

Next Generation Urban Air Quality Monitoring Technologies

Jim Mills

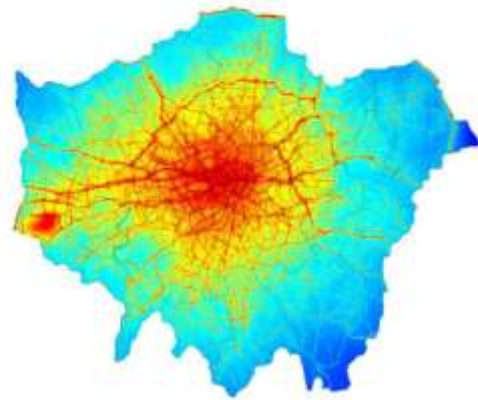
Air Monitors / Envirologger Ltd
United Kingdom



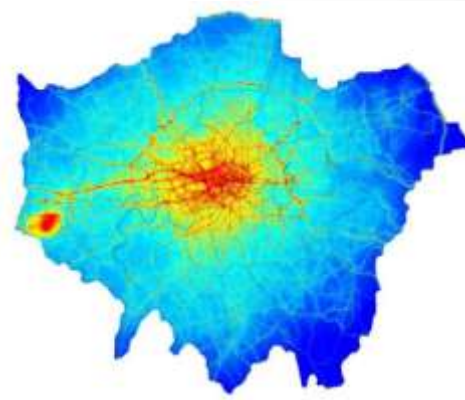
ENVIROLOGGER
ENVIRONMENTAL MONITORING & DATA MANAGEMENT TECHNOLOGY

London Air Pollution in Context

2004



2010



Compliance based on 2008/50/EC CAFE Directives
UK and 18 other countries failing to meet 2010 targets

UK potentially now faces **£300m EU** fine

Impact of air pollution estimated at **50,000** deaths/year

Air pollution estimated to cost **UK £20bn/pa**

2015 final deadline, but understanding and strategies required to be demonstrated by member states

Greater need for higher time/space resolution indicated, short and long term strategies



A few weeks in, London exceeds EU's pollution limit for the year

Mark Price
Times Correspondent

LONDON has already breached new EU pollution limits for the second year - weeks after they were introduced. Monitoring stations across the capital show that limit areas have exceeded the number of times that levels of nitrogen dioxide are allowed in the same site levels.

Found primarily in exhaust fumes, NO₂ can harm lung function and cause respiratory problems, especially among children and the elderly. Simon Roberts, of the Campaign for Clean Air in London, said today: "This shows a systematic failure of government to comply with pollution targets. This affects every Londoner, and just weeks into the year we have already exceeded the yearly target, which is a disaster."

"The Mayor needs to implement a central London low emission zone as soon as possible." EU rules state that NO₂ monitoring stations, which report levels every hour, cannot exceed 200µg per cubic metre more than 35 times in a calendar year. The Britain Road, London, has exceeded the limit 140 times, Portway High Street 71 times, Elephant & Castle 34 times and Epsom Road 28 times. The breaches mean the EU case law takes action and require an unlimited fine on Britain, although it is believed this could take years to progress.

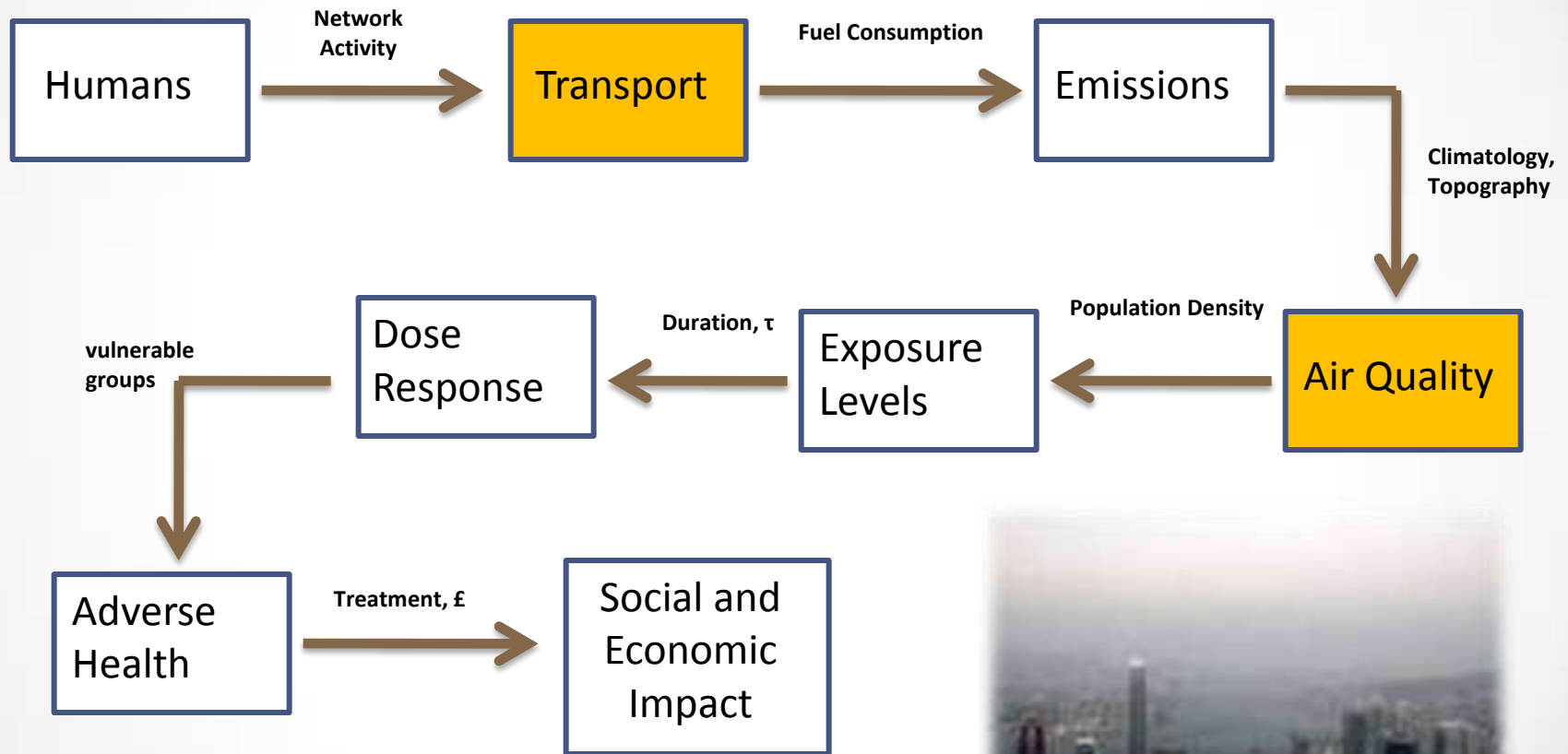
CAPITALS WORST POLLUTED AREAS

Four years in for London, how many breaches for the year ahead? The EU allowed 35 breaches.

| Location | Breaches |
|-----------|----------|
| London | 140 |
| Madrid | 100 |
| Paris | 70 |
| Rome | 60 |
| Stockholm | 50 |
| Vienna | 40 |
| Zurich | 30 |

through the courts. Assembly member Darren Johnson said: "Millions of Londoners will be affected by air pollution in the coming year." "Over the last decade, Londoners have suffered the consequences of complacency and inaction at all levels of government. The Mayor is supporting the Government's application for a five year delay in meeting the European legal limits for NO₂." The Mayor's office admits that target will not be met. A spokesman said: "The Mayor is 100 per cent committed to improving air quality, which is why he is developing a comprehensive plan to tackle the problem, but even this will not be enough to meet the limit value for NO₂ pollution in 2015."

There is a strong link between transport activity, air quality, and its eventual impact on society



Current Monitoring Technology

- ❑ Existing monitoring technology is out-dated, expensive to buy and maintain and cumbersome
- ❑ Local and Regional authorities do not want to maintain many monitoring stations neither is there space or money for additional monitoring stations
- ❑ Sparsely distributed fixed monitoring sites do not provide representative data
- ❑ Quality of information limited by low time/space resolution
- ❑ Value of existing data analysis limited by heavy assumptions and inaccurate modelling in urban areas

What do we need?

