A Portable Low-Cost High Density Sensor Network for Air Quality at London Heathrow Airport

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UNIVERSITY OF CAMBRIDGE

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1. SNAQ HEATHROW PROJECT

(a) Objective

- Deployment of state-of-the art network of pollution sensors (SNAQ sensor nodes) in and around LHR airport.
- Establishing pollution data for science and policy studies
- Comparing data with emission inventories and pollution models.
- Source attribution for LHR airport.
- Creation of novel tools for data mining, network calibration, data visualisations and interpretation.
- Optimisation of sensor network for different environments.

(b) Instrumentation

- **Gas phase species:**
  - ✓ **CO, NO, O_3, SO_2, NO_2** (electrochemical (EC) at 2 s)
  - ✓ **CO_2 and total VOCs** (optical at 10 s).
- **Size-speciated particulates** (0.38 to 17.4 µm, optical (OPC) at 20 s)
- **Meteorology:**
  - ✓ **wind speed and directions** (sonic anemometer).
  - ✓ **Temperature and relative humidity** (RH)
- **GPS and GPRS** (position and real time data).
- **Temperature and relative humidity** (RH)

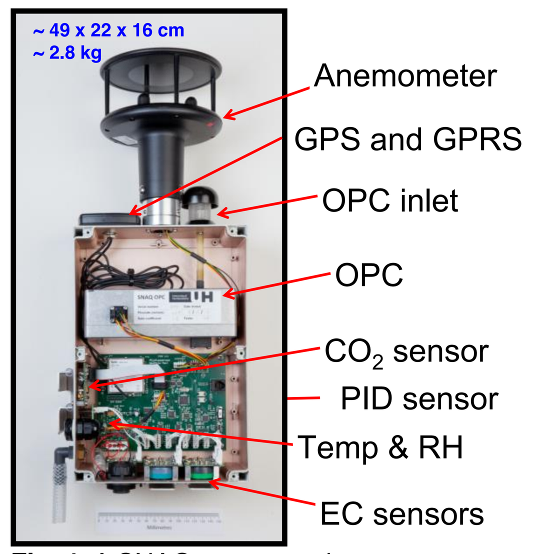
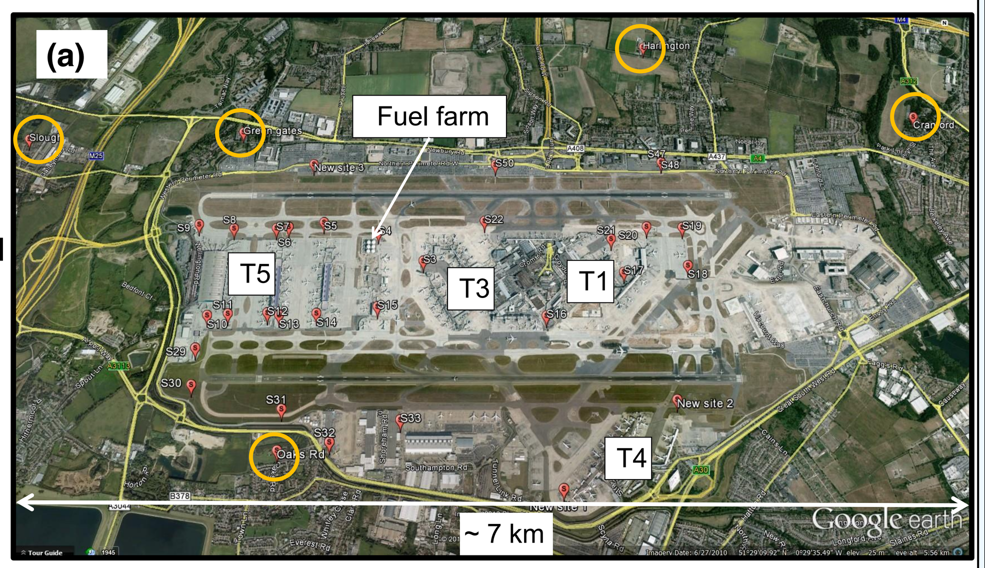


Figure 1: A typical SNAQ sensor node showing different components including gas sensors, particulate instrument, meteorology sensors and the GPS & GPRS module.

