High-Density, High-Resolution, Low-Cost Air Quality Sensor Networks for Urban Air Monitoring. The SNAQ Heathrow Project

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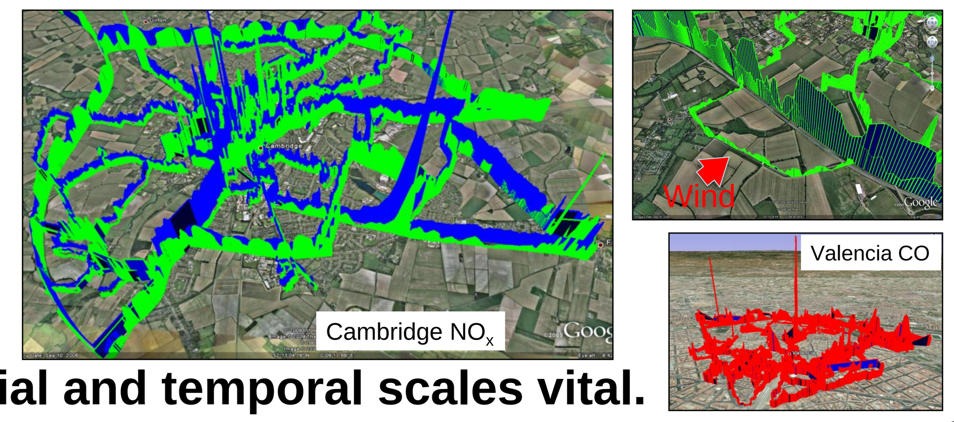
Sensor Network for Air Quality Heathrow

ABSTRACT: Monitoring air quality in highly granular environments such as urban areas which are spatially heterogeneous with variable emission sources, measurements need to be made at appropriate spatial and temporal scales. Current routine air quality monitoring networks generally are either composed of sparse expensive installations (incorporating e.g. chemiluminescence instruments) or higher density low time resolution systems (e.g. NO_2 diffusion tubes). Either approach may not accurately capture important effects such as pollutant "hot spots" or adequately capture spatial (or temporal) variability. As a result, analysis based on data from traditional low spatial resolution networks, such as personal exposure, may be inaccurate.

A state of the art multi species instrument package for deployment in scalable sensor networks has been developed which has general applicability. This is a a sophisticated, low-cost, multi species (gas phase, speciated PM, meteorology) air quality measurement network methodology incorporating GPS and GPRS which has been developed for high resolution air quality measurements in urban areas. This is currently being employed as part of a major 3 year UK program at London Heathrow airport (Sensor Networks for Air Quality (SNAQ)). The main project outcome is the creation of a calibrated, high spatial and temporal resolution data set. The network incorporates existing GPRS infrastructures for real time sending of data with low overheads in terms of cost, effort and installation.

AIR QUALITY PROBLEM

- Spatially heterogeneous.
- Highly variable (multiple species).
- Non-linear chemical processes.
- Complex largely uncertain sources.
- Complex micro-meteorology.
- **Measurements at appropriate spatial and temporal scales vital.**



ROUTINE MONITORING NETWORKS

- Expensive relatively sparse networks of instrumentation (e.g. UV/IR absorption).
- or higher density networks with lower time resolution (e.g. NO_2 diffusion tubes, >bi weekly averages).
- Important aspects of urban air quality not reliably captured (spatial and temporal granularity).
- Urban air quality not be adequately constrained.
- Derived parameters e.g. personal exposure will be unreliable. ⇒ **Alternative solutions?**

THE FUTURE: CONCLUSIONS

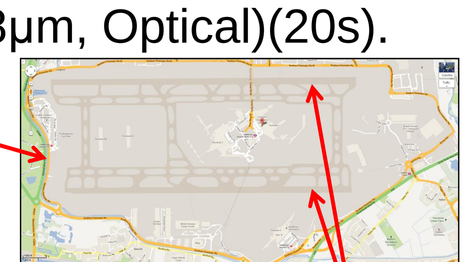
Low-cost miniature air quality sensors now feasible for widespread, real-time ambient monitoring use.

