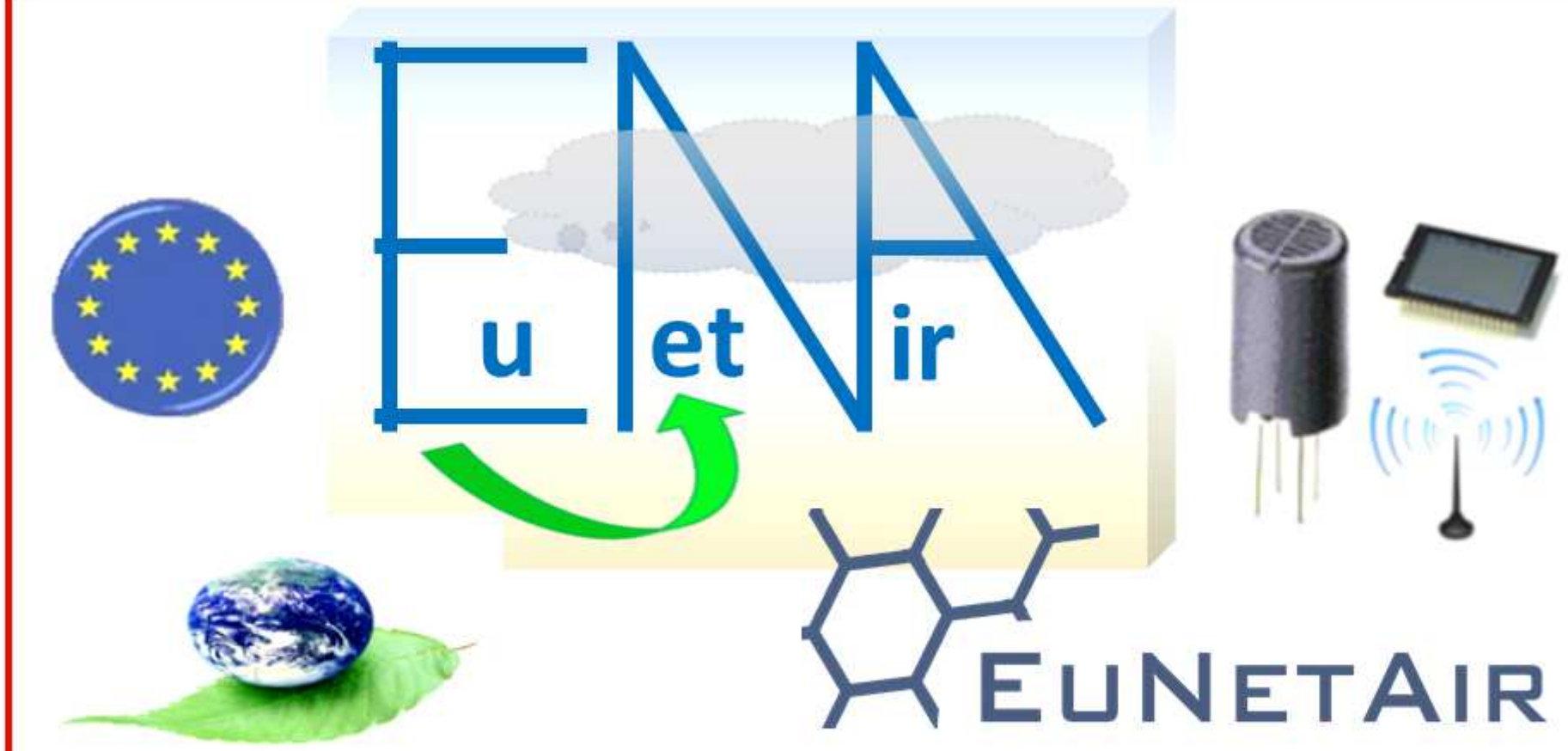
Materials advances for ppb gas detection

John Saffell
Technical Director
Alphasense Ltd.
Great Notley, Essex UK
jrs@alphasense.com

EuNetAir Crete October 2012

European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability - EuNetAir



Who are we?

Alphasense Limited

A private UK limited company

Started: January 1997

First product: O2-A1 Oxygen sensor
September 1997

Markets: Industrial Safety and Air Quality
gas sensors

Electrochemical

Not only industrial safety, but now also air quality sensors

New factory: finished 2008

250 solar panels installed 2012

USA and EU regulations are demanding more knowledge of urban air quality; this requires mapping in space and time

Species	Conc ($\mu g\ m^{-3}$)	Conc (ppb)	Period	Standard Date
NO_2	200	106	Hourly mean	Dec 2005
	40	21	Annual mean	Dec 2005
CO	10 (**mg m^{-3}**)	8.7 (**ppm**)	Max daily running 8 hr mean (running 8 hr mean in Scotland)	Dec 2003
O_3	100	50	8 hr running or hourly mean (not to be exceeded 10 times a year)	Dec 2005

VOC and inorganic gas sensor advances and challenges

What technologies are leading the race?

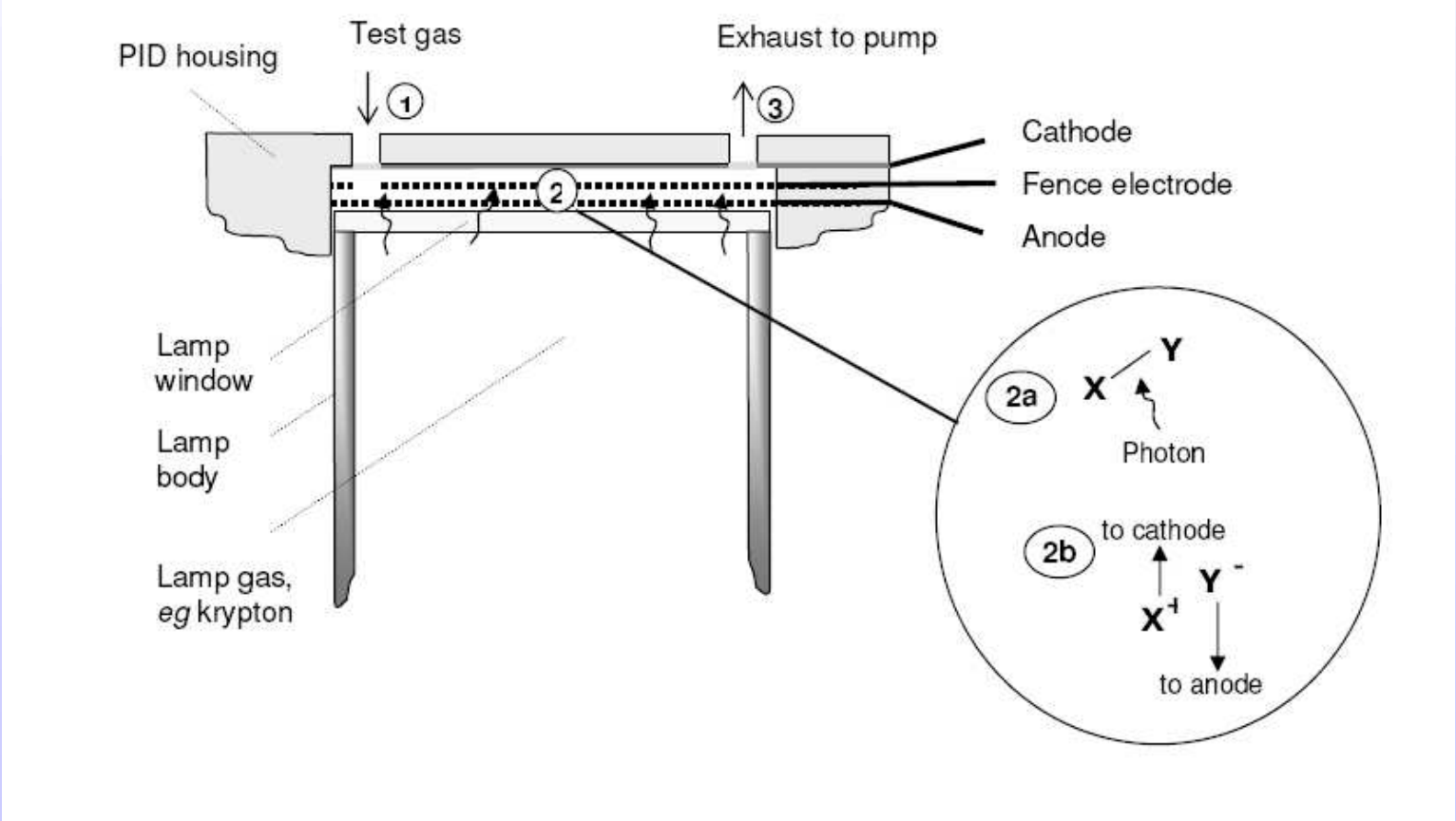
- Photo Ionisation Detector (PID)
- Field Asymmetric Ion Mobility Spectroscopy (FAIMS)
- Tunable Diode Laser Absorption Spectroscopy (TDLS)
- Detector Tubes
- Thermal desorption & GC/MS (laboratory analysis)

- **Electrochemical cells**
- **Metal Oxide semiconductors**

Photoionisation detector (PID)