- ❑ Compact, credible and affordable monitoring technologies for real-time ppb analysis of multi species pollutants
- ❑ Robust deployable fixed and mobile sensor networks
- ❑ On-demand modelling and analysis tools
- ❑ Supportive datasets (*traffic, meteorology, health, epidemiology etc*) to demonstrate the value of sensor networks, and influence policy change

MESSAGE Research Programme

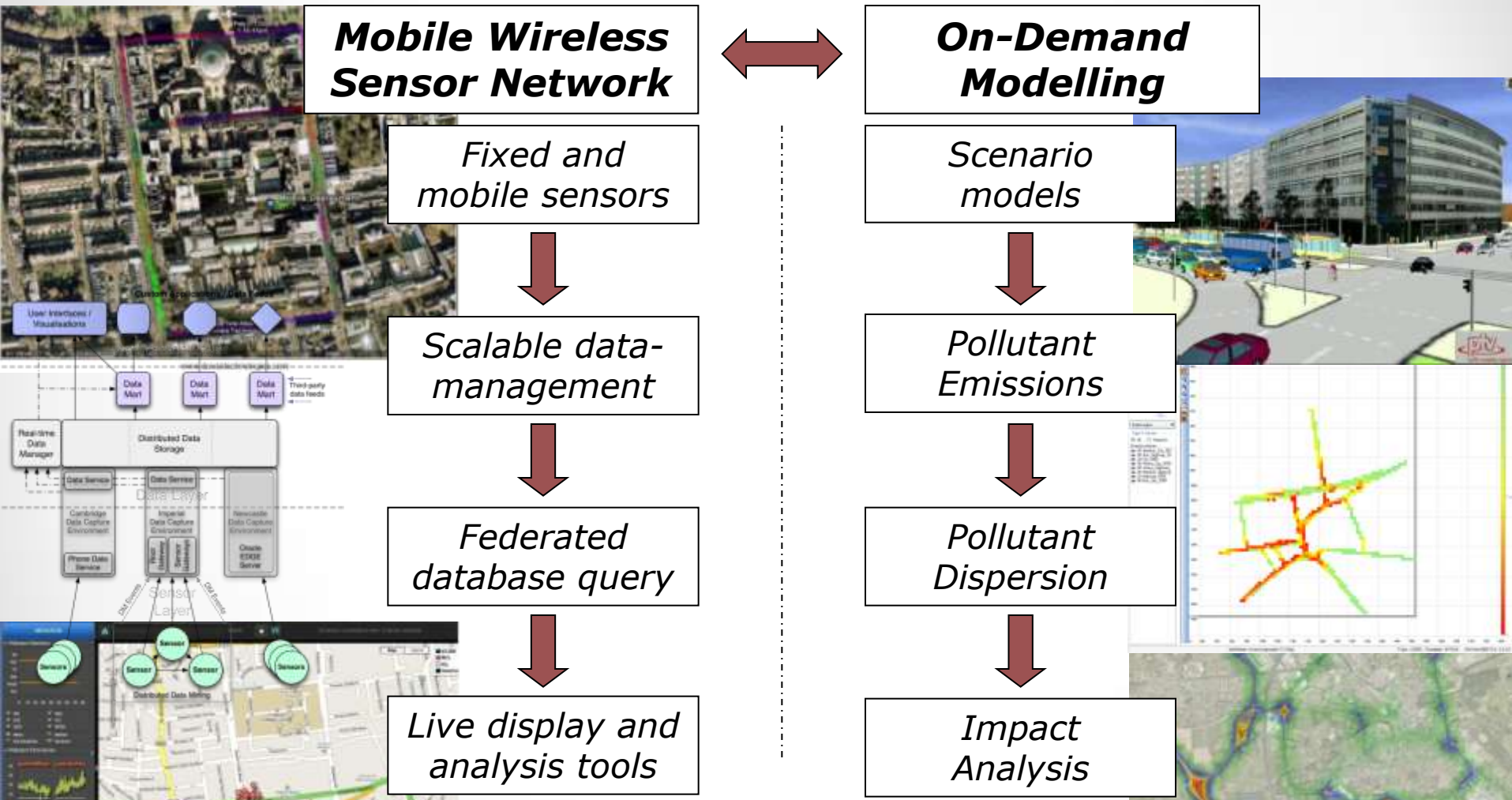
- ❑ Mobile Environmental Sensing System Across Grid Environments
- ❑ 3 year project initiated October 2006
- ❑ Funded jointly by EPSRC and DfT (~€5m), under EPSRC's e-Science demonstration programme
- ❑ 5 Universities, 20 industrial partners
- ❑ Pioneering combination and extension of leading edge grid, sensor, communications and positioning technologies
- ❑ Create radically new sensing infrastructure based on combination of mobile and fixed sensors



The MESSAGE “System”



Measurement and Modelling



Fixed & Portable

- Fixed Sensor Network (low cost)

- Enhanced Electrochemical Sensors
- Optical PM Monitor
- Cellular and Mesh Communications
- Extremely low power
- Small, Robust Sensor Pods
- Open Data Format
- Pushed via Cloud Servers
- Verifiable by std gas

- Portable Spectrometer

- DUVAS
- Multi Gas Monitor
- Fast Response < 1sec
- Portable on foot or on vehicle
- Battery Operated
- Open Data Format
- Pushed via Cloud Servers
- Verifiable by std gas

Low Cost Network Sensor Technologies

- Metal Oxide
 - Sensitive but insufficiently selective
 - Require mains power
 - Require stable humidity
- NDIR
 - Mainly for CO and CO₂
- PID
 - Good for VOC's
- **Electrochemical**
 - Selective but until recently not sufficiently sensitive
 - Many gases available
 - Until recently not sensitive enough



Electrochemical Sensors

- Can they be made sensitive enough ?
- Can they be made robust enough ?



- Are they specific enough ?
- Are there any interferences ?

Enhancements

- Hardware

- Improved sensitivity and stability
- Improved selectivity
- Quantification of ambient temperature & humidity effects

