Application of a High Density Low Cost Sensor Network for Air Quality (SNAQ) at London Heathrow Airport

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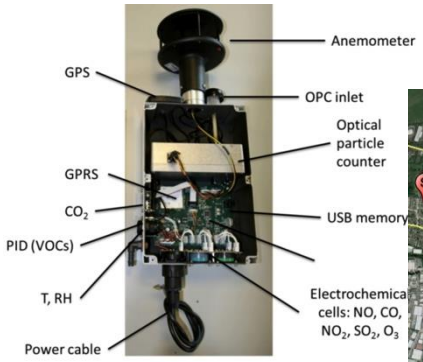
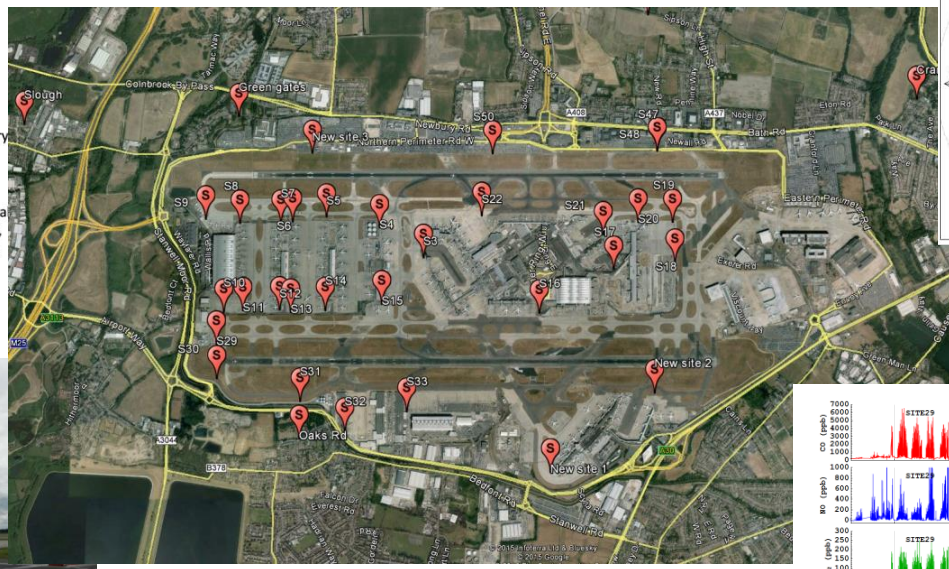
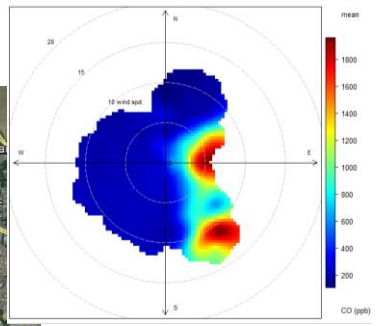
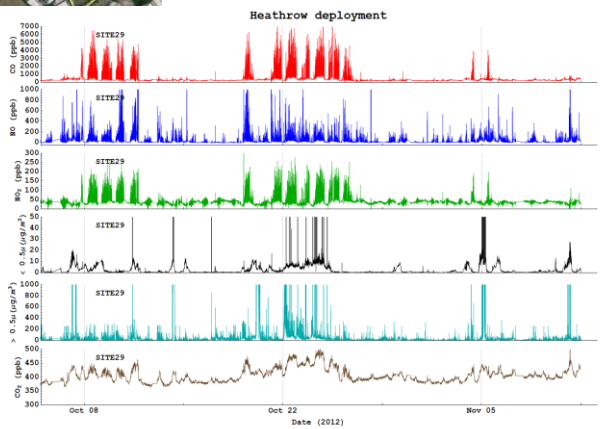


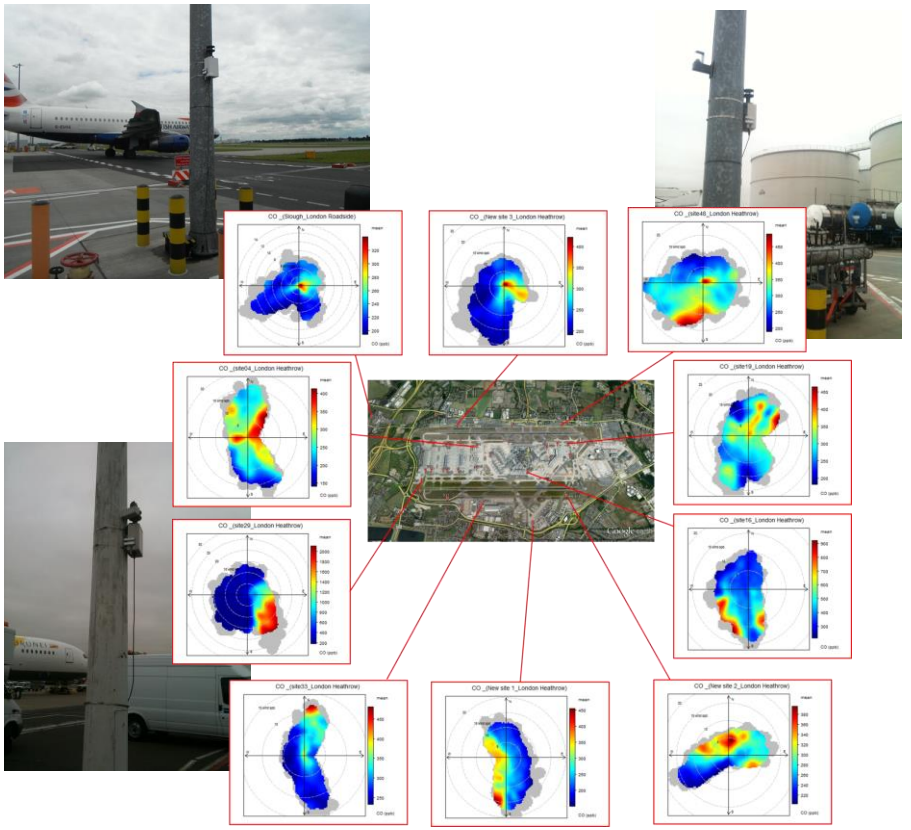




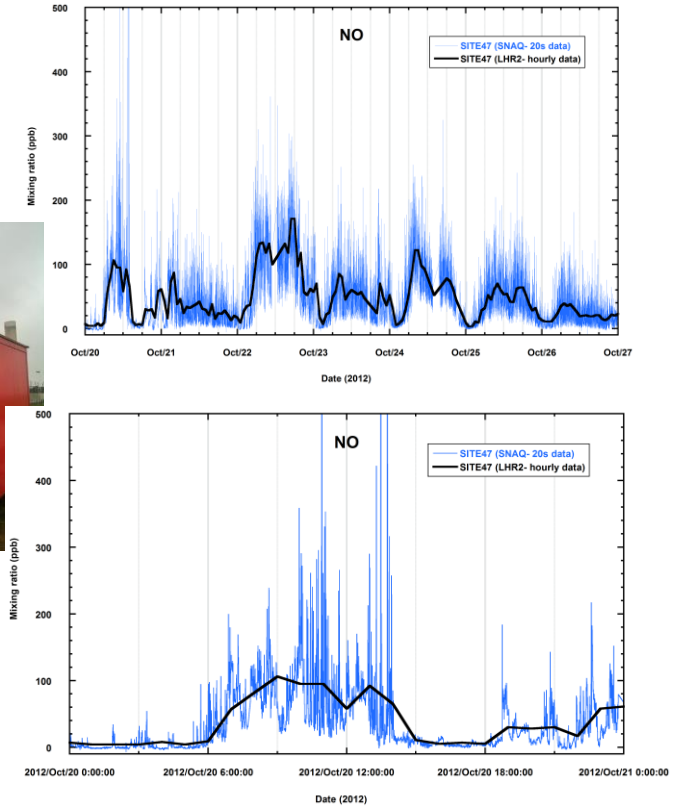


Philosophy of Approach:

information content vs *instrument precision*



vs



Low spatio-temporal high precision measurement in the *wrong* place has less value than a high spatio-temporal poor/indicative measurement in the *correct* place……

(But actually they're not that bad……..)

David Carslaw and Karl Ropkins (2012). openair: Open-source tools for the analysis of air pollution data. R package version 0.7-0.

Sensor network system at Heathrow airport: Objectives

- 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.