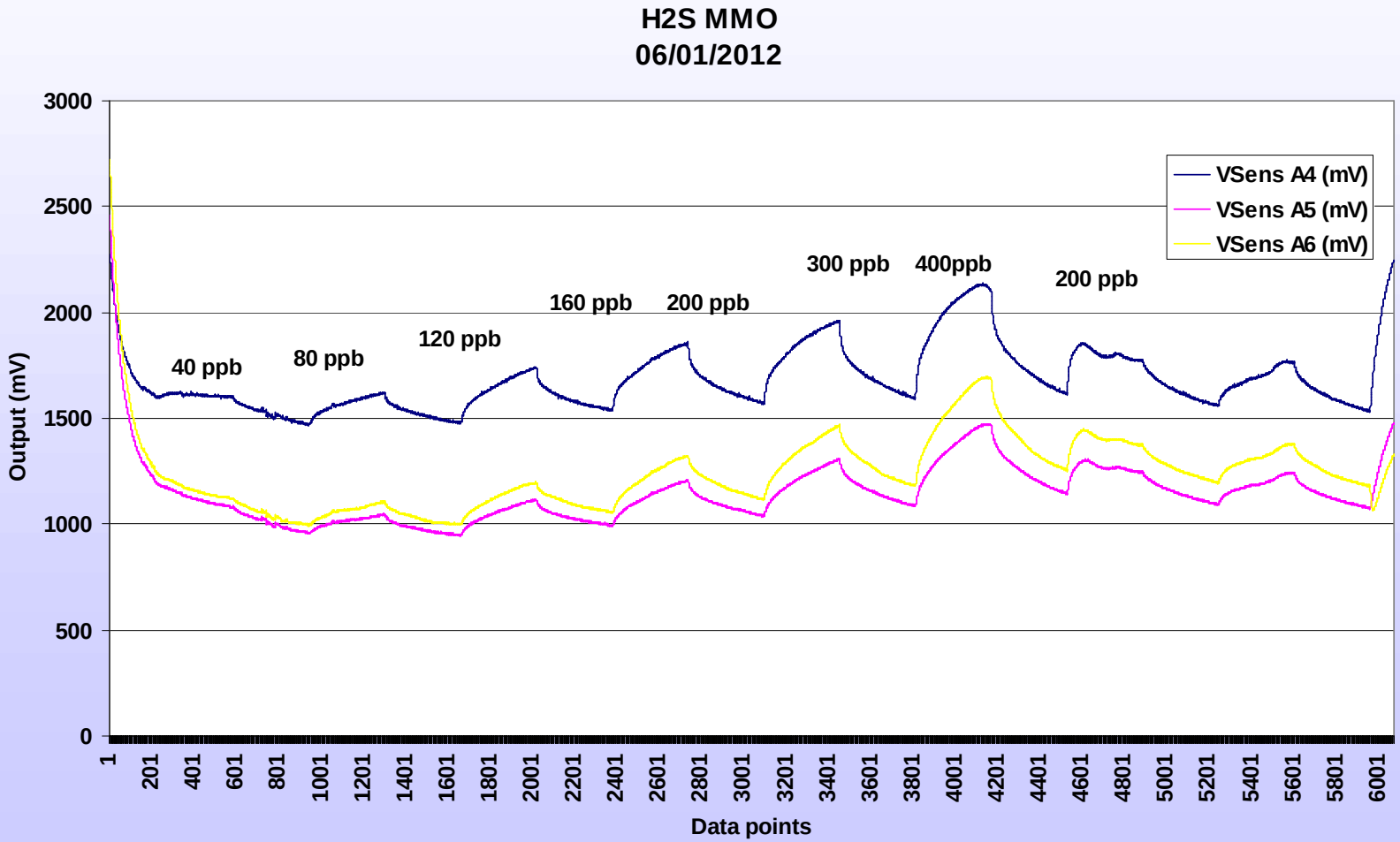
lower cost than IMS

1 ppb resolution for VOCs

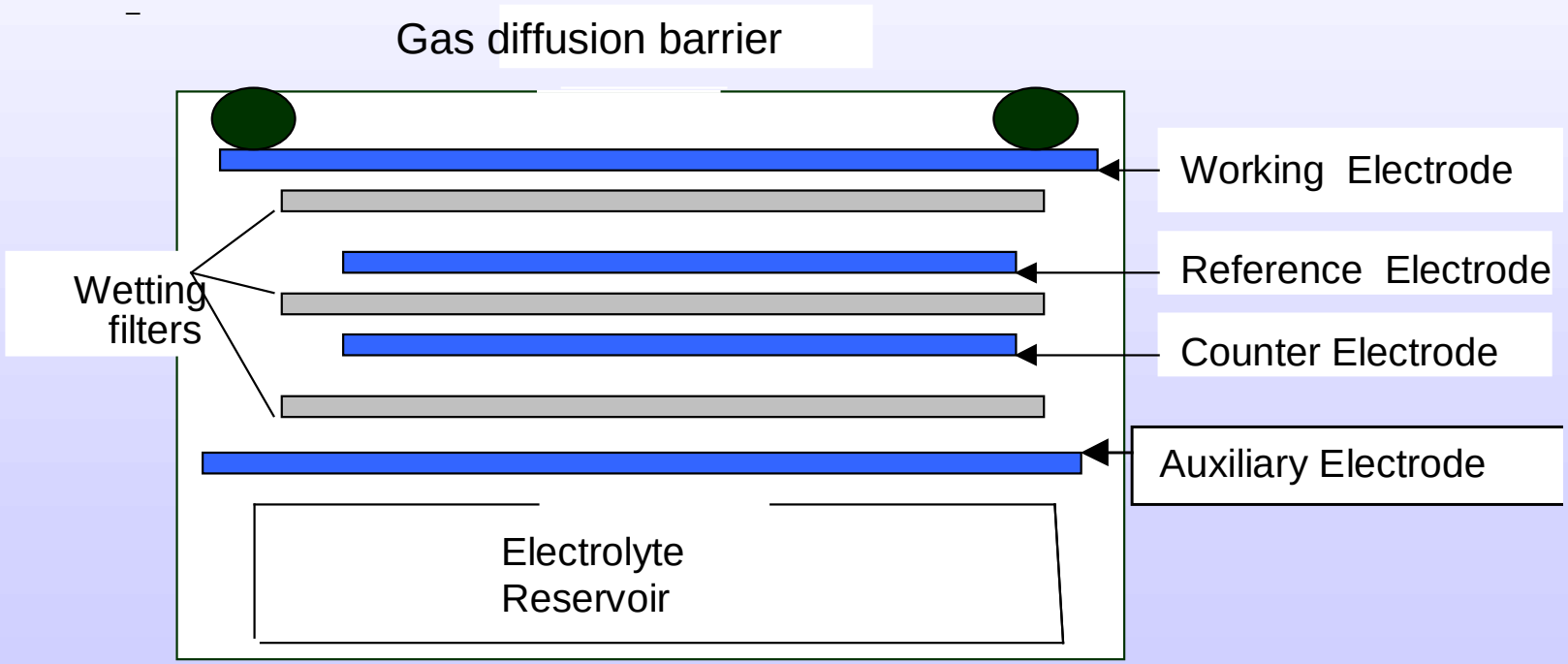


Metal oxides respond to ppb

but amperometric gas sensors do better

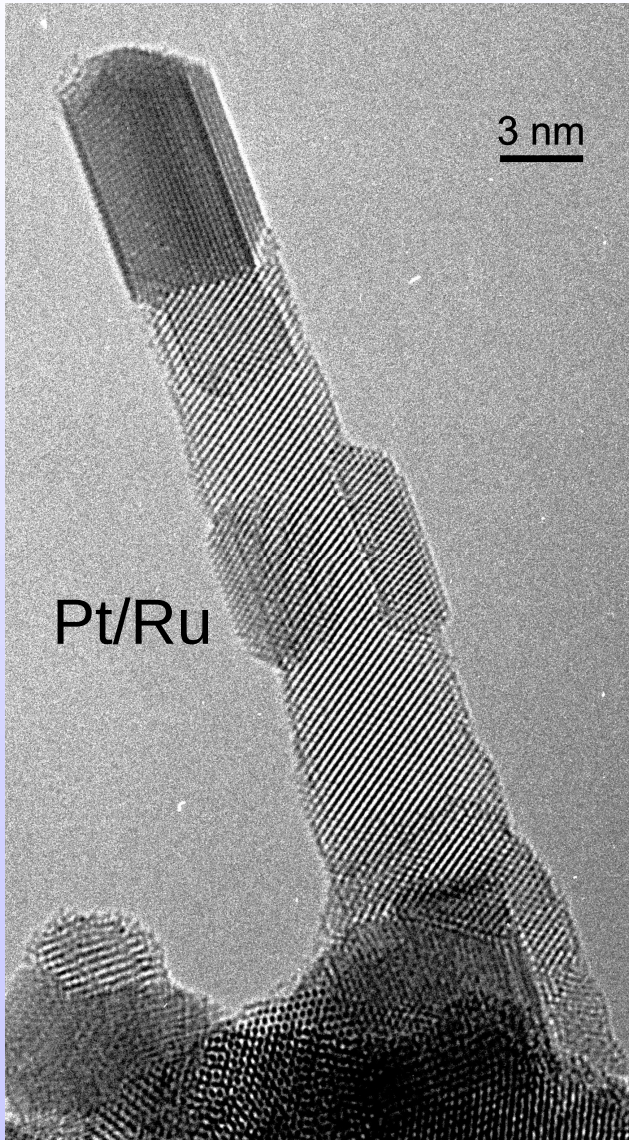


4- electrode amperometric electrochemical gas sensor



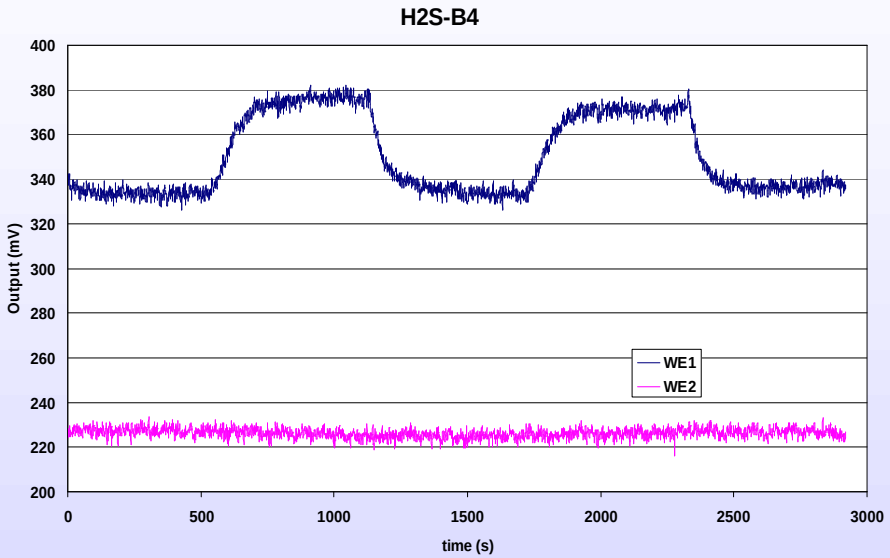
Catalysts have always been nanomaterials

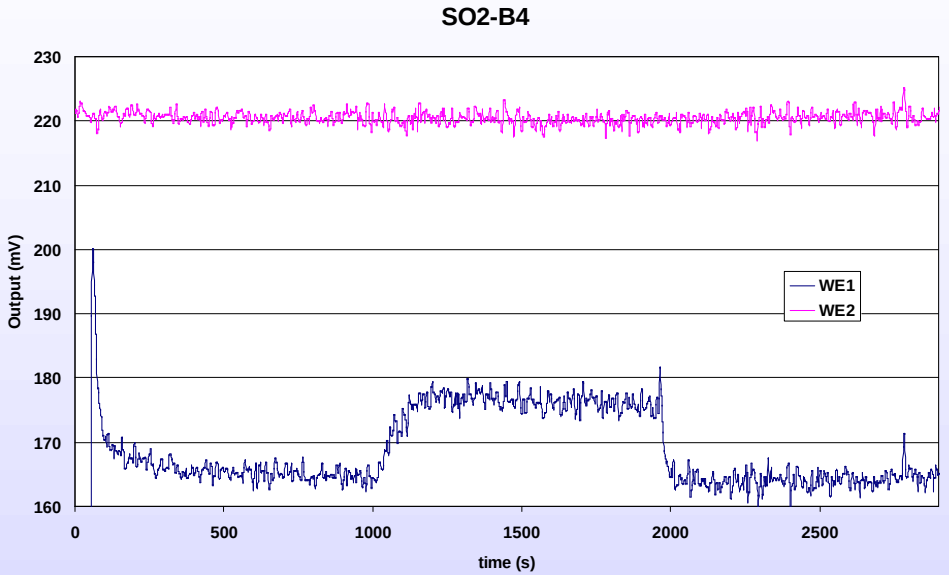
Catalysts are complex alloys, in many cases.