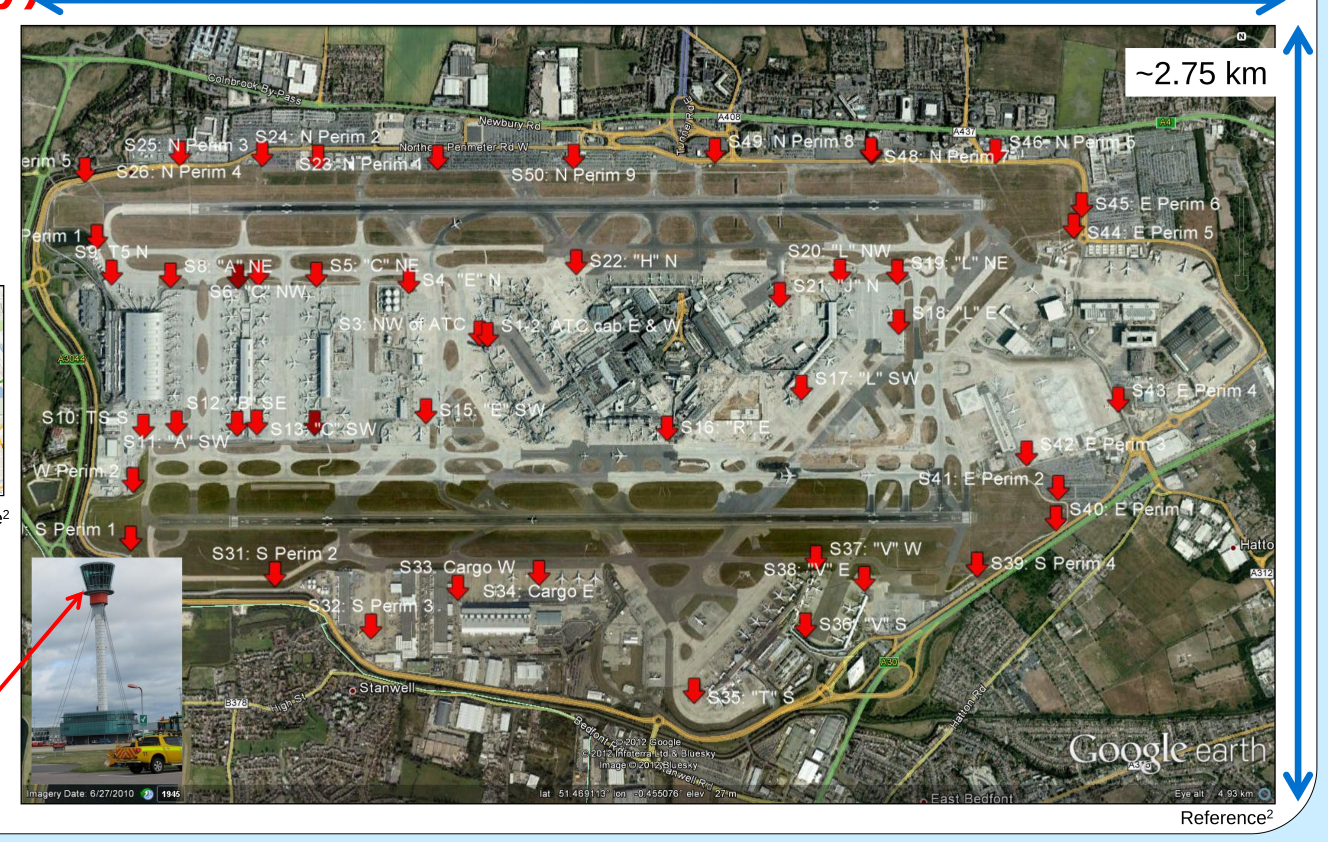
- **Environmental science.**
- **Air quality monitoring and regulation.**
- **Source attribution.**
- **Exposure studies.**

SNAQ HEATHROW (Sensor Network for Air Quality)