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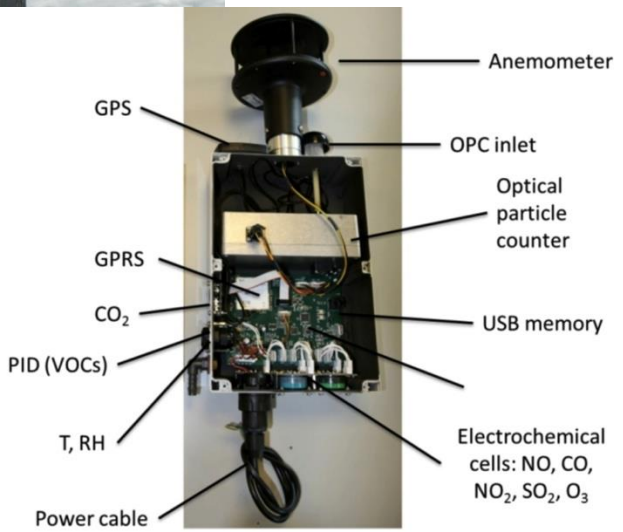
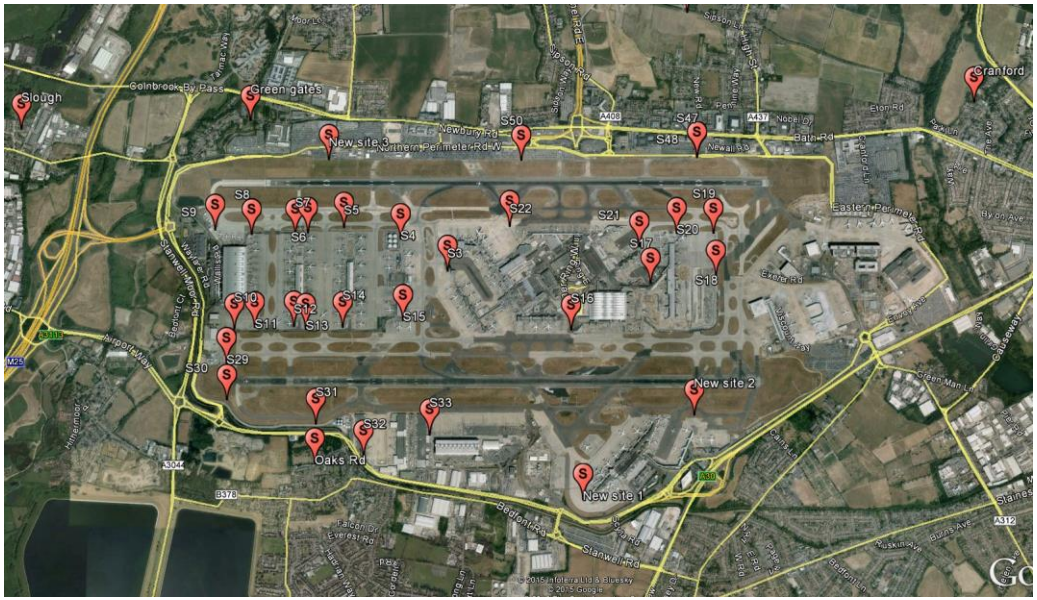
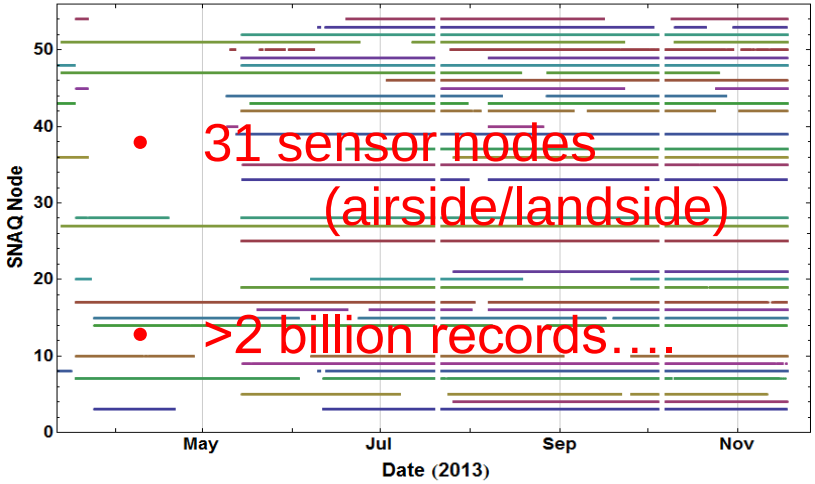
Sensor network system at Heathrow airport: Instrumentation and deployment

- 36 sensor nodes (in and around LHR)
  (Electrochemical, NDIR, PID, Optical)
- Real time data transfer (GPRS)
- NO, NO_2, CO, CO_2, SO_2, O_3, VOCs, PM
- Meteorology: wind speed and direction, RH and temperature
- Sampling period mid 2012 to end of 2013

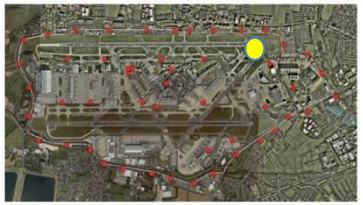


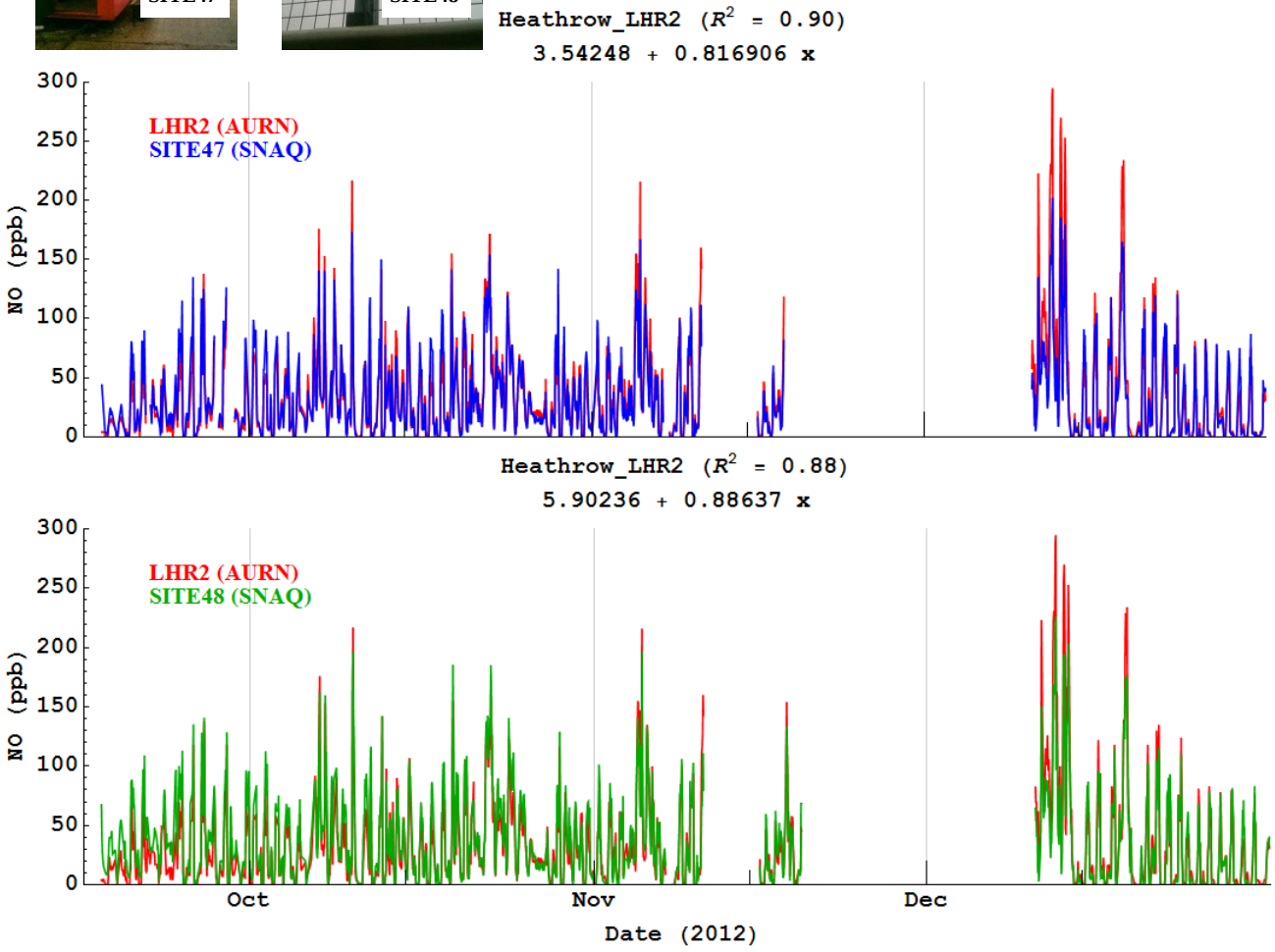


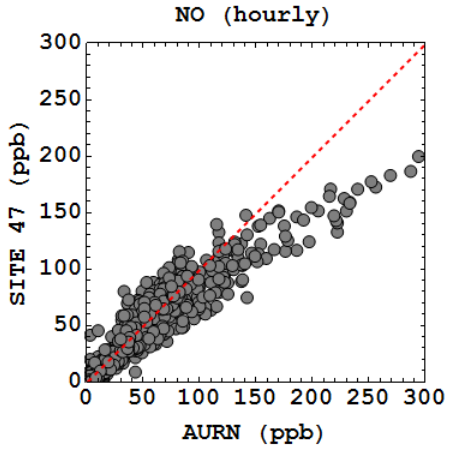


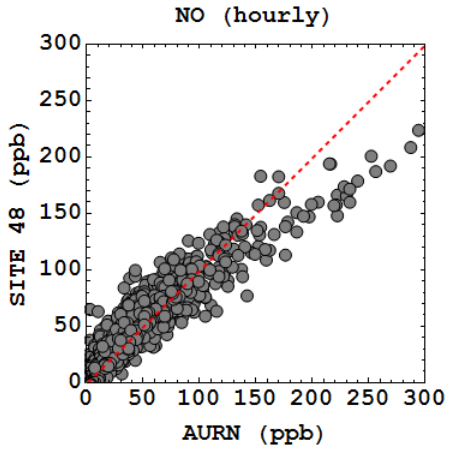
Field validation: SNAQ vs AURN (LHR2 reference method)