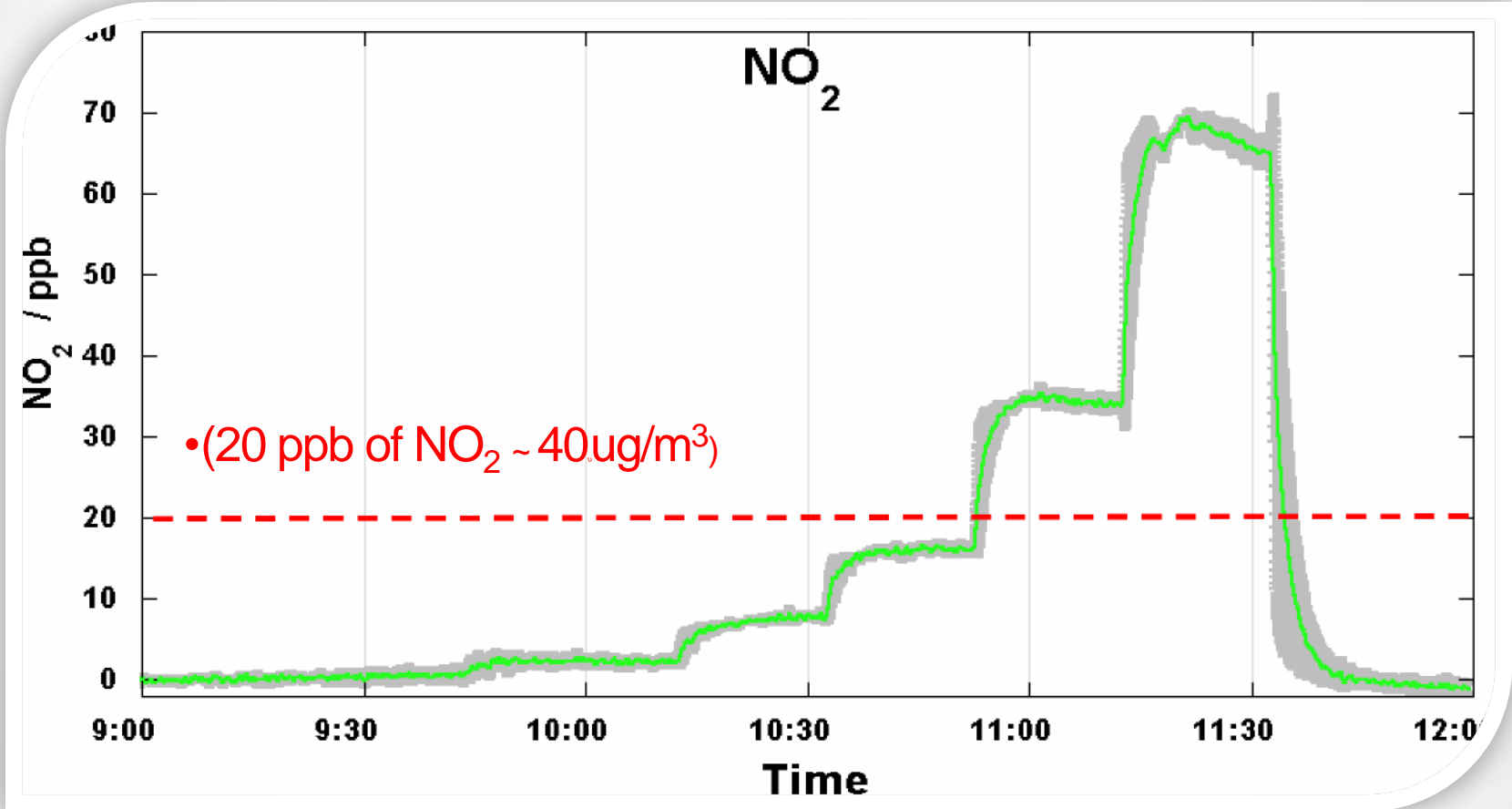
- Control electronics

- Improved stability/noise characteristics

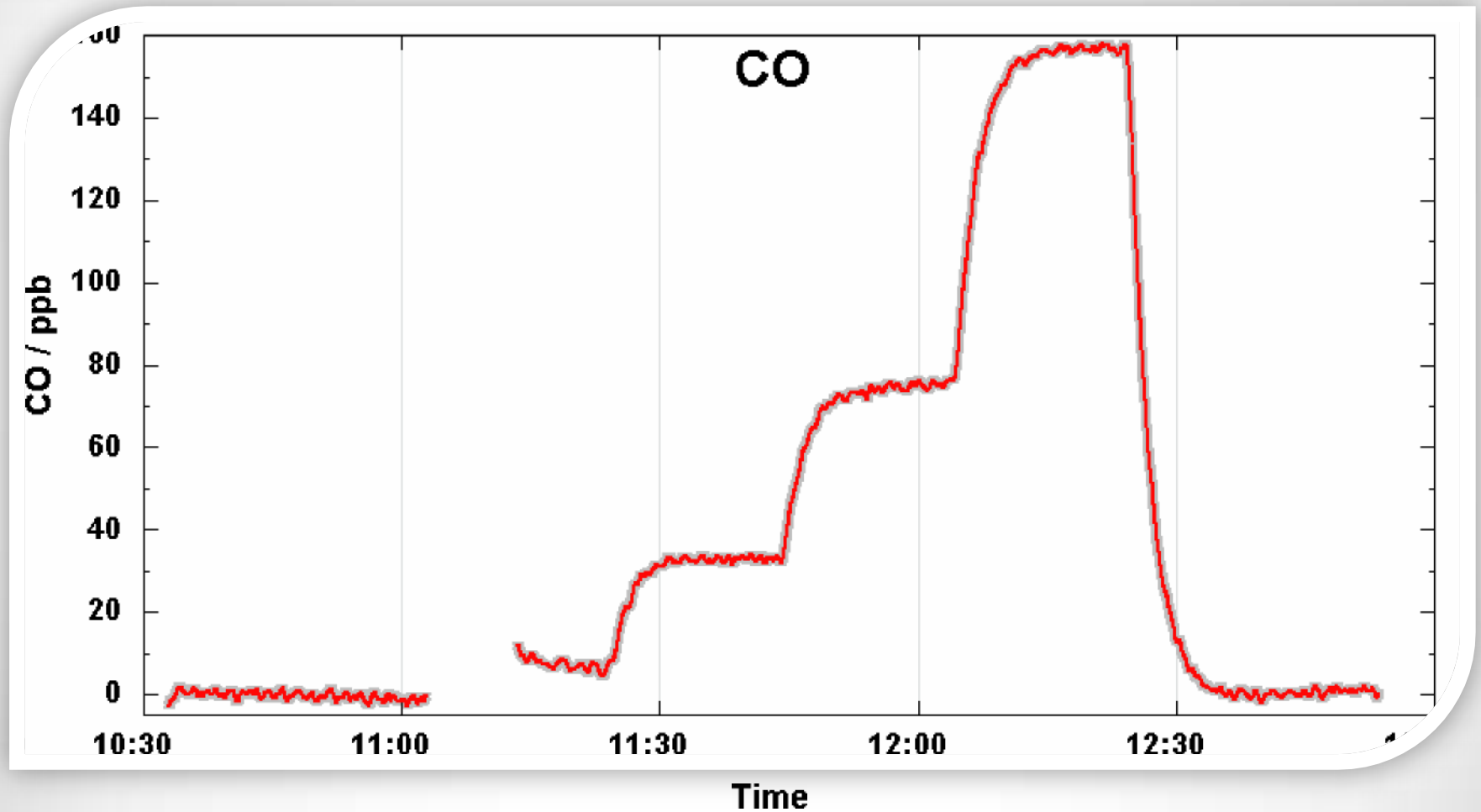
- Software

- Algorithms for baseline correction
- Performance monitoring
- Calibration methodologies

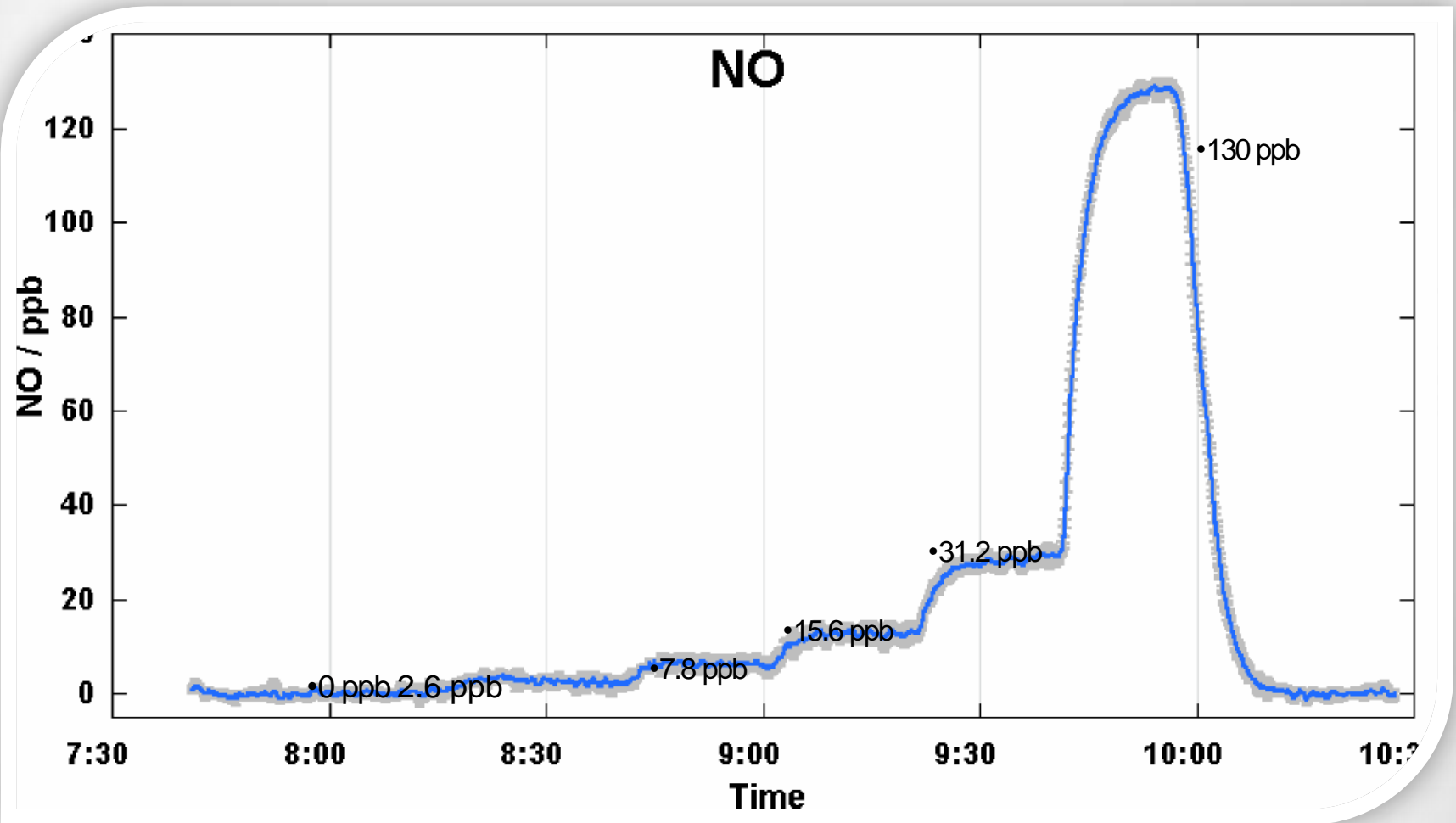
Performance of (enhanced) electrochemical sensors NO₂ sensitivity (laboratory)



Performance of (enhanced) electrochemical sensors CO sensitivity (laboratory)



Performance of (enhanced) electrochemical sensors NO sensitivity (laboratory)