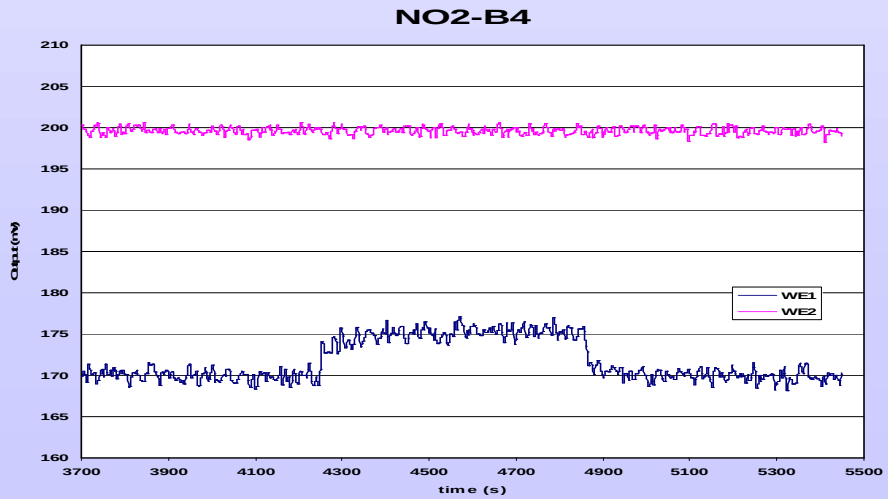


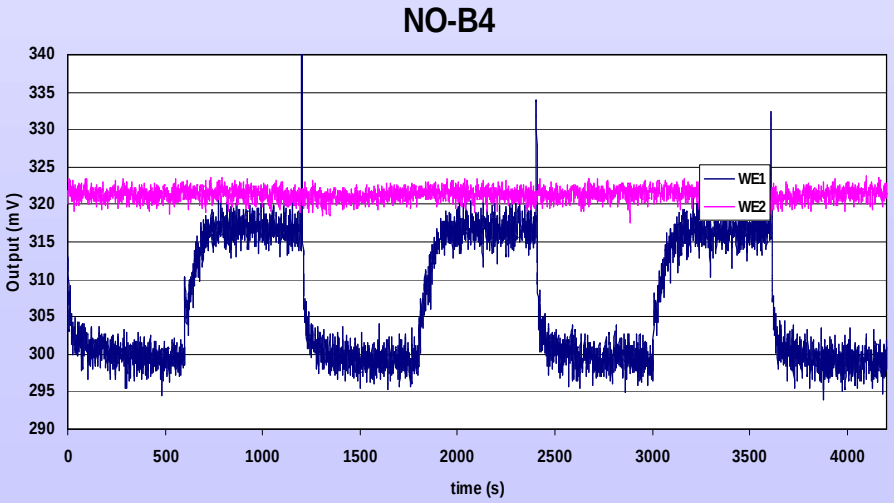
20 ppb and better can now be achieved

NO, NO_2, H_2S, SO_2

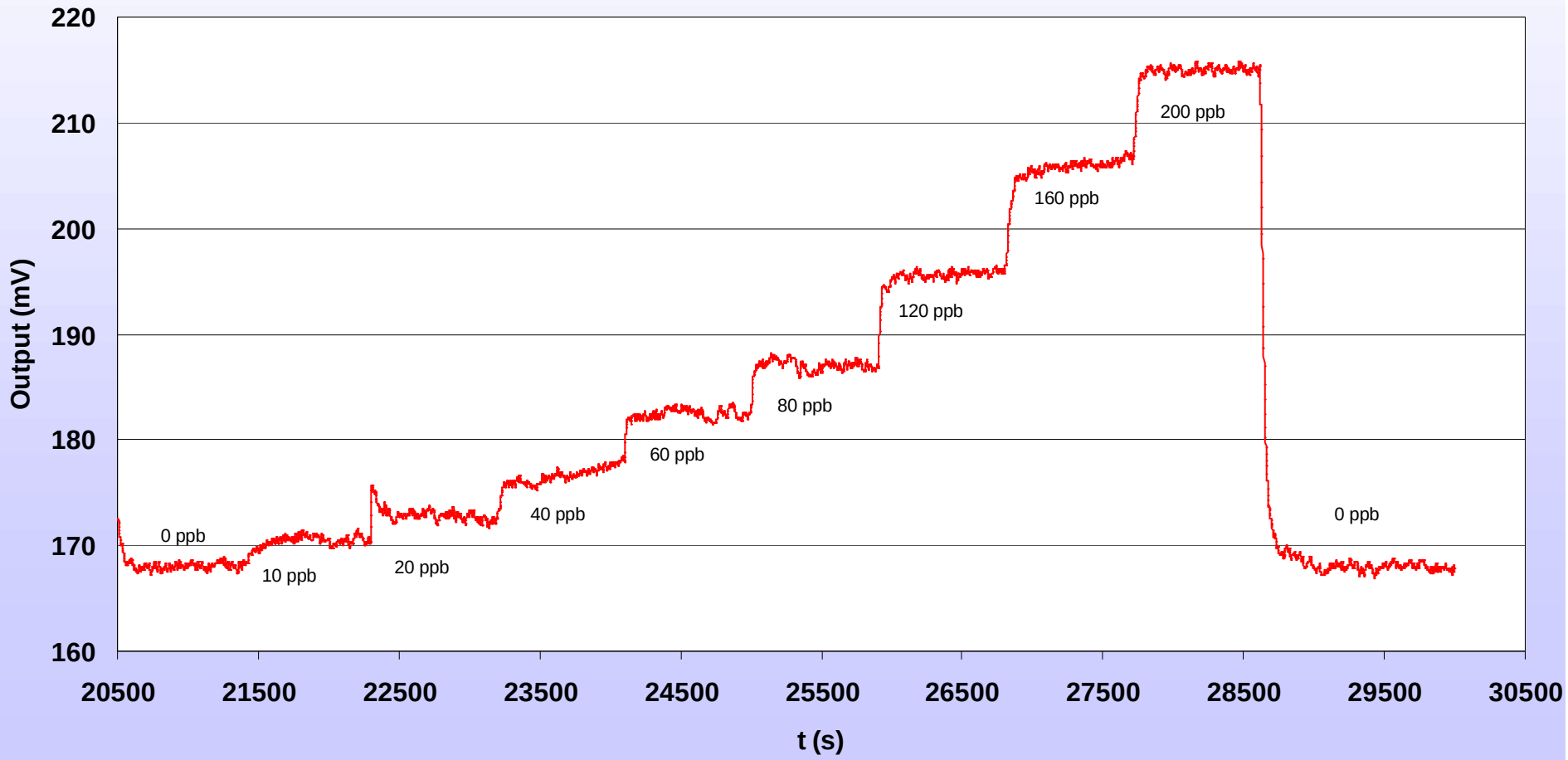




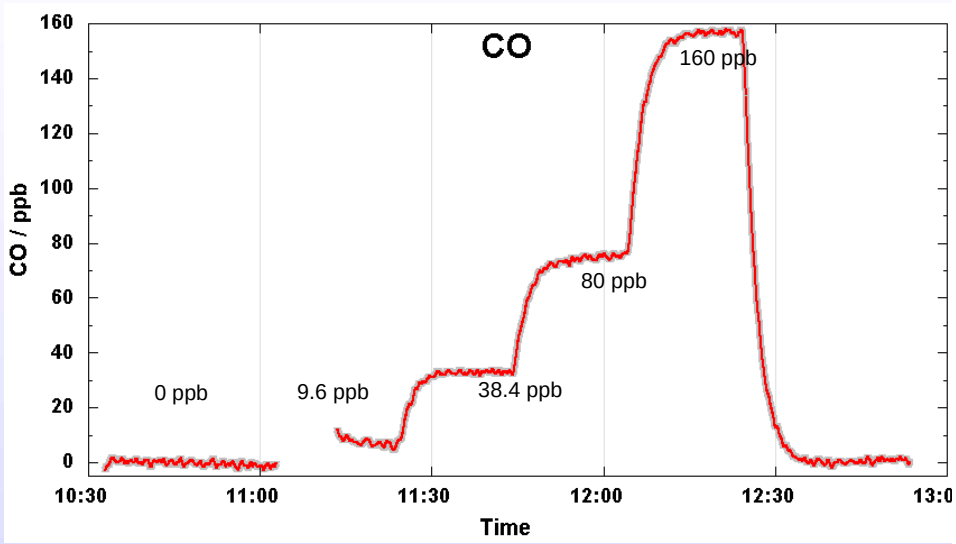


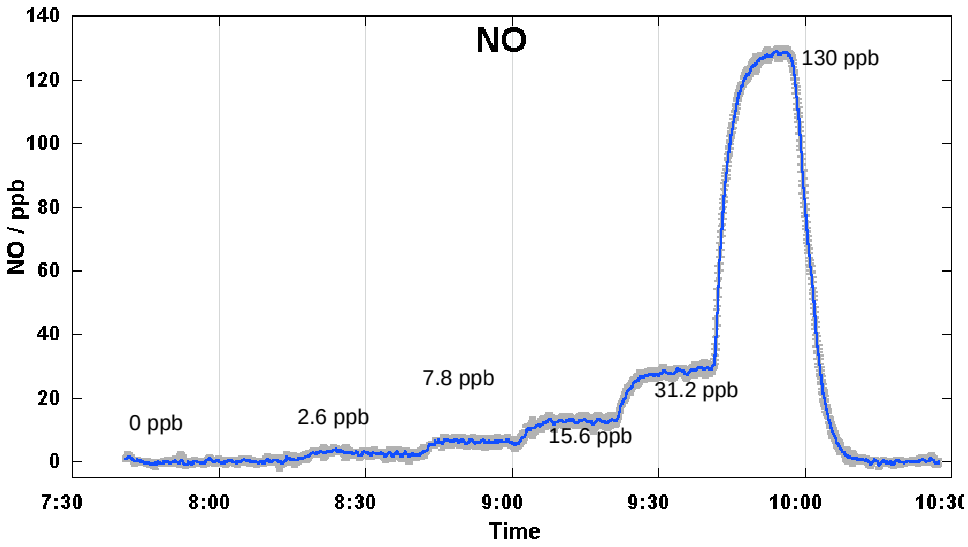


NO_2 up to 200 ppb



Indication of electrochemical sensor CO sensitivity (laboratory)





Improvements in: **Hardware**, control **electronics** and **analysis**

Viable tools for urban air quality monitoring.

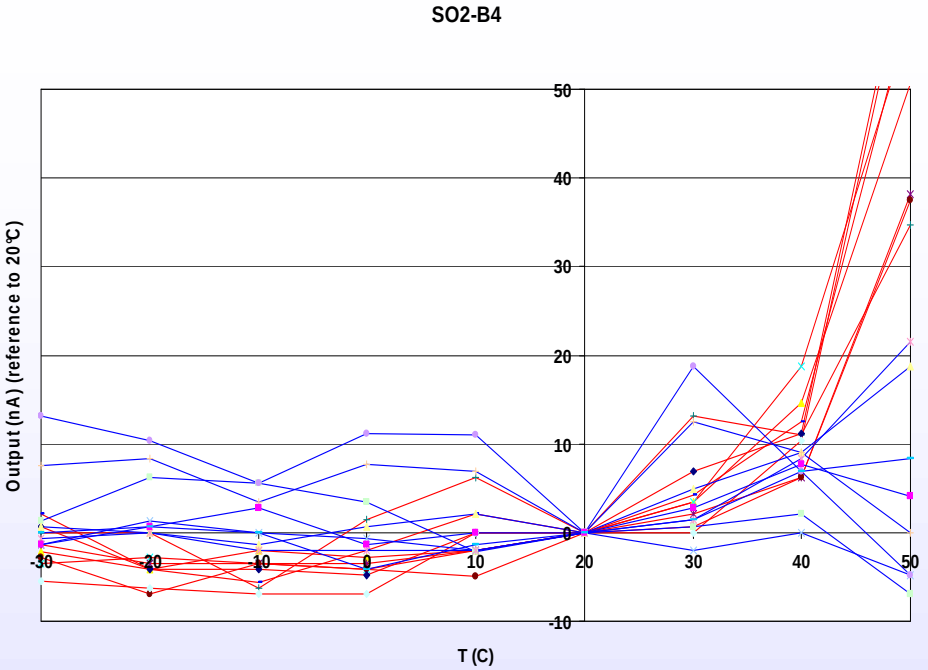
Need to carefully consider data processing

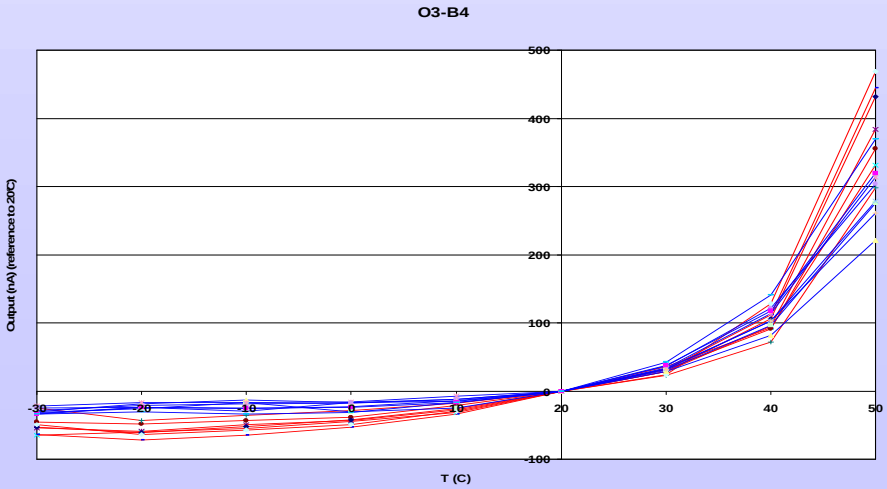
What has advanced?

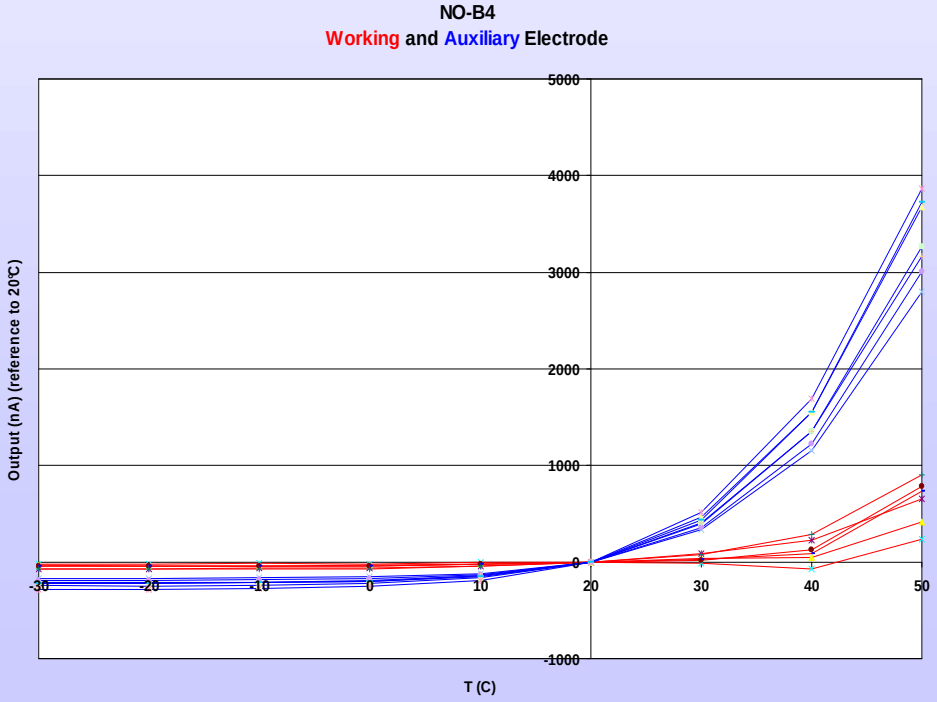
Catalyst control,
Electronics,
4-electrode designs

Zero current

changes with temperature,
but the scale of the current
is very different (x10)

