.

npj | climate and atmospheric science

Explore content ▾ About the journal ▾ Publish with us ▾

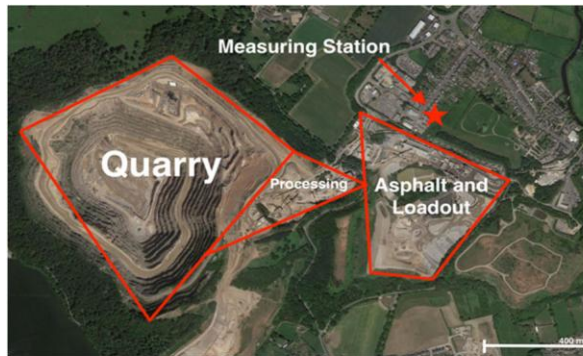
[nature](#) > [npj climate and atmospheric science](#) > [articles](#) > [article](#)

Article | [Open access](#) | [Published: 22 August 2023](#)

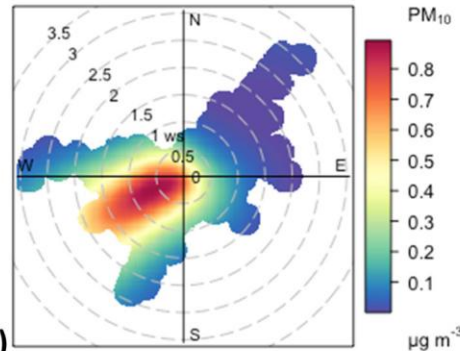
Towards comprehensive air quality management using low-cost sensors for pollution source apportionment

[Dimitrios Bousiotis](#), [Gordon Allison](#), [David C. S. Beddows](#), [Roy M. Harrison](#) & [Francis D. Pope](#)

[npj Climate and Atmospheric Science](#) **6**, Article number: 122 (2023) | [Cite this article](#)



(a)



Transparent assessment of commercial low-cost sensor devices in multiple UK urban environments



- Commercial sensor units deployed at 3 locations for 3 years alongside research/reference grade instruments.
- 5 different commercial devices being tested
- Multiples (4-6) of each
- Cover range of technologies and calibration approaches
- All data now open access