Sensor Performance (laboratory)

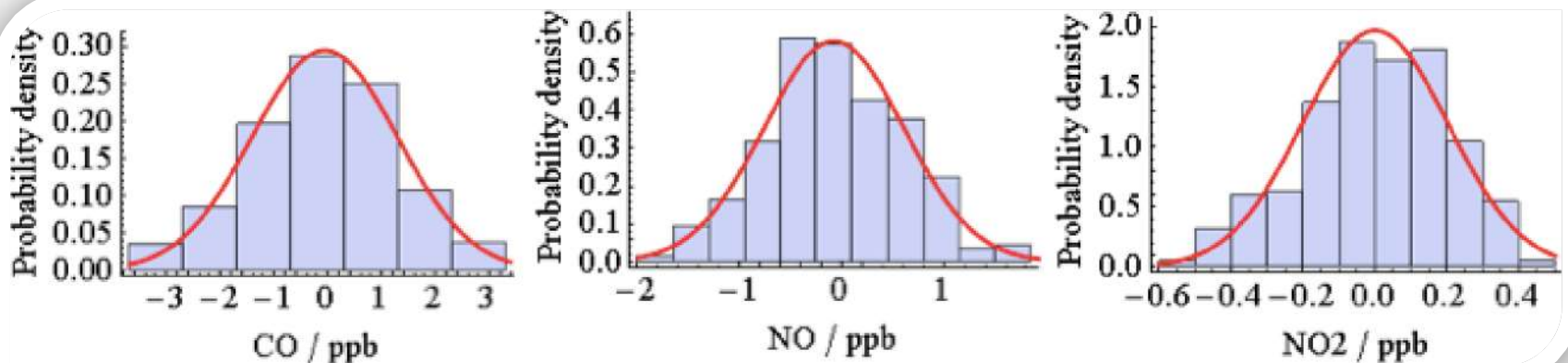
- Typical LDL's ...

- $< 5 \text{ ppb}$ ($< 7 \text{ ug/m}^3$) for CO,

- $1\text{-}2 \text{ ppb}$ ($\sim 2\text{-}4 \text{ ug/m}^3$) for SO₂, O₃, NO & NO₂.

- Typical sensor $T_{90} \sim 10\text{-}20\text{s}$ (determined by diffusion)

- Very low power consumption



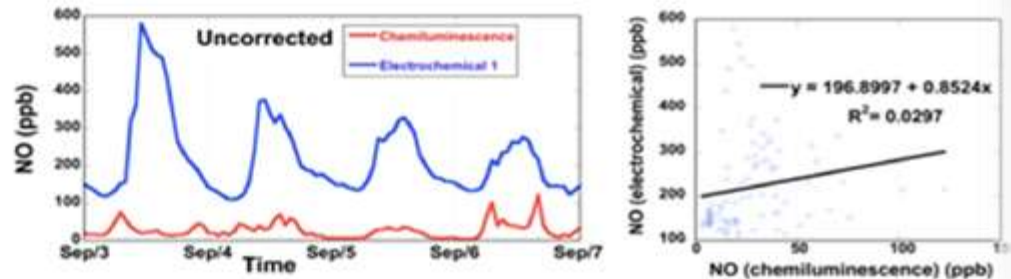
Performance - In the Field

Is laboratory performance
replicated in the field ?

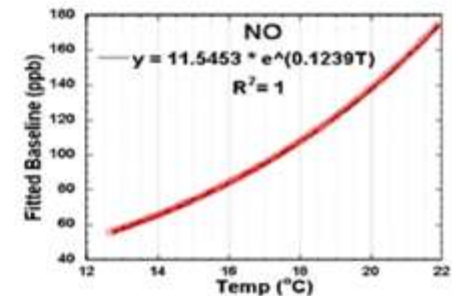
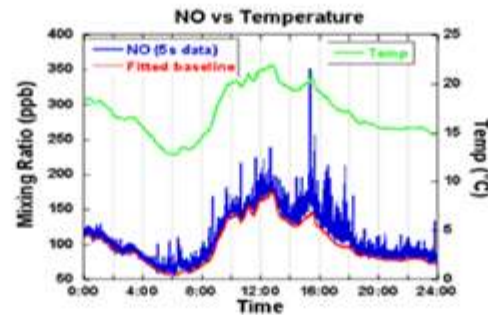


Electrochemical sensor baseline & temperature correction

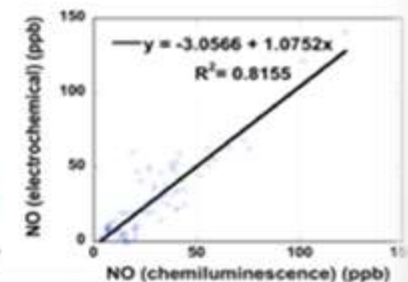
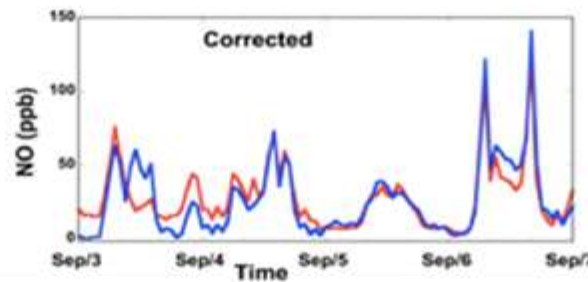
Electrochemical vs
Chemiluminescence



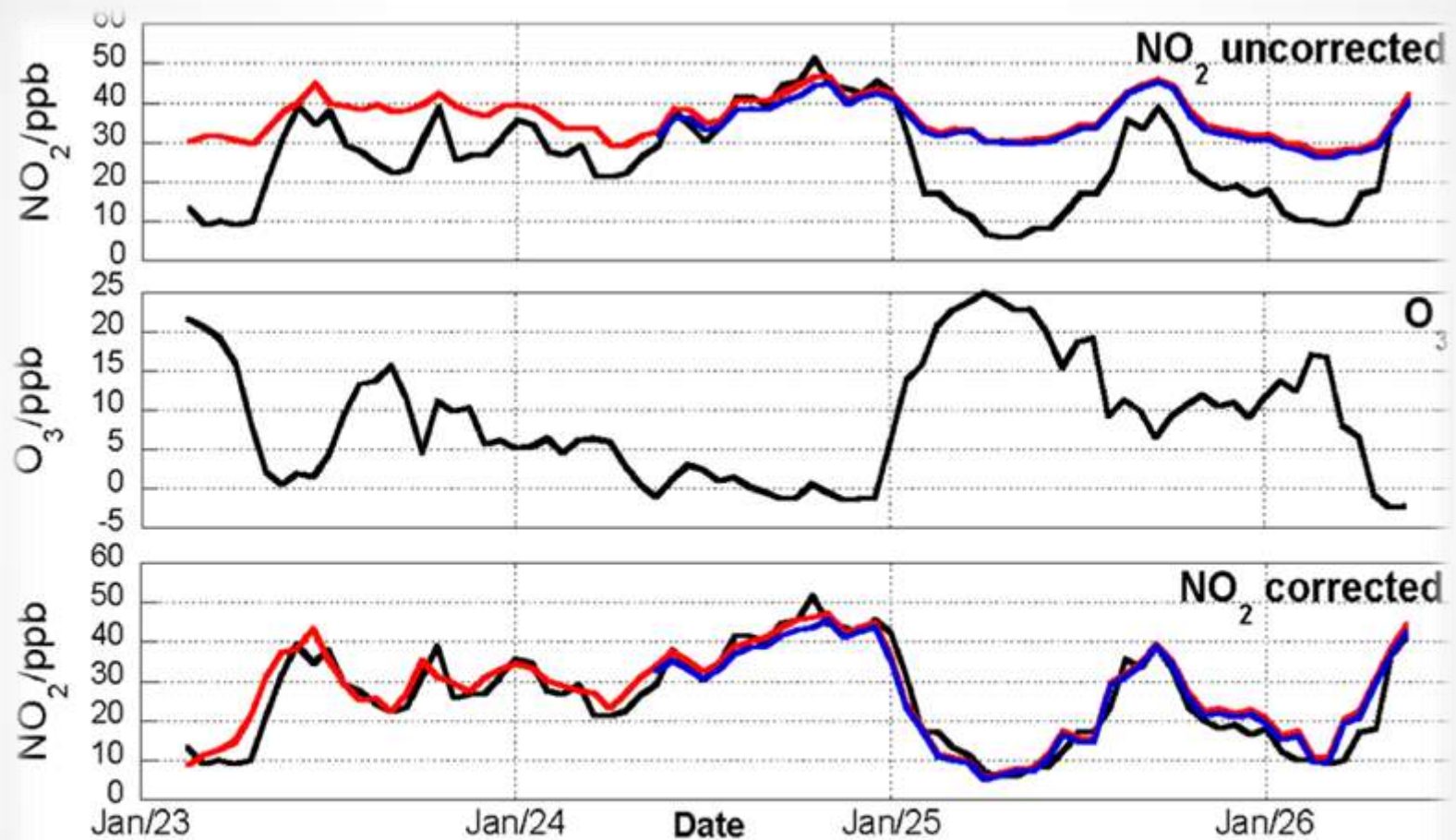
Sensor temperature and
baseline correction