http://www.snaq.org/

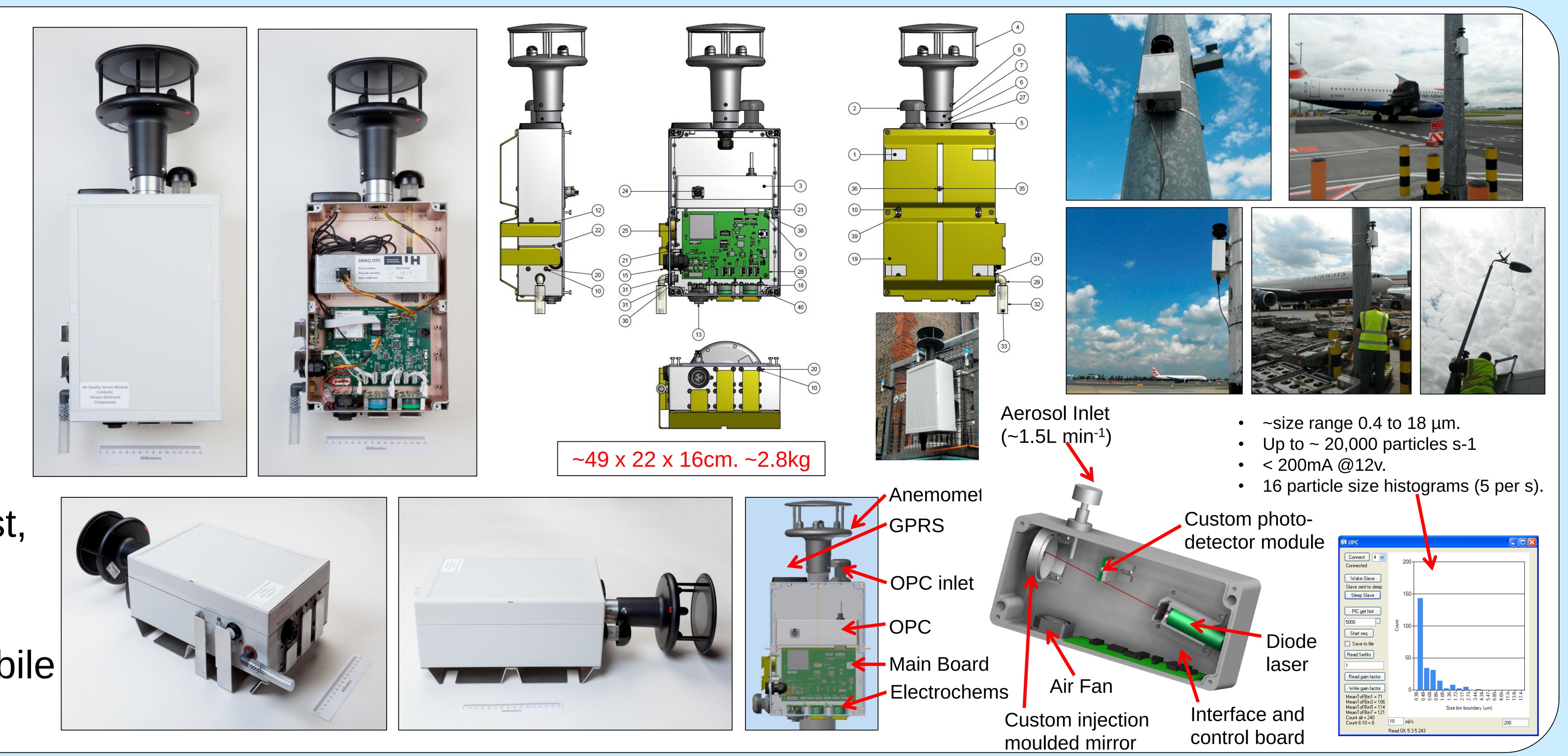
- 50 sensor nodes, real time data transmission.
- Autonomous operation for 12 months.
- **NO, NO_2, CO, SO_2, O_3** (Electrochemical)(10s).
- **Size-speciated Particulates** (0.4-18μm, Optical)(20s).
- **CO_2** (NDIR).
- **ΣVOCs** (PID)(10s).
- **Meteorology** (sonic anemometry).
- **Temperature and humidity** (capacitive).
- Source attribution/model validation for area.
- Methodology for optimising sensor network design.
- Novel software tools for calibration, data-mining, visualisation & interpretation.