NO
hourly





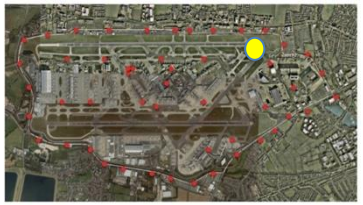


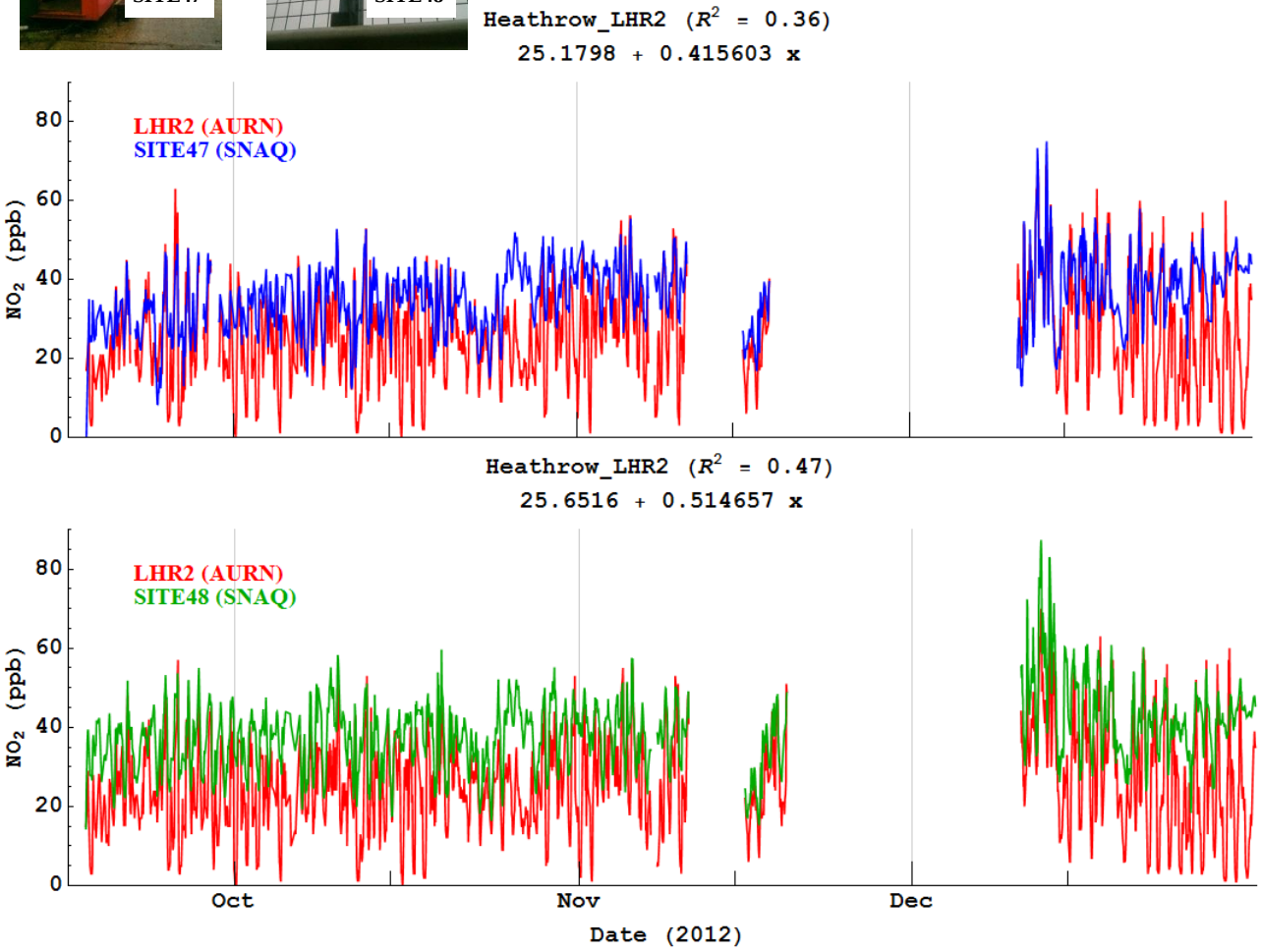


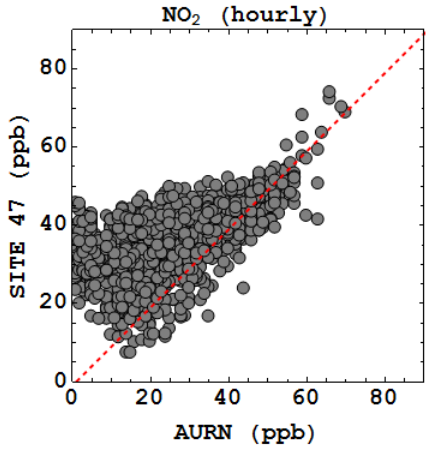
Excellent NO agreement

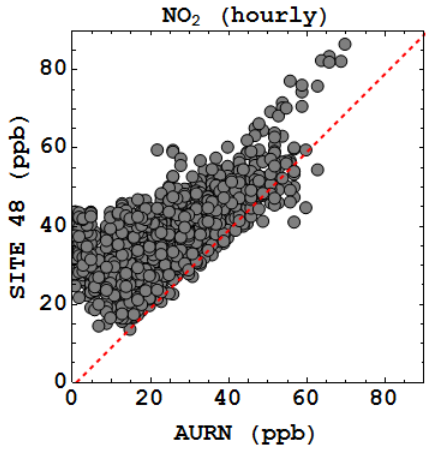
Field validation: SNAQ vs AURN (LHR2 reference method)

NO_2 hourly









Considerable NO_2 (NO_2 + O_3) agreement but …

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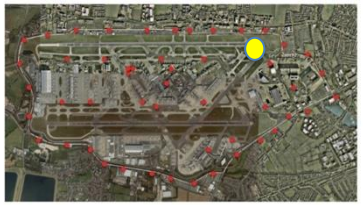
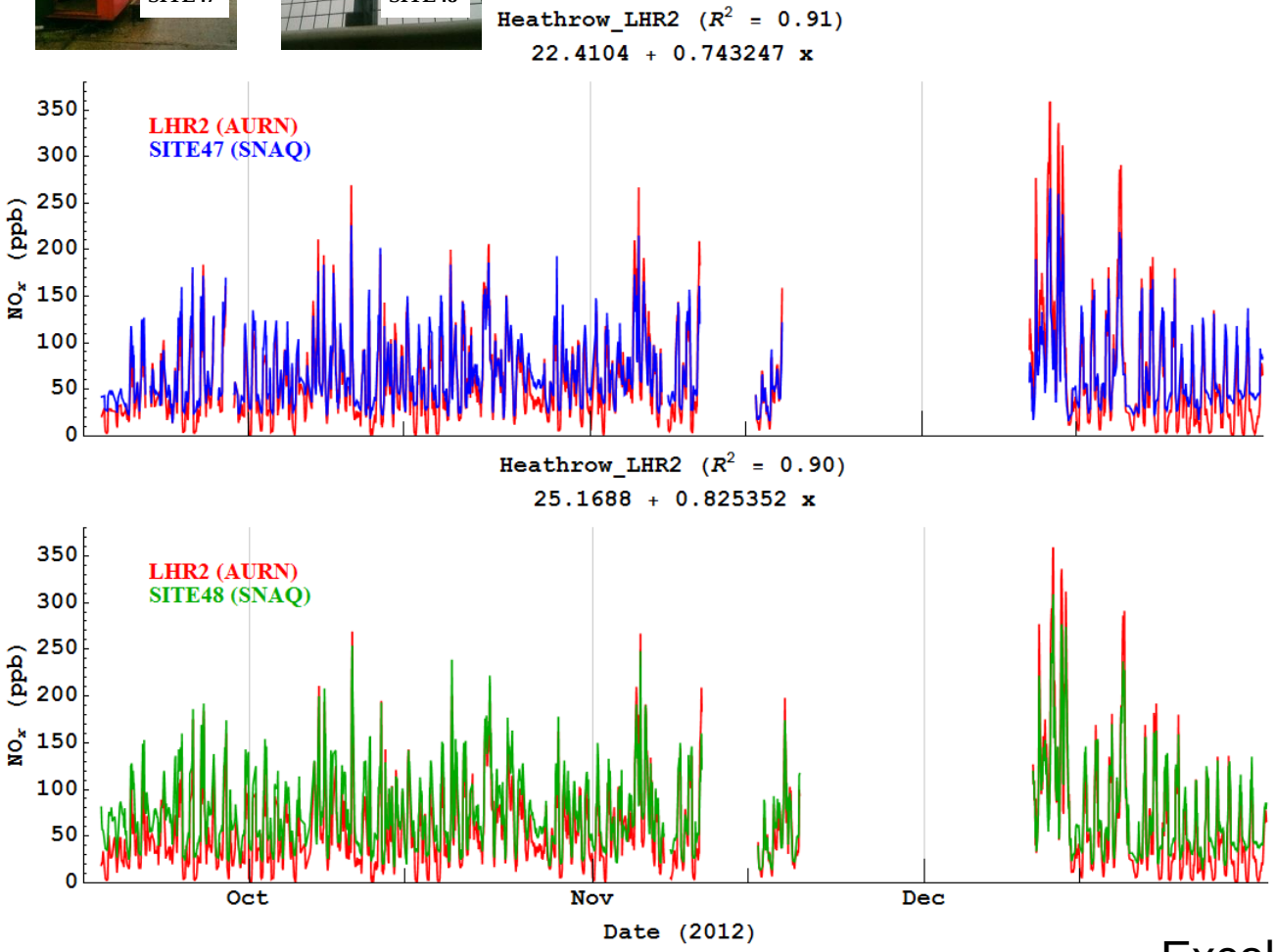
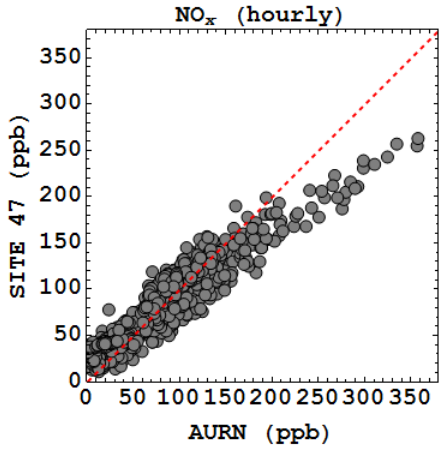
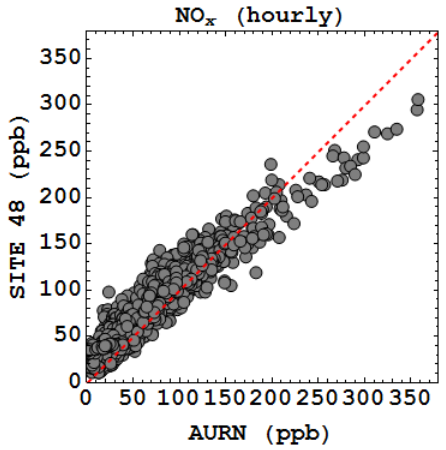
Field validation: SNAQ vs AURN (LHR2 reference method)

NO_X hourly









Excellent NO_X agreement

NO_X present mainly as NO !!!!

