

Low Cost Sensor Networks for Urban Air- Quality Monitoring Applications

Dr Vivien Bright
University of Cambridge



**Lekan Popoola, Iq Mead, Gregor Stewart, Ines Heimann, Christoph
Hüeglin, Michael Müller and Rod Jones**

High density sensor network system for air quality studies at Heathrow airport

Participants:

Institution

University of Cambridge (PI)
Imperial College London
University of Hertfordshire
University of Manchester
CERC Ltd
National Physical Lab.



Imperial College
London

Input

sensors, a/q models
traffic models, data visualisation
aerosol measurements
aerosol measurements
a/q modelling – ADMS
metrology, calibration



Cambridge Environmental Research Consultants
Environmental Software and Services

Heathrow Airport Ltd
British Airways
Alphasense Ltd

logistic, flight movements
flight movements, throttle settings
sensors, support



Heathrow

- **The SNAQ project**
- Network calibration
- Separation of emission scales
- Source attribution
- Absolute emission factors (from data)
- ADMS model/measurement comparison
- High-resolution activity and emissions estimates
- Low cost PM – validation and next steps
- Commercial links/collaborations
- Acknowledgements

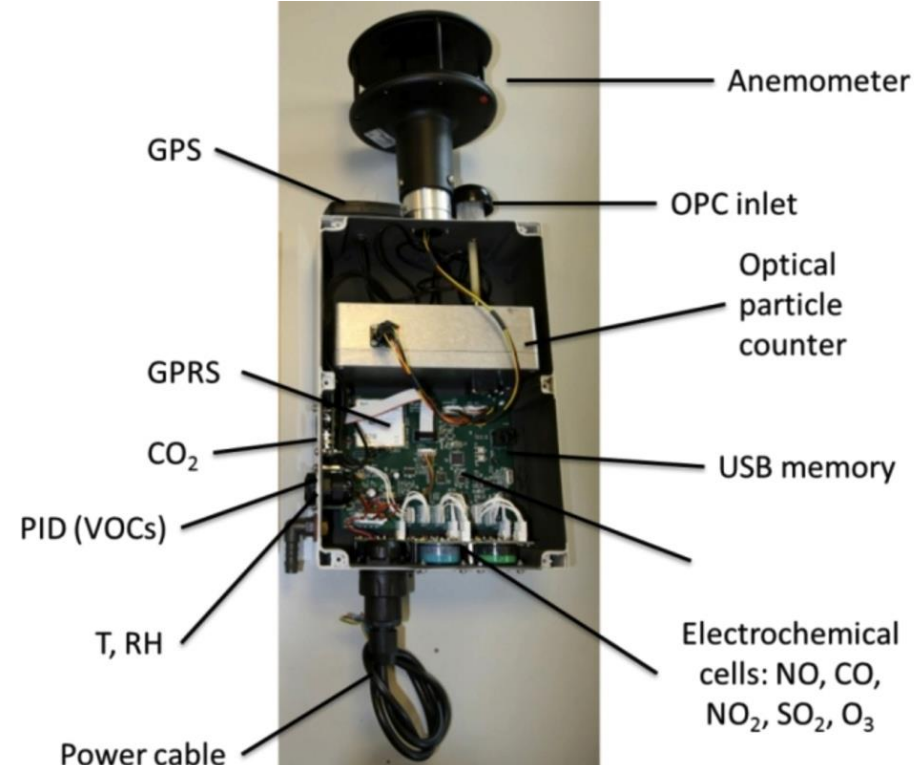
Sensor network system at UK Heathrow

airport:

- 50 sensor nodes, real time data transfer
- NO, NO₂, CO, CO₂, SO₂, O₃, VOCs and size-speciated PM.
- Source attribution/model validation for area.
- Novel software tools for calibration, data-mining, visualisation/interpretation.
- Emissions inventory for LHR
- Network design optimisation.

(Electrochemical, NDIR, PID, Optical)

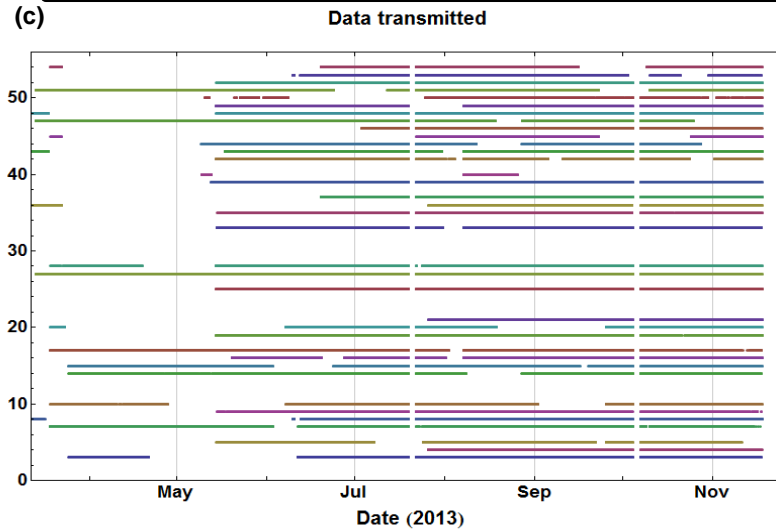
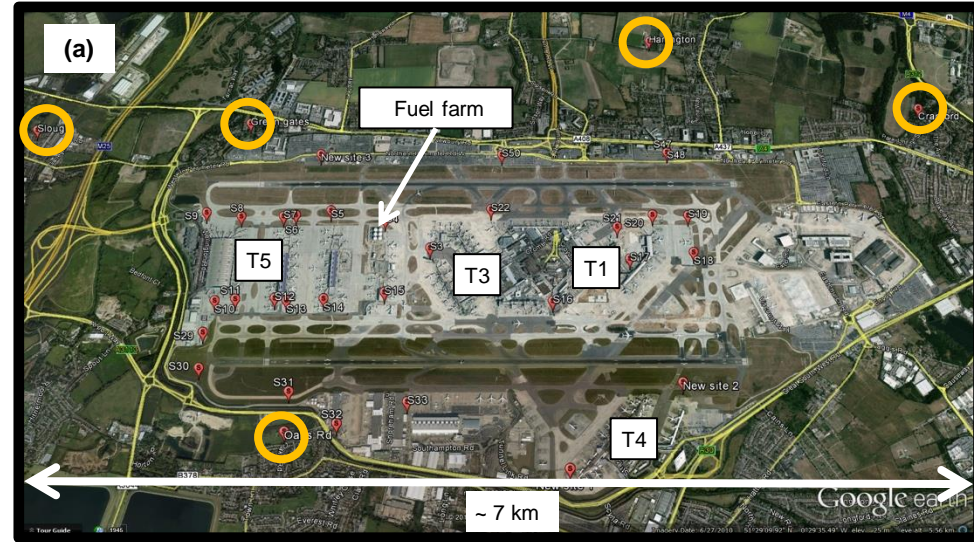
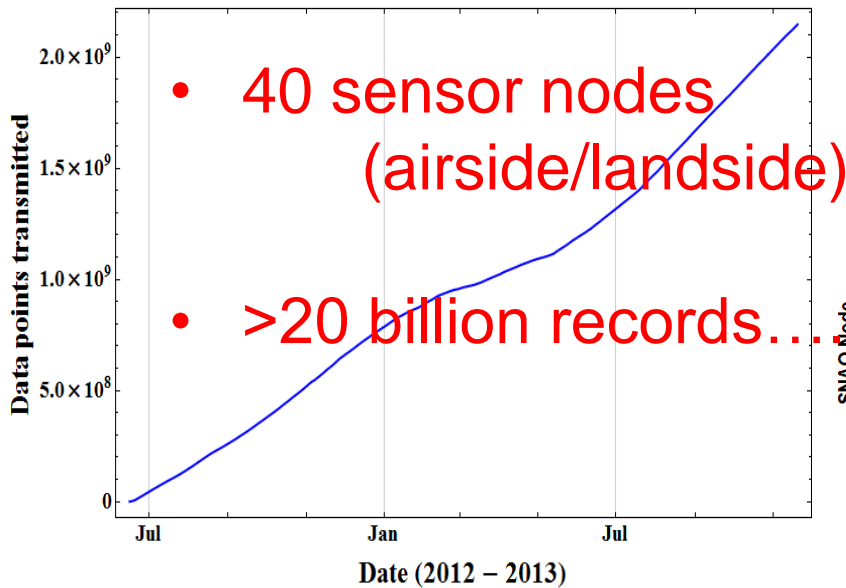
Information content.....