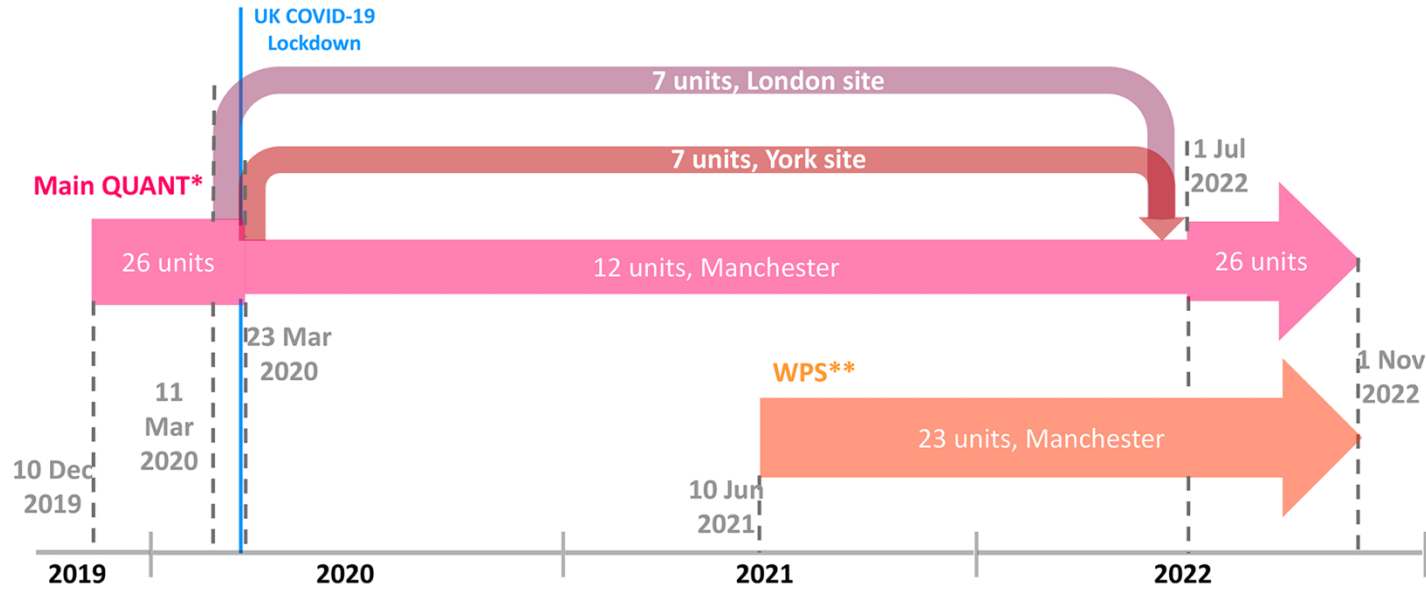


Dr Sebastian Diez



Dr Stuart Lacy

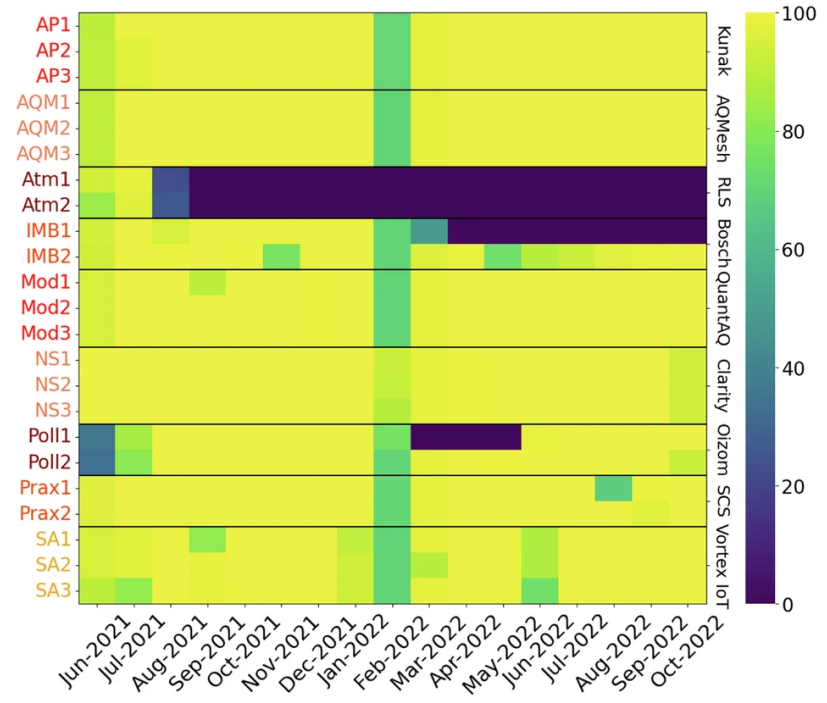
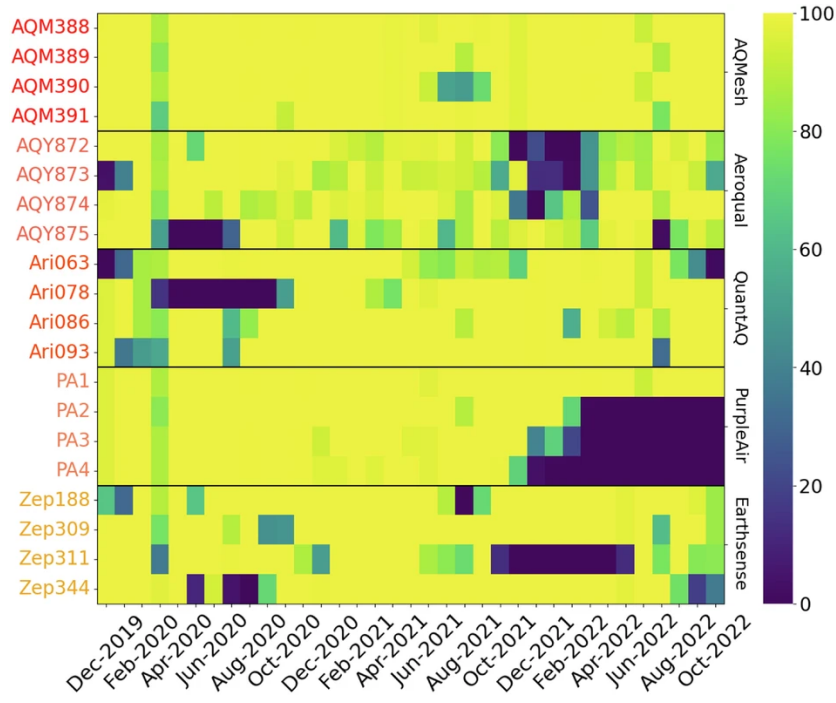
Transparent assessment of commercial low-cost sensor devices in multiple UK urban environments



*: Aeroqual (x4), AQMesh (x4), Zephyr (x4), QuantAQ (x4), PurpleAir (x10)

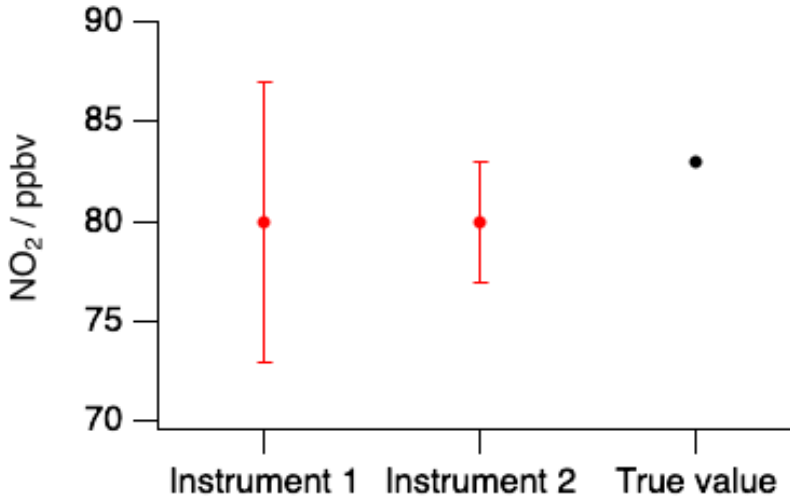
** : AQMesh (x3), Bosch (x2), Clarity (x3), Kunak (x3), Oizom (x2), QuantAQ (x3), South Coast Science (x2), Respirometer Living Sciences (x2), Vortex (x3)