Fig. 1: A SNAQ sensor node

(c) Sensor network and data capture

- 36 sensor nodes deployed starting mid 2012.
- **31 nodes** located within LHR covering all terminals, close to two runways and in proximity of the major roads within LHR.
- **5 nodes** are co-located with local monitoring stations outside LHR (all < 2 km from LHR)
- **~ 2×10⁹ records** (CO, NO, NO_2, O_3, SO_2, Σhydrocarbons, CO_2, size speciated PM, meteorology) transmitted (20 seconds data)
- 1-2 second data recorded on USB storage (**~ 9 ×10⁹ records**)



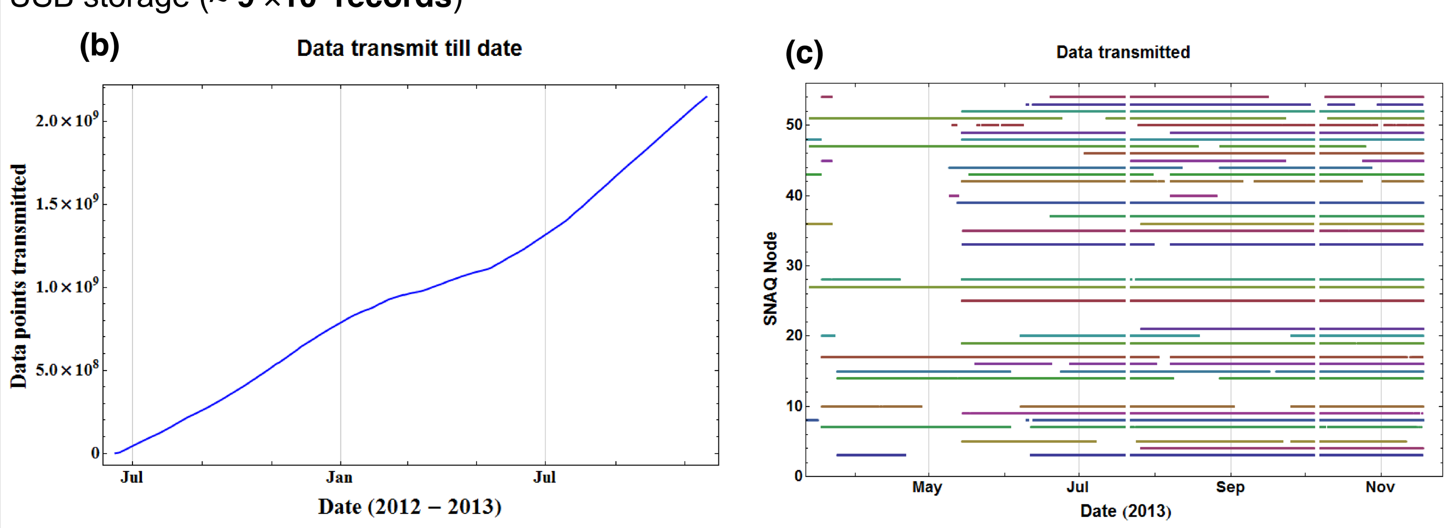


Figure 2: SNAQ network deployment (a) showing nodes within and outside LHR (orange circles) including the terminals (T1, T3,T4 & T5), data captured from the 36 nodes till date (b) and individual node coverage from Mar – Nov, 2013 (c).