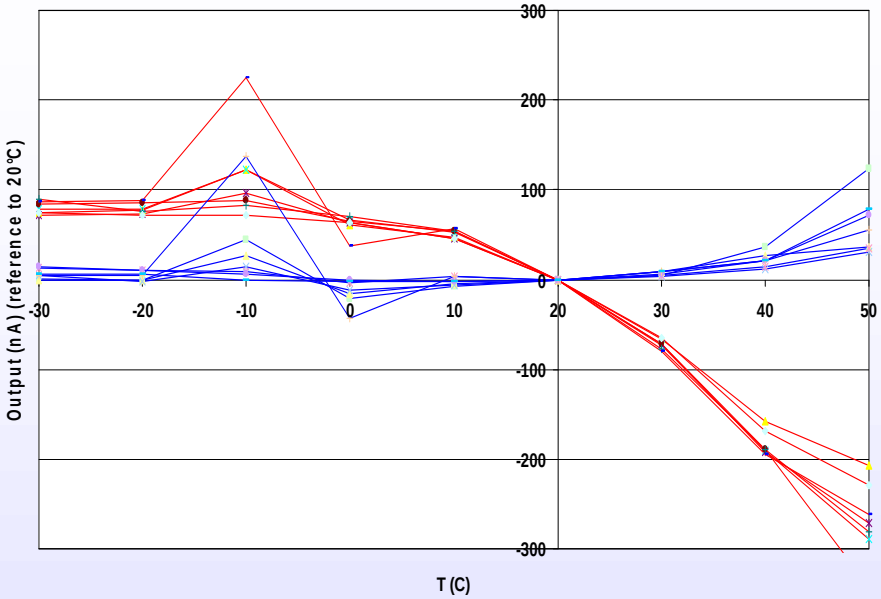






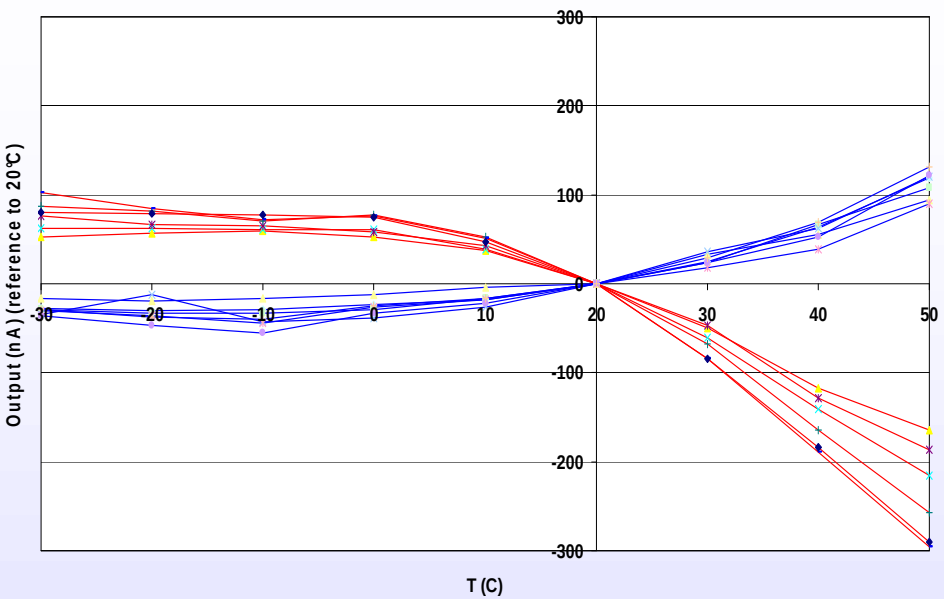
CO-B4

Working and Auxiliary Electrode

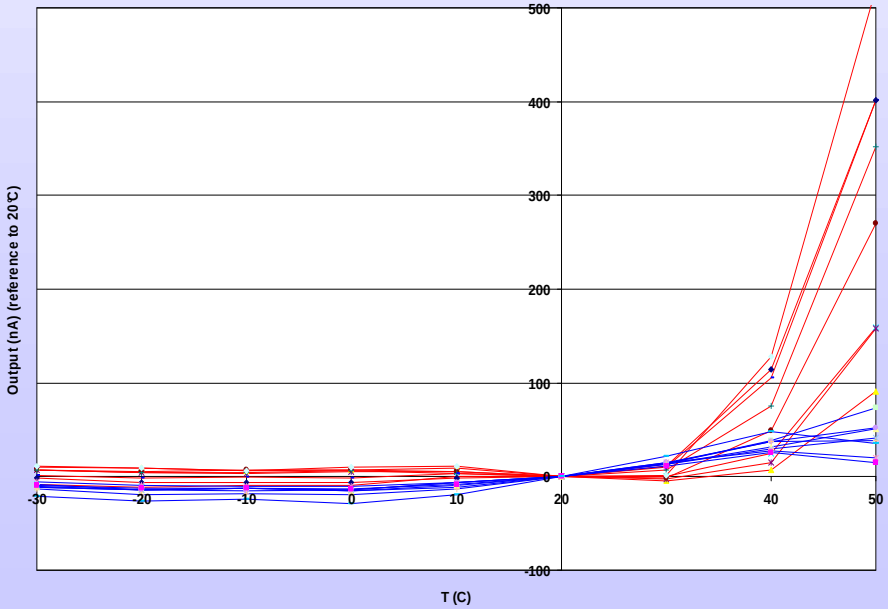


H2S-B4

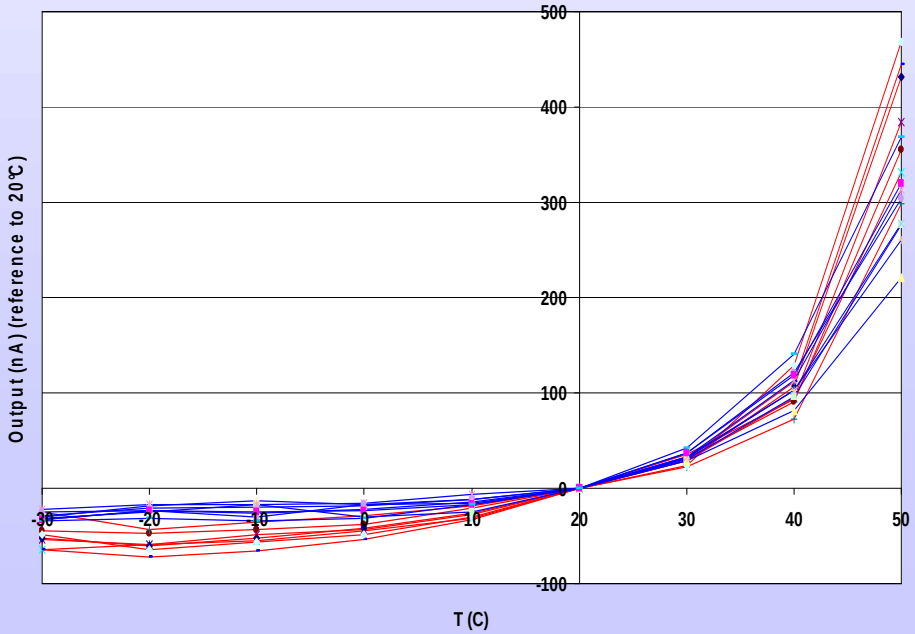
Working and Auxiliary Electrode



NO2-B4

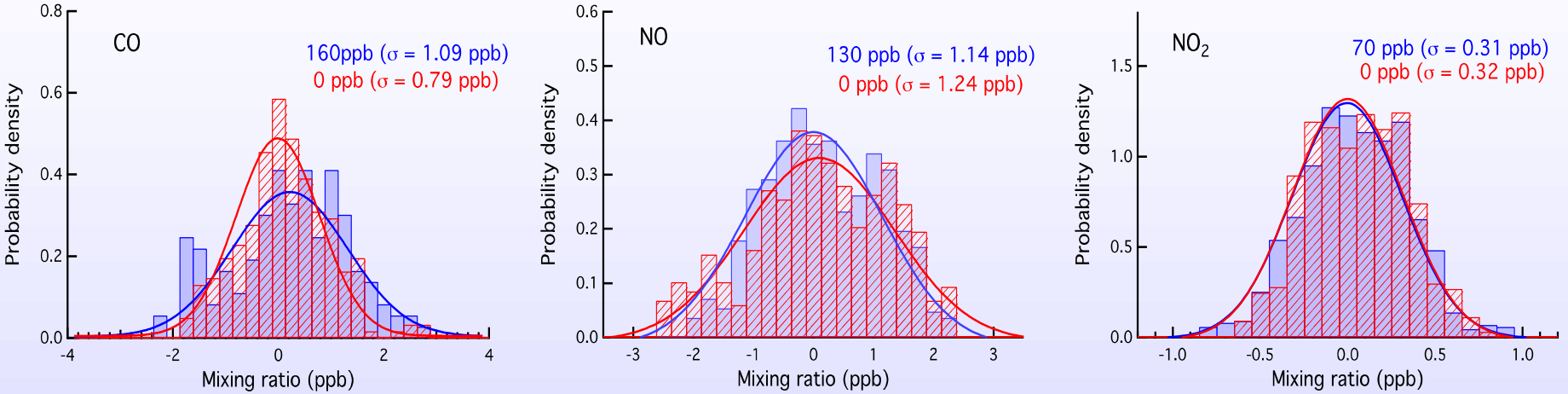


O3-B4



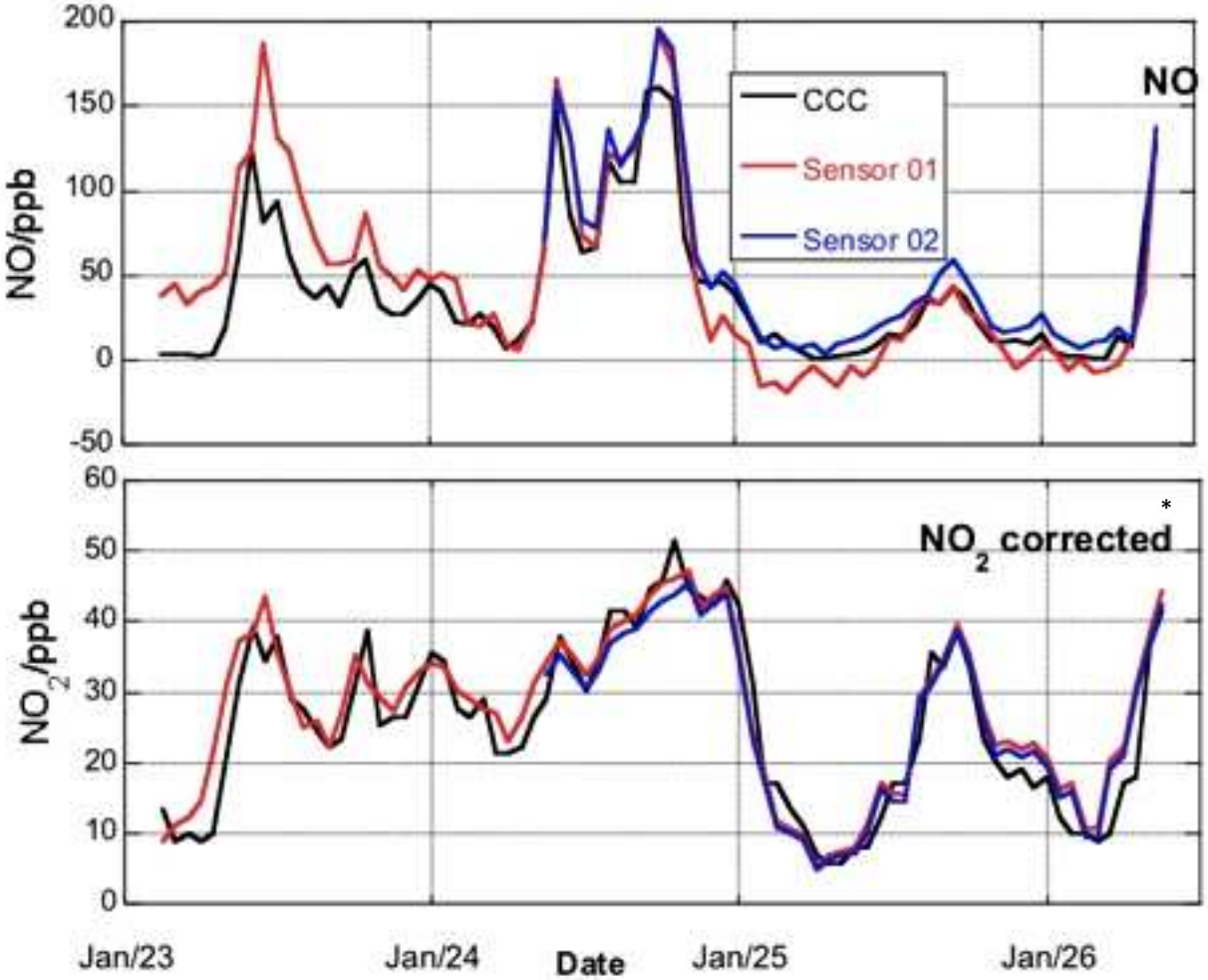
Electrochemical sensor CO/NO/NO_2 sensitivity performance (laboratory)

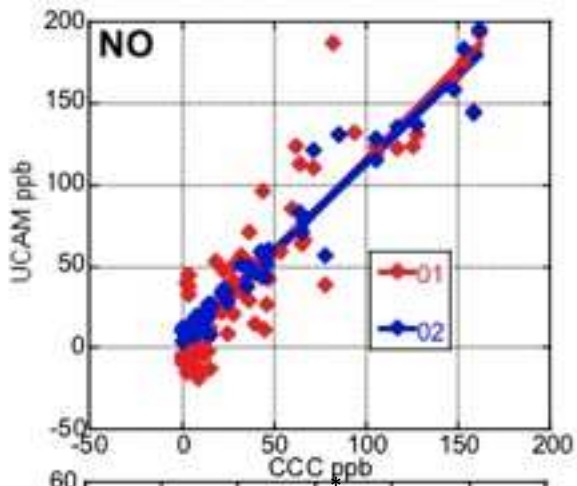
Noise characteristics:

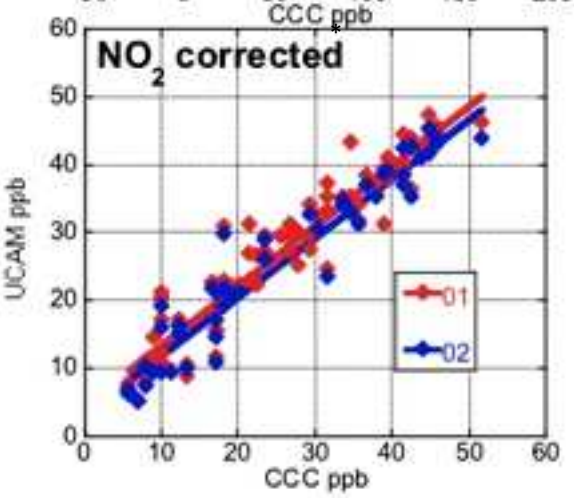


- Typical sensor sensitivities/LoD are < 5ppb (< 7µg/m^3) for CO, 1-2 ppb (~2-4 µg/m^3) for NO and NO_2.
- SO_2, O_3 have comparable performance to NO_x.
- Typical sensor T_{90} ~ 10-20s (determined by diffusion)
- Very low power consumption (µW)

‘Real world’ comparison of NO_2 and NO with ratified AURN site







Performance replicated in the field….

* Corrected for O_3 interference

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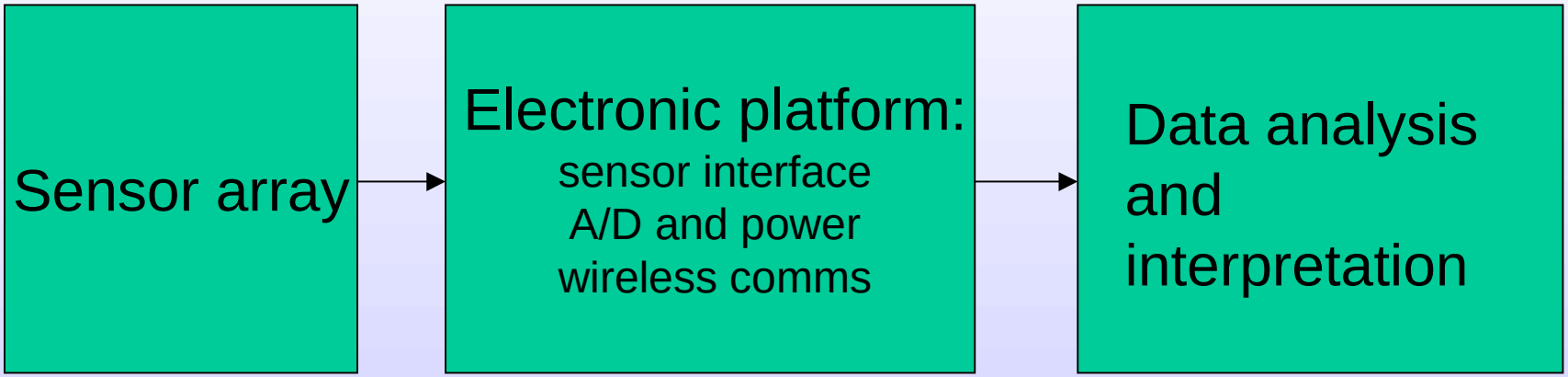
Wireless air quality networks seem to be simple-



Wireless networks in the UK

- MESSAGE: NERC funded project (2008)
- Cambridge 50-boxes (25 million data points (2010)
- Low cost modules- Envirowatch (2011)
- Heathrow airport -50 boxes (2012)
- Urban air quality boxes (Universities-2012)

Combine technologies to provide sensitive *low cost* sensor network

Other data
(met, traffic….)