Transparent assessment of commercial low-cost sensor devices in multiple UK urban environments



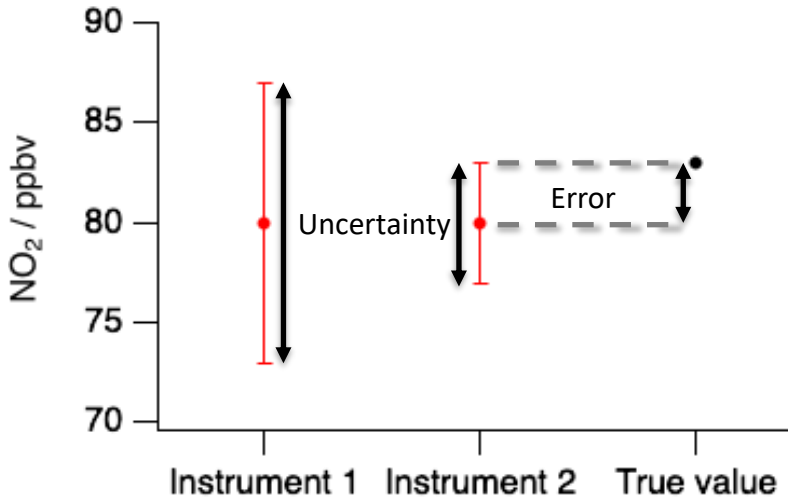
Measurement uncertainties

- All measurements have an associated uncertainty
- The ability of measurement data to answer a specific question is ultimately determined by the data uncertainty

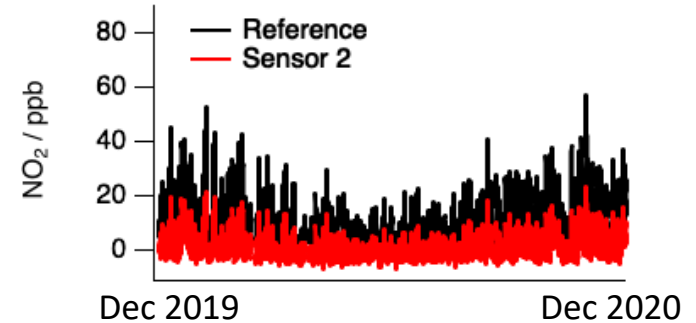
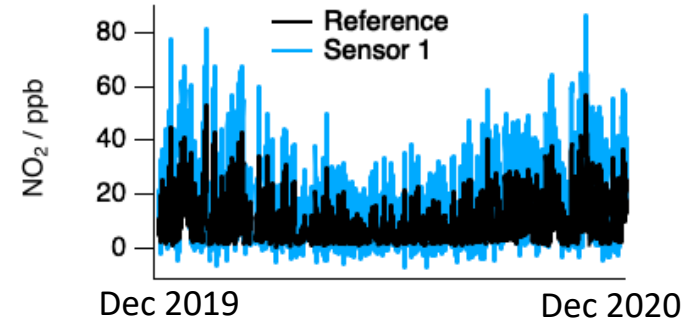


Measurement uncertainties

- All measurements have an associated uncertainty
- The ability of measurement data to answer a specific question is ultimately determined by the data uncertainty
- Measurement error is typically unknown in most monitoring situations, with an uncertainty providing a likely range of the error based on prior knowledge

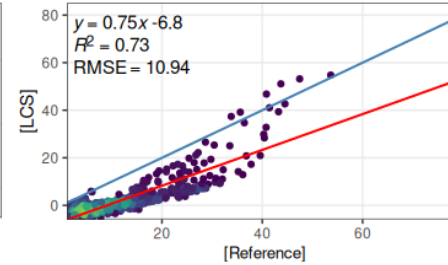
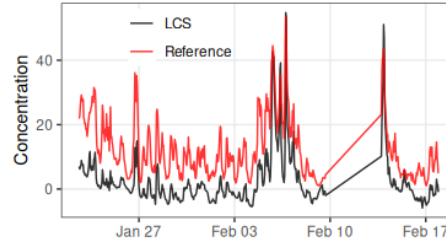


- Many different types/sources of error, e.g.:
 - Random noise
 - Constant bias (offset error)
 - Proportional bias (slope error)
 - Interference on signal
- These source of error all contribute to the overall measurement uncertainty, but the nature of the error has significant implications for how the data can be used.