2. CHARACTERISATION

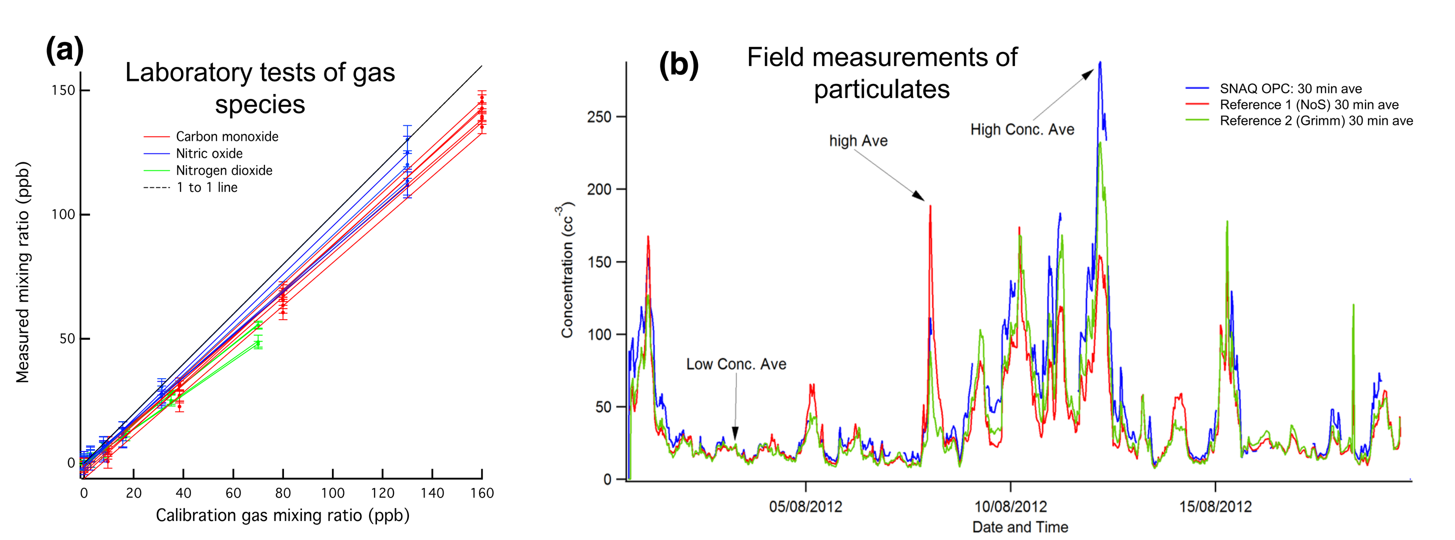


Figure 3: Laboratory calibration[1] (a) of CO, NO, NO_2 sensors against known gas mixing ratios and time series showing field measurement comparison between 30 minute average OPC measurements and two reference particle instruments.

- Excellent laboratory response at ppb mixing ratios[1] (**fig. 3 (a)**).
- Good instrumental performance against reference techniques under ambient conditions (**fig. 3 (b)**).