archive

Real time data processing/ data assimilation

PRODUCTS

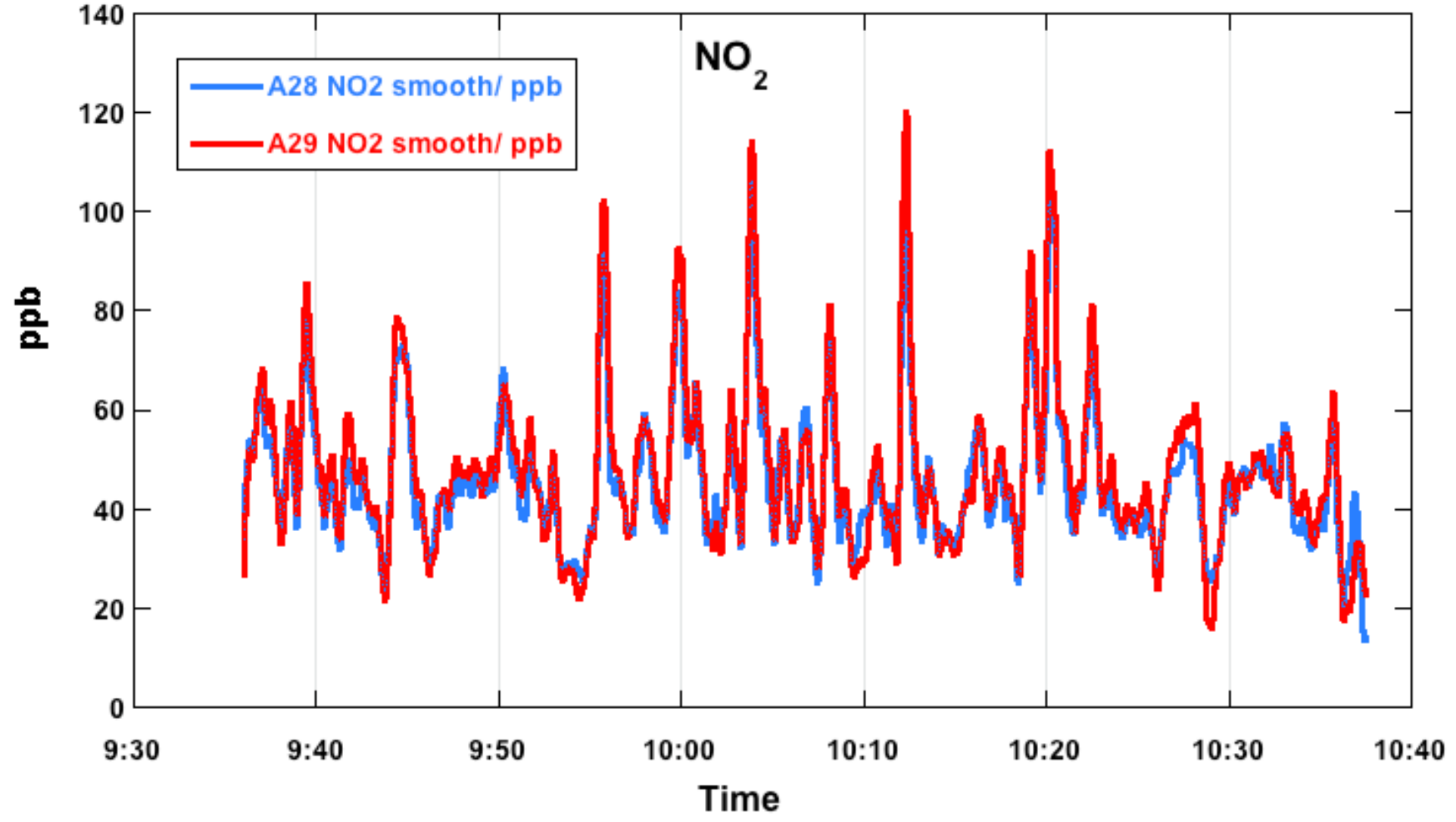
Environment…..
Regulation……
Exposure…..
Transport…..
……

GPS
(location)

GPRS
(data
transmission)

SENSORS

Co-located sensors (NO_2) – real structure



(Uncorrected for O_3)

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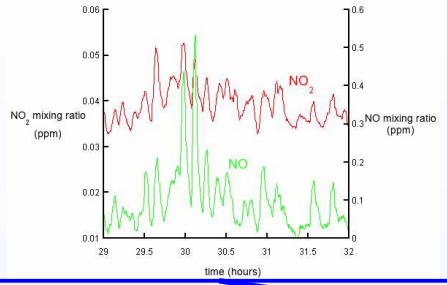
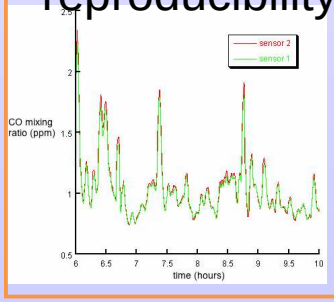
Multiple species measurement

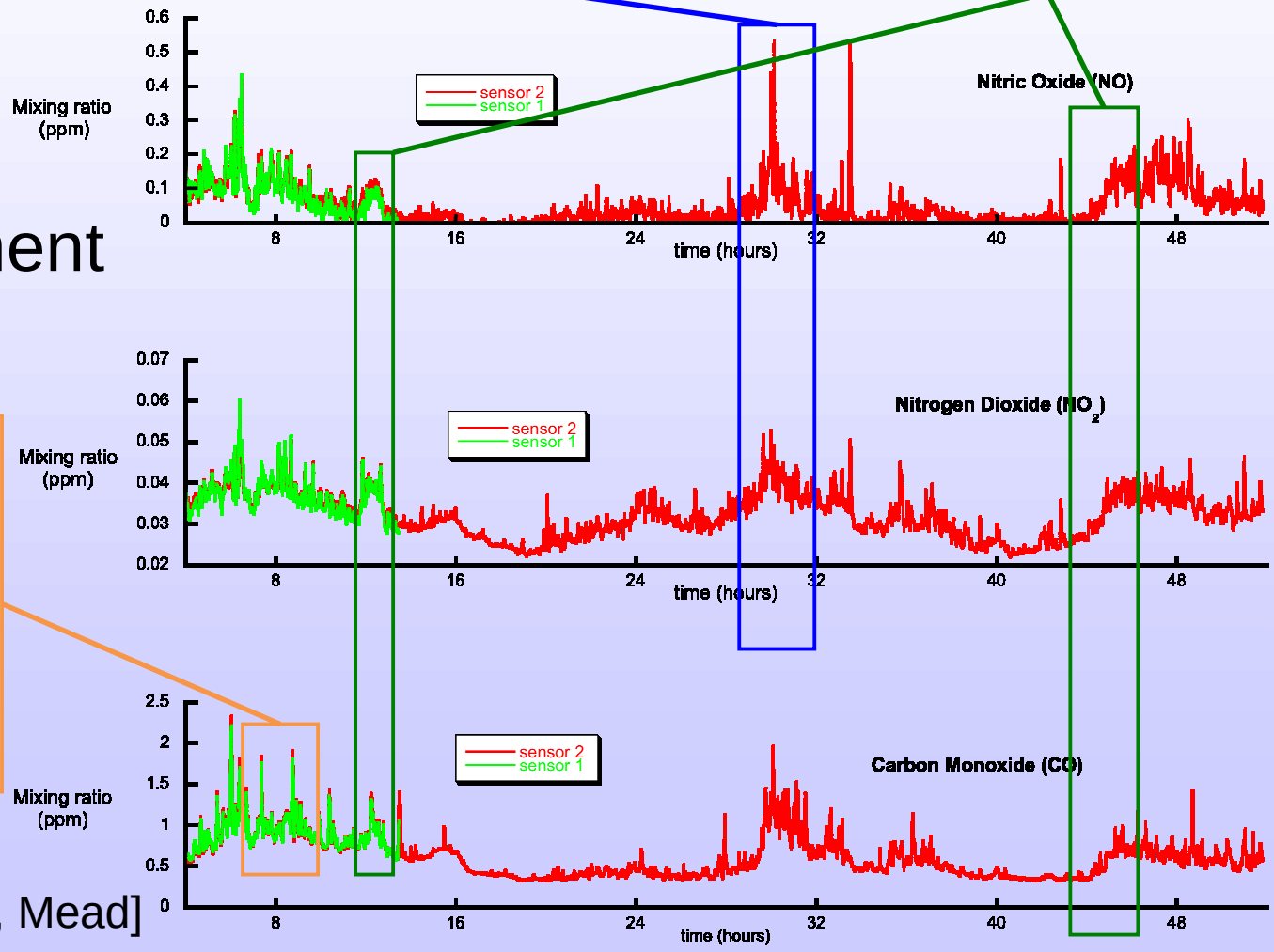
Pollution events



Changes in air quality driven by both traffic and meteorology

Sensor reproducibility

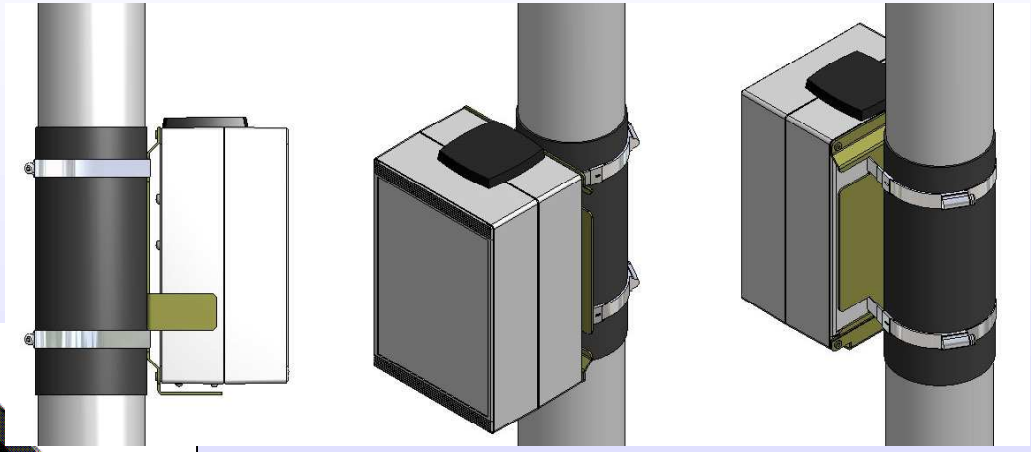


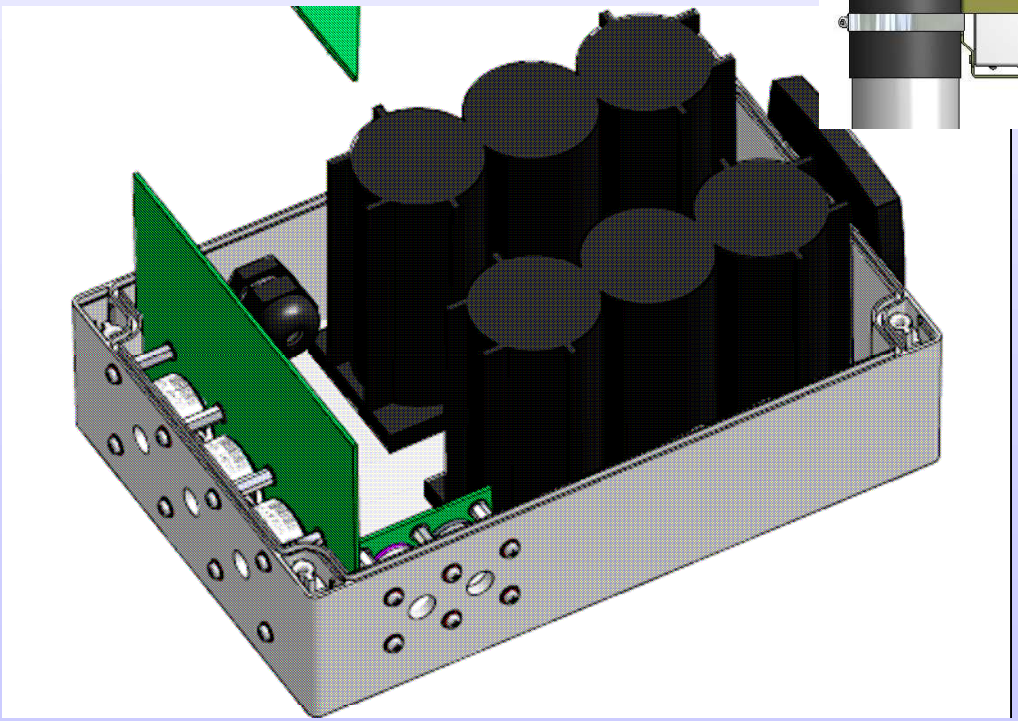


[Stewart, Jobalja, Mead]

PIC.