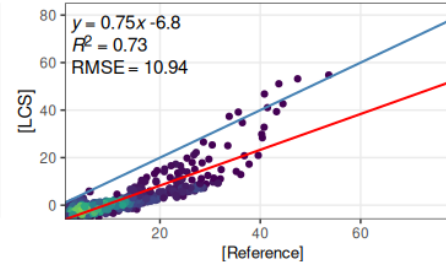
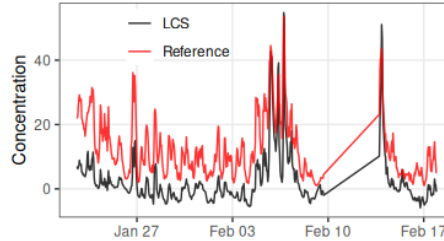
The benefits of colocation calibrations

“Out-of-box” NO₂ data

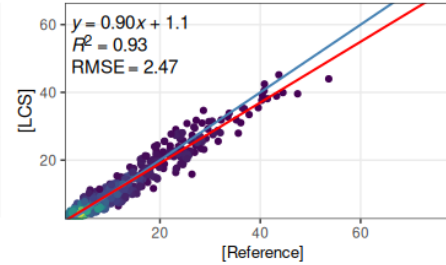
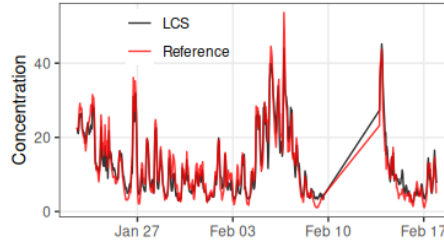


The benefits of colocation calibrations

“Out-of-box” NO₂ data

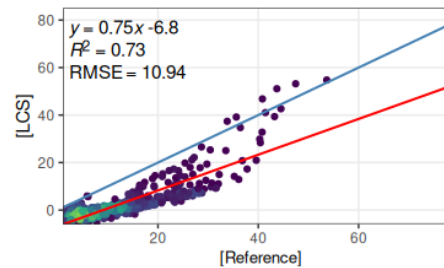
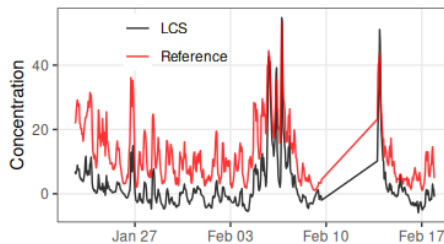


Colocation calibration
impact on training data

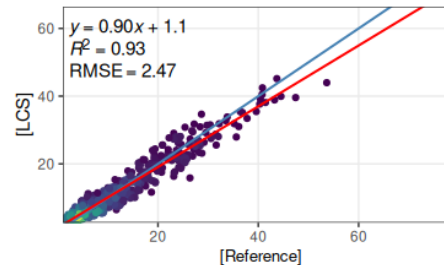
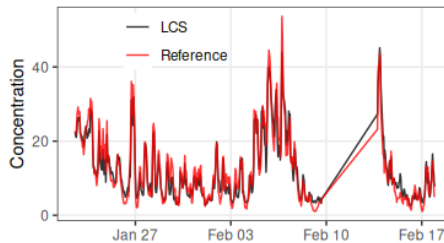


The benefits of colocation calibrations

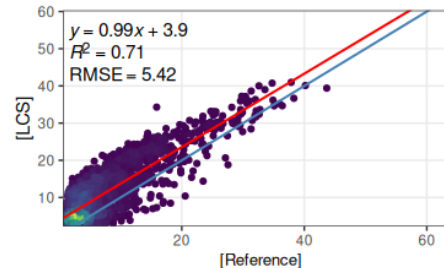
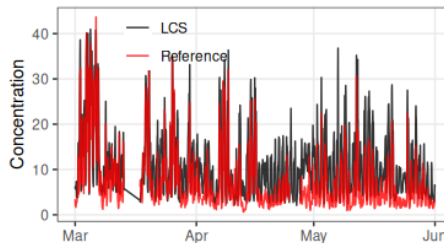
“Out-of-box” NO₂ data