MULTI-SENSOR NODES

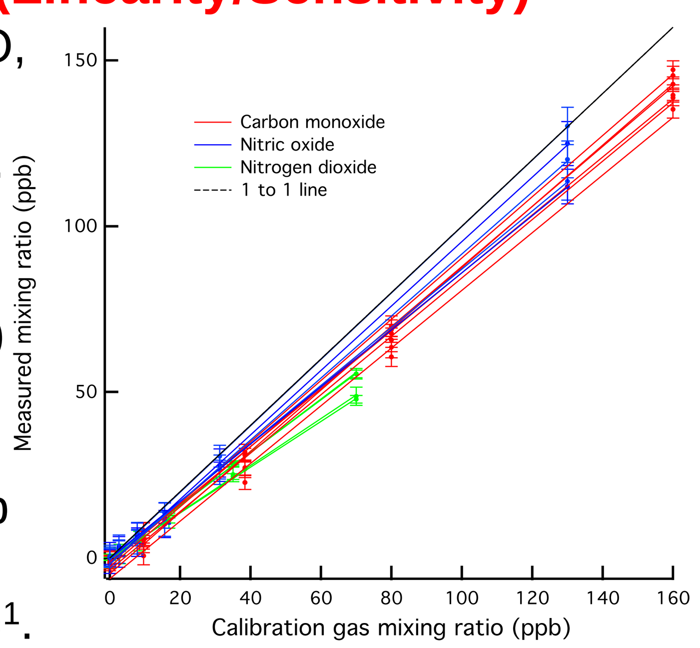
- State of the art multi species instrument package.
- Gas phase, PM and Met data.
- Scalable sensor networks.
- General applicability.
- Calibrated, high spatial and temporal resolution data.
- Exploits existing GPRS infrastructures (real time data).
- Low overheads in terms of cost, effort and installation.
- Highly portable.
- Complementary static and mobile configurations (CO, NO, NO_2).

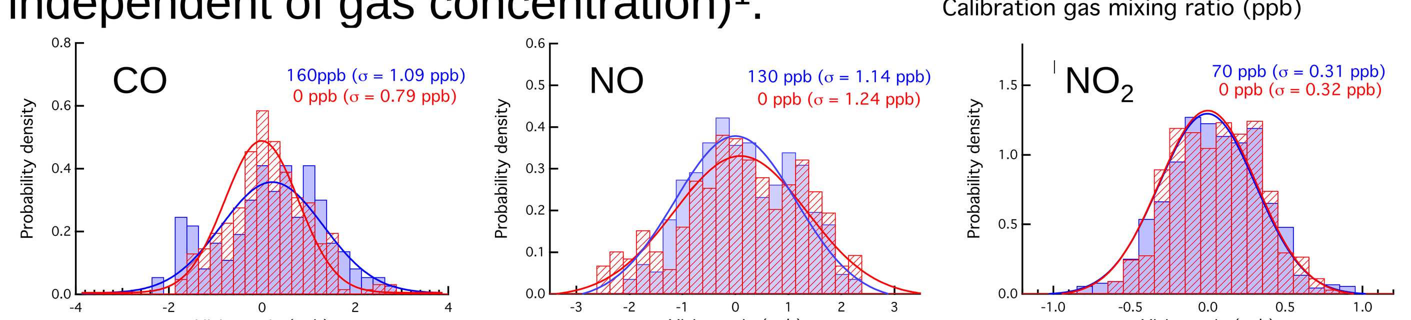


EARLIER STUDIES: ELECTROCHEMICAL CELLS FOR AIR QUALITY MONITORING

LABORATORY VALIDATION (Linearity/Sensitivity)

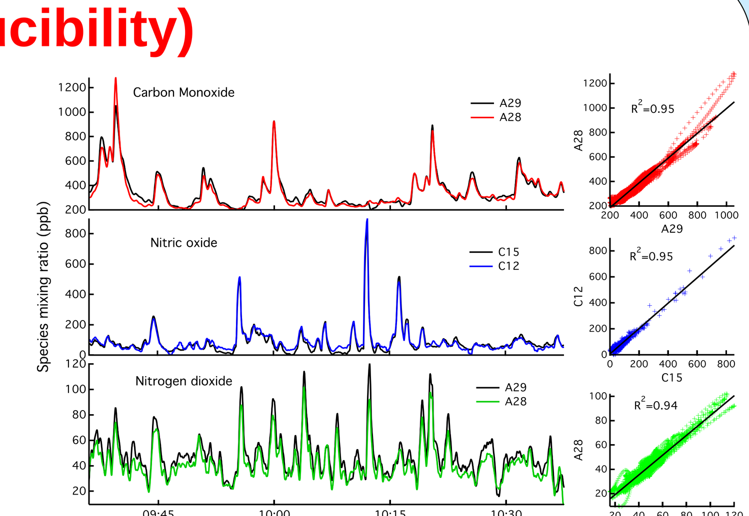
Mixing ratio correlation plots of CO, NO and NO_2 measured against calibrant gasses (Error bars: ±1σ). Regression coefficients were ≤0.99. Intrinsic ppb equivalent noise (instrumental detection limit) illustrated by probability density functions (S:N = 3, i.e. 3σ) estimated to be <4, <4 and <1 ppb for CO, NO and NO_2 (largely independent of gas concentration)[1].