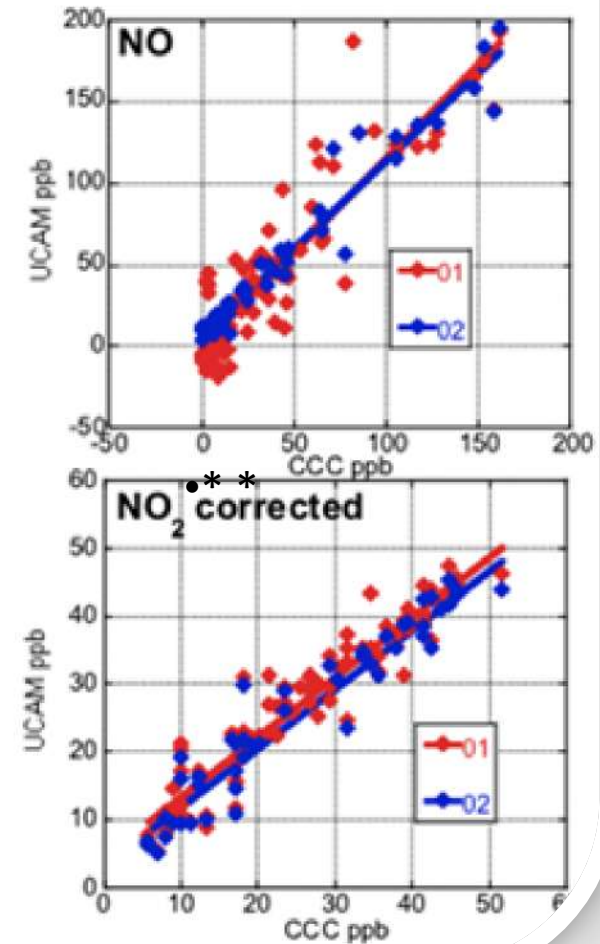
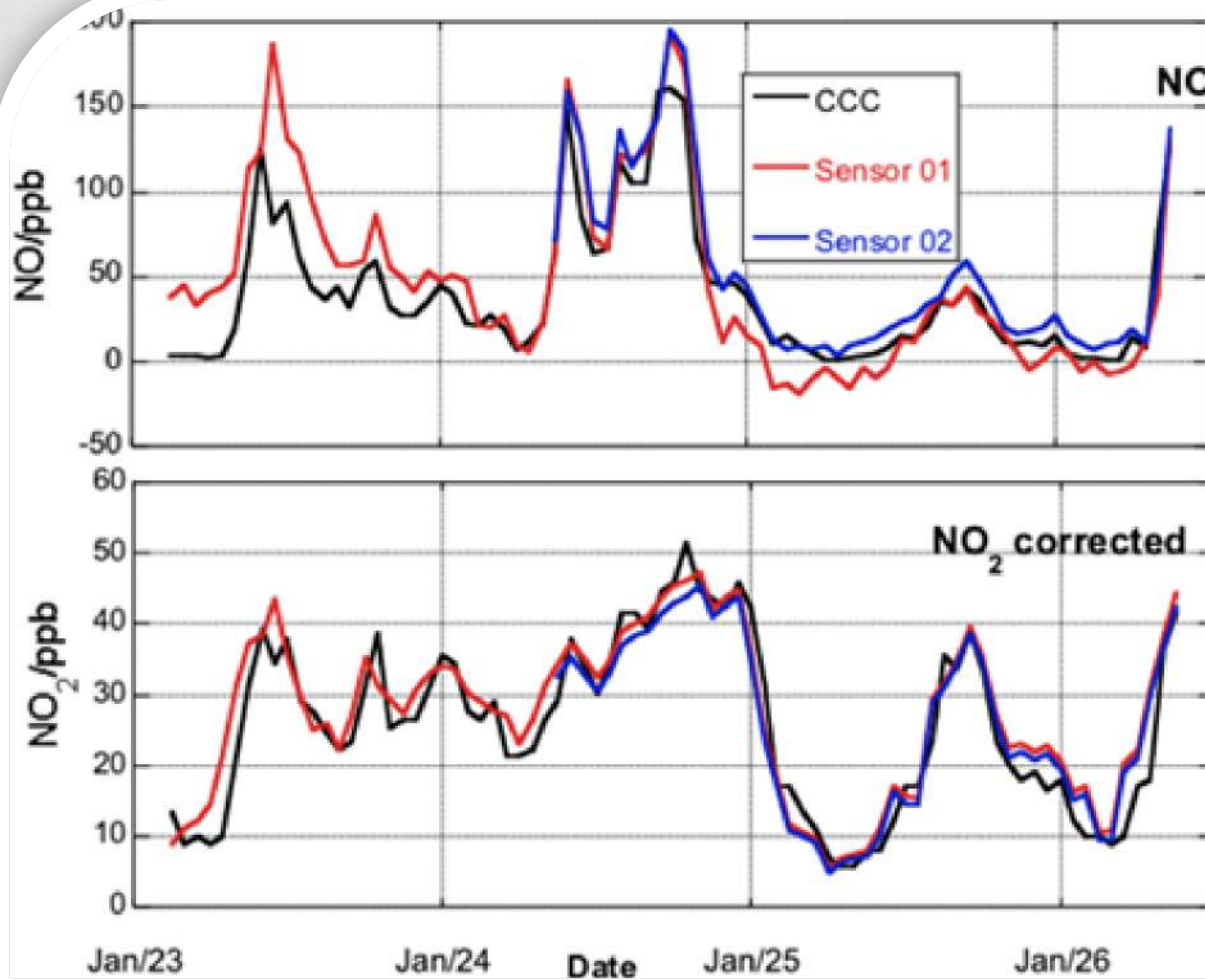
Baseline temperature
corrected
(compared to
ratified data)



Cross interference (NO_2/O_3) + comparison with reference monitor (1 hr averages)



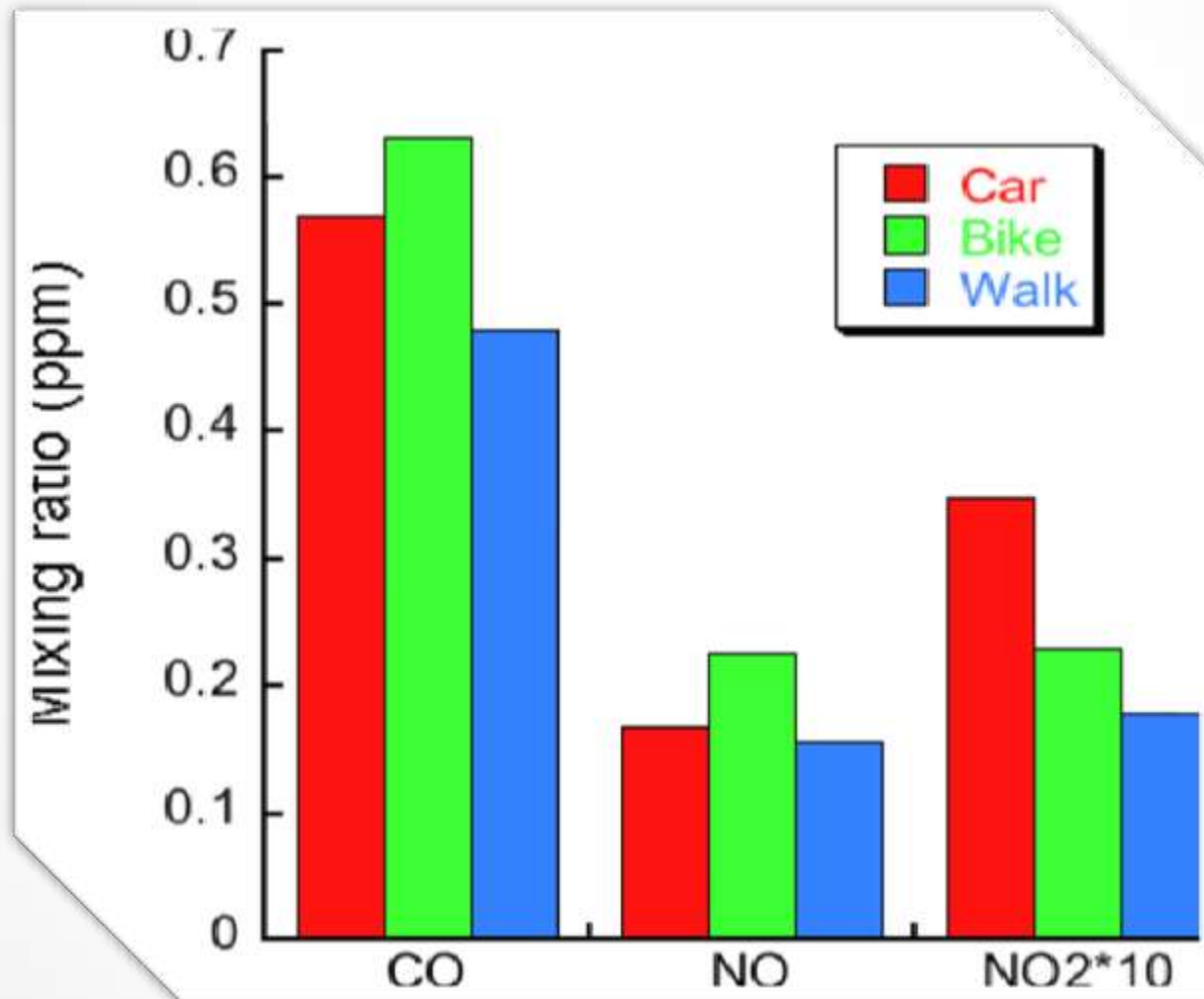
Field comparison of NO₂ and NO with ratified reference site