Colocation calibration
impact on training data

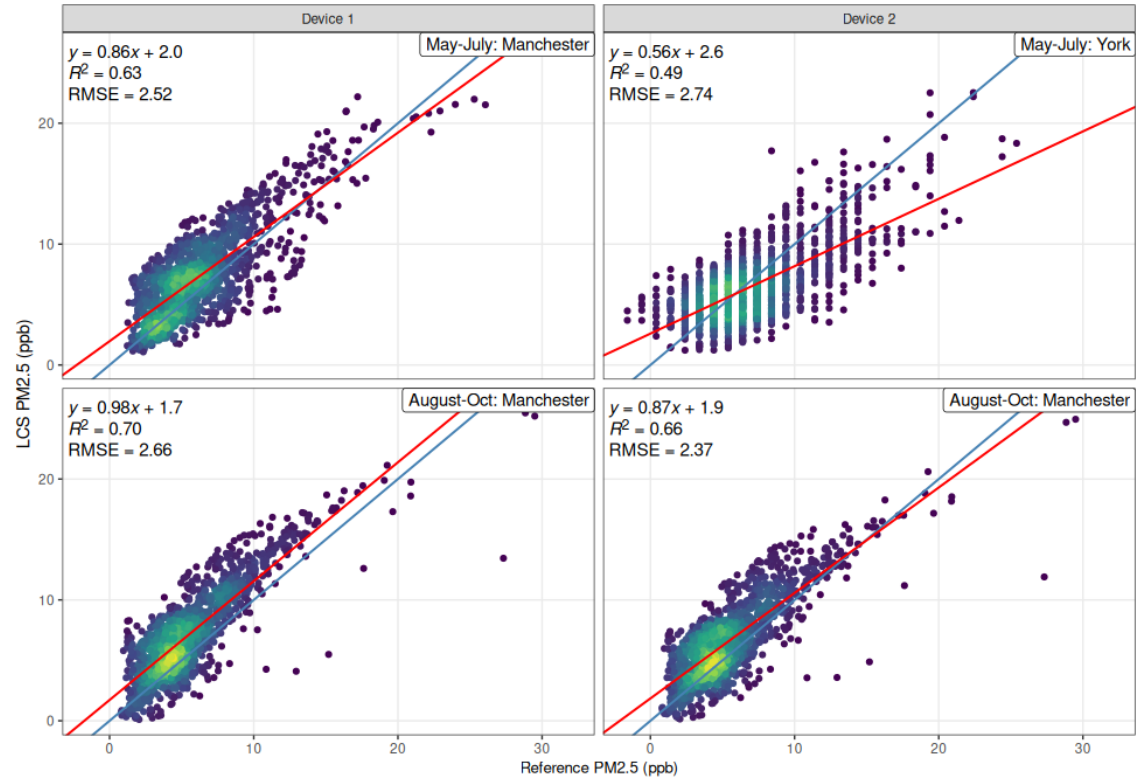


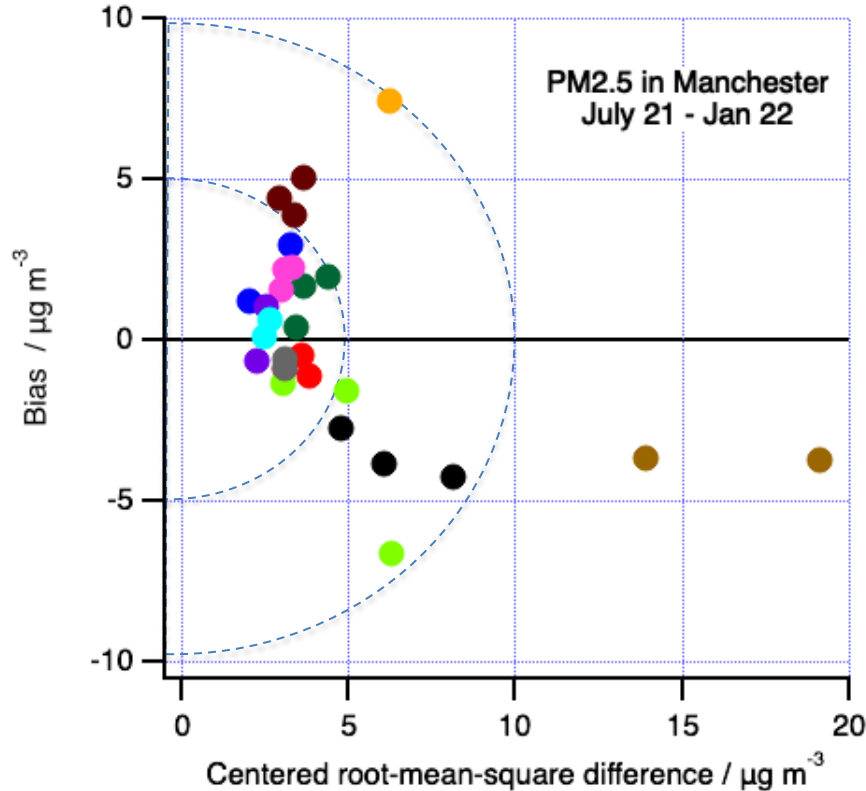
Colocation calibration
impact on test data



Impact on sensor location changes

Sensor calibrations can be location dependent





- Inter-device precision is how similar data from identical devices is when measuring the same air
- Important to understand if using multiple devices (e.g. network)

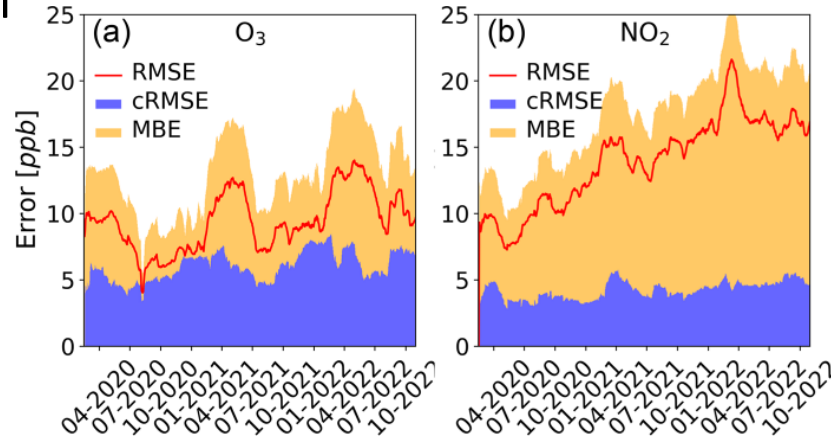
Do air quality sensors provide an affordable and reliable solution to local air quality monitoring?