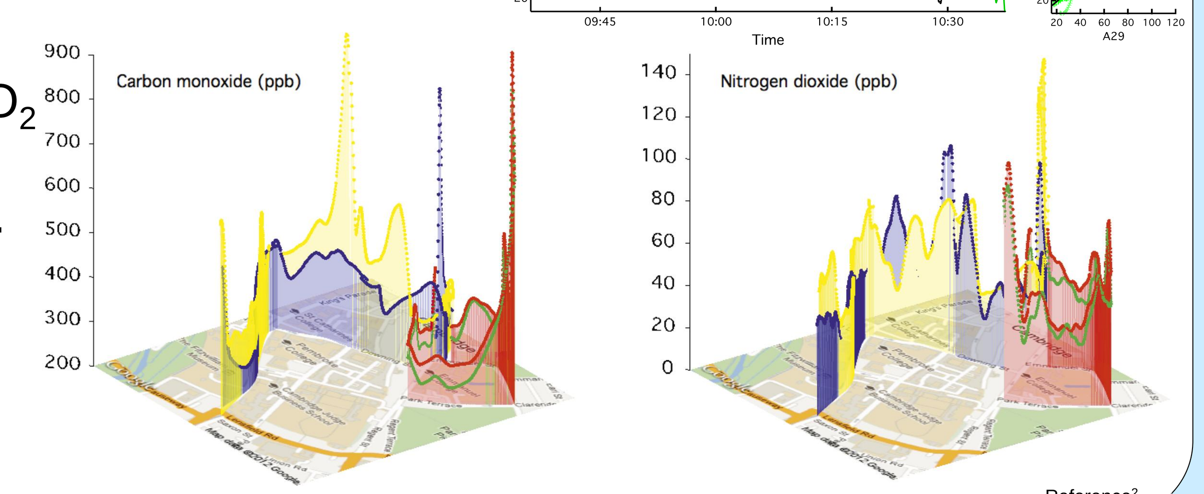


REAL-WORLD (Variability/Reproducibility)

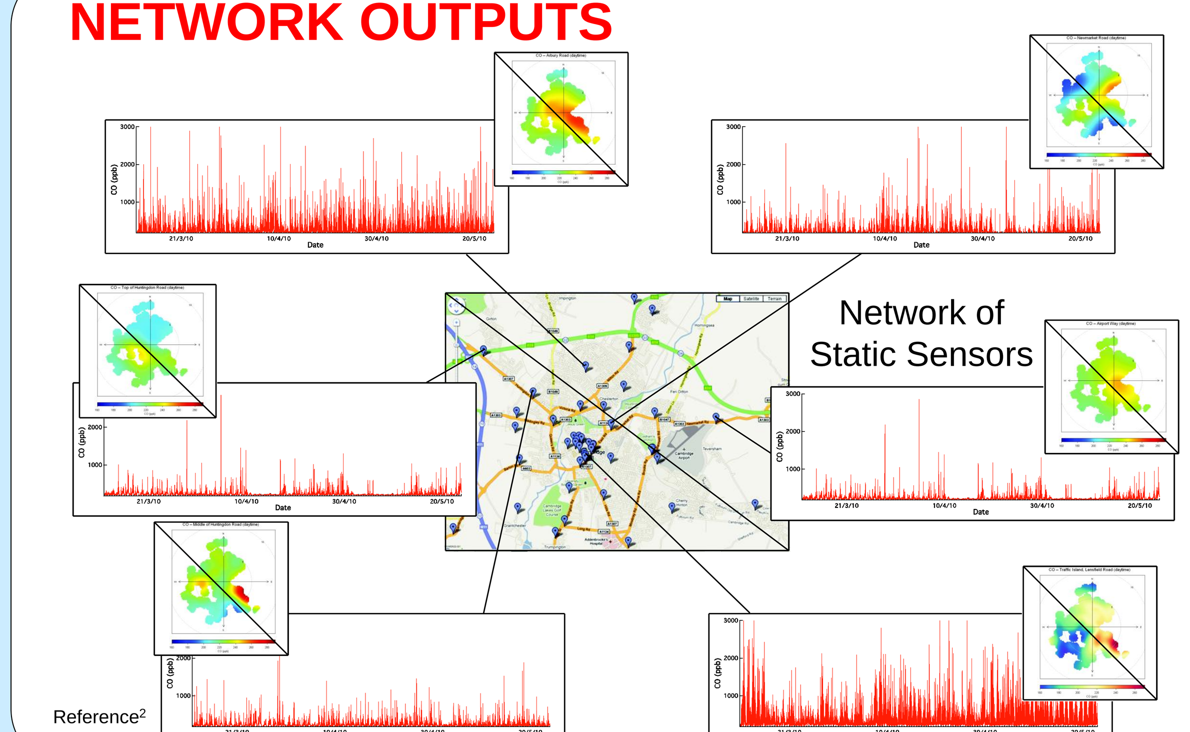
Co-located mobile sensor nodes shows variability in the species measured over small spatial and temporal scales. Sensors are responsive at ambient urban environment mixing ratios. Scatter plots show high reproducibility (R^2: 0.95, 0.83 and 0.93 for CO, NO and NO_2)[1].