LHR sensor network summary

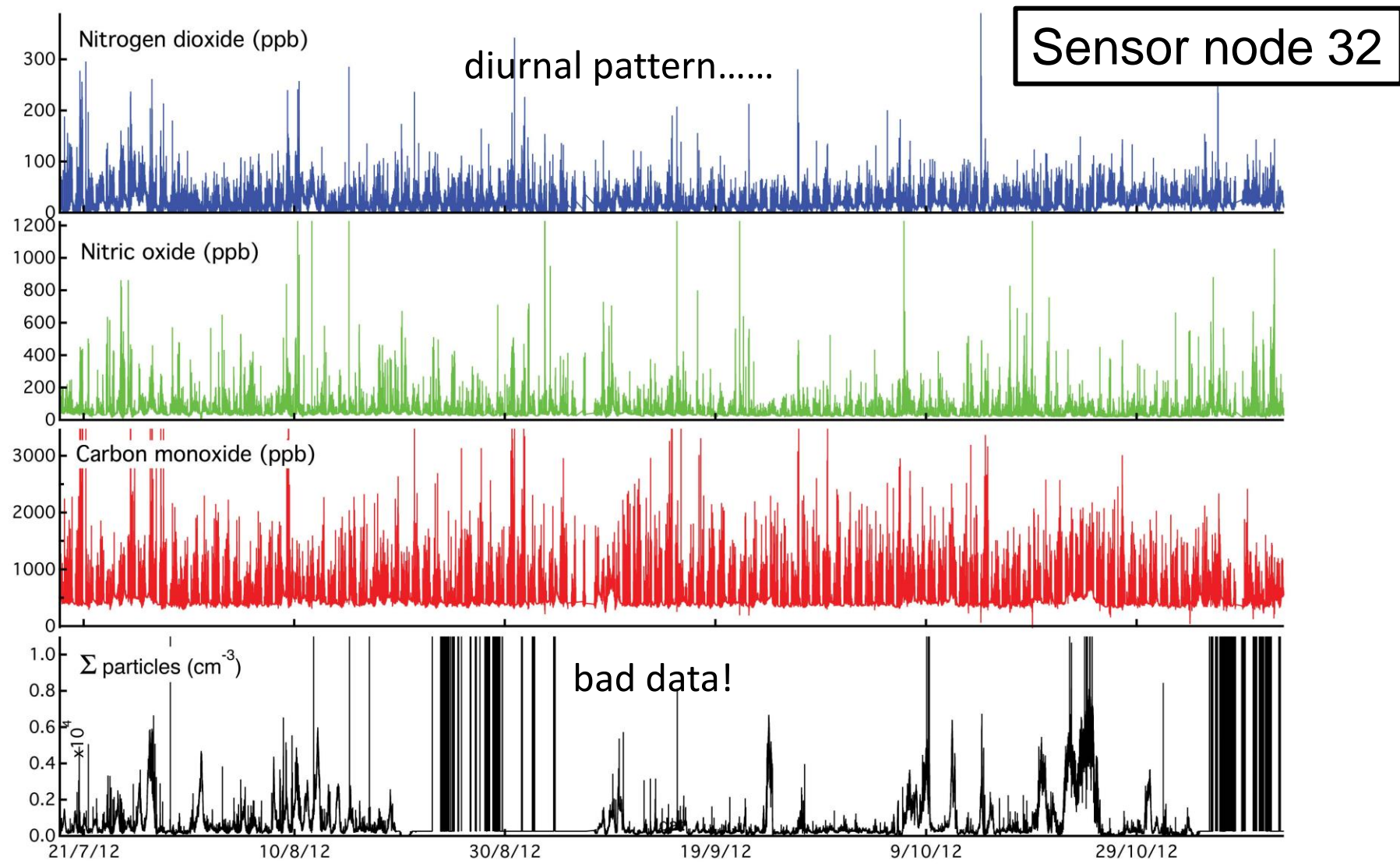


Data transmit till date



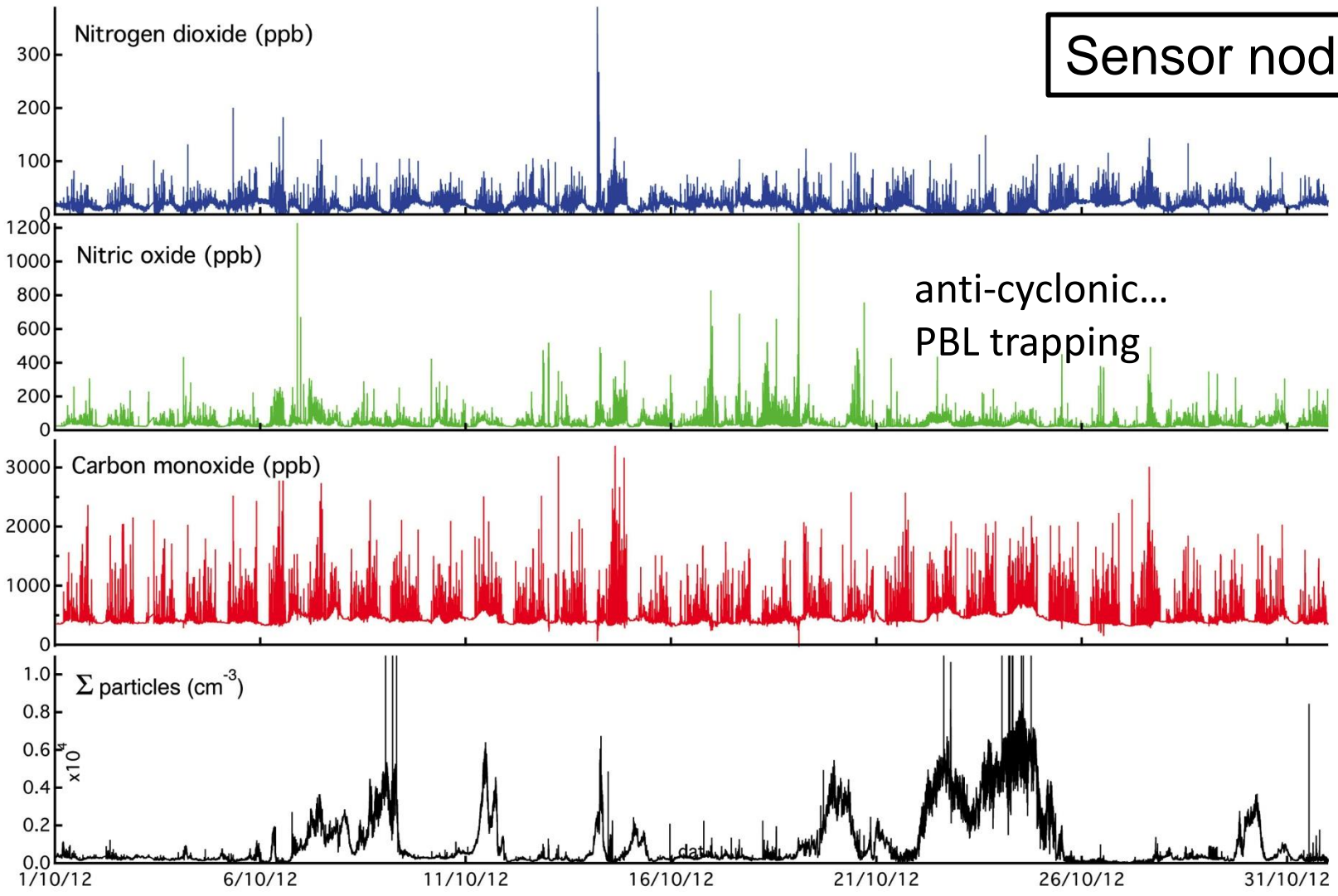
Data collection complete, data analysis/interpretation underway

Example LHR results3 months

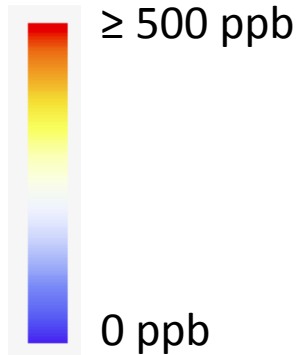


Example LHR results1 month

Sensor node 32



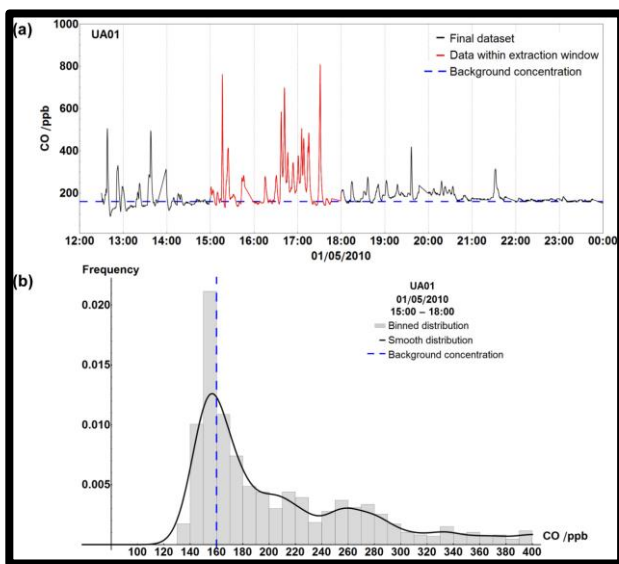
Visualisation of data (Ethiopian Airways fire)



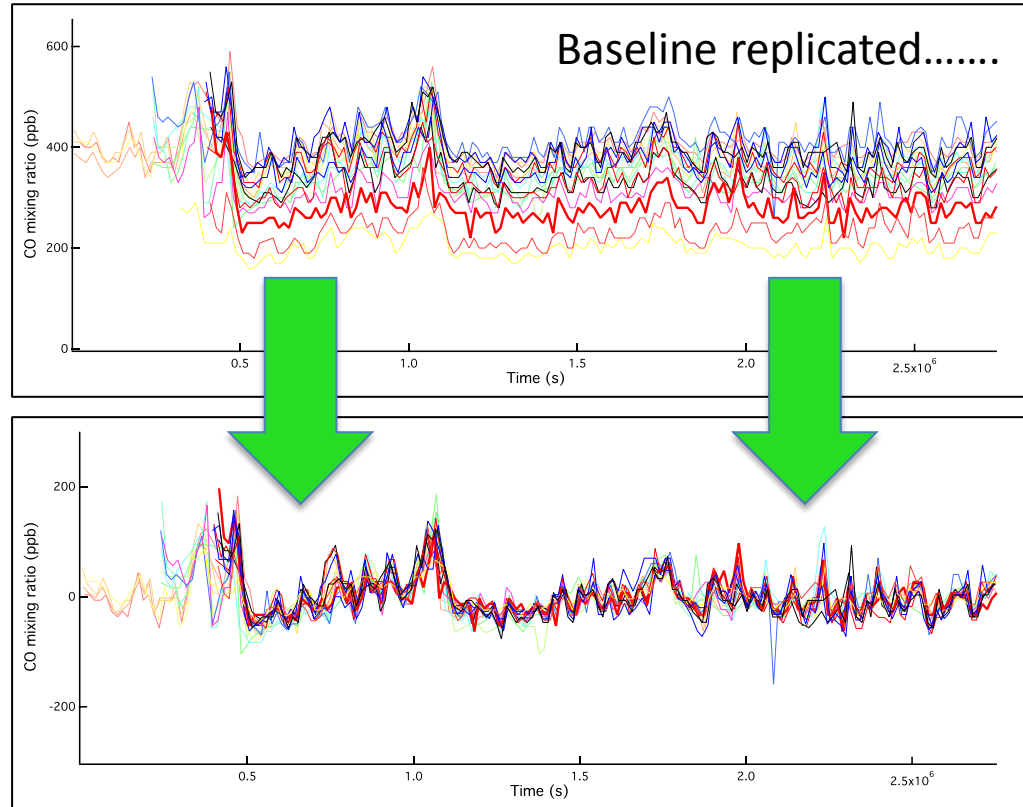
- The SNAQ project
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Sensor baselines (usually*) similar