- Low-cost air pollution sensors can provide useful measurements with quantified uncertainties, depending on operation
- Sensor error characteristics need to be assessed in order to understand data uncertainties
- Ultimately, end-users need to understand the data needs of the application **before** selecting an appropriate measurement tool
- Once data requirements and measurement uncertainties are understood, strategies can be implemented to improve performance

Reducing sensor bias – case study

Understanding the nature of the error is key!

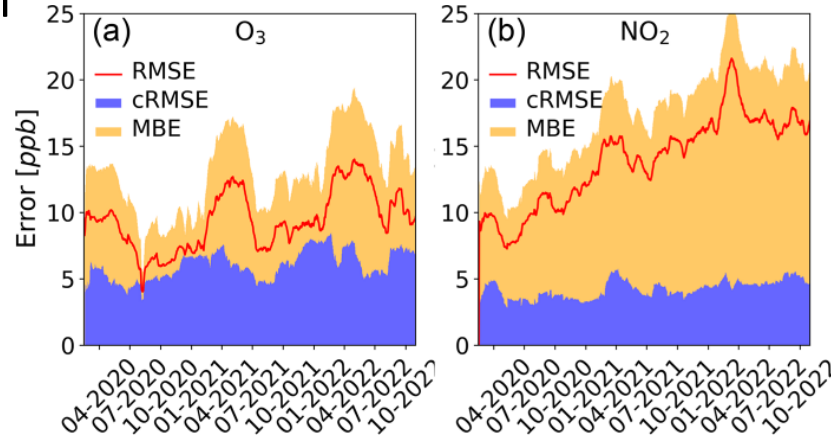
- Ozone has a clear seasonal bias component (higher between March – July)
- Nitrogen dioxide shows a steadily increasing bias (drift)



Reducing sensor bias – case study

Understanding the nature of the error is key!

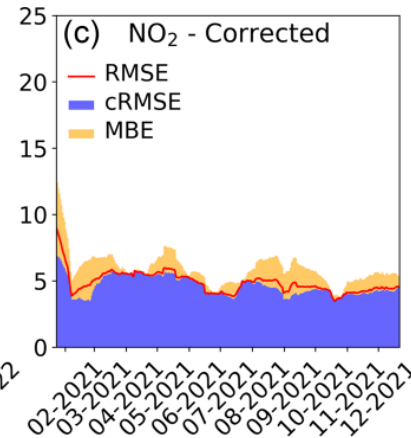
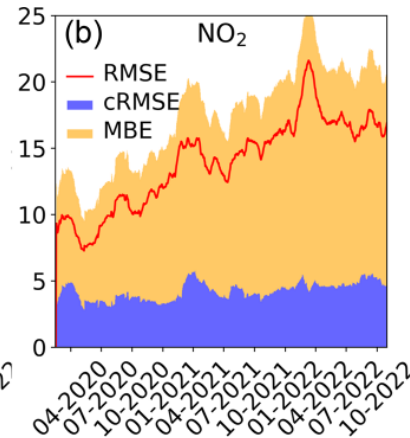
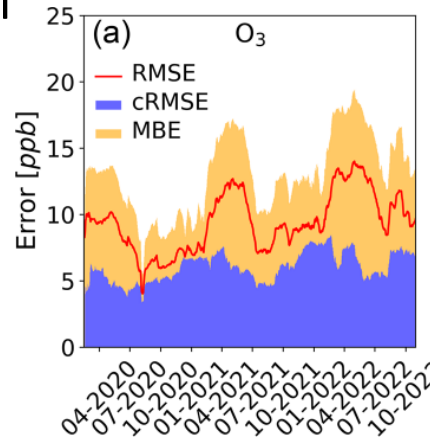
- Ozone has a clear seasonal bias component (higher between March – July)
- Nitrogen dioxide shows a steadily increasing bias (drift)
- Can we use a collocated NO_2 diffusion tube to correct this drift?



Reducing sensor bias – case study

Understanding the nature of the error is key!