Each box is battery powered for 3 months, with sensors, electronics and dual purpose aerial





High-density mapping

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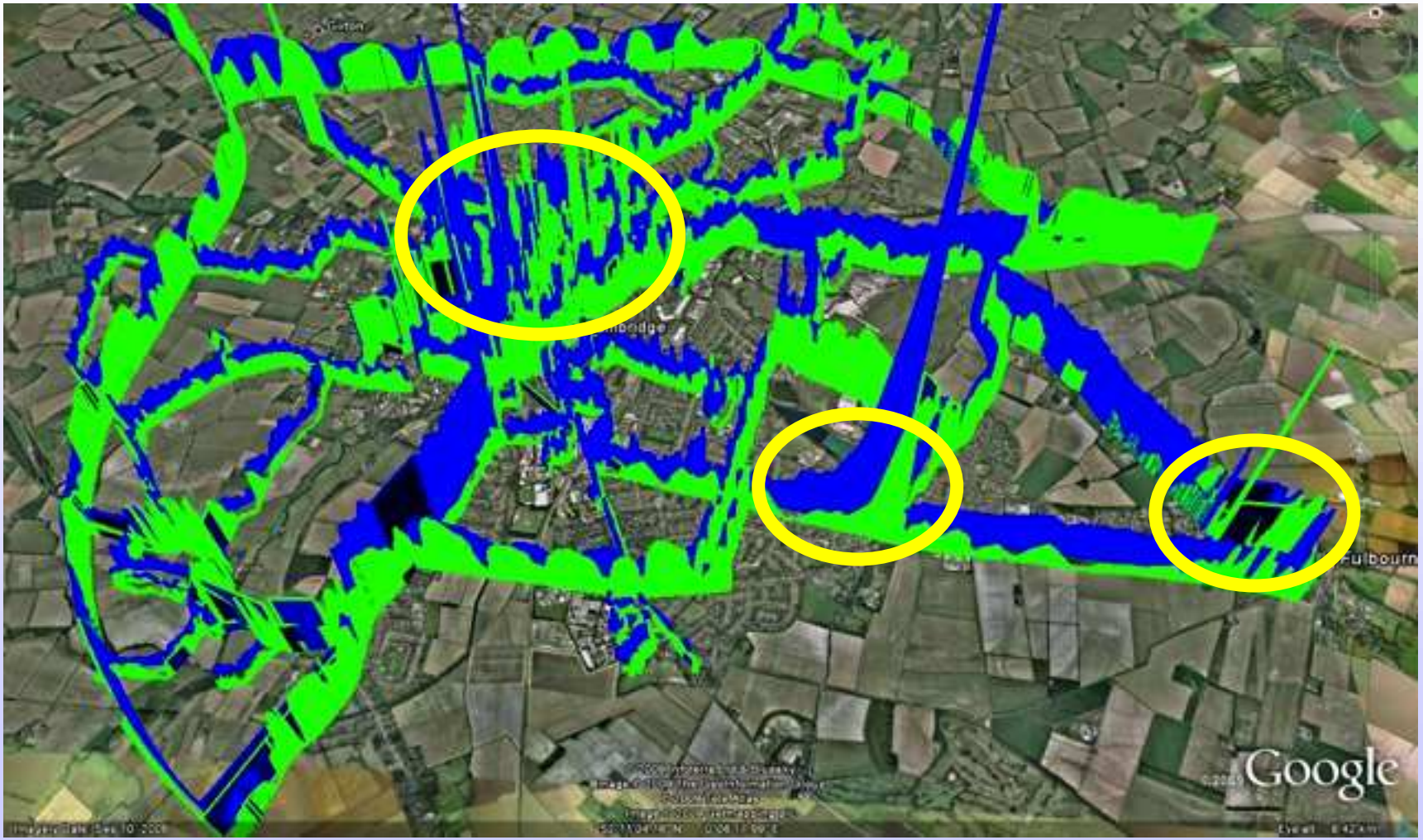
Cambridge deployment September 2009: NOx

Visual determination of pollution hotspots – *not possible with static sites*



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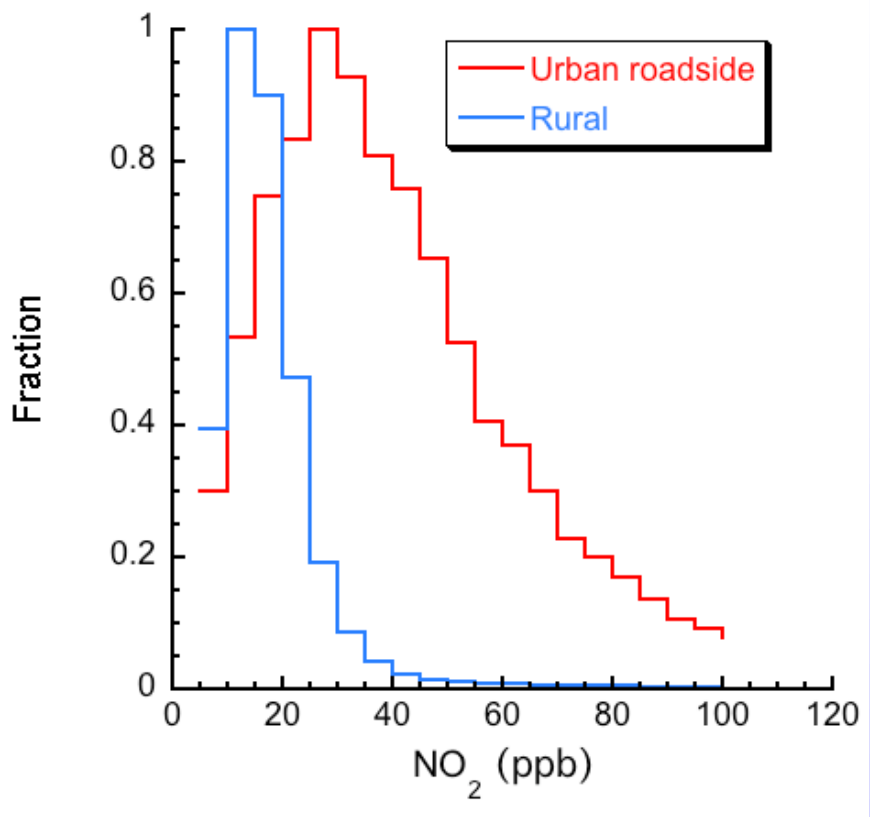
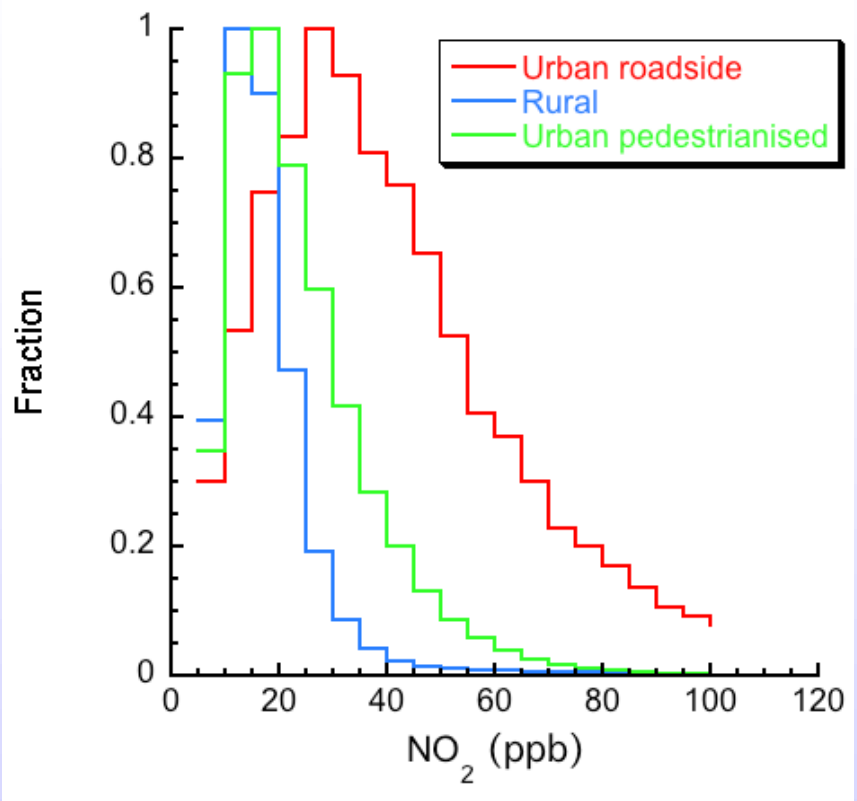
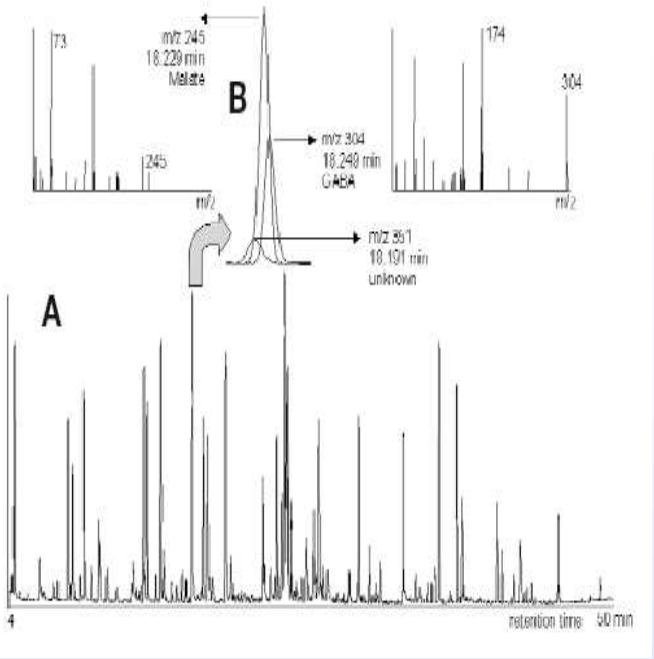
Examine homogeneity in pollution (NO_2)

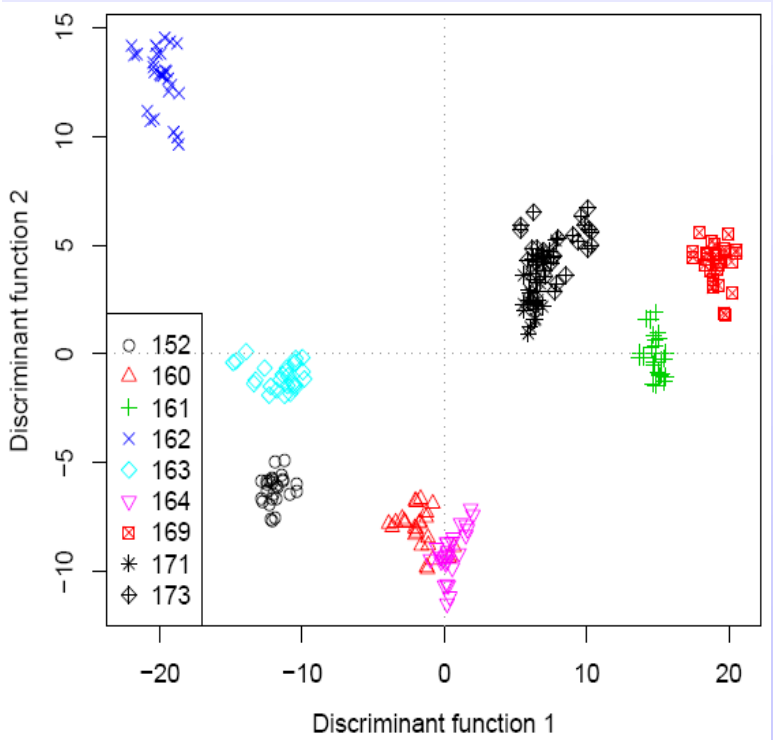


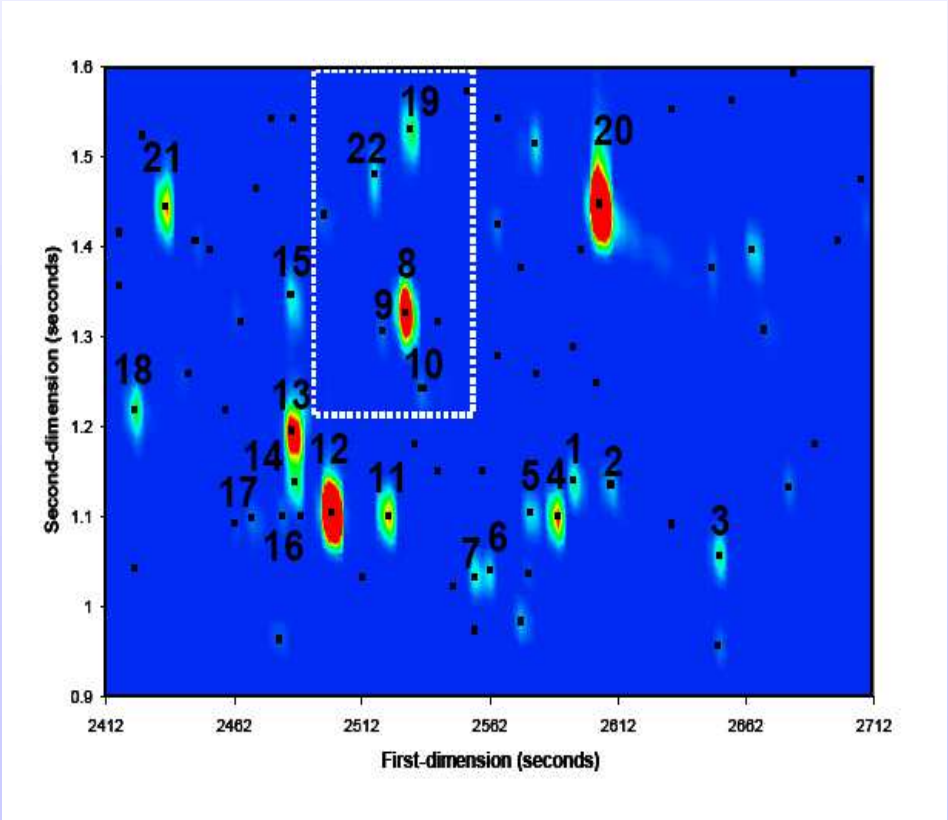


Urban roadside *vs* rural (expected), but also urban roadside and nearby pedestrianised difference

Chemometrics Data Analysis: the mathematical approach for separating multiple measurements