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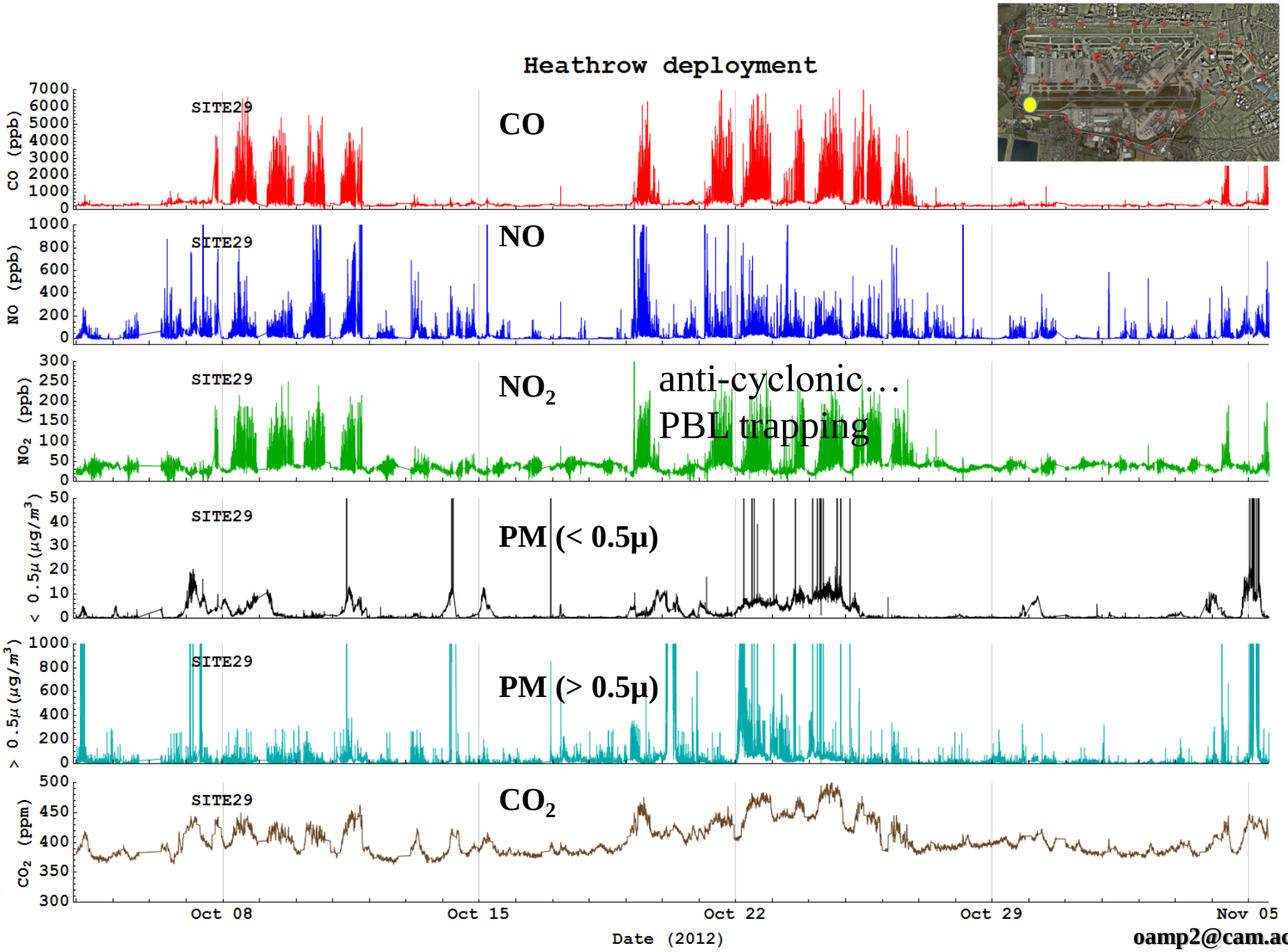
Example LHR results …….1 month (4 Oct – 4 Nov, 2012)



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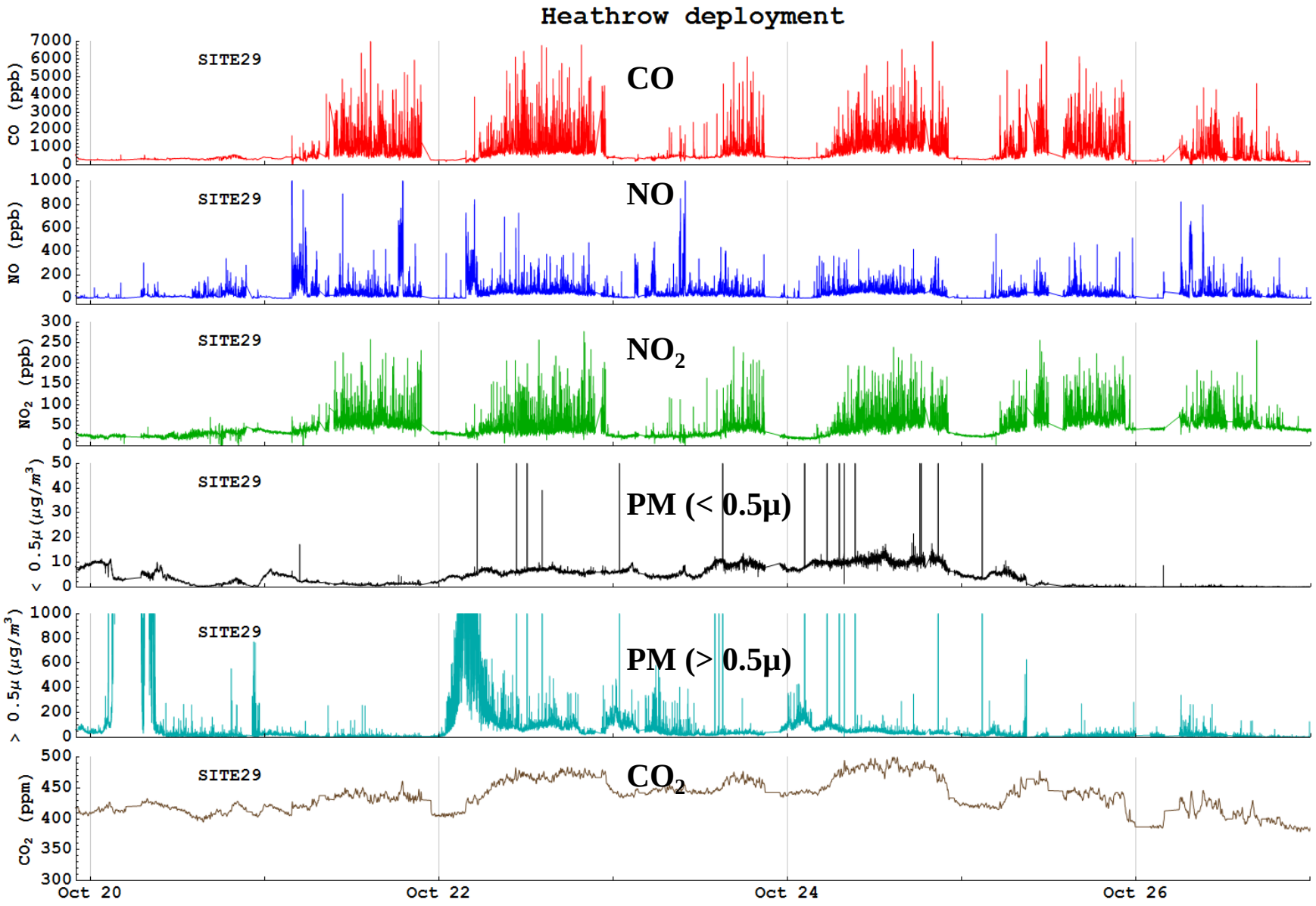
Real observations: near /far field emissions, LHR: diurnal operations, runway use….