⇒ network calibration

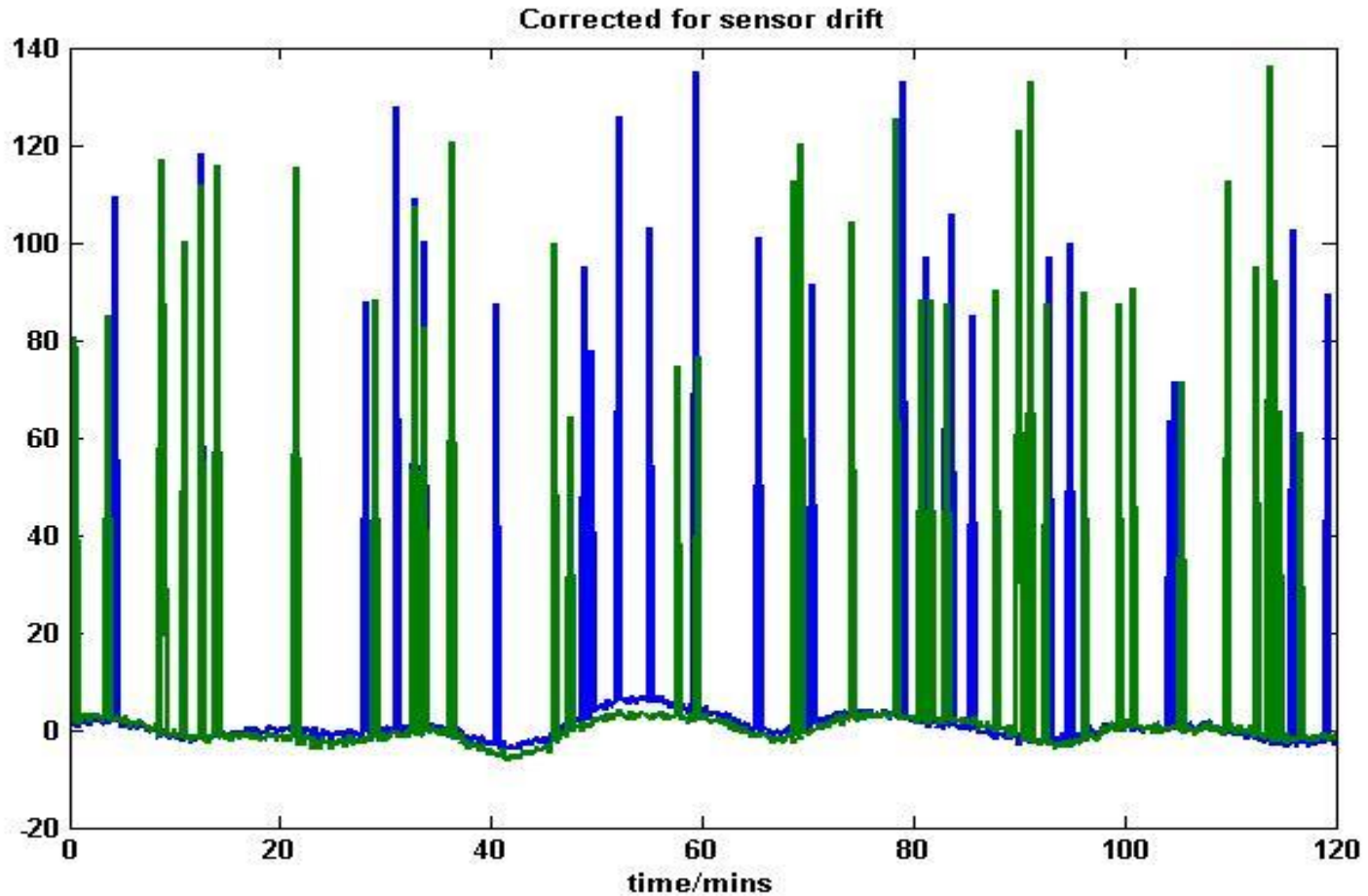


Filtering methodologies for event removal



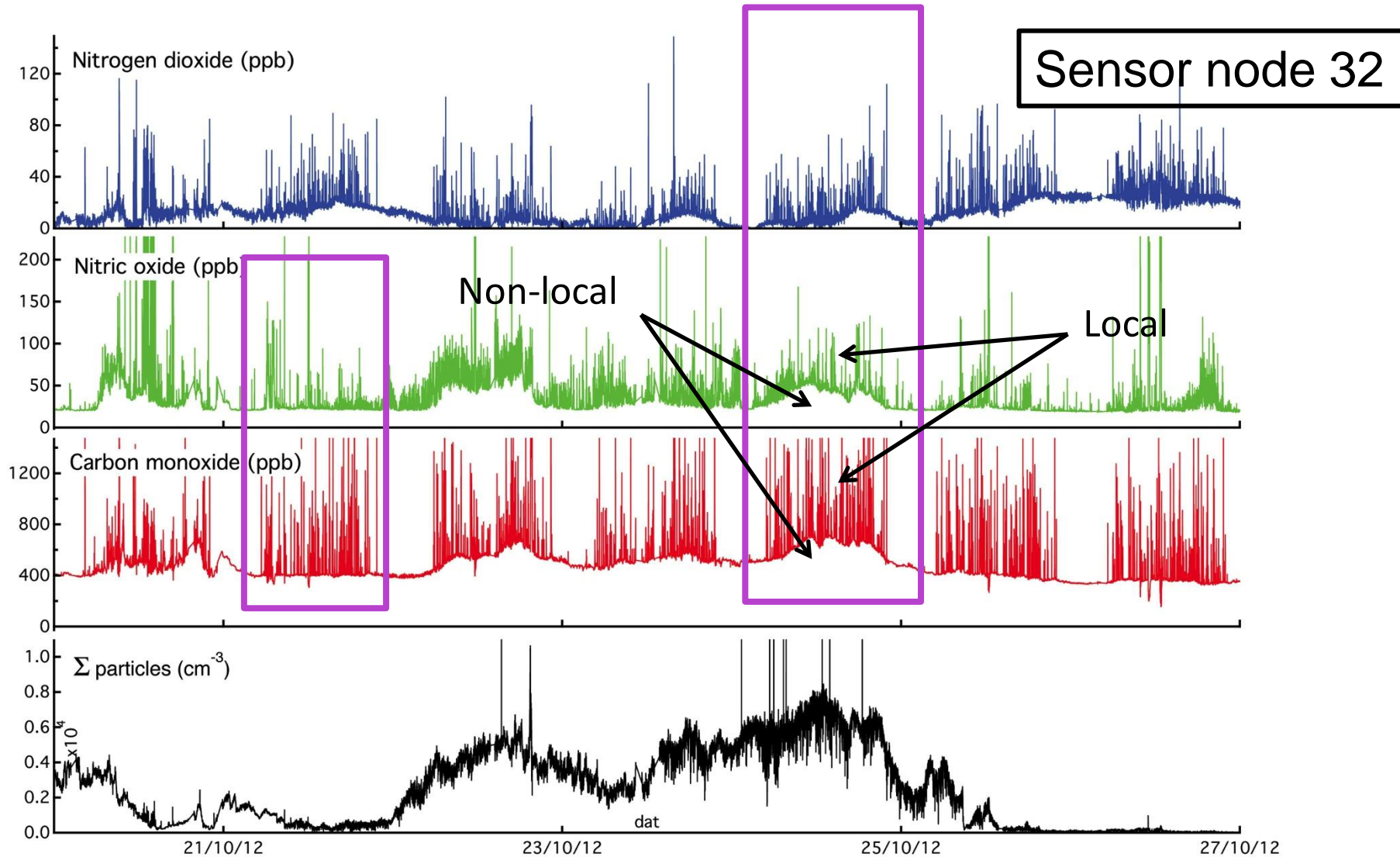
Method for intra-calibrating (and error checking) sensor networks

Algorithms for correction of sensor drift, separation of scales – interpolation methods (physical (e.g. ADMS); statistical (LUR, Kriging))



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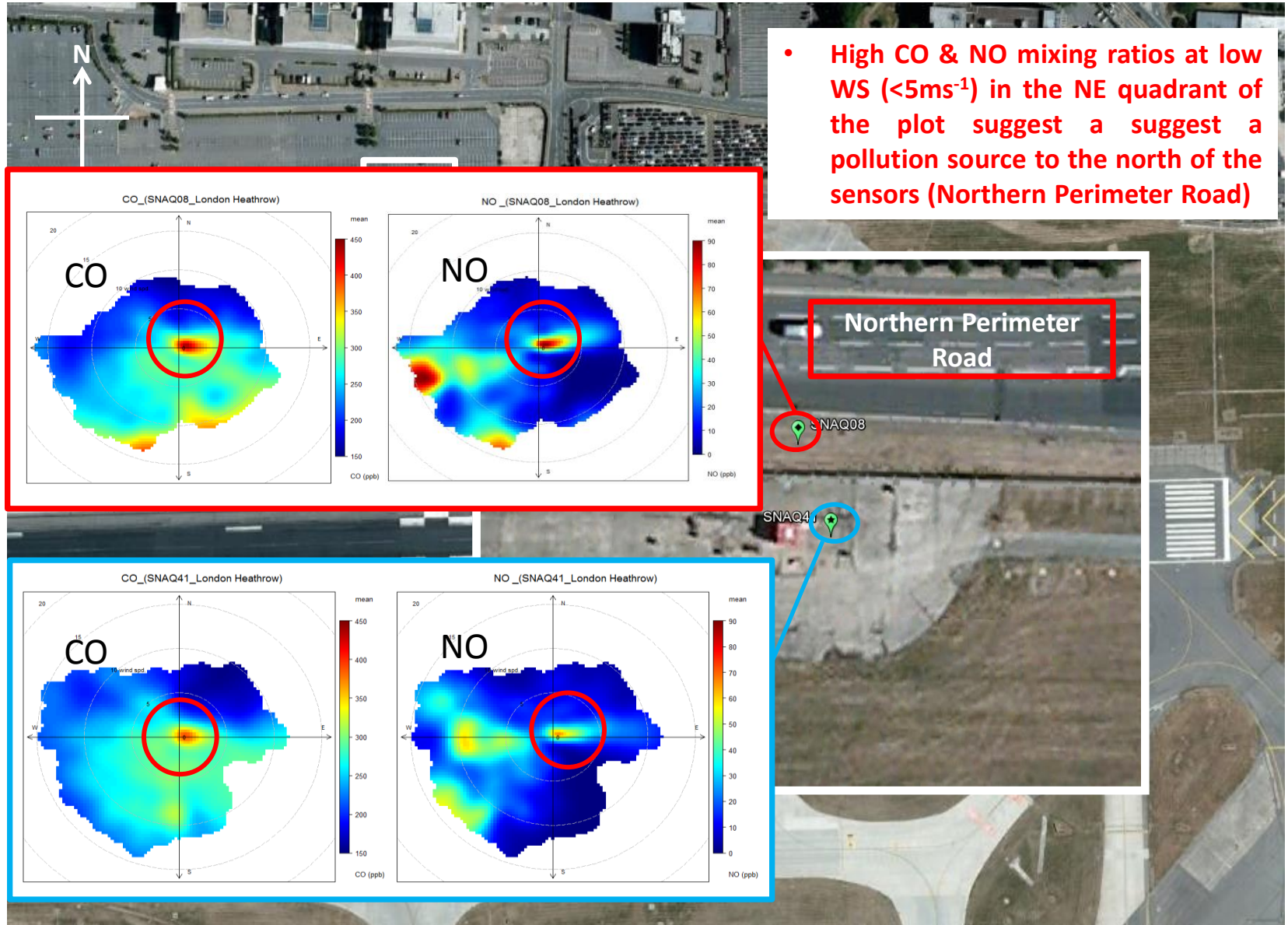
*Source attribution: local vs non-local