3. PRELIMINARY RESULTS AND DISCUSSION

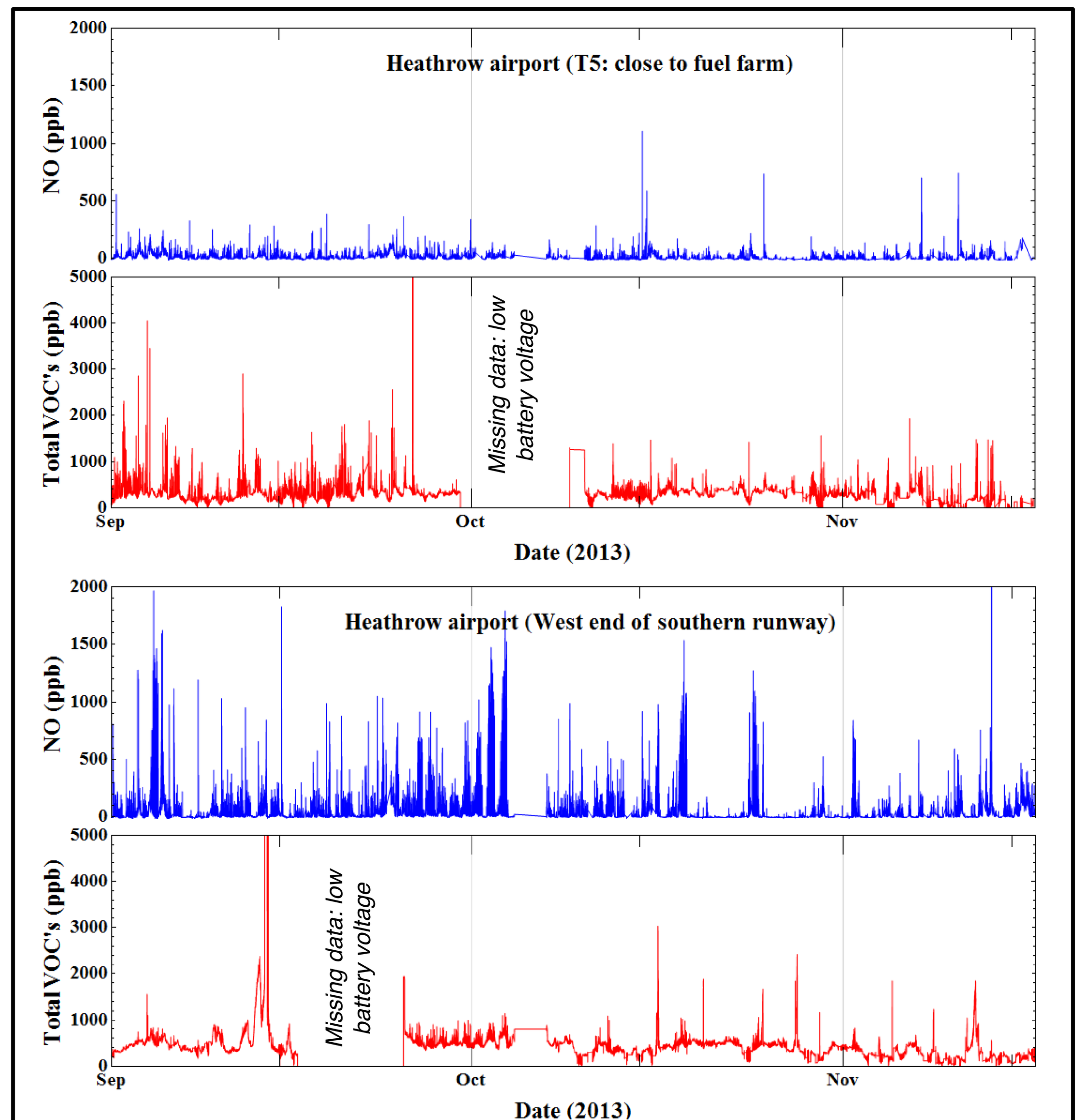


Figure 4: Time series of CO and total VOCs at two different location within the airport from Oct – Nov 2013.