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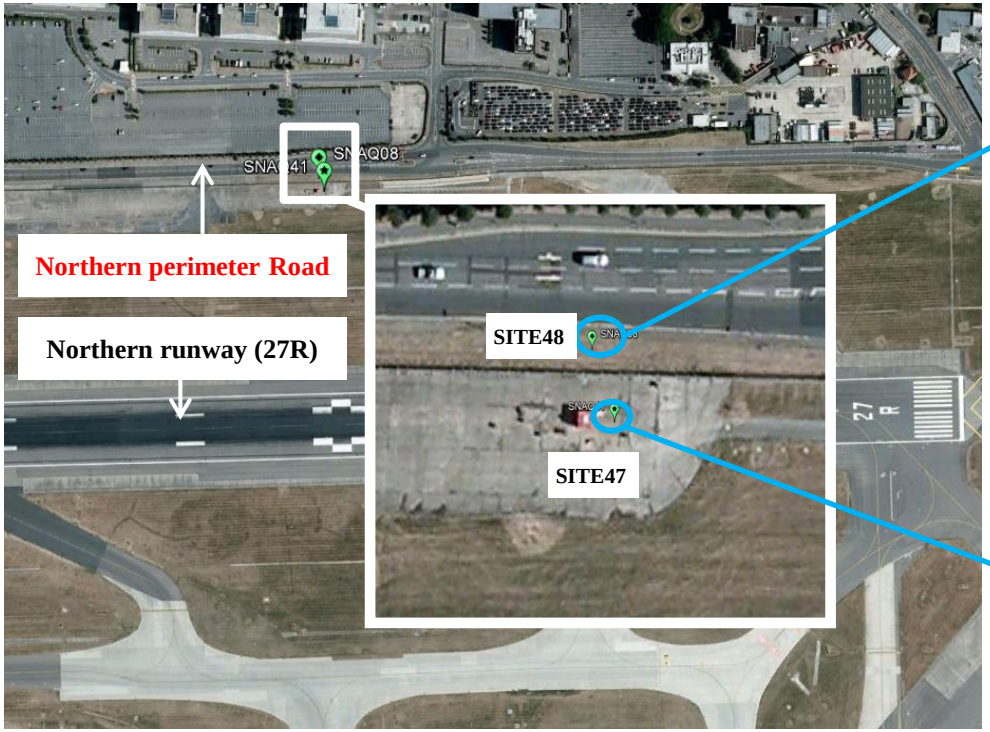
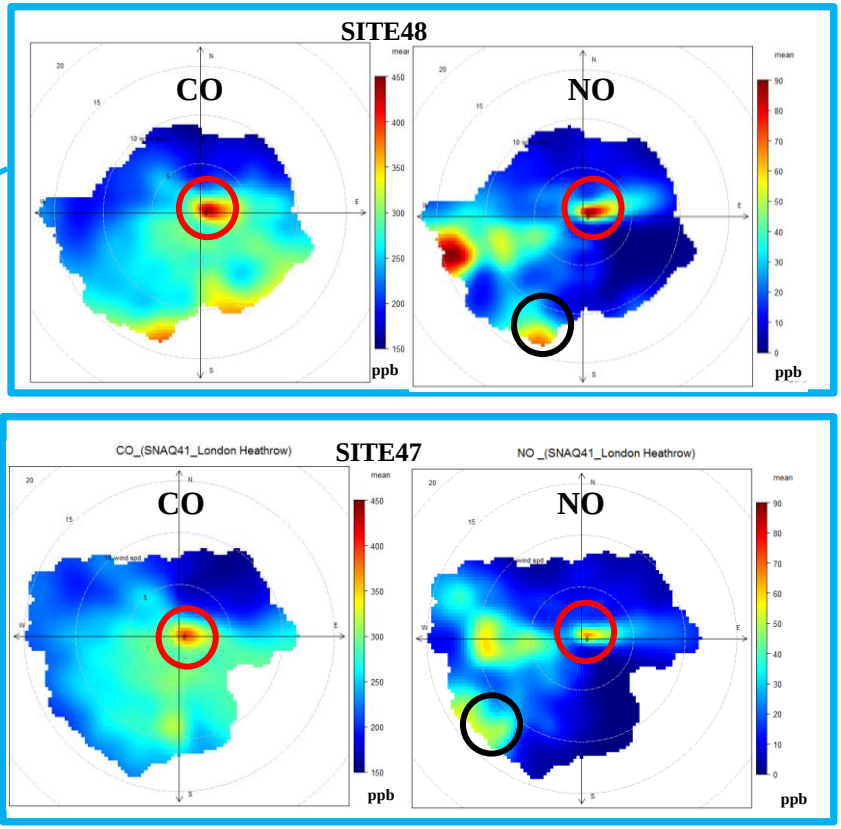
Source attribution: East-end of northern runway (27R)

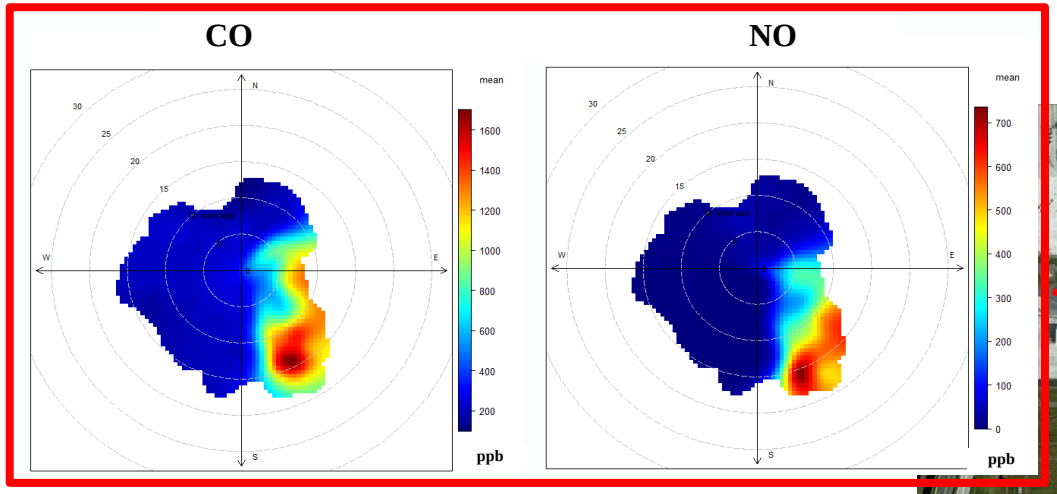


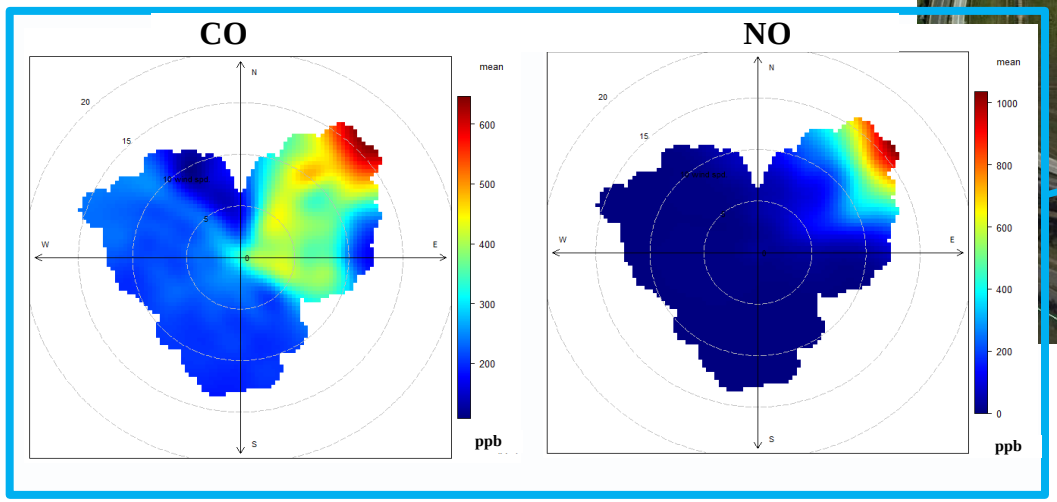


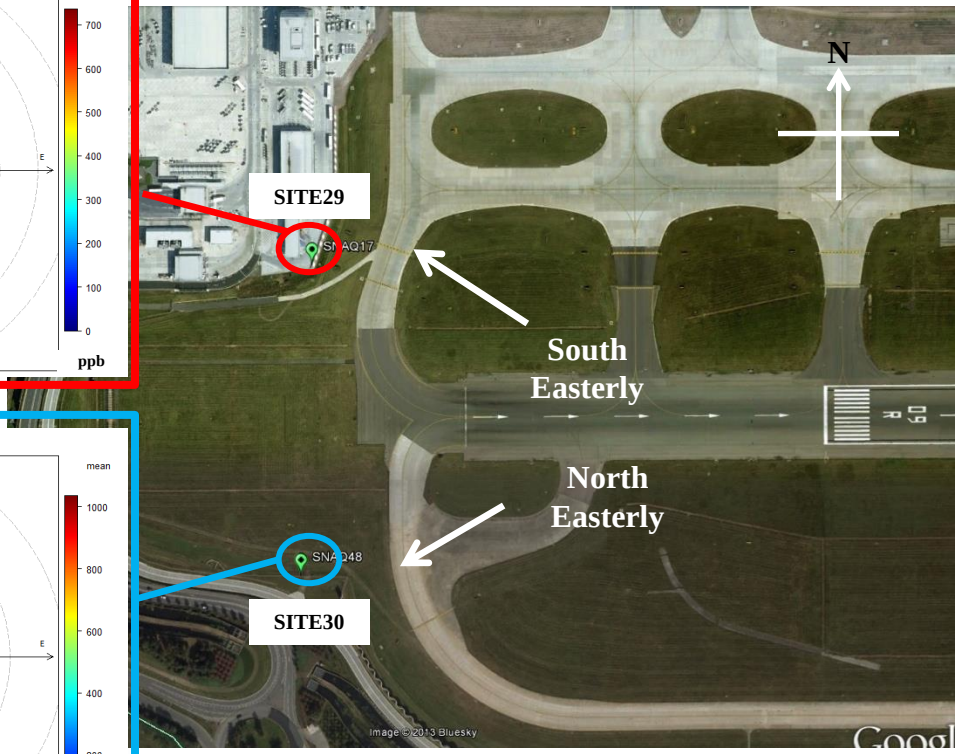
- High CO & NO mixing ratios (**red circles**) at low WS (<5ms^{-1}) in the NE quadrant suggest a pollution source to the north of the sensors (northern perimeter Road).
- High NO mixing ratios (**black circles**) at high WS (>15ms^{-1}) in the SW quadrant suggest a pollution source to the south-west of the sensors (aircraft landings/take-offs on the northern runway)

David Carslaw and Karl Ropkins (2012). openair: Open-source tools for the analysis of air pollution data. R package version 0.7-0.