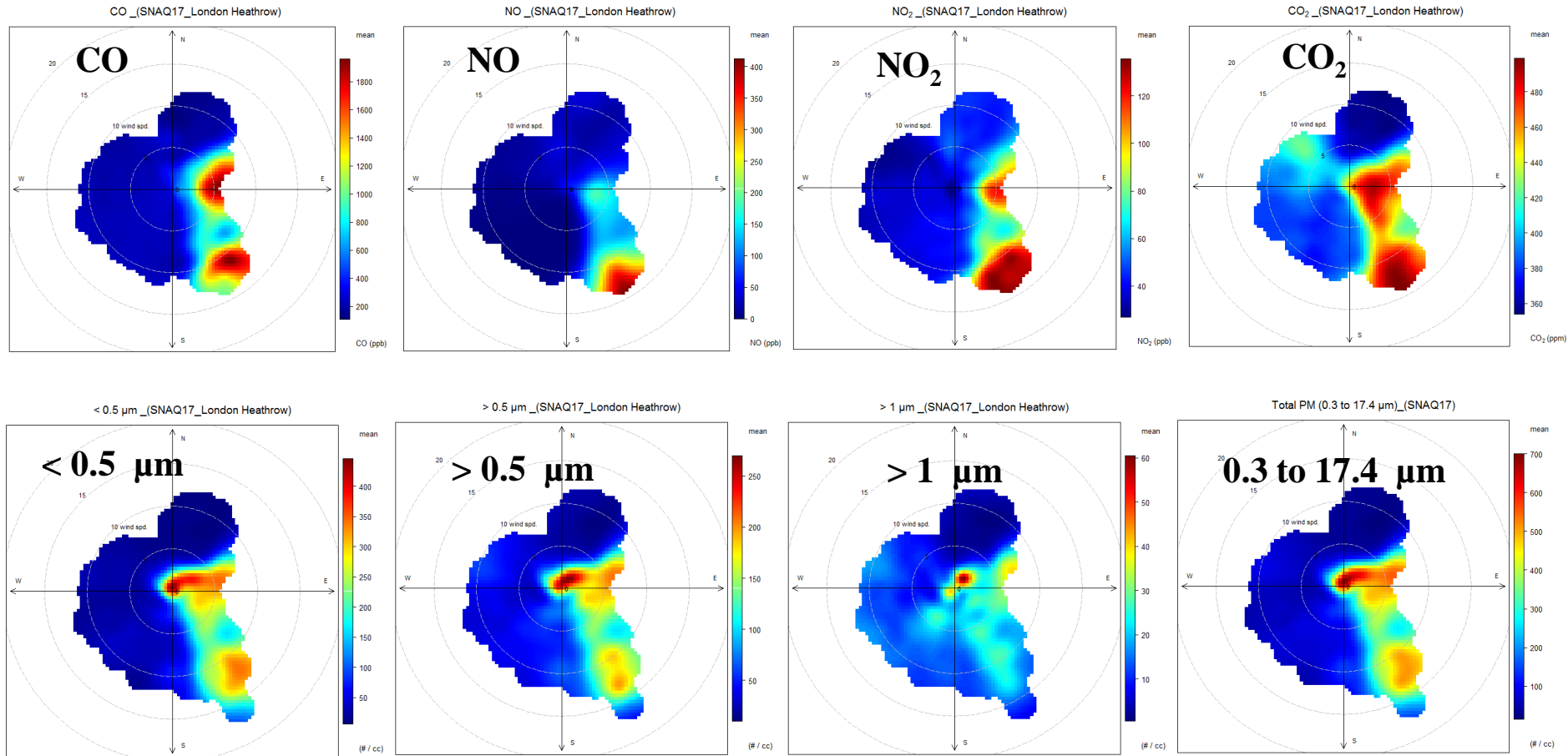
Network calibration *and* scale information

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Landside vs airside sources



Source attribution: **SNAQ17** at the west-end of southern runway (09R) , 1 month data



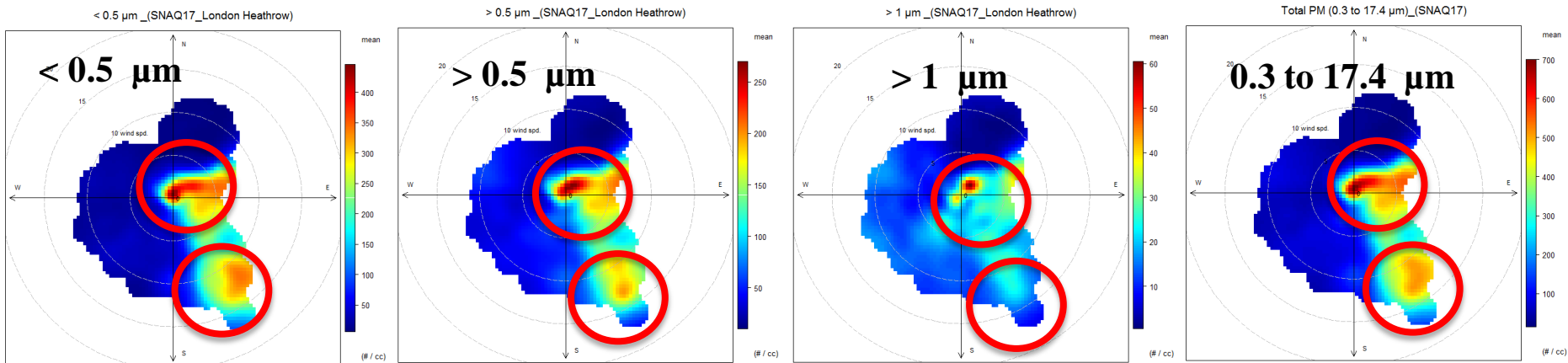
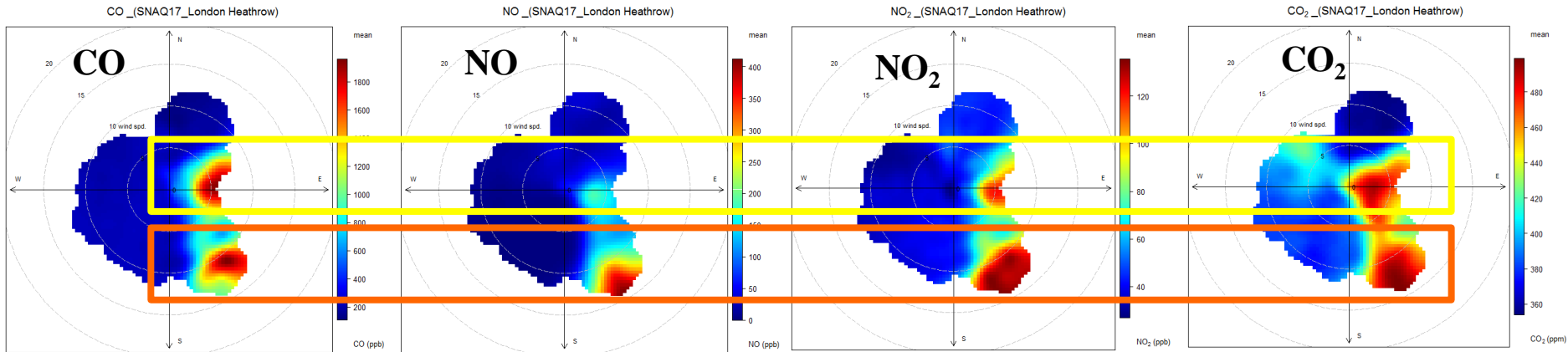
OPC (number / cc)

Excluding fog events



Direct determination of transport activities

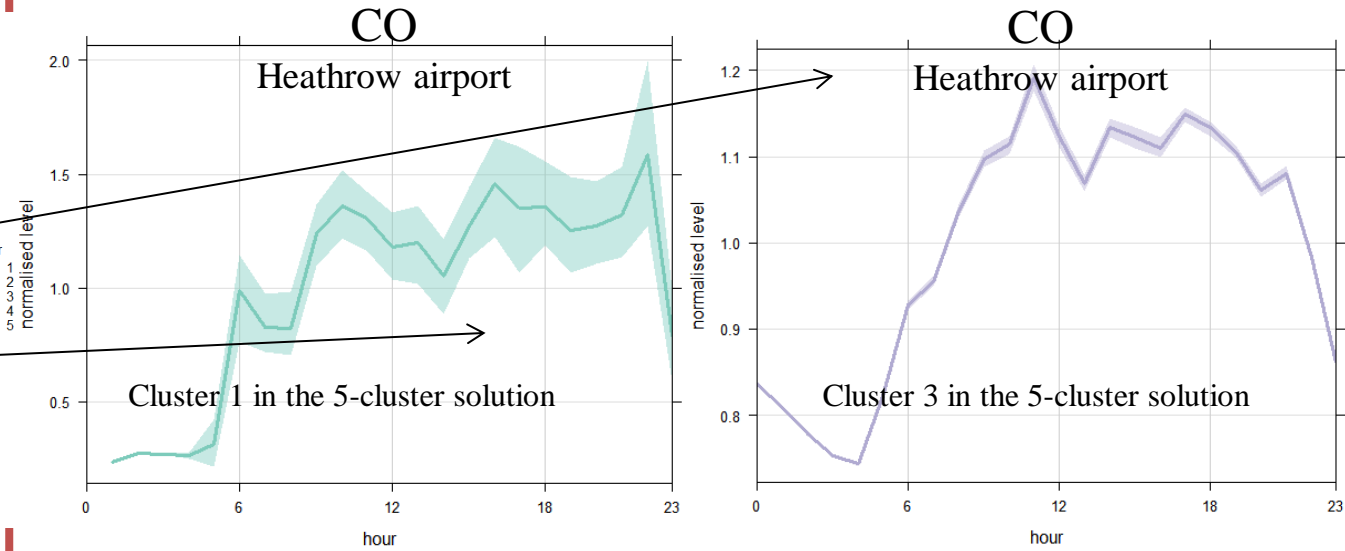
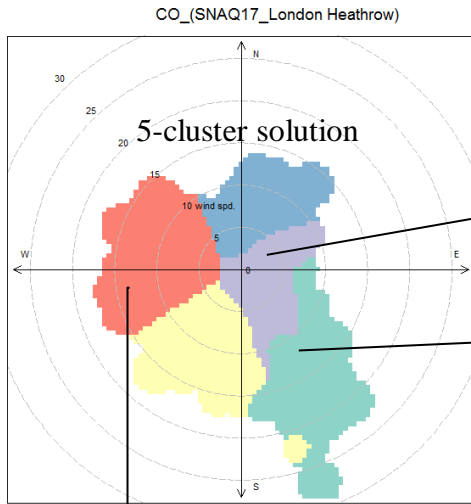
High CO₂, high NO_x, medium CO – take offs
Medium CO₂, low NO_x, medium CO – taxiing



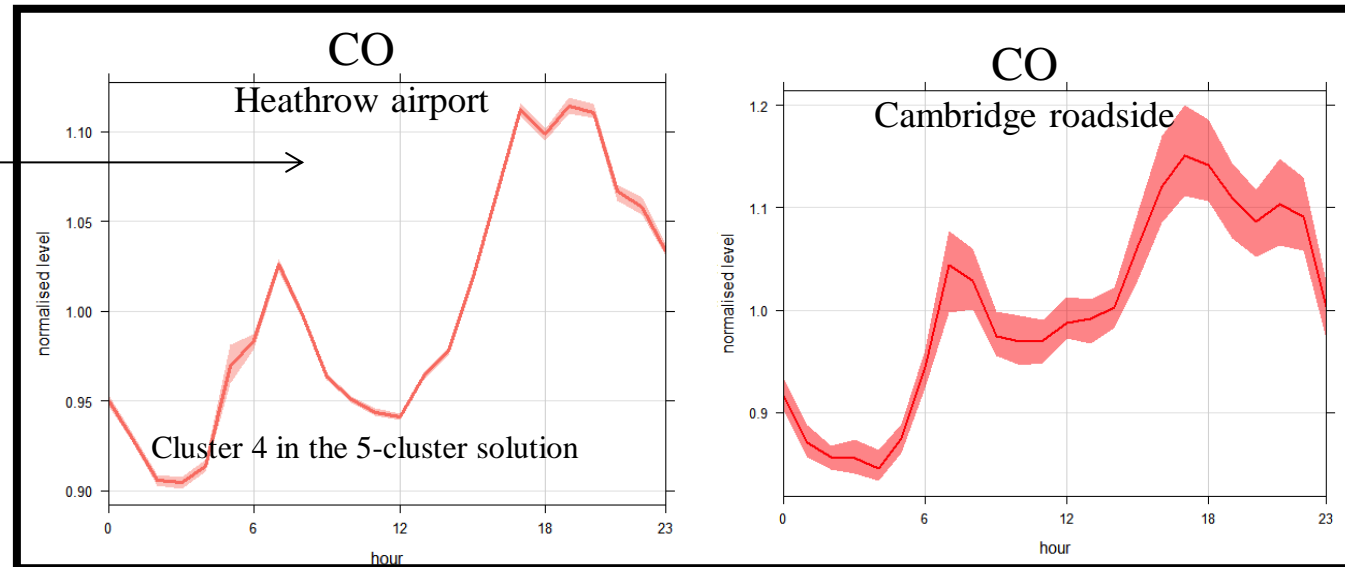
OPC (number / cc)

Also PM apportionment.....