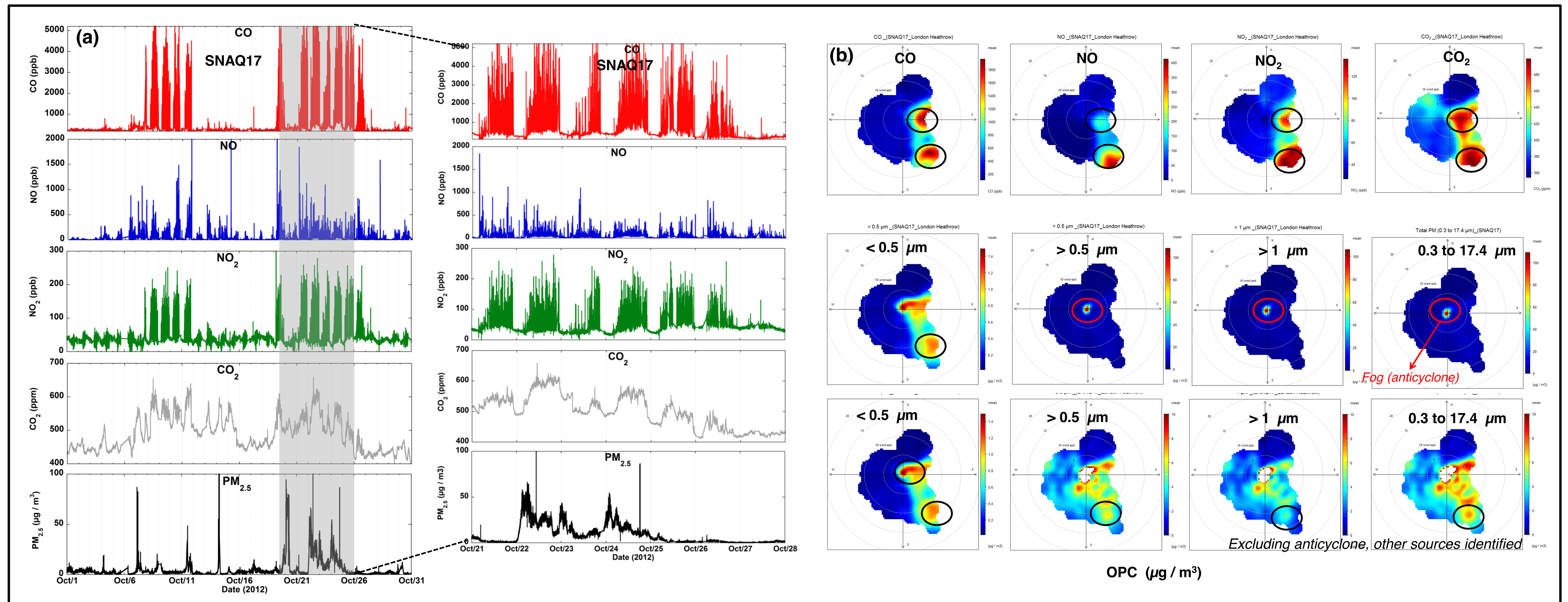
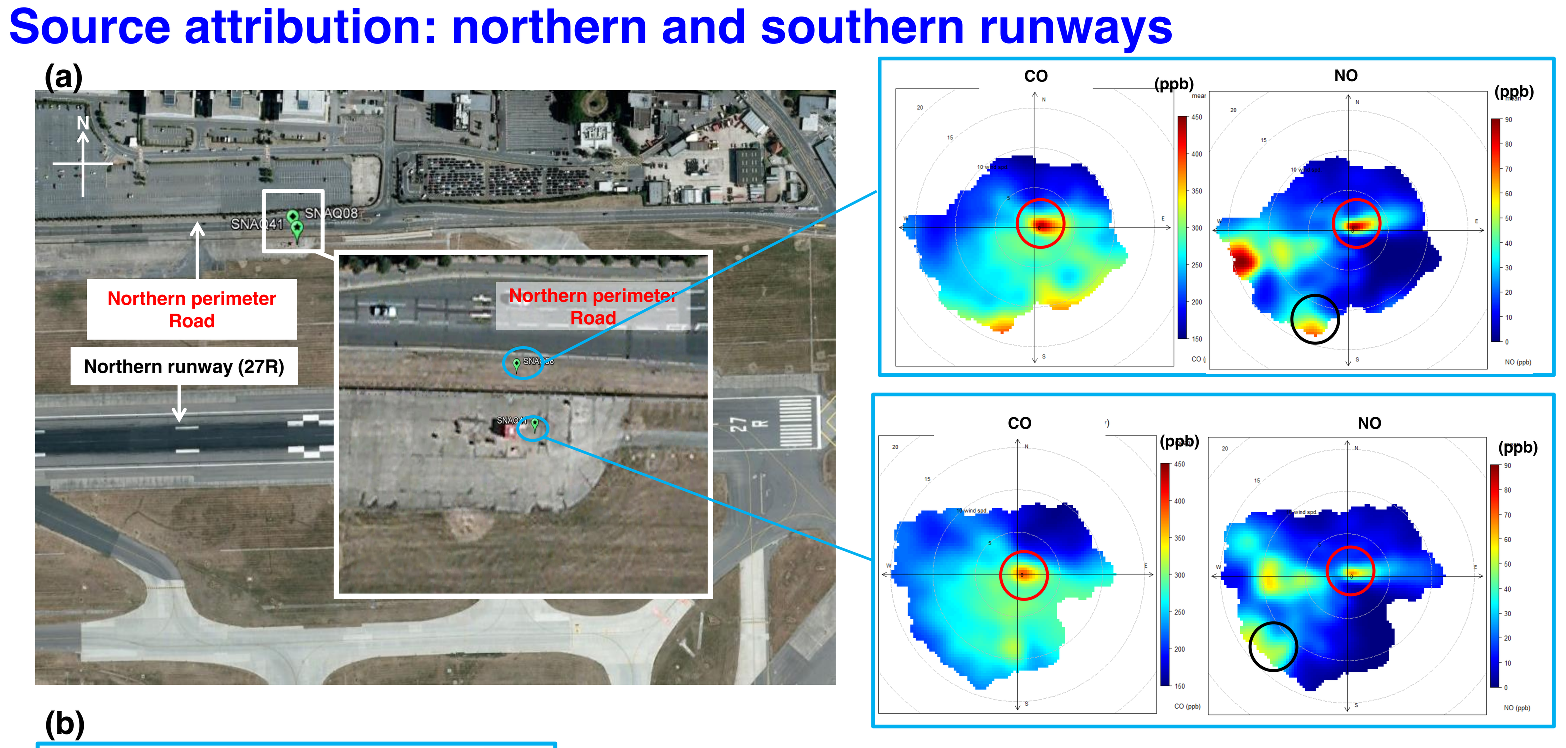
