What can we learn from nested IoT low-cost sensor networks for air quality? A CASE STUDY OF PM2.5 IN BIRMINGHAM UK.

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Birmingham is in the West Midlands region of the UK. In 2021, multiple low-cost IoT sensor networks for air pollution were deployed by both the University and the local authority. Whilst low-cost sensors are often associated with uncertainty, optical particle counters have been show to perform well at measuring PM2.5, giving indicative insight into concentrations following calibrations and corrections for humidity.
This poster presents findings from this combined network, considering the successes and pitfalls of low-cost monitoring and insight into regional and local PM2.5 concentrations.

1) Method

- Data from 1st June 2021-31st May 2022
- 28 locations across the city sampled using either Zephyrs by Earthsense or AltasensePM, both of which use the Plantower PMS5003. Units installed at 2.5-3m on existing street furniture.
- Collaborative monitoring effort with local authority and project partners in selecting locations.
- Thorough data validation steps of all sensor data before analysis. including filtering outliers, static data, checking data completeness and by meteorology.
- Data was hosted on an open-access online platform

2) Insights into PM2.5 concentrations

- In-field collocation with reference instrument had slopes of 0.98-1.3 and collocation of multiple sensors had a correlation of 0.96.
- Sensor network provided similar regional results to regulatory network with a citywide average of 8.56µgm-3 for low-cost network and 8.37 µgm-3 regulatory network. Sensors were also able to detect regional PM events, including a dust storm.
- Sensor network gave greater insight into spatial variability of concentrations, ranging between background sites and roadside locations. Whilst the 3 regulatory instruments across the city gave a range of 7.05-9.05µgm-3, sensors were able to demonstrate variation of 6.18-13.16µgm-3, highlighting hot spots that the sparse regulatory station cannot capture.
- Sensor averages were compared to a high res model. Sensors generally reported lower concentrations than the model, but were able to detect some of the spatial variability predicted by the model.

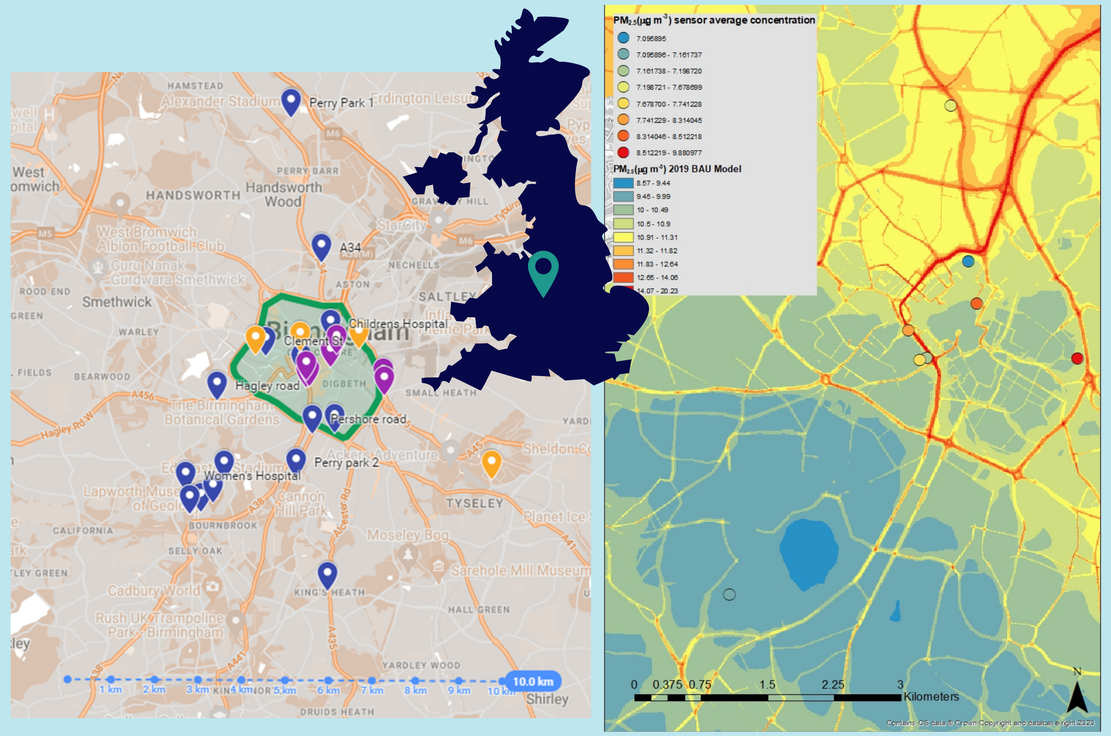

Figure 1- left: a map of sensor location in Birmingham UK with the Clean Air Zone which was introduced on 01/06/21 highlighted in green. right: a high resolution model (10m x 10m) for PM2.5 overlayed with sensor average concentrations. (1)