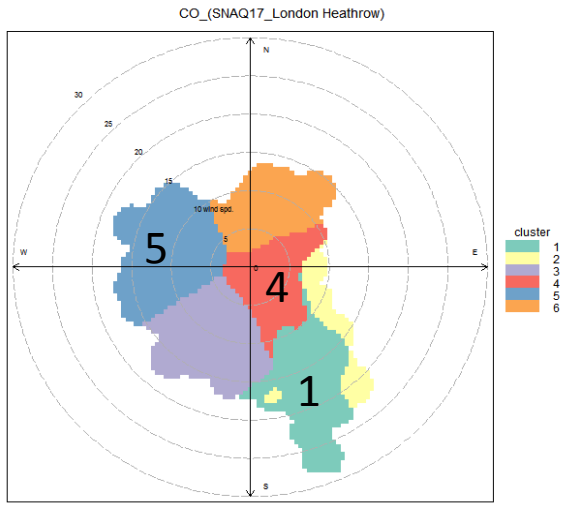
Airside/roadside source attribution: diurnal signatures



CO source
apportion: aircraft vs
roadside sources...

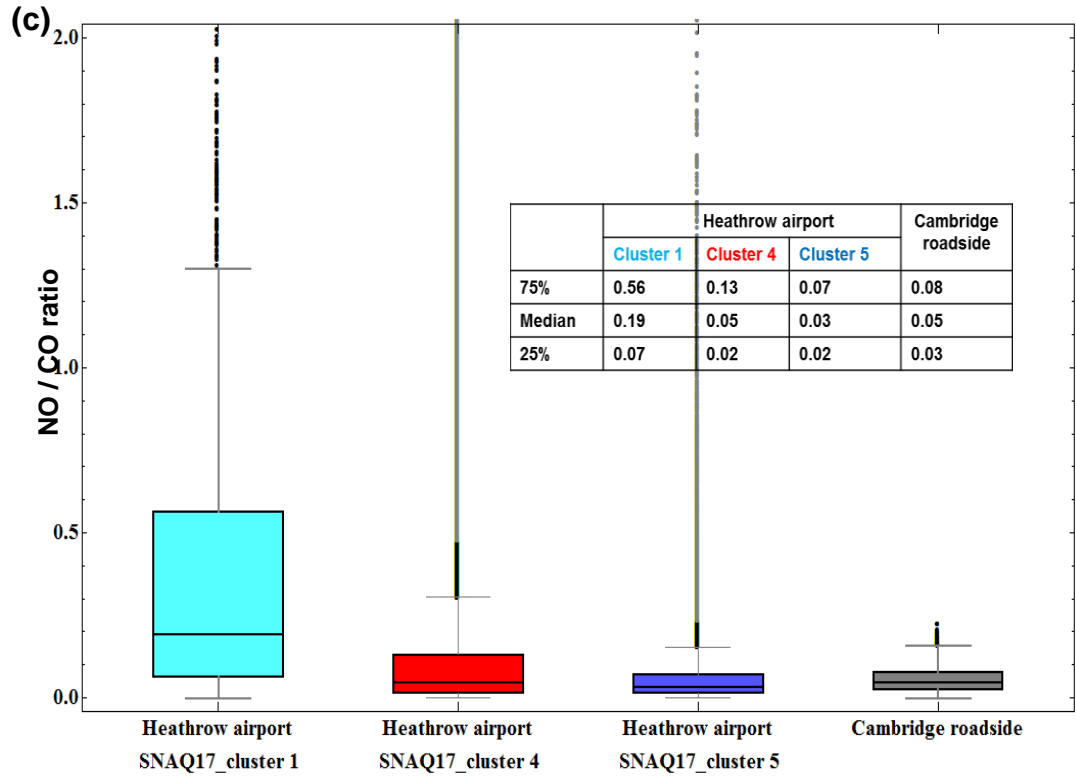


Source attribution: Sensors at the west-end of southern runway (09R)



Inferences from NO_x/CO ratios:

- 1. Take-off
- 4. Taxiway
- 5. Perimeter road traffic



NO_x/CO ratios

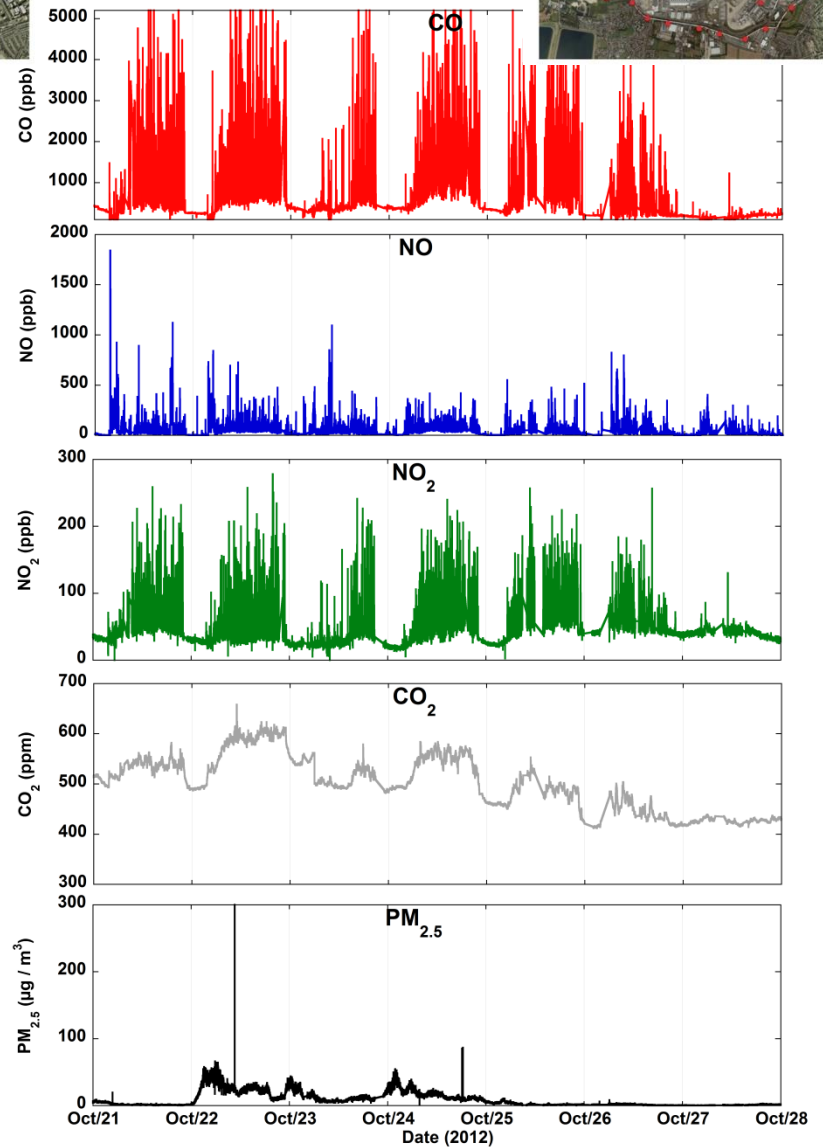
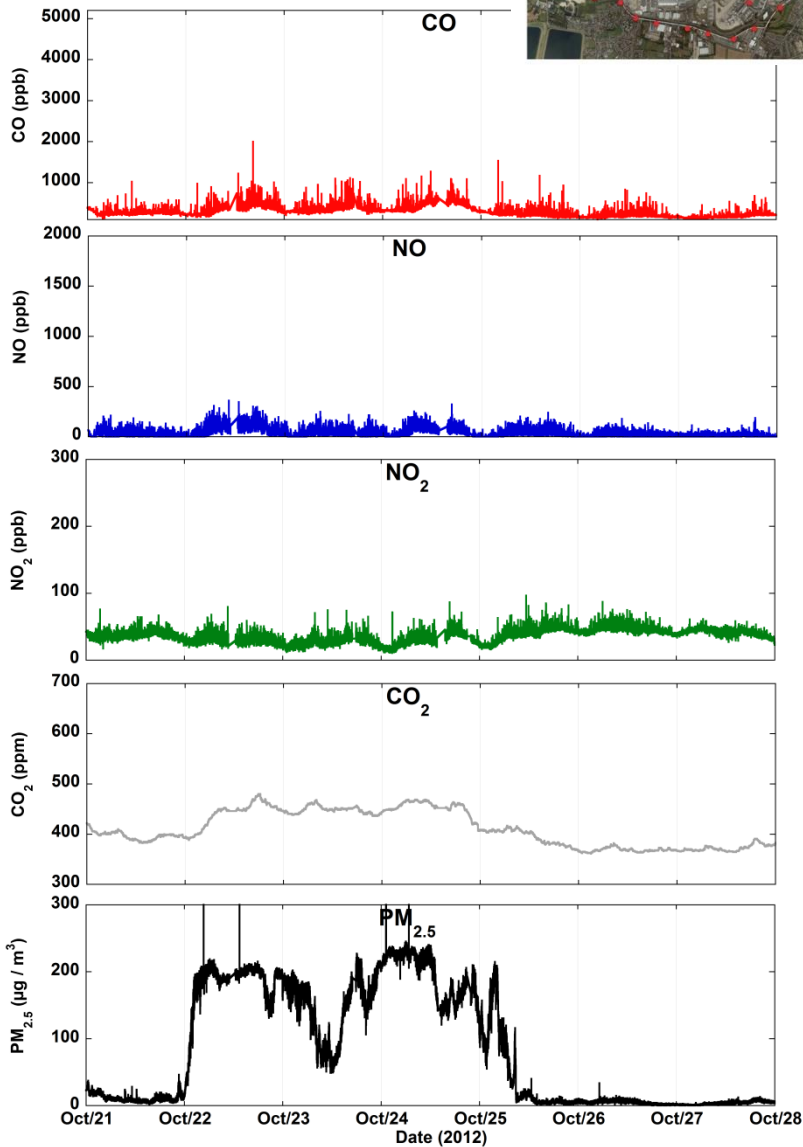