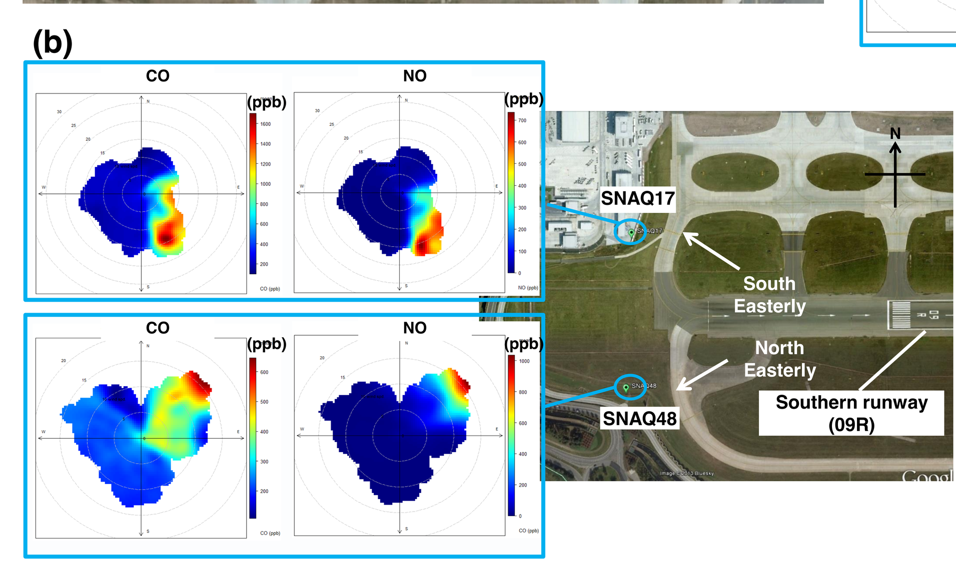