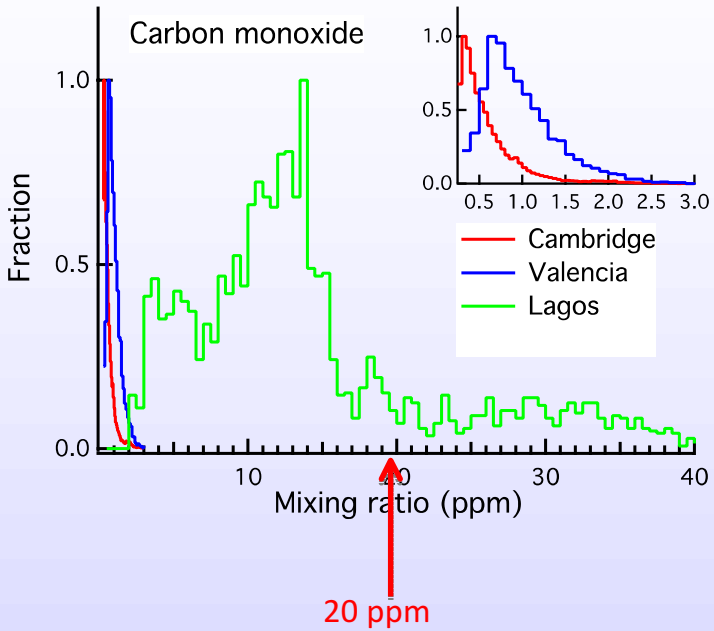


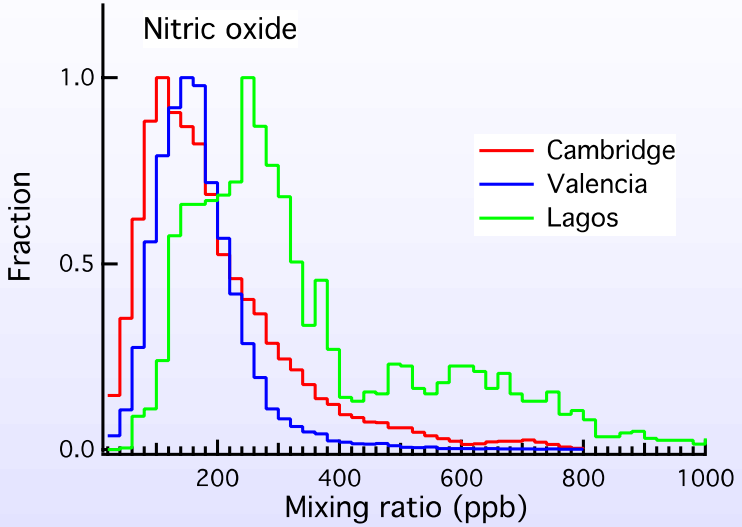




Regional air quality (snapshots):

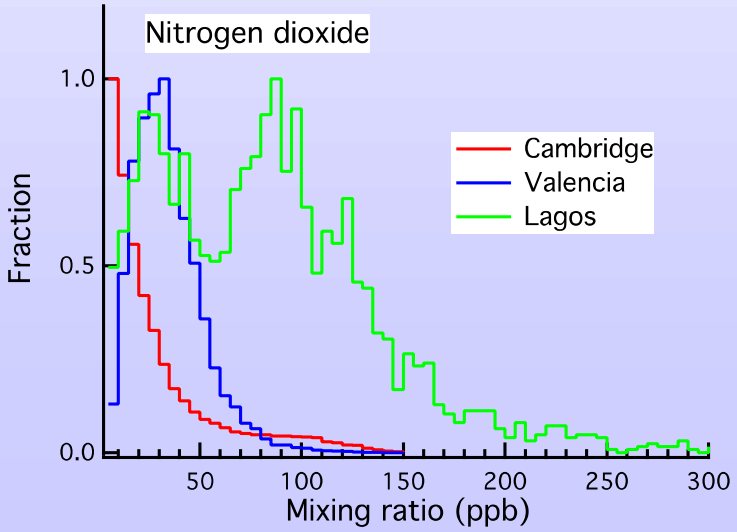
Cambridge, Valencia, Lagos





Dramatic differences…….

Flexible low cost way of characterising A/Q



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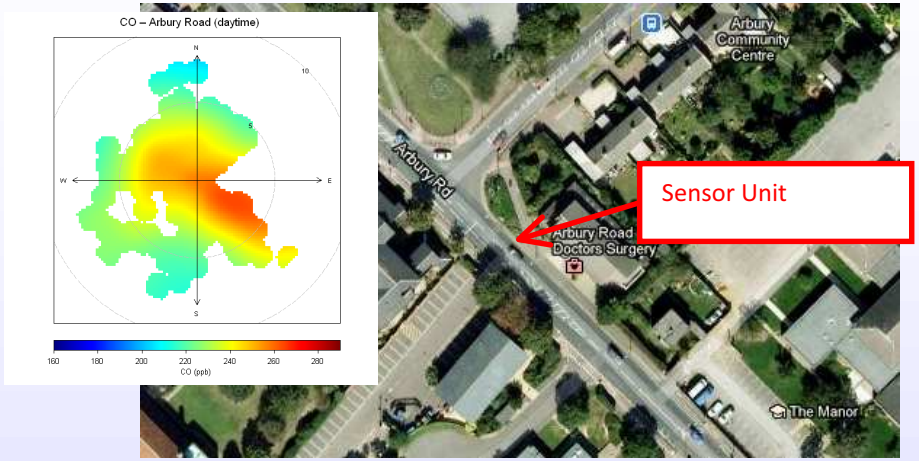
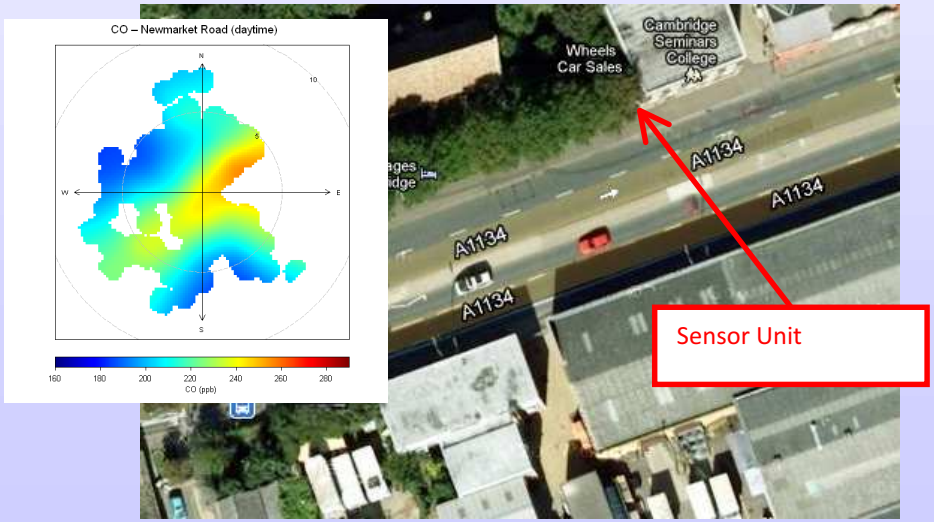
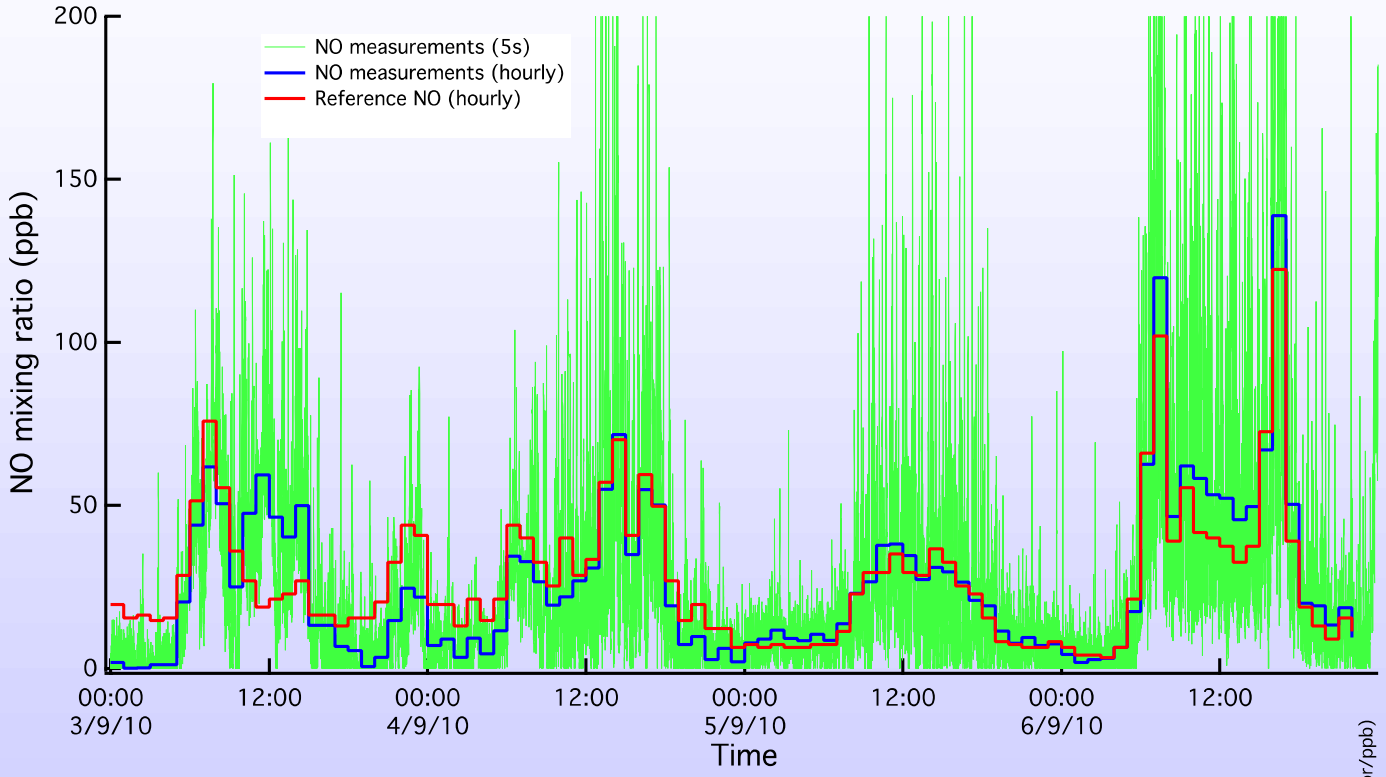
Street canyon effects: wind direction and re-circulation



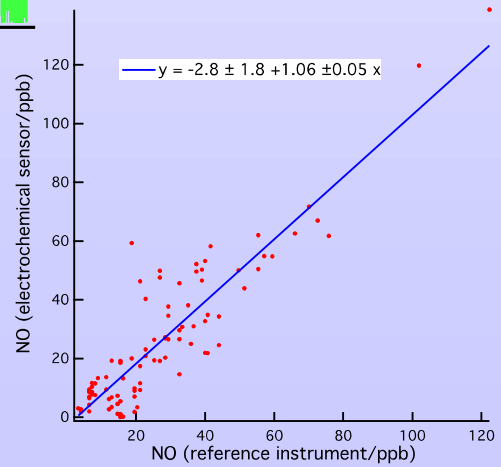
High concentrations when wind direction aligned to road



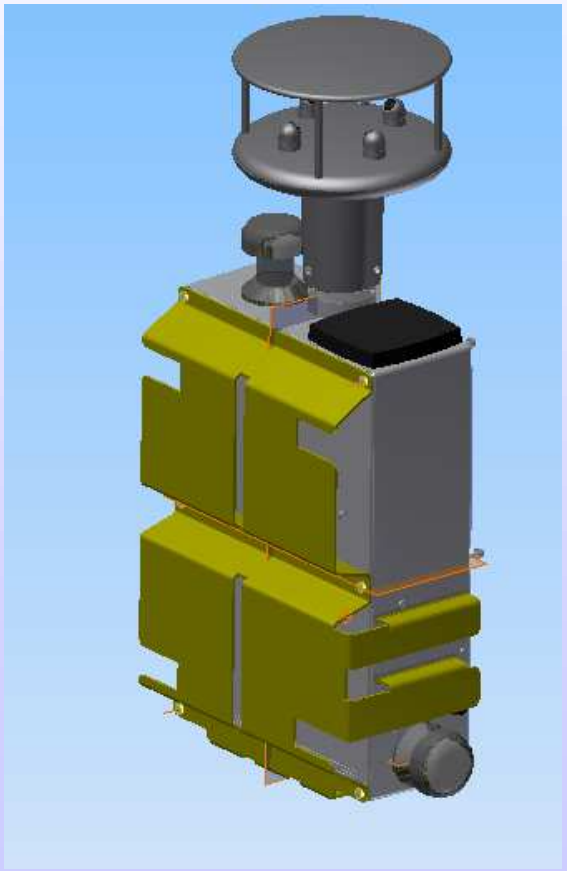
Hourly average *vs* fast response – near co-located instruments



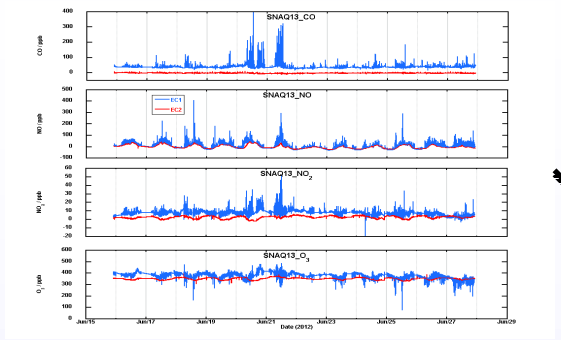
Structure present on all measured scales