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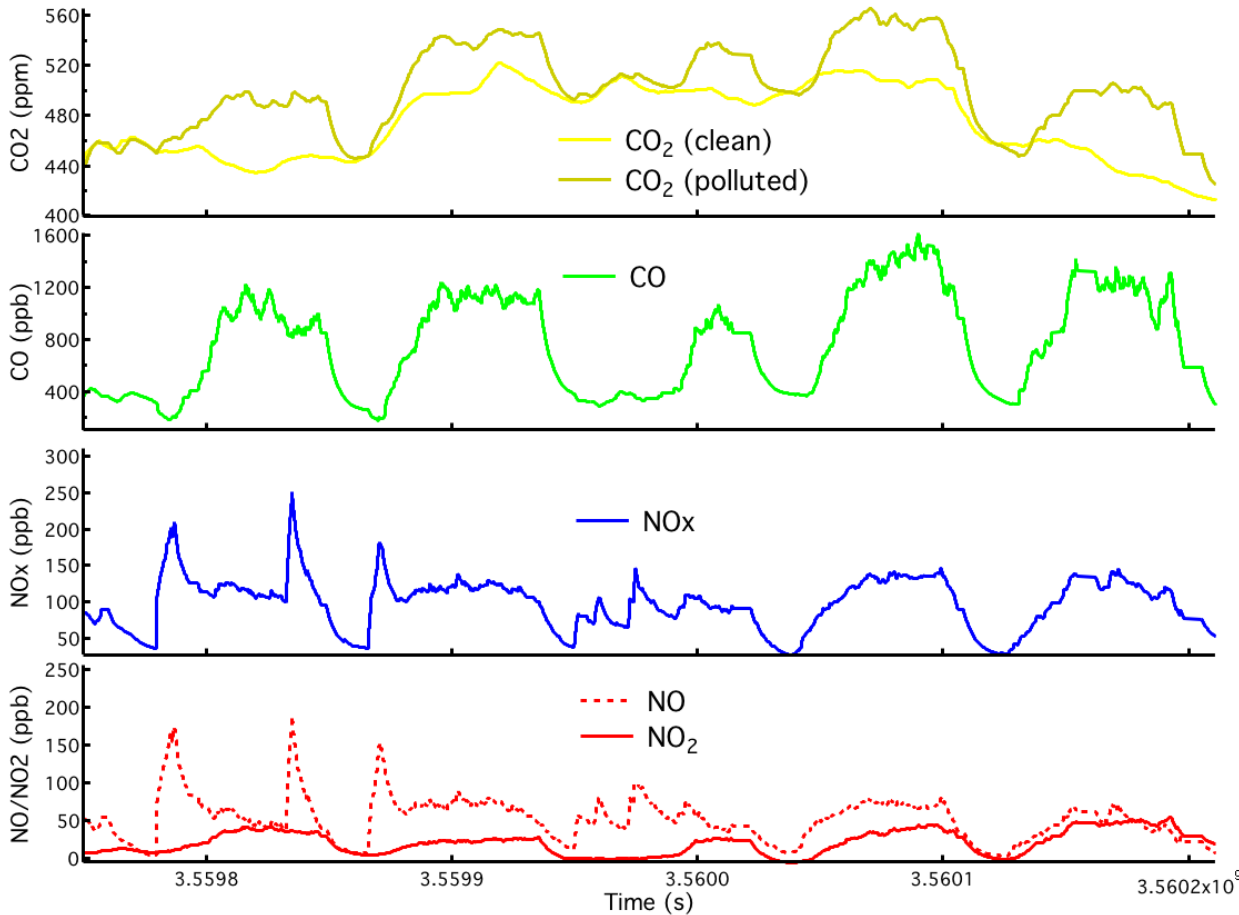
Low



High

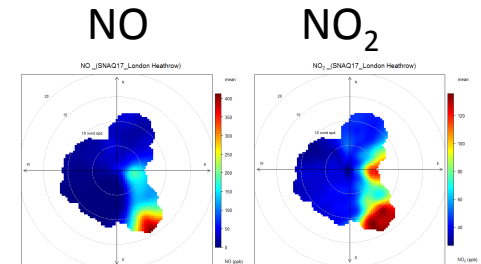


Next steps: *direct determination* of LHR average *absolute* emissions for NOx and CO:



Correlation of CO₂ with other species allows absolute emissions of NOx and CO (PM etc.) to be derived...

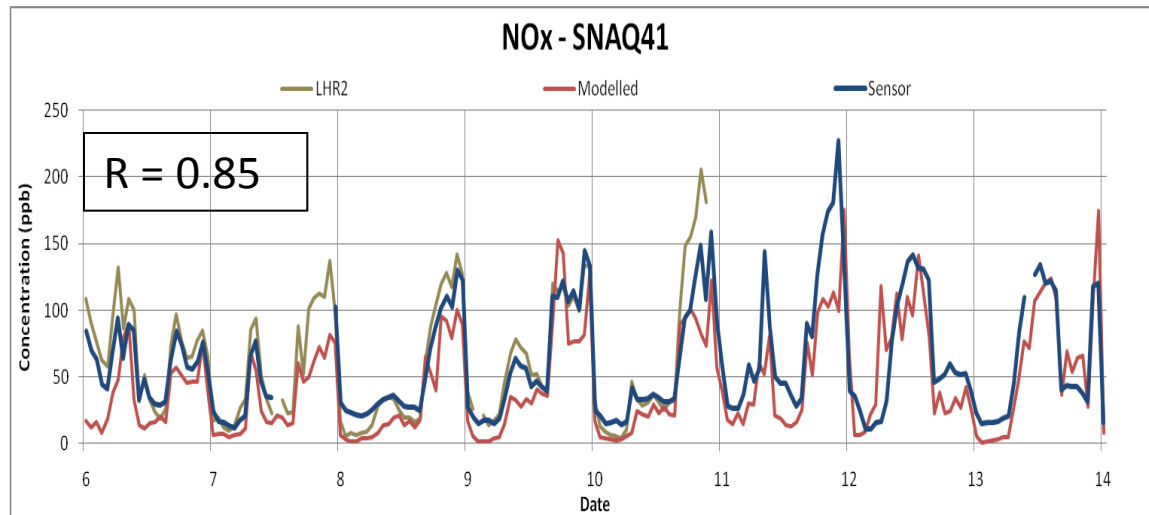
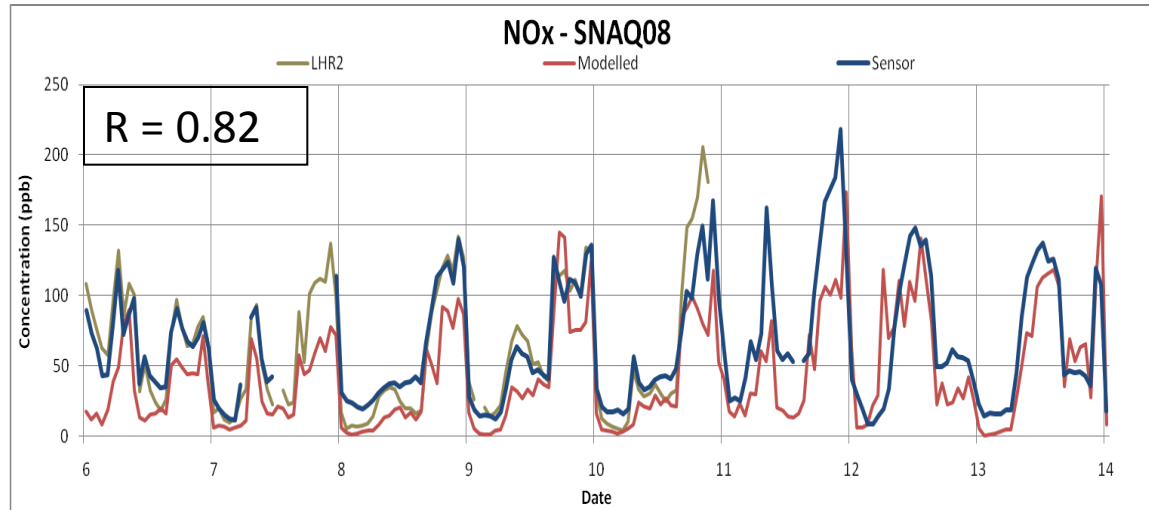
..



$\Delta\text{CO}_2 \sim 50 \text{ ppm}$, $\Delta\text{CO} \sim 1000 \text{ ppb}$, $\Delta\text{NO}_x \sim 100\text{ppb}$

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Comparison of sensor data and ADMS-Airport model predictions