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

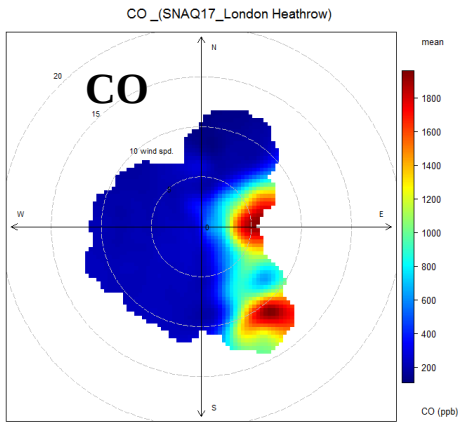


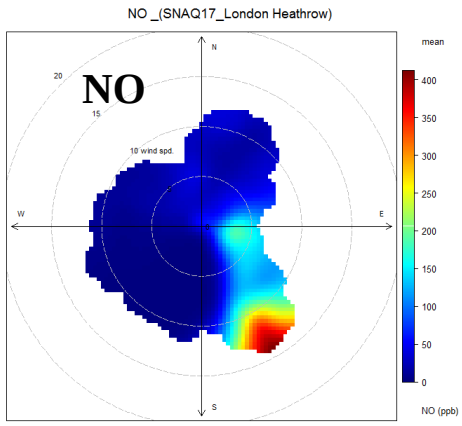


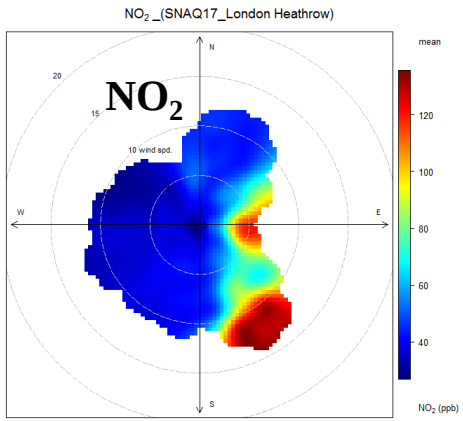


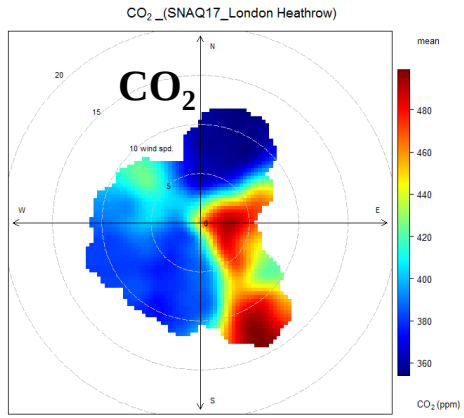
- Mirror image pollution mixing ratios observed in the two sensor nodes
- High CO & NO mixing ratios (at high wind speeds) suggests aircraft take-offs

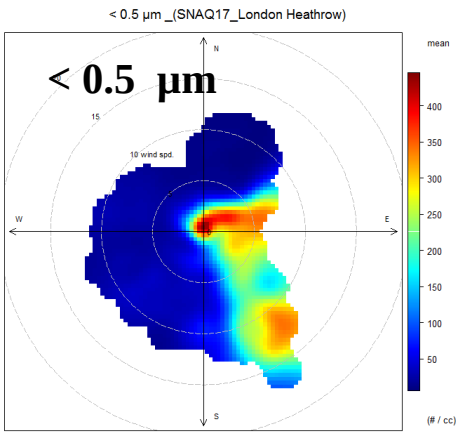
Source attribution: Site 29 at the west-end of southern runway (09R) , 1 month data

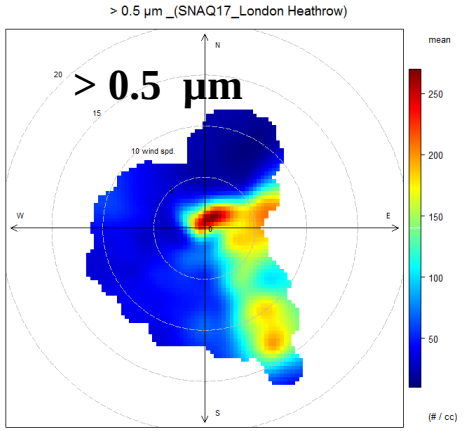


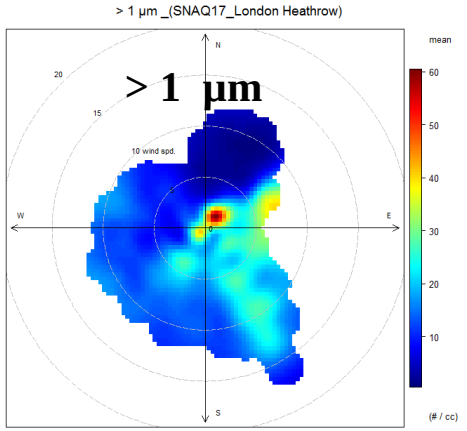


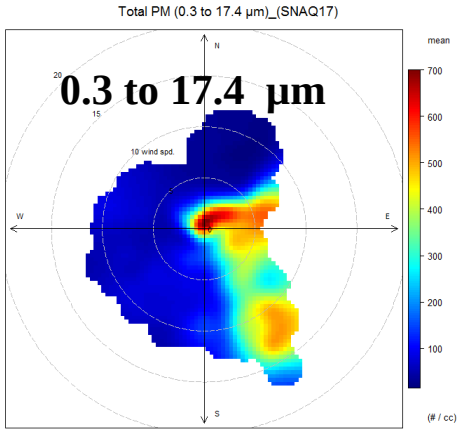












OPC (number / cc)

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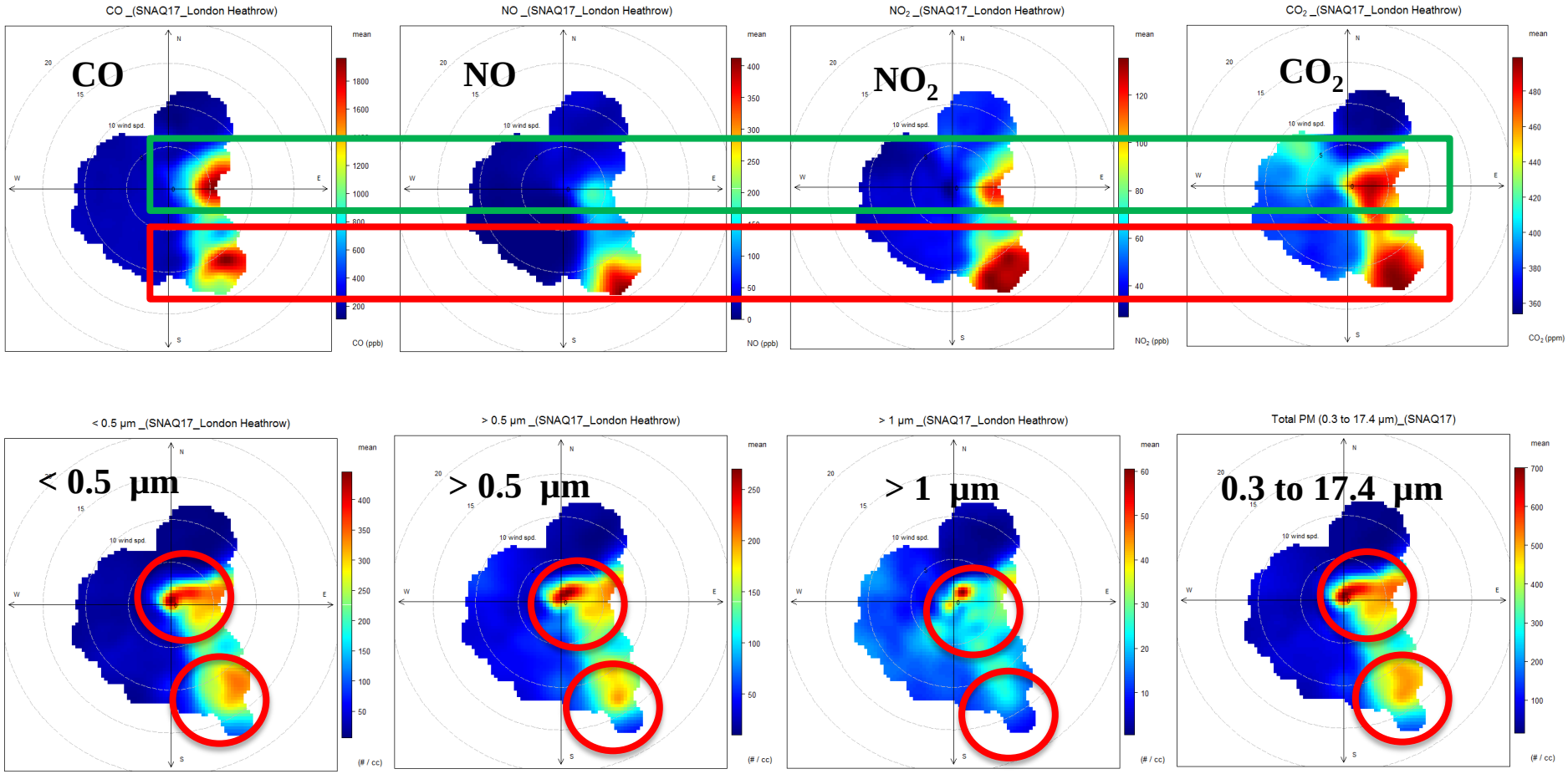
Direct determination of transport activities

High CO_2, high NOx, medium CO – take offs

Medium CO_2, low NOx, medium CO – taxiing



OPC (number / cc)