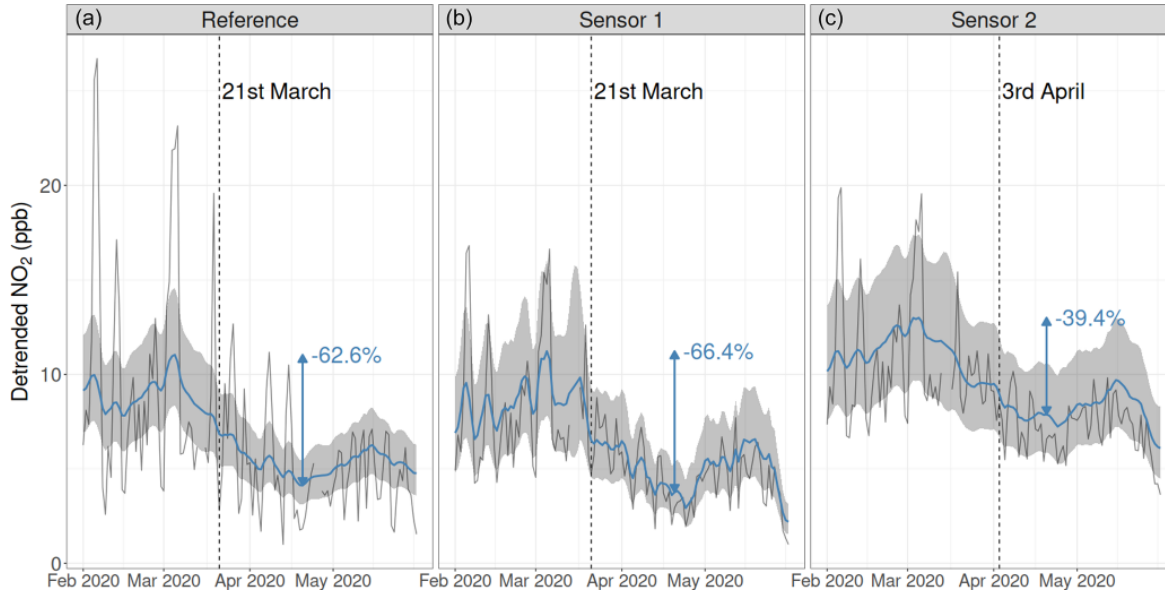
- Ozone has a clear seasonal bias component (higher between March – July)
- Nitrogen dioxide shows a steadily increasing bias (drift)
- Can we use a collocated NO_2 diffusion tube to correct this drift?