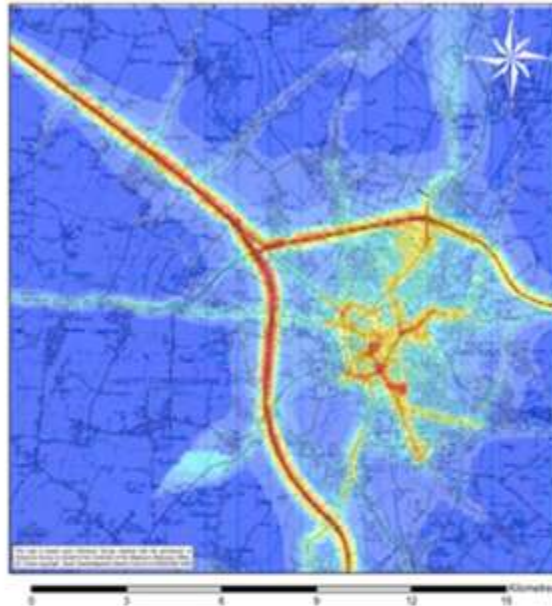
Hot Spot Identification



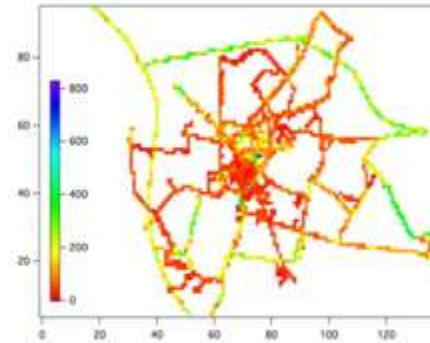
Statistical assessment of mobile air quality data by transport mode (simplest possible!)



Verification of Models



- Allows for calculation of
- Canyon Effects
 - Personal Exposure
 - Spatial and Temporal Variations



•CERC ADMS model (David Caruthers)



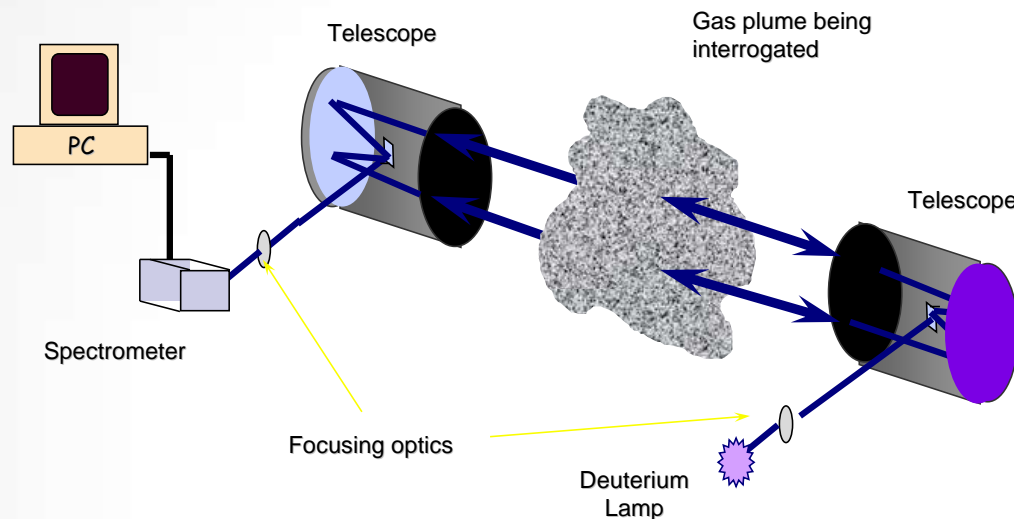
On Going Trials

UK Nationally funded high density sensor network system at UK Heathrow airport (2011-2013)

- NO, NO₂, CO, CO₂, SO₂, O₃, PM (x) and VOC's
- Source attribution/model validation for airport area
- Development of software tools for presentation and data mining