Also PM apportionment……

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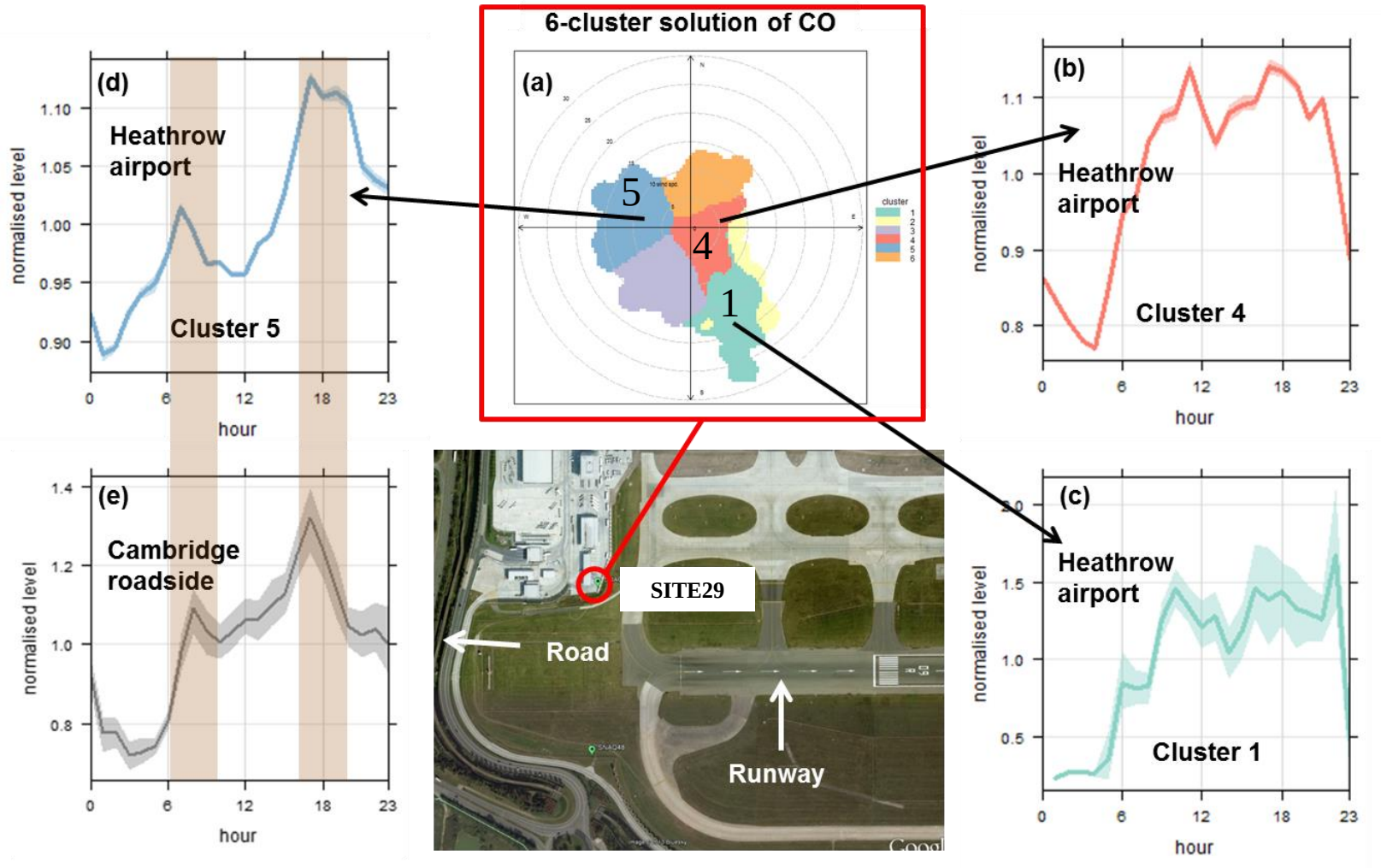
Airside/roadside source attribution: diurnal signatures



CO source apportion: aircraft vs roadside sources…

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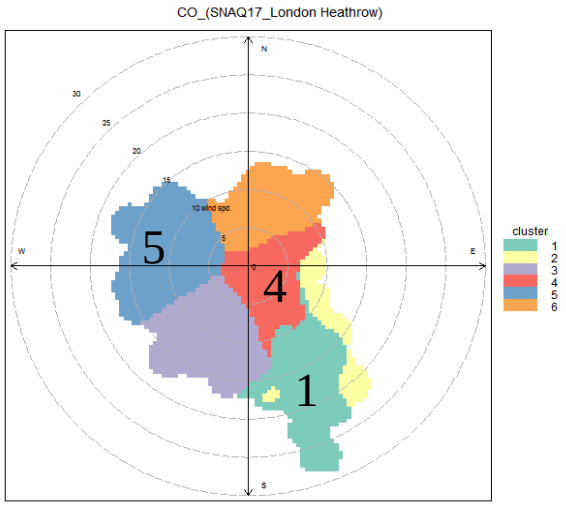
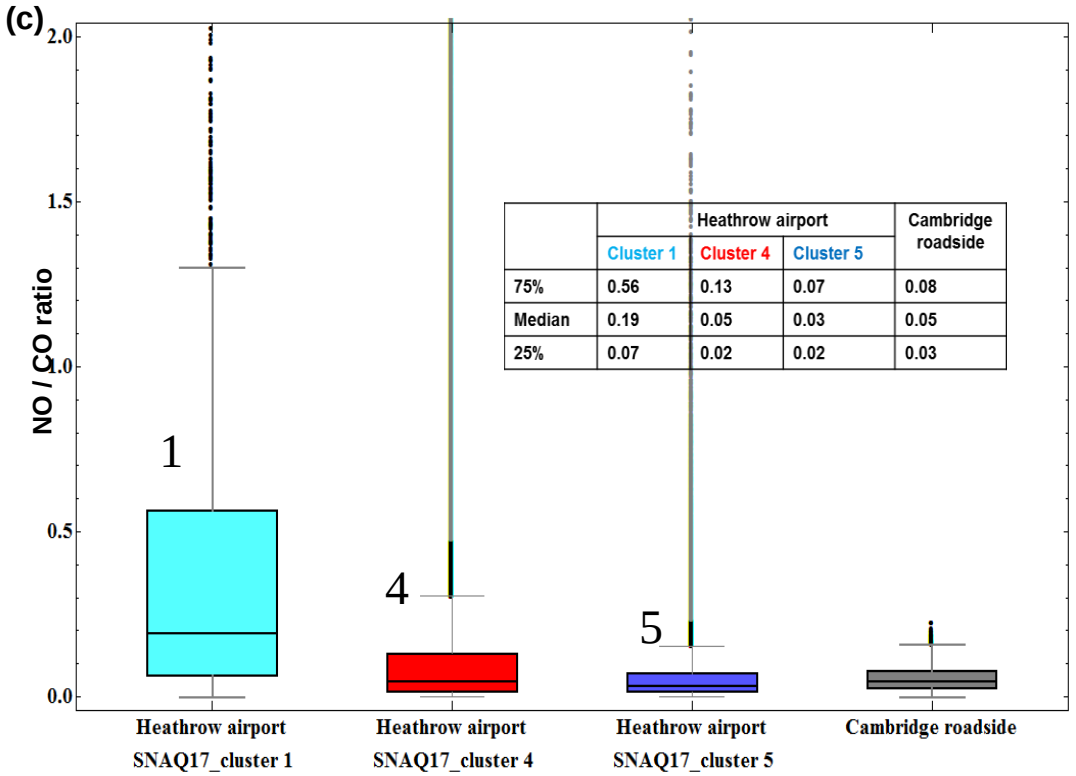
Source attribution: Sensors at the west-end of southern runway (09R)



Inferences from NOx/CO ratios:

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



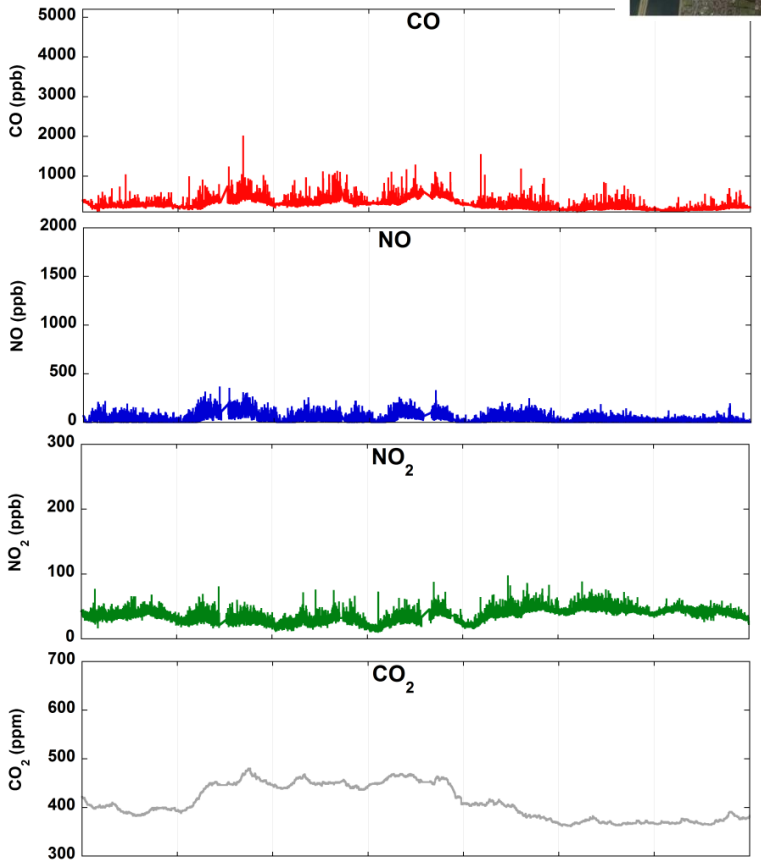
	Heathrow airport			Cambridge roadside
	Cluster 1	Cluster 4	Cluster 5	
75%	0.56	0.13	0.07	0.08
Median	0.19	0.05	0.03	0.05
25%	0.07	0.02	0.02	0.03

NOx/CO ratios

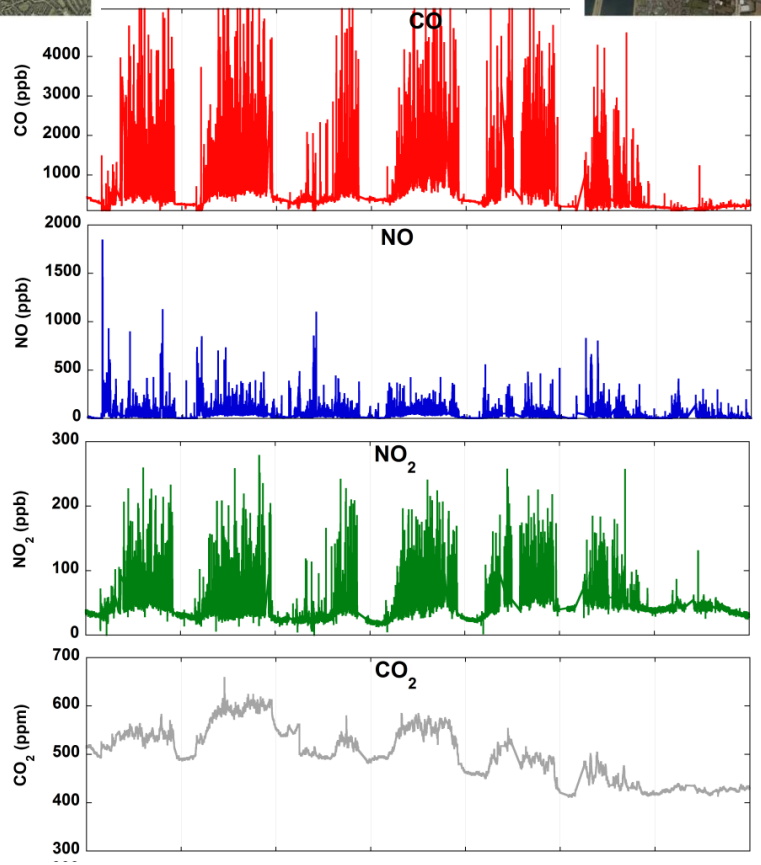
Quantitative source attribution…..