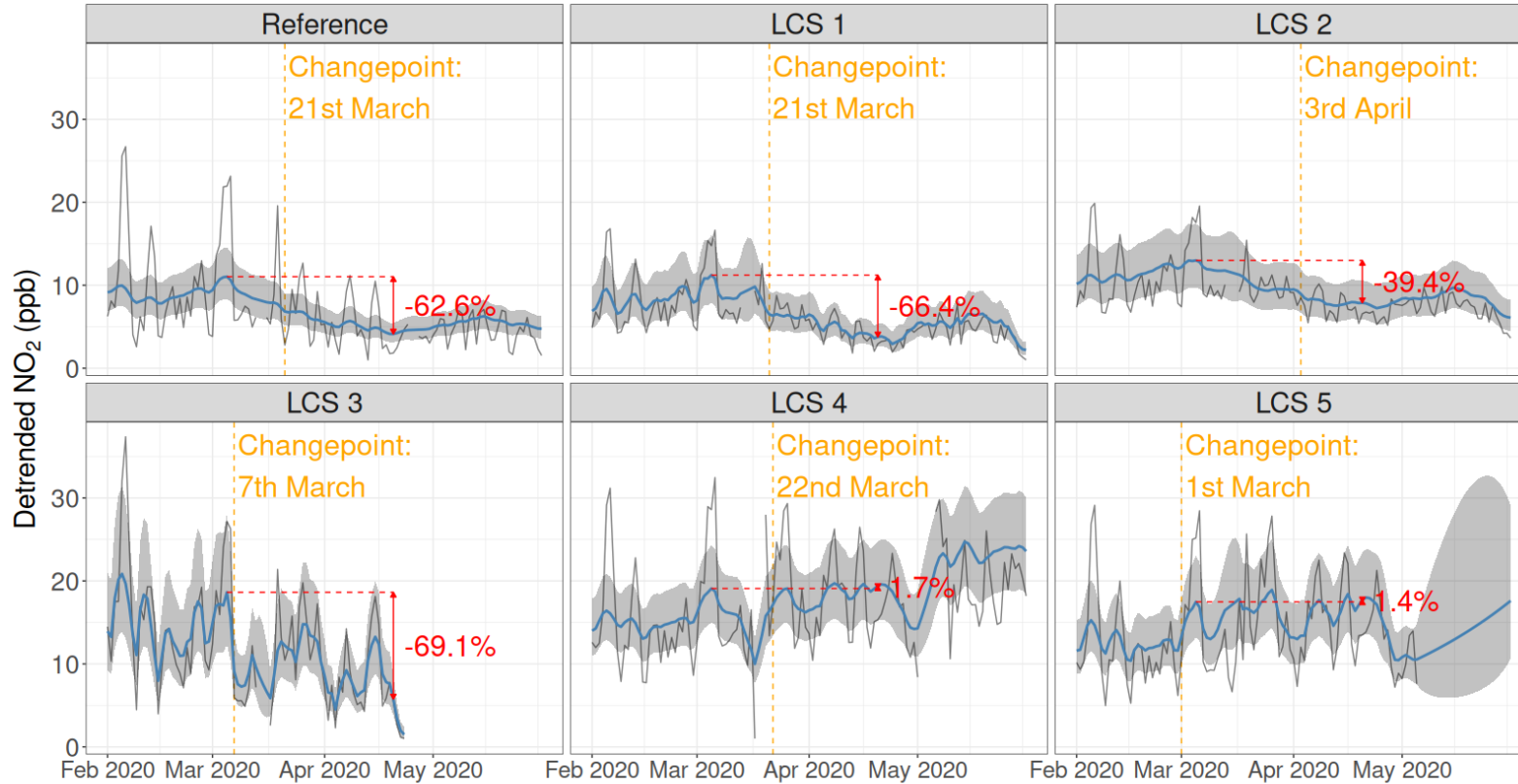
Change point detection – case study

Potential sensor use case – NO₂ change point detection

- COVID-19 lockdown
- Data (black) was detrended for weather influence (blue)
- 2 of the 8 NO₂ sensors successfully identified the COVID-19 lockdown, despite only 3 months training data



Change point detection – case study



Key considerations when making measurements

- Understand the question being asked and what data is required to answer it.
- How do these data requirements map onto measurement requirements (what, how well, for how long)?
e.g. what changes in concentration are expected? What measurement accuracy and precision is needed to see the signal over normal variability in the timescales available?
- Do I need to make new measurements or is data already available that can provide what is needed?
- What measurement technologies are available that meet your data requirements?
- Are these practical / affordable? If not, do I need to rethink my question?

Summary

- The QUANT project worked to enable LCS use in the UK
- Unique WP1 dataset assessing LCS performance in UK urban environments
- WP2 looking at the power of the network
- WP3 using low-cost sensors to provide PM source information
- Understanding the requirements of the monitoring challenge and the uncertainty characteristics of the available tools is key!

Atmos. Meas. Tech., 17, 3809–3827, 2024
https://doi.org/10.5194/amt-17-3809-2024
© Author(s) 2024. This work is distributed under the Creative Commons Attribution 4.0 License.



Long-term evaluation of commercial air quality sensors: an overview from the QUANT (Quantification of Utility of Atmospheric Network Technologies) study

Sebastian Diez^{1,2}, Stuart Lacey³, Hugh Coe³, Josefina Urquiza^{1,3}, Max Priestman⁶, Michael Flynn¹, Nicholas Marsden¹, Nicholas A. Martin¹, Stefan Gillott⁴, Thomas Bannan¹, and Pete M. Edwards^{2,8}

Atmos. Meas. Tech., 14, 4139–4155, 2021
https://doi.org/10.5194/amt-14-4139-2021
© Author(s) 2021. This work is distributed under the Creative Commons Attribution 4.0 License.



Assessing the sources of particles at an urban background site using both regulatory instruments and low-cost sensors – a comparative study

Dimitrios Bousiotis¹, Ajit Singh¹, Molly Haugen¹, David C. S. Beddows¹, Sebastián Diez¹, Killian L. Murphy¹, Pete M. Edwards¹, Adam Boles¹, Roy M. Harrison^{1,2}, and Francis D. Pope¹

Atmos. Meas. Tech., 15, 4091–4105, 2022
https://doi.org/10.5194/amt-15-4091-2022
© Author(s) 2022. This work is distributed under the Creative Commons Attribution 4.0 License.



Air pollution measurement errors: is your data fit for purpose?

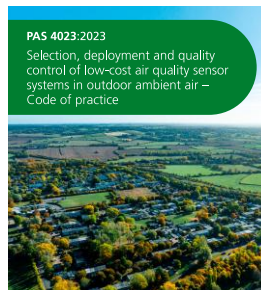
Sebastian Diez¹, Stuart E. Lacey¹, Thomas J. Bannan², Michael Flynn², Tom Gardiner³, David Harrison¹, Nicholas Marsden¹, Nicholas A. Martin¹, Katie Read^{1,5}, and Pete M. Edwards¹

Atmos. Meas. Tech., 15, 4047–4061, 2022
https://doi.org/10.5194/amt-15-4047-2022
© Author(s) 2022. This work is distributed under the Creative Commons Attribution 4.0 License.



A study on the performance of low-cost sensors for source apportionment at an urban background site

Dimitrios Bousiotis¹, David C. S. Beddows¹, Ajit Singh¹, Molly Haugen¹, Sebastián Diez¹, Pete M. Edwards¹, Adam Boles¹, Roy M. Harrison¹, and Francis D. Pope¹



scientific **data**

OPEN DATA DESCRIPTOR **QUANT: a long-term multi-city commercial air sensor dataset for performance evaluation**

Sebastian Diez^{1,2,8}, Stuart Lacey³, Josefina Urquiza^{1,3} & Pete Edwards¹



Natural
Environment
Research Council



National Centre for
Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL



Department
for Environment
Food & Rural Affairs

Thank you



UNIVERSITY
of York



UNIVERSITY OF
CAMBRIDGE



UNIVERSITY OF
BIRMINGHAM

Cranfield
UNIVERSITY



UK Centre for
Ecology & Hydrology

NPL 
National Physical Laboratory

 **Met Office**

 **Clean Air
Programme**