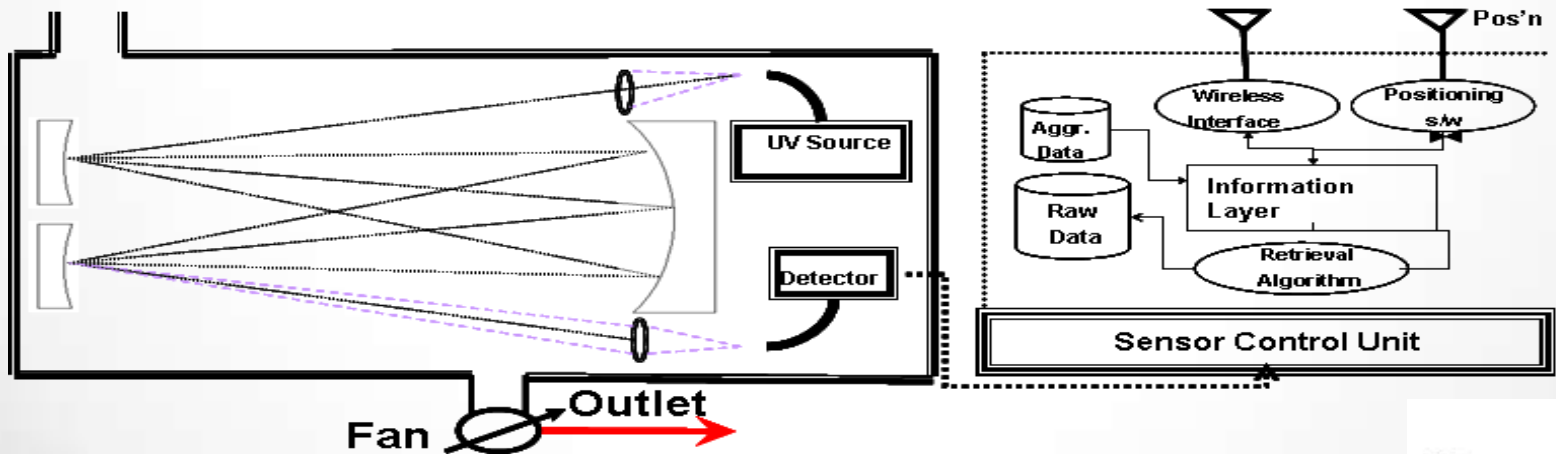


Portable Technology DUVAS

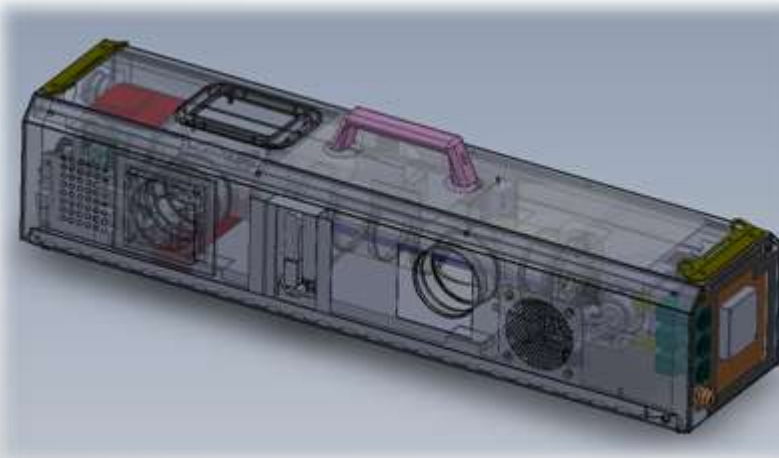
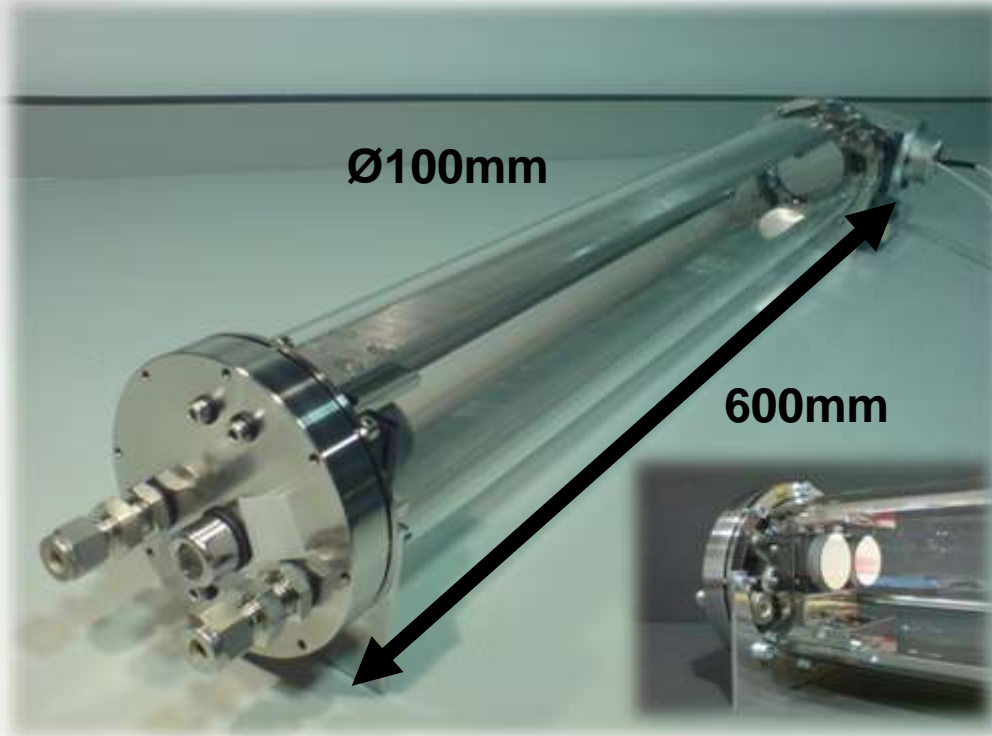


$$T = \frac{I_1}{I_0} = e^{-\int \alpha' dz} = e^{-\sigma \int N dz}$$

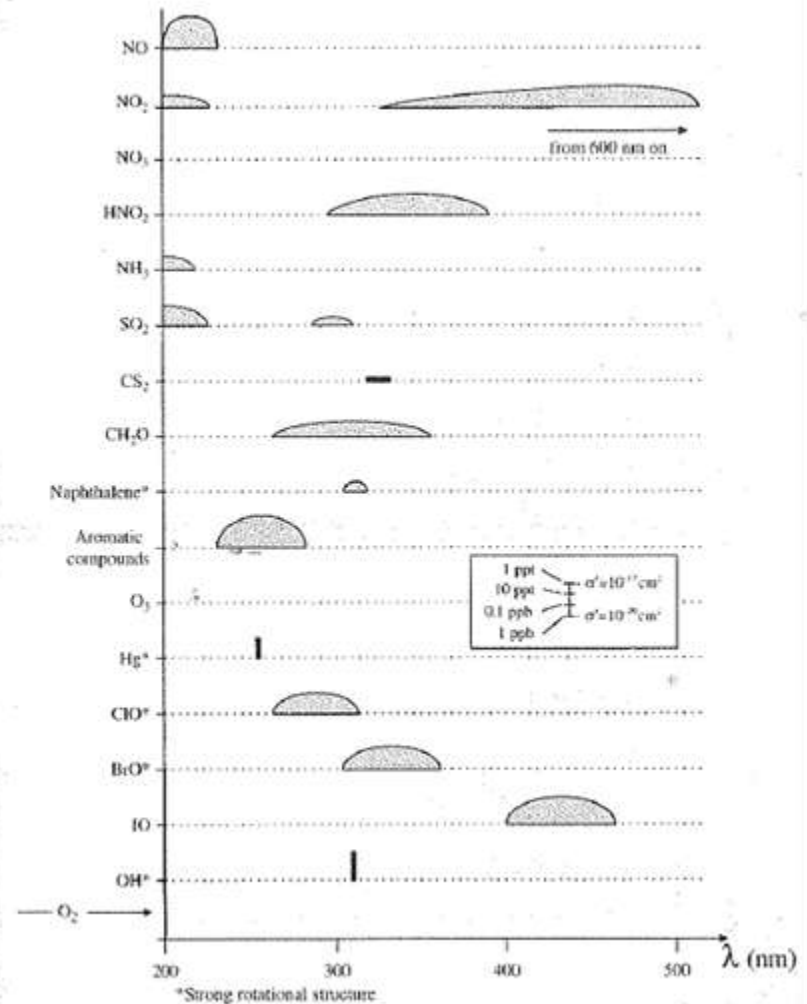
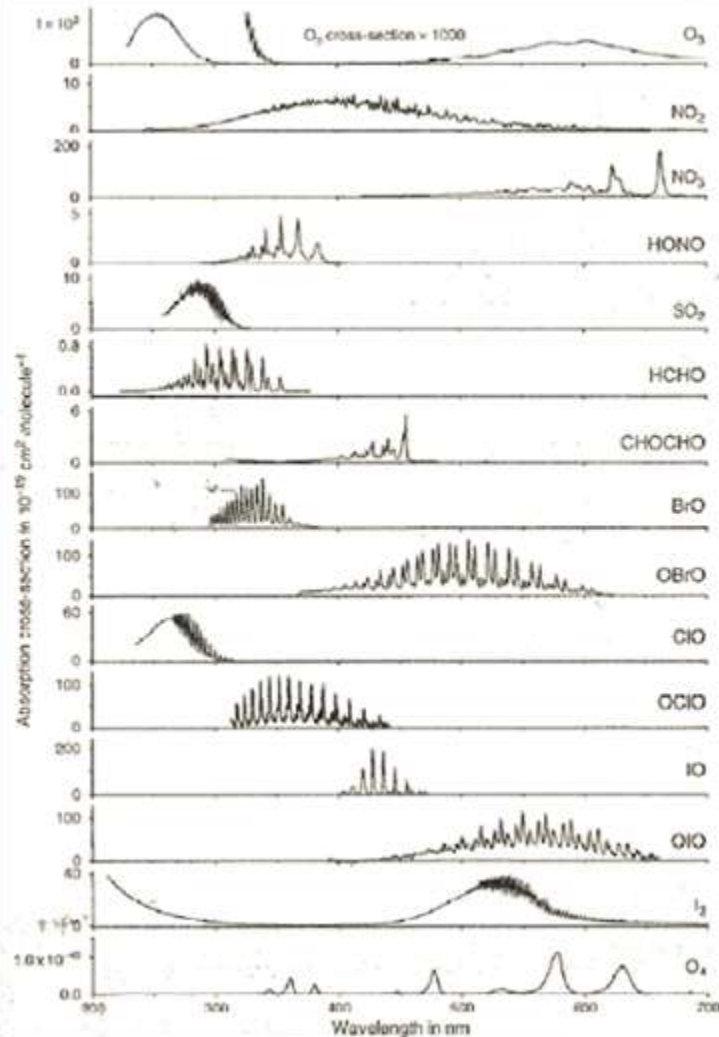
Beer-Lambert Law