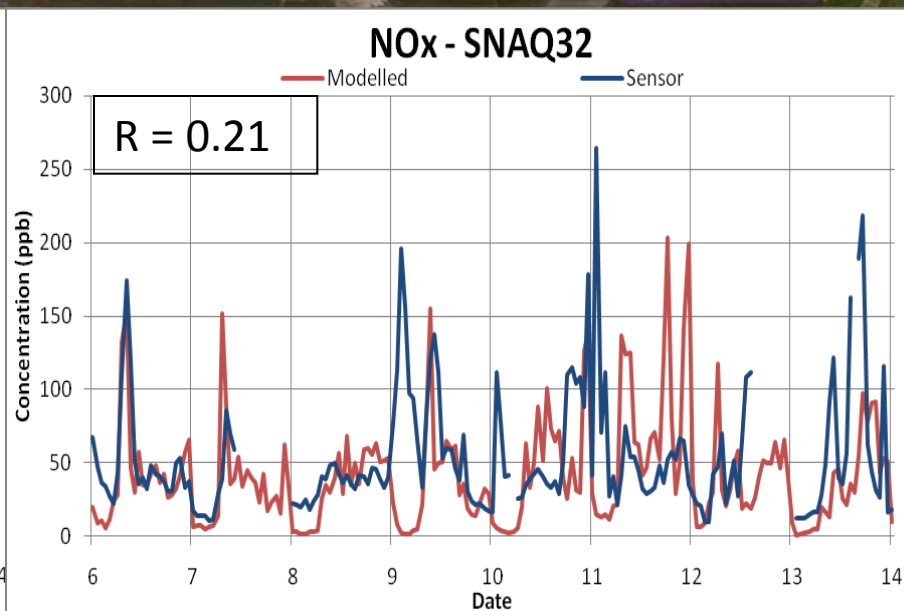
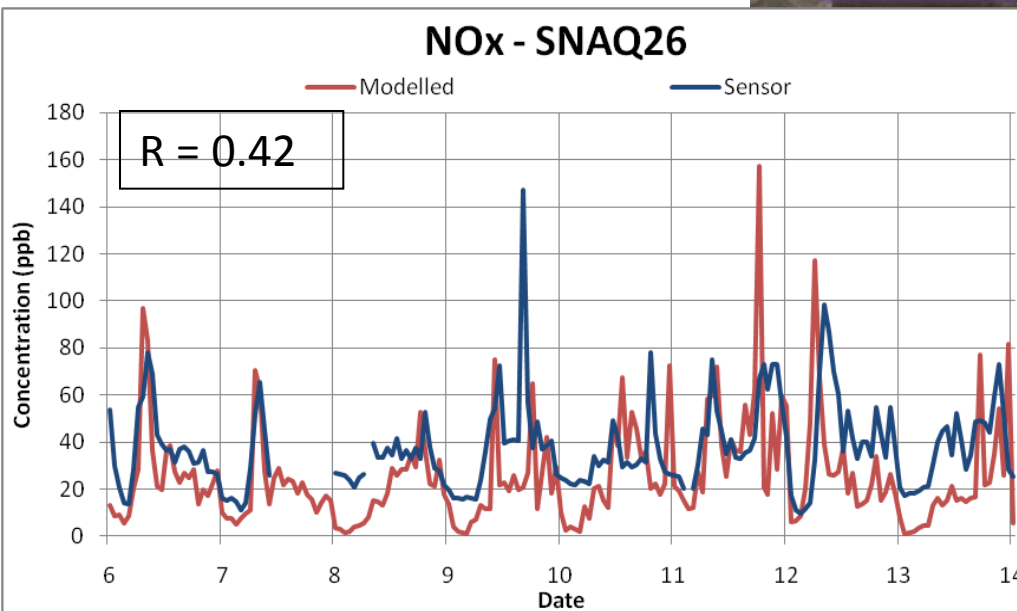
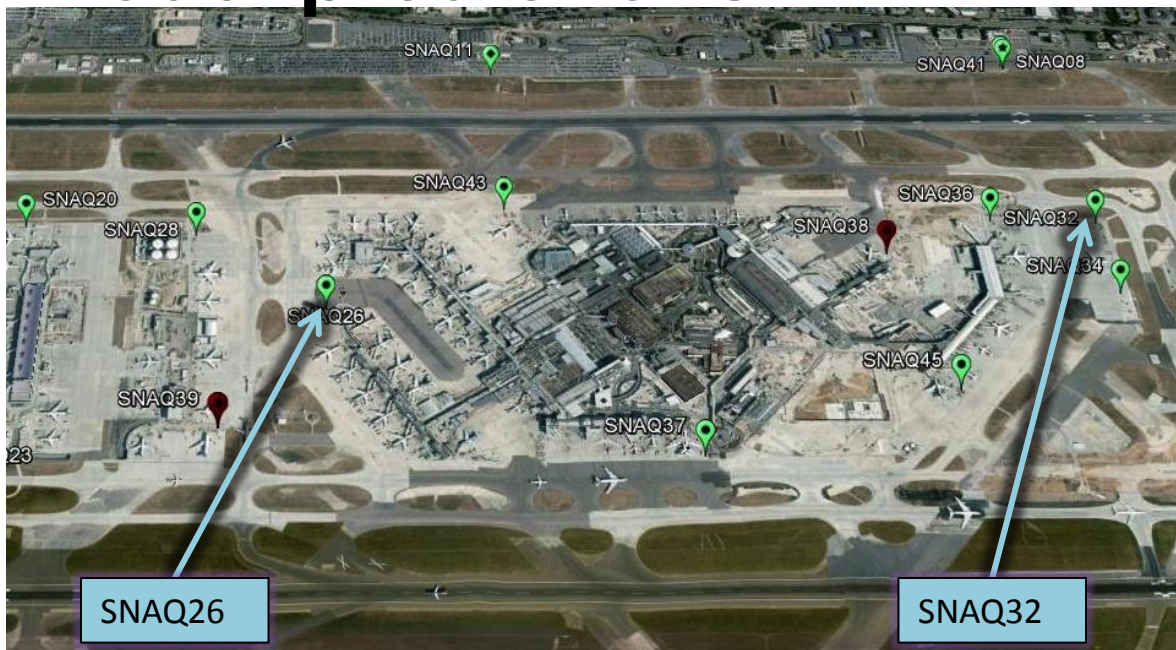


- Hourly averages during focus period from November 2012
- Sites near runway
- Similar NO_x concentration patterns for model predictions and SNAQ sensor time series



Comparison of sensor data and ADMS-Airport model predictions

- Sites between runways
 - NO_x concentration time series for model and SNAQ sensors not well correlated
 - Measured concentrations affected by many, less well-defined sources
 - Operations uncertainty e.g. taxi routes not known



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High-resolution activity and emissions estimates

Airport activity database (BOSS) for 4th-18th November 2012

18,770 arrivals and departures at 1 min accuracy specifying runways, stands, aircraft type and engine
Developed to provide detail beyond the normal hourly resolution emissions inventory

8,331 (48%) Flight Data Records;
1Hz 4D trajectory, fuel flow and thrust

10,439 (52%) Summary data only;
limited trajectory, no fuel or thrust data

Ricardo-AEA
Emissions Estimator

SNAQ Emissions
Proxiation Method

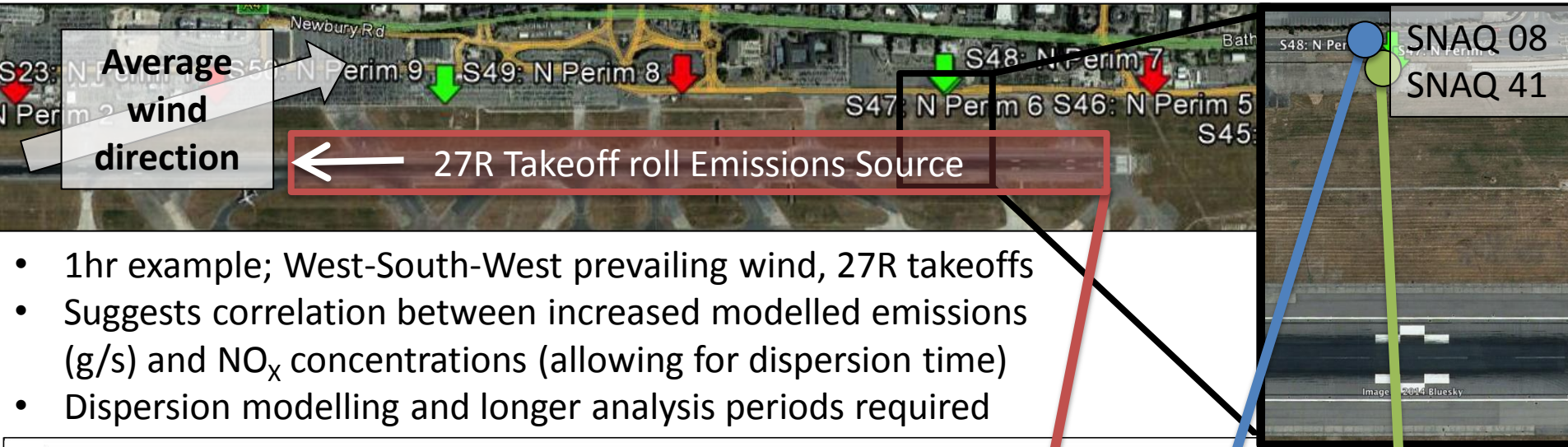
BUCAir
A/C-Engine
assignment

ICAO
Emission
Factors DB

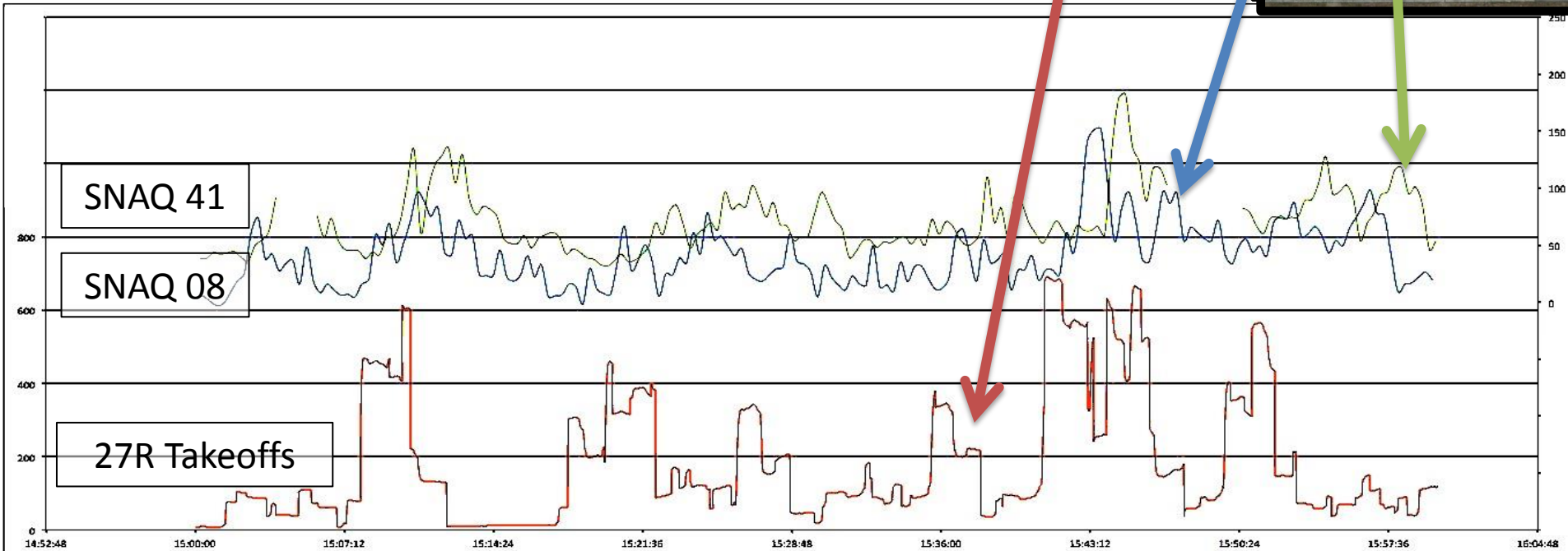
Number of matches	Aircraft	Engine type	Origin/ Destination	Confidence (Binary)	Confidence (Integer)
591	X	X	X	000	0
3103	X	X	X	001	1
18	X	✓	X	010	2
0	X	✓	✓	011	3
1672	✓	X	X	100	4
2848	✓	X	✓	101	5
712	✓	✓	X	110	6
1519	✓	✓	✓	111	7

~30 million source emission datapoints capturing aircraft activity at 1Hz
Spatial, temporal and categorical queries used to examine behaviour