Direct determination of LHR average *absolute* emissions for NOx and CO using CO_2:

Low emissions



High emissions



(1 week of data)

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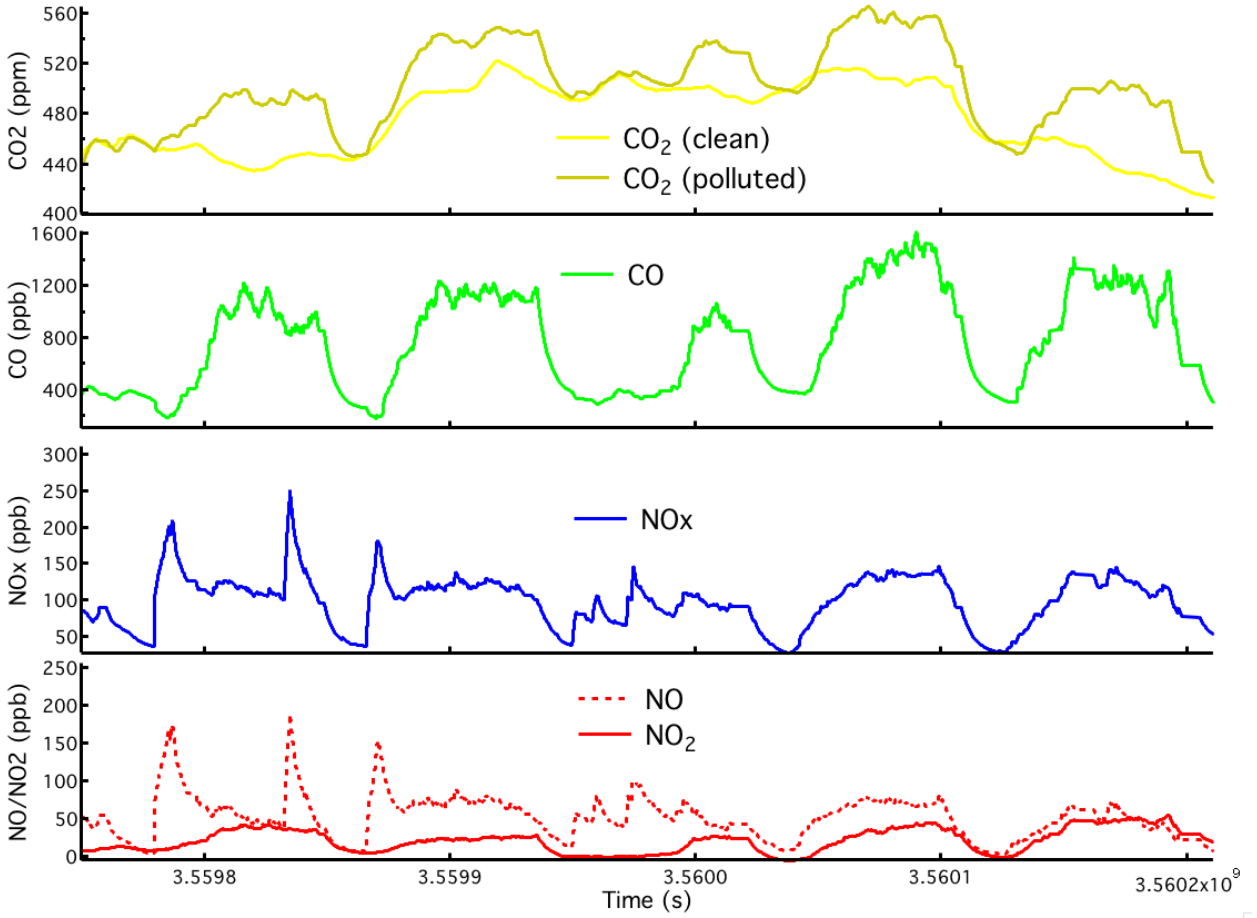
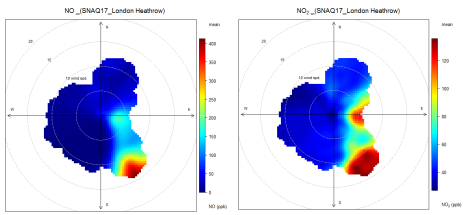
Direct determination of LHR average *absolute* emissions for NO_X and CO:



Correlation of CO_2 with other species allows *absolute emissions* of NOx and CO (PM etc.) to be derived…

NO NO_2



ΔCO_2 ~ 50 ppm, ΔCO ~ 1000 ppb, ΔNOx ~ 100ppb

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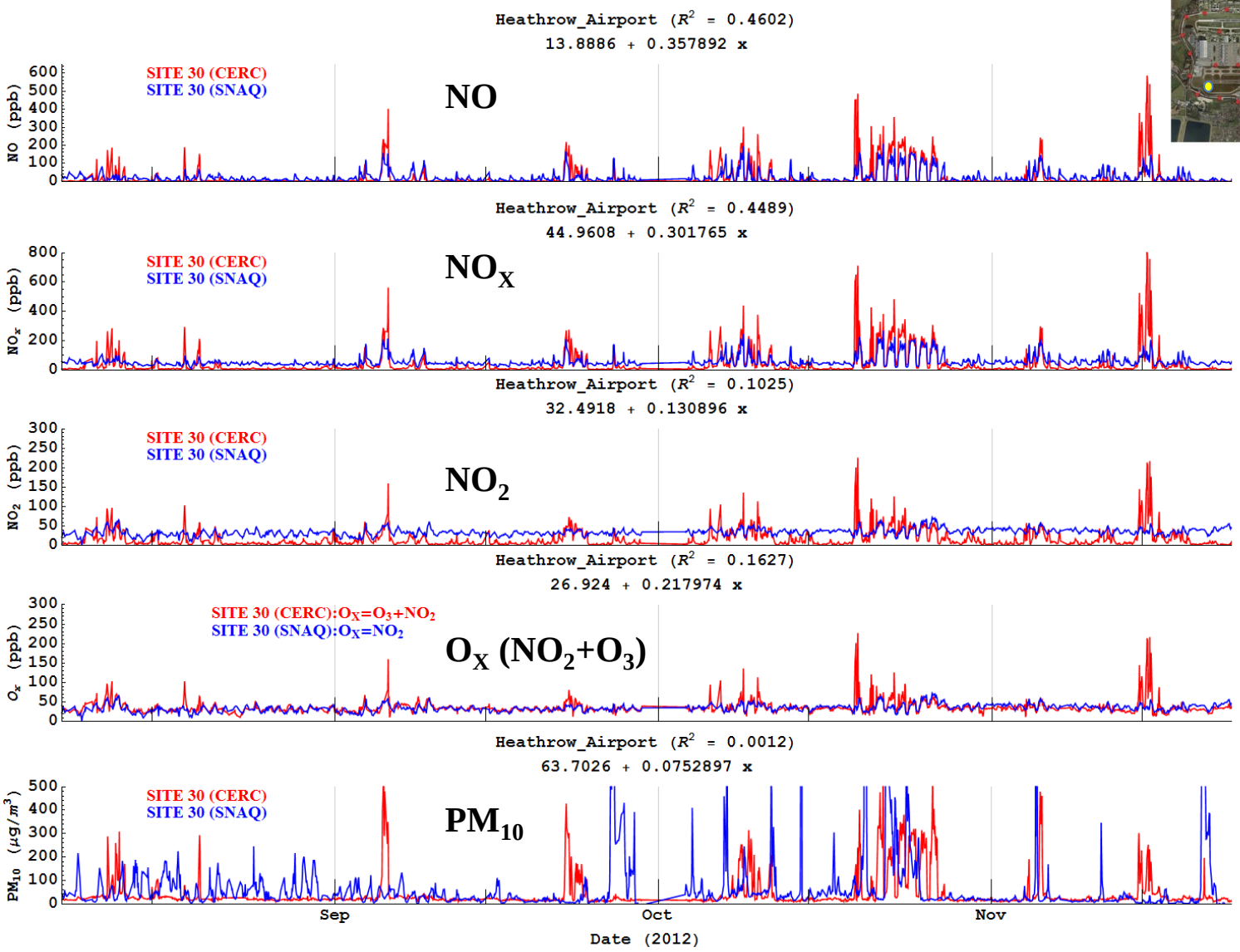
Preliminary model comparison results: CERC – ADMS airport vs SNAQ data (hourly)



Similar trends in NO, NO_X and O_X especially during high emission events

Conclusions and next steps

- Low cost sensors/sensor networks viable for A/Q monitoring – gases, PM
- Some outstanding issues…..
- Source attribution (gas phase, PM)
- Direct emission indices estimation
- Future work include comparison with CERC model and sensor network calibration using baseline approach

Bottom line…..

If configured rightly, low cost air quality sensor networks are effective for characterising air pollution in multiple environment (airport, rural and urban)

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Paul Kaye (and UH team)

David Carruthers, Chetan Lad (and CERC team)

…..

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