Figure 5: Time series (a) of CO, NO, NO_2 and $PM_{2.5}$ (equivalent) for Oct. 2012 and (b) the corresponding polar bivariate plots[2]. This sensor node is located at the west end of the southern runway.

- High spatial variability in gas species noticed across the SNAQ network in LHR (**fig. 4**). High VOCs and low NO (fuel farm close to terminal 5) compared to high NO and periodic high VOCs (close to end of runway)
- Increase in observed background concentrations associated with stable atmospheric condition (anticyclone) **fig. 5 (a)**, while combining wind data with concentration measurements reveal potential pollution source(s) shown in black circles in **fig. 5 (b)**.

Source attribution: northern and southern runways

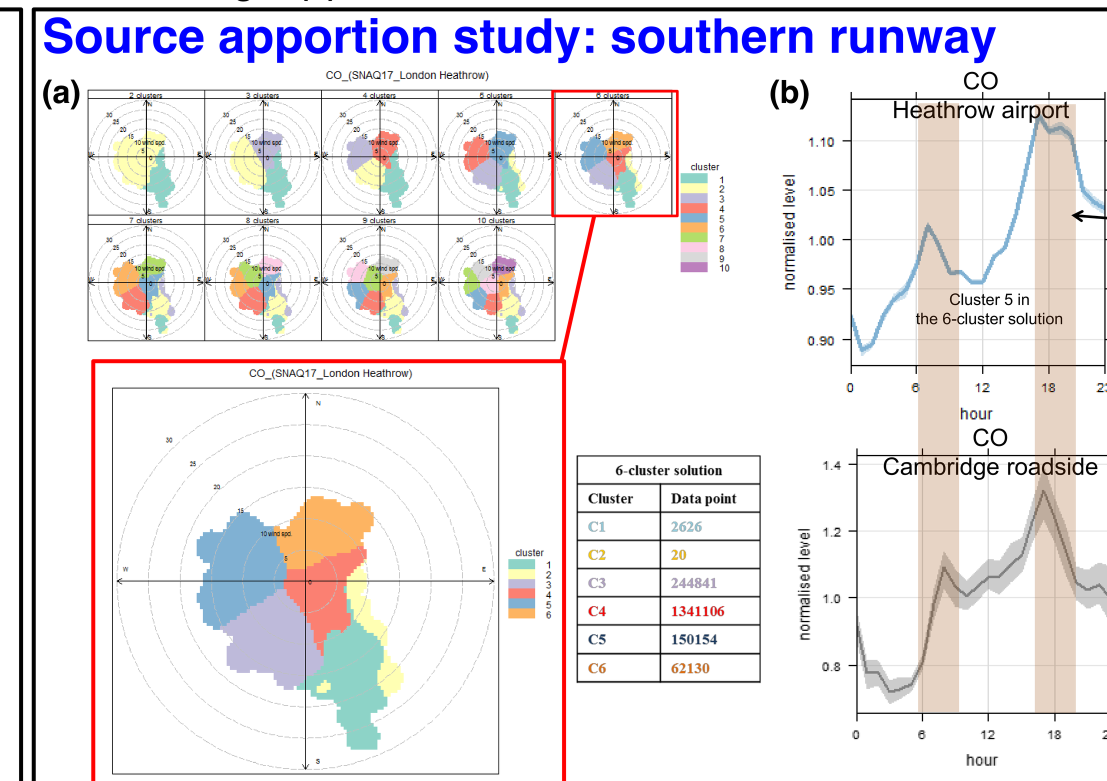


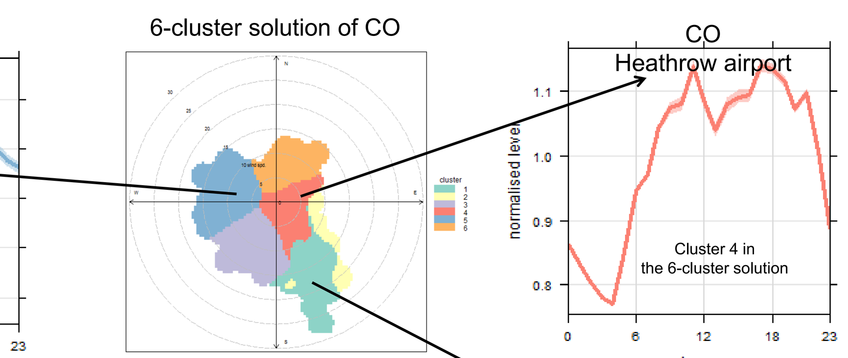


- High CO & NO mixing ratios (red circles) at low WS (<5ms⁻¹) in the NE quadrant **fig. 6 (a)** suggest a pollution source to the north of the sensors (northern perimeter Road).
- High NO mixing ratios (**black circles**) at high WS (>15ms⁻¹) in the SW quadrant in **fig. 6 (a)** suggest a pollution source to the south-west of the sensors (aircraft landings/ take-offs on the northern runway)
- Mirror image pattern (**fig. 6 (b)**) observed in the polar bivariate plots of the two sensor nodes (SNAQ17 & SNAQ48) deployed at the end of the southern runway (09R).
  - ✓ This suggests a common source (southern runaway) located perpendicular to the distance between the two sensors.
  - ✓ High CO & NO mixing ratios (at high wind speeds) suggests aircraft take-offs.