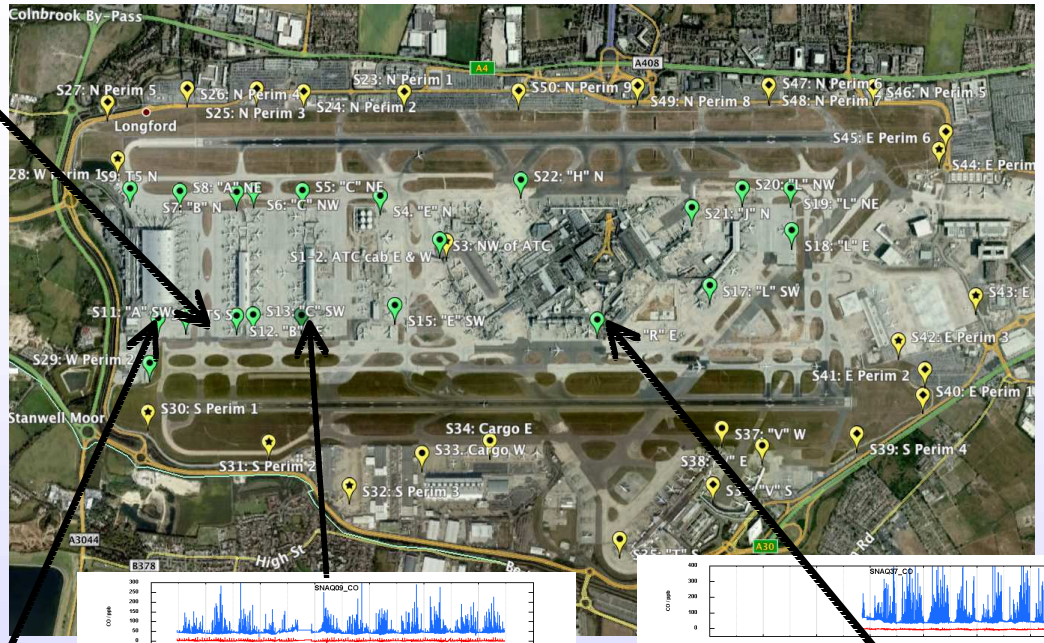


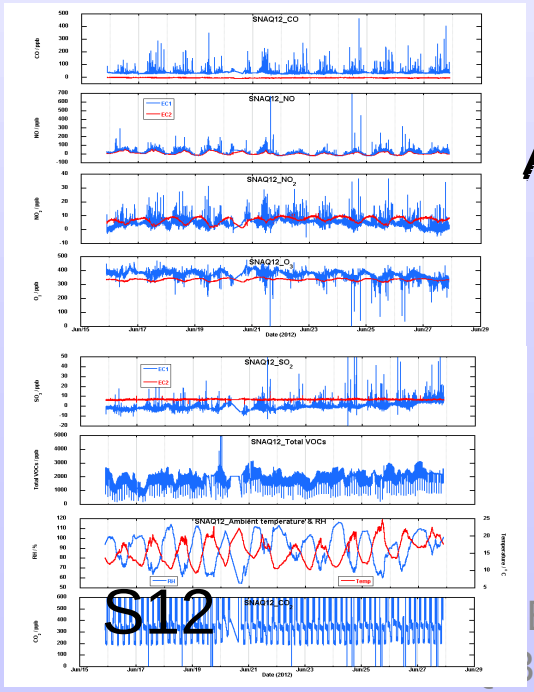
UK Heathrow air quality network - 50 wiresless AQMs

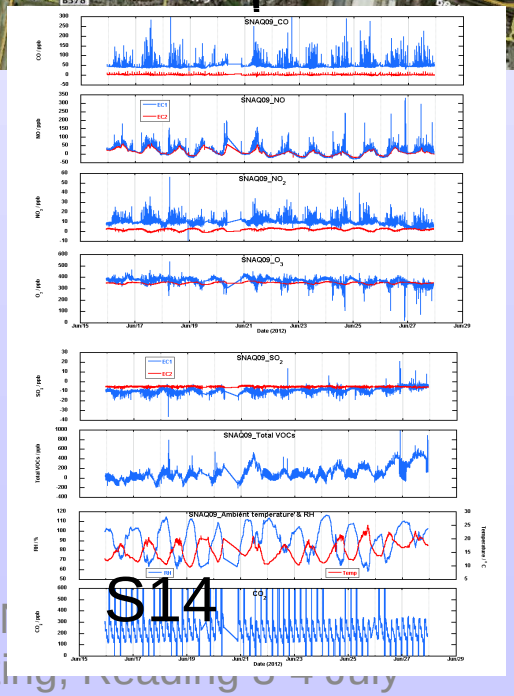


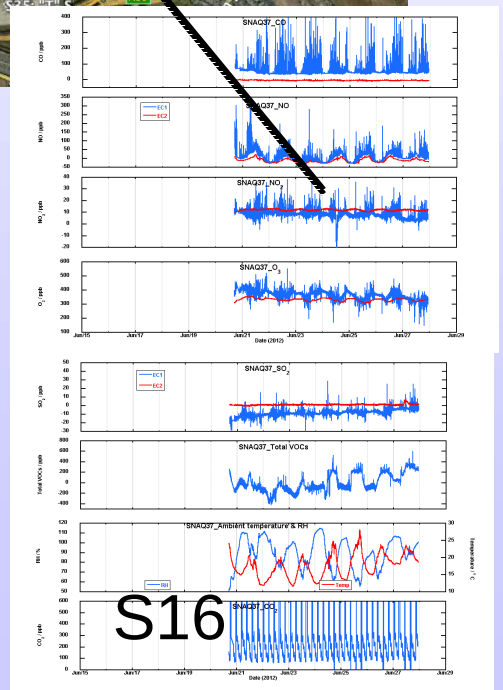
Some initial data……







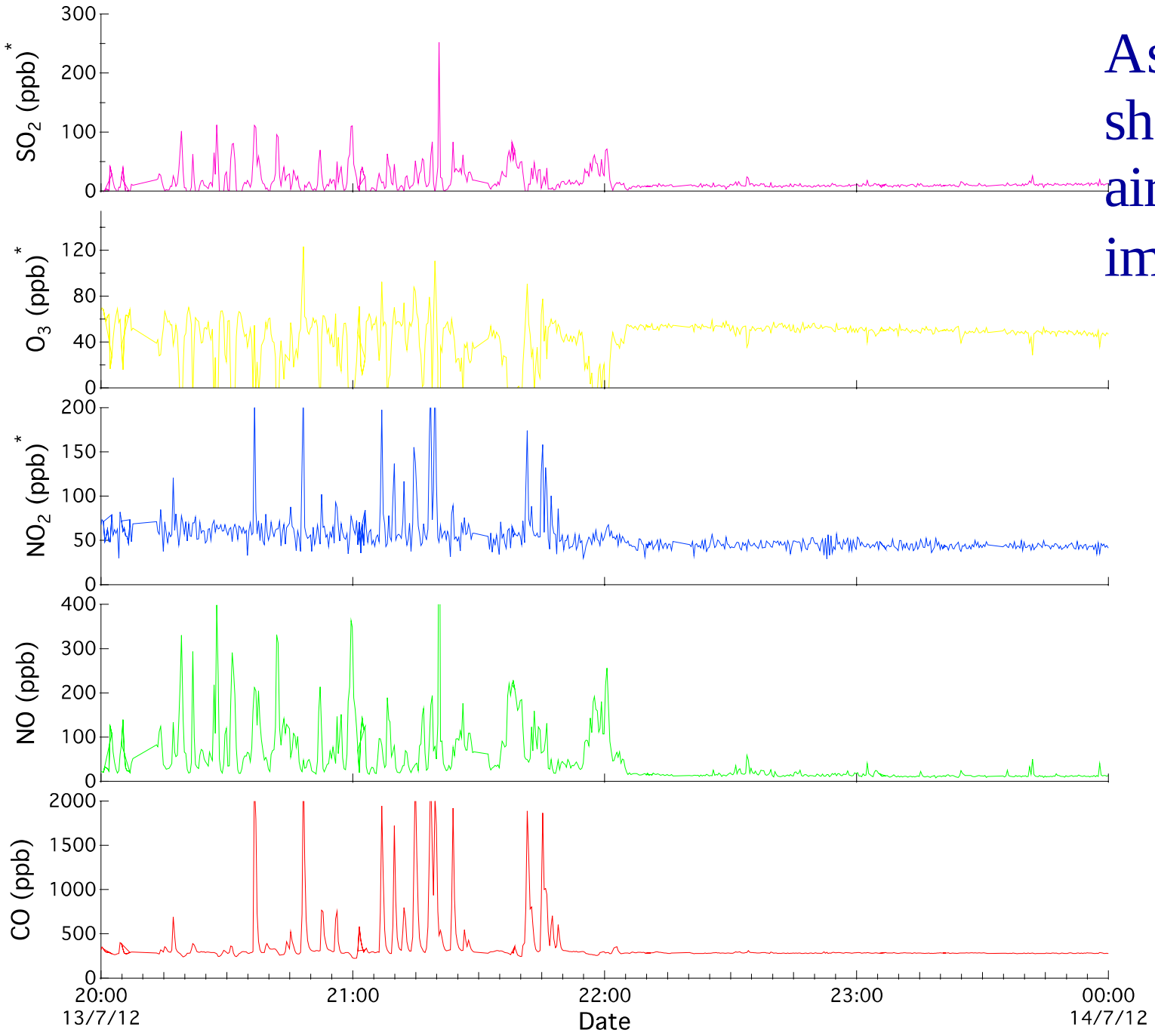




High density sensor network system for air quality studies at Heathrow airport

Participants:

Institution	Input
University of Cambridge (PI)	a/q models
Imperial College London	traffic models, visualisation
University of Hertfordshire	aerosol measurements
University of Manchester	aerosol measurements
CERC Ltd	a/q modelling – ADMS
National Physical Lab.	metrology, calibration
Alphasense Ltd	sensors and electronics

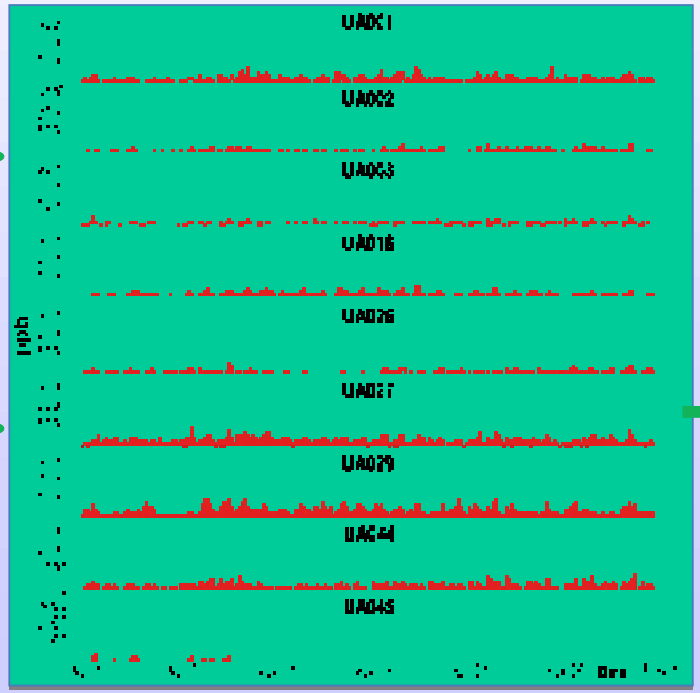


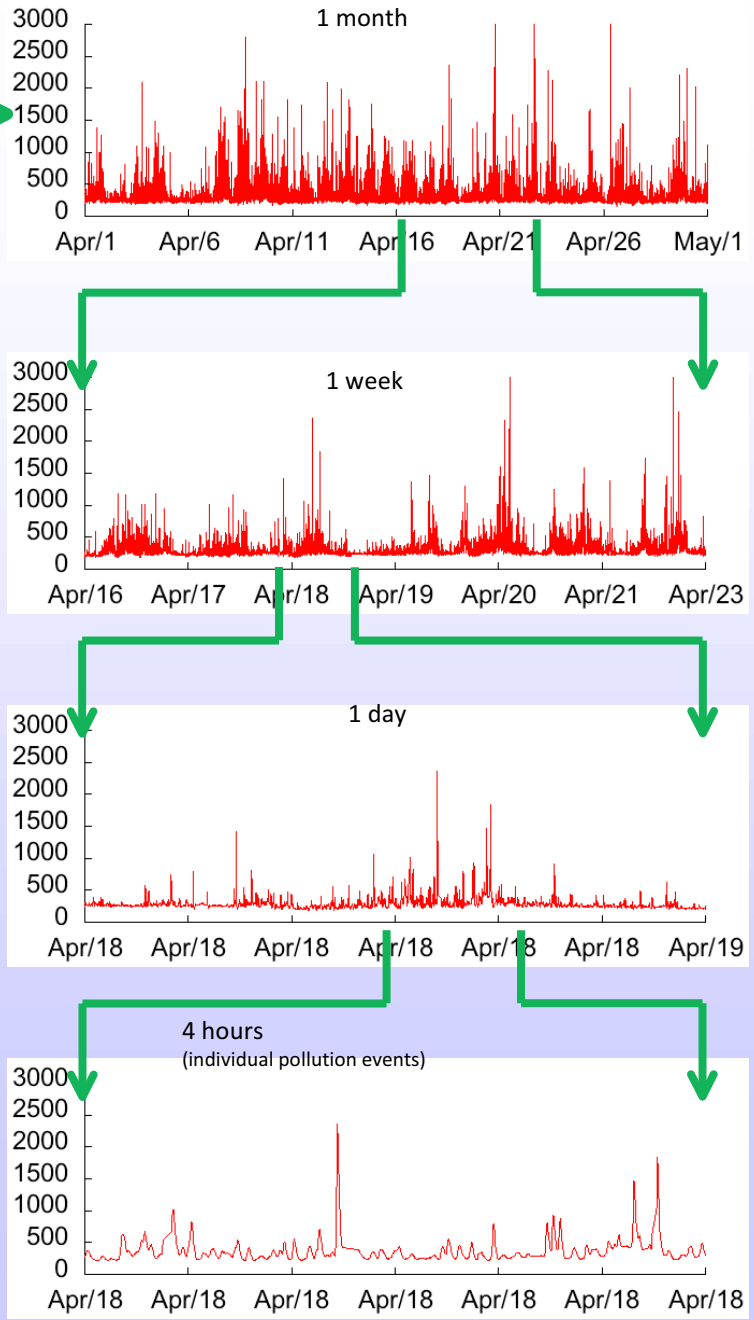
As Heathrow shuts down, air quality improves

Static deployments (carbon monoxide)

Grid
(46 sites)

vs





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Conclusions

- Wireless, better batteries, GPS/Google maps are ready for wireless networks- **sensors are the key**

- ppb is achievable and low cost for inorganic gases
- ppb for VOCs without selectivity is achievable
- ppt for VOCs is the difficult target

- Metal oxides and electrochemical cells are affordable

- **Data analysis** will become as important as the sensors

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Thank you for your attention.
Any questions?