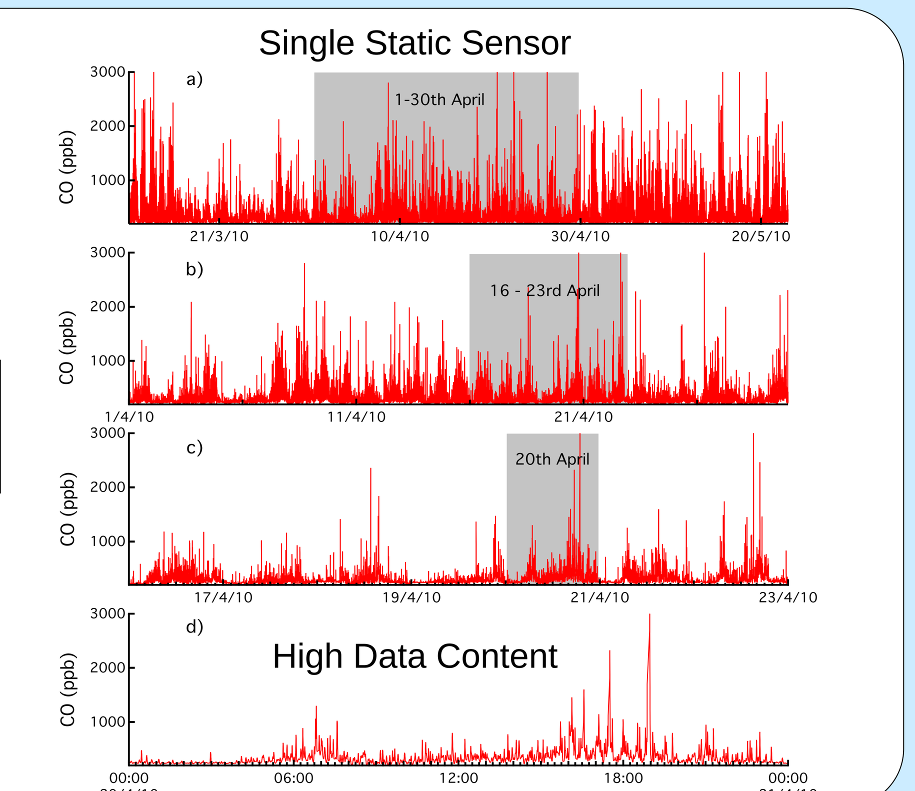


Selected CO and NO_2 sensor nodes (central Cambridge). Volunteers walking together (red/green) and apart (yellow/blue)[1,2].



NETWORK OUTPUTS





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1. **Mead MI**; Popoola, OAM; Stewart, GB; Landshoff, P; Calleja, M; Hayes, M; Baldovi, JJ; Hodgson, TF; Mcleod, MW; Dicks, J; Lewis, A; Cohen, J; Baron, R; Saffell, JR; Jones, RL. Low-cost electrochemical sensors for monitoring air quality. Including the deployment of a real time high density autonomous network. **Atmospheric Environment.** (Accepted November 2012).
2. Map data © 2012 Google. © 2012 Infoterra Ltd & Bluesky. Image © 2012 Bluesky.