Figure 6: Bivariate polar plot of CO and NO (a) of two sensor nodes located to the north of the northern runway and a pair of sensor node located to the west-end of the southern runway (b).

Source apportion study: southern runway





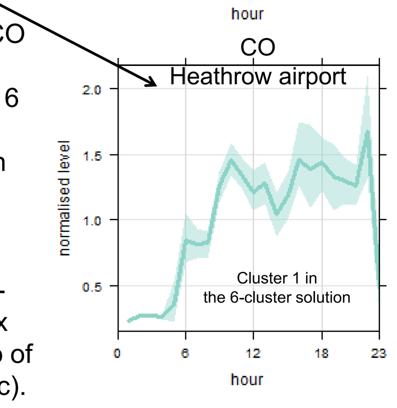
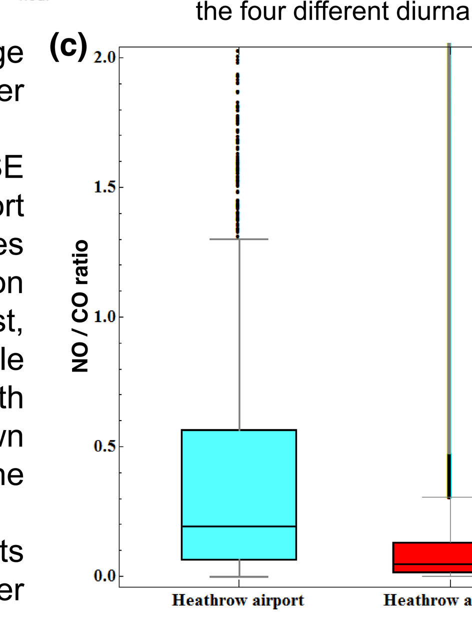


Figure 7: K-cluster analysis of CO data (a) of SNAQ 17 located to west of southern runway (see fig. 6 (b)) showing results of from 2-cluster to 10-cluster solutions with the 6-cluster solution highlighted, diurnal profile plots (b) from Cambridge roadside as well as three different clusters from the 6-cluster and the corresponding box whisker plots of the NO / CO ratio of the four different diurnal profiles (c).

- 6-cluster solution (**fig. 7 (a)**) used because it gives large enough potential sources and number of data per cluster solution.
- The diurnal profiles of cluster 1 and 5 (**fig. 7 (b)**) in the SE quadrant in the 6-cluster solution show pattern similar to airport operations (low activities before 6 and increase in activities throughout the rest of the day) which suggests contribution from aircraft especially from the southern runway. In contrast, the diurnal profile of cluster 5 shows remarkable similar profile to roadside locations (in this case Cambridge roadside) with characteristic morning and even rush hours shown in brown shades (**fig. 7 (b)**), suggesting this CO contribution is from the road located to the east / SE.
- The NO / CO box whisker plots (**fig. 7 (c)**) also suggests different sources account for the CO observed in the 6-cluster solution, with LHR contribution more NO / CO (0.19) than the roads (0.03).



	Heathrow airport			Cambridge roadside
	Cluster 1	Cluster 4	Cluster 5	
75%	0.56	0.13	0.07	0.08
Median	0.19	0.05	0.03	0.05
25%	0.07	0.02	0.02	0.03

4. CONCLUSIONS AND FUTURE WORK

- First, high-temporal and spatial, long-term deployment of pollution sensor networks in LHR airport measuring multiple gas species and particulates as well as meteorology.
- Exciting findings from preliminary results: **1.)** Large temporal variations in mixing ratios of pollutants observed across the network. **2.)** Anticyclone effect of pollution well captured. **3)** Pollution source attribution and source apportion study within the airport.
- Future work includes deploying the remaining sensor nodes, comparing measurement data with dispersion models and emission inventories.
- Detailed analysis of data using information on airport operations to apportion pollution sources.
- Calibration of sensor network (baseline approach)

References and acknowledgements

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