NO_x vs. Time for takeoff emissions and SNAQ air quality

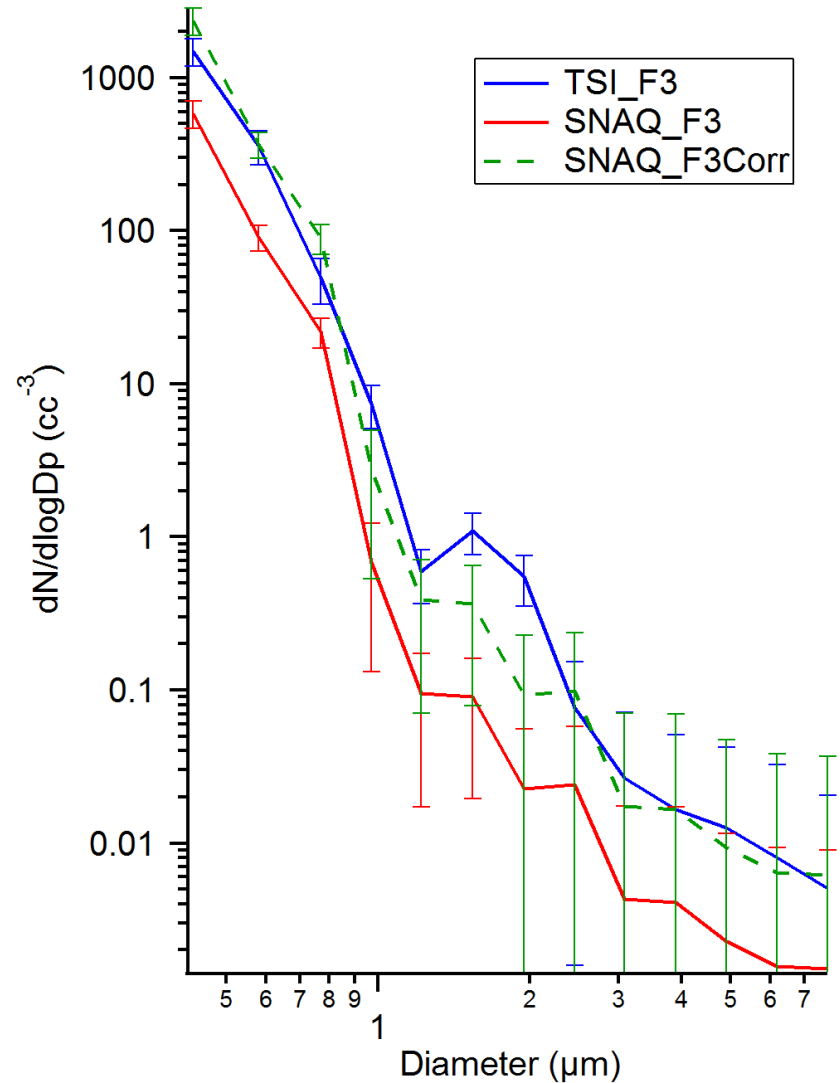
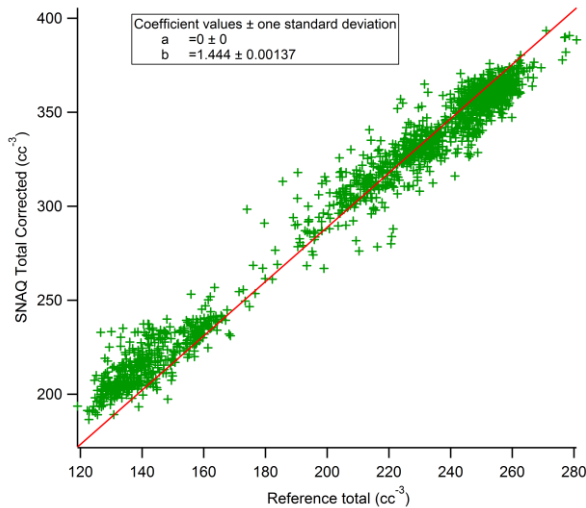
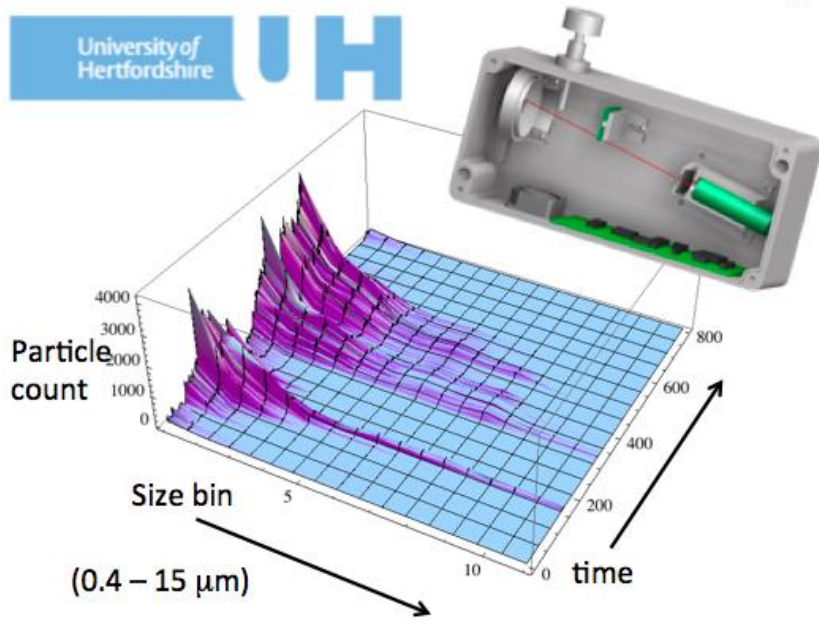


- 1hr example; West-South-West prevailing wind, 27R takeoffs
- Suggests correlation between increased modelled emissions (g/s) and NO_x concentrations (allowing for dispersion time)
- Dispersion modelling and longer analysis periods required

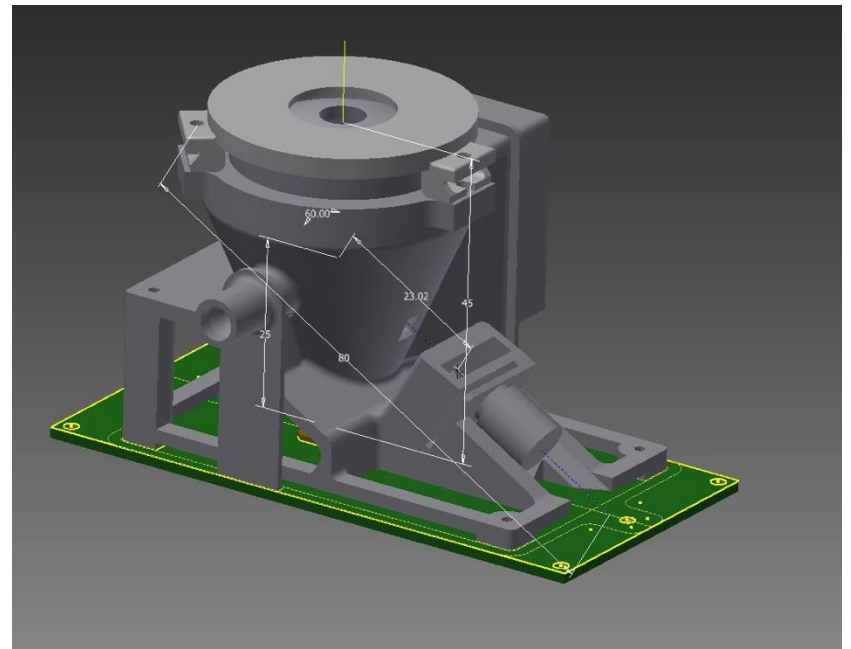
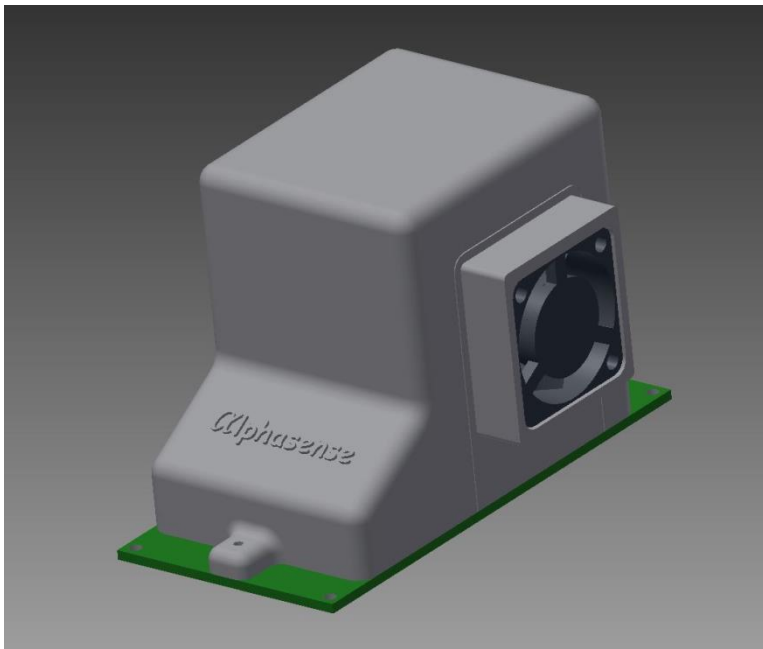


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Validation of low cost OPC



SNAQ OPC - mini commercial variant - fog variant

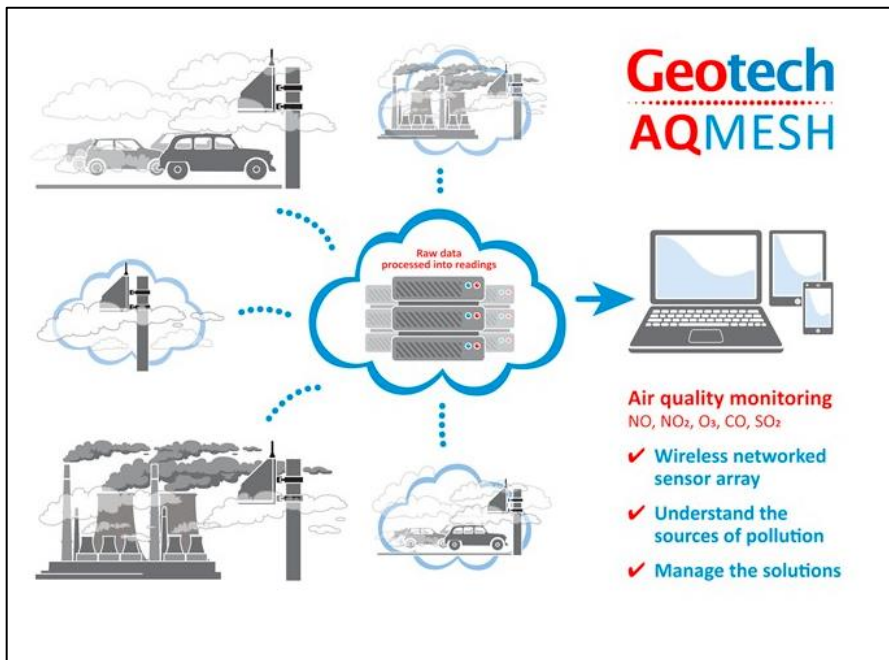


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Commercial/technical links/partnerships

Geotech Ltd.

(Instrument developer/manufacturer)



Alphasense Ltd.

(Sensor developer/manufacturer)

Welcome to Alphasense
The Sensor Technology Company

Alphasense safety
SENSORS FOR INDUSTRIAL SAFETY
Safety, Confined Space & Process Monitoring and more...
ENTER WEBSITE

Alphasense air
SENSORS FOR AIR QUALITY NETWORKS
Urban, Rural & Indoor Air Quality, Odours and more...
ENTER WEBSITE

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Acknowledgements

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Jeremy Cohen

Paul Kaye, Edwin Hirst, Warren Stanley

Alastair Forbes, Paul Quincey (NPL)

Paul Williams (UMAN)

David Carruthers, Chetan Lad.... (CERC)

.....

Funding Agencies: NERC, EPSRC

SNAQ project achievements (to date)

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Other applications: e.g. GHG networks, upper air, medical/personal exposure...