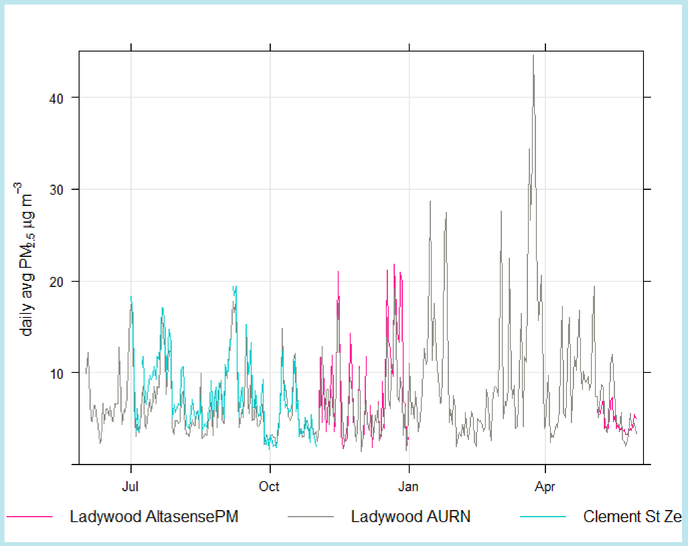

Figure 2- infield colocation of a Zephyr and Altasense PM with a FIDAS at a regulatory site in field.

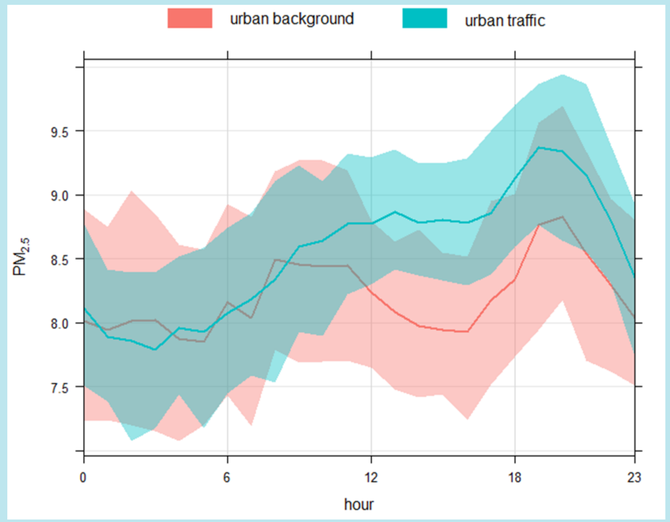

Figure 3- diurnal profile of sensor data grouped by site type demonstrating how urban roadside locations experienced a different diurnal pattern to the urban background sites

3) Successes

- Sensing units were semi-mobile, so were able to be moved around the city easily to capture various events or areas of interest.
- Sensors captured additional insight into spatial variation in concentrations, including differences between roadside and urban background, giving insight into road emissions contribution to local concentrations.
- Lessons learnt from the sensor network and it's data management are being shared with local and central government to ensure a legacy of best practice in low-cost sensor use and live stream data management.

4) Pitfalls

- Sensor data capture at each site varied (6.8-94.4% with an average of 51.2% cover of the sampling period). Some of this is due to sensors being relocated sites, but some units did suffer from comms/hardware issues. Solar powered Zephyr experienced winter power outtages- ensuring good solar insolation in a city centre is challenging.
- The bureaucracy of installing sensors on street furniture was lengthy and caused delays to install/maintenance
- Data was open-source, so it is important to disclose the caveats of low-cost sensing to potential non-specialist users without causing unnecessary distrust of the data.

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(1) ZHONG, J., HOOD, C., JOHNSON, K., STOCKER, J., HANDLEY, J., WOLSTENCROFT, M., MAZZEO, A., CAI, X. & BLOSS, W. J. 2021. Using Task Farming to Optimise a Street-Scale Resolution Air Quality Model of the West Midlands (UK). Atmosphere, 12, 983.

Photography encouraged

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