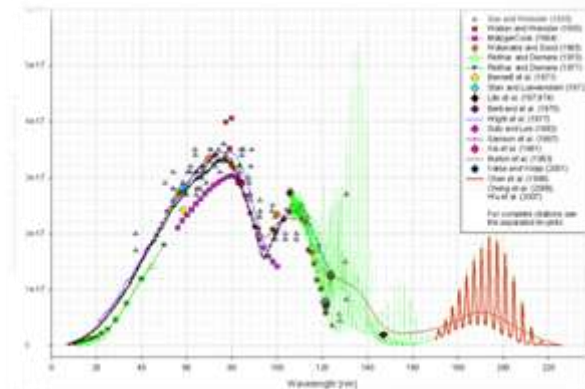
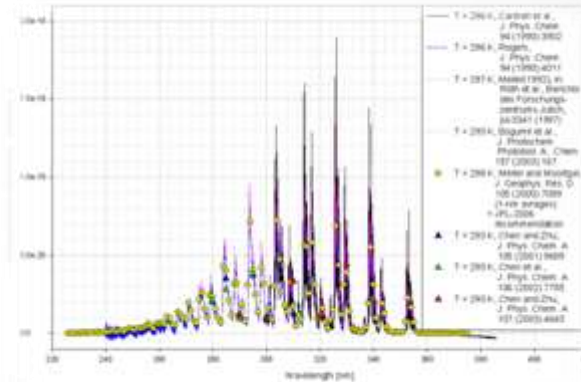
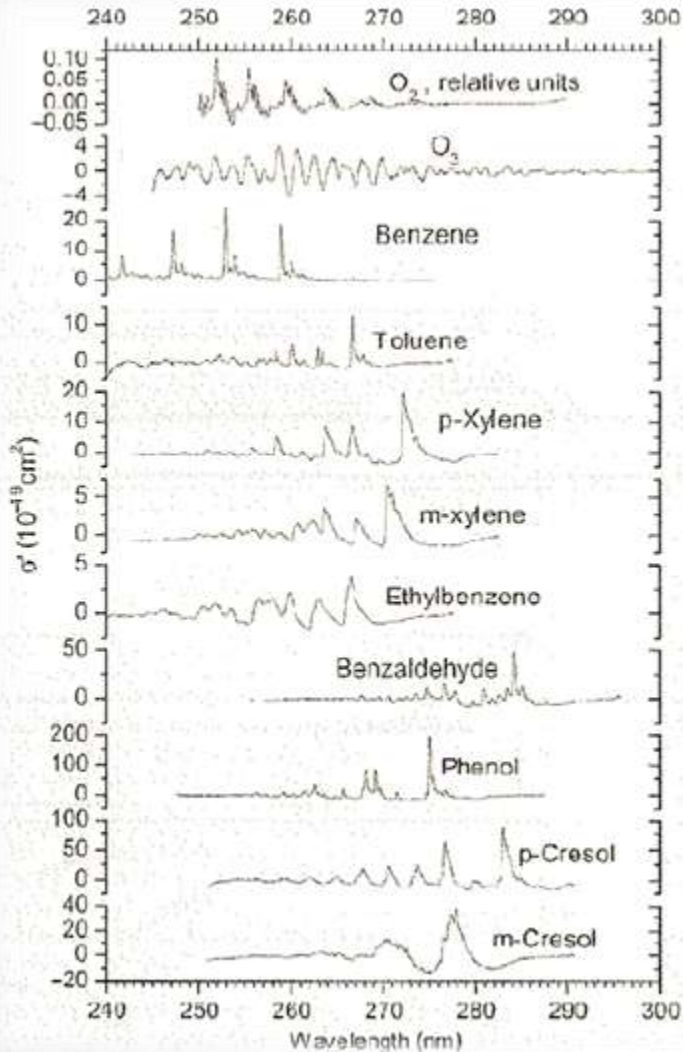
DUVAS Cell Design



Typical Gas Signatures



Typical Differential Signatures



Performance Assessment (NO)

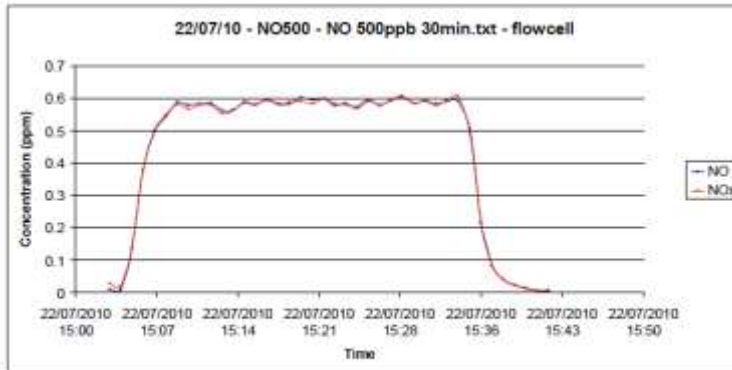


Figure 5 Ecotech Analyser exposed to NO mid concentration
NO = 587 ± 9ppb

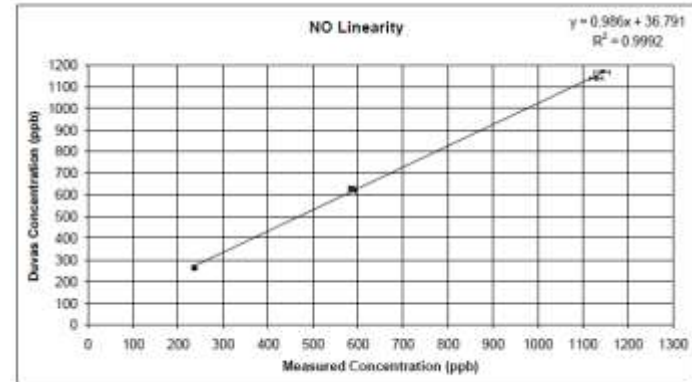


Figure 13 Duvas NO linearity

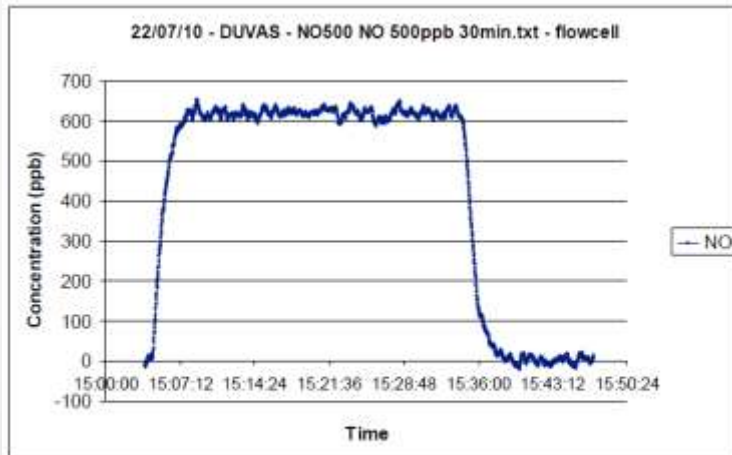


Figure 6 Duvas device exposed to NO mid concentration
Duvas NO = 619 ± 11ppb
Rolling length = 20 seconds



Performance Assessment (NO₂)

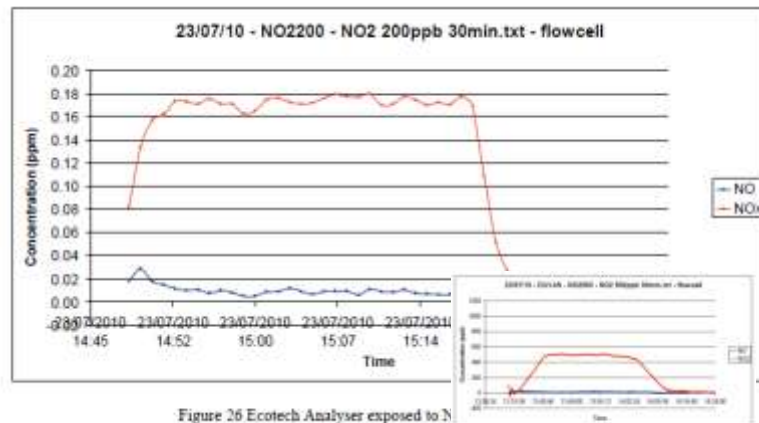


Figure 26 Ecotech Analyser exposed to N
NO_x = 174 ± 4ppb

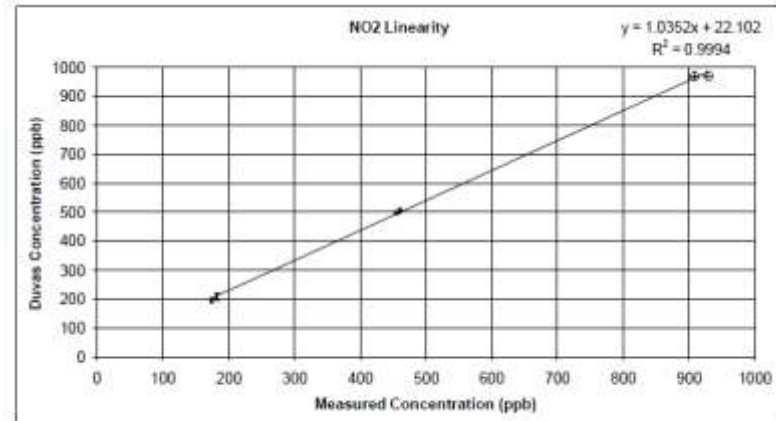


Figure 28 Duvas NO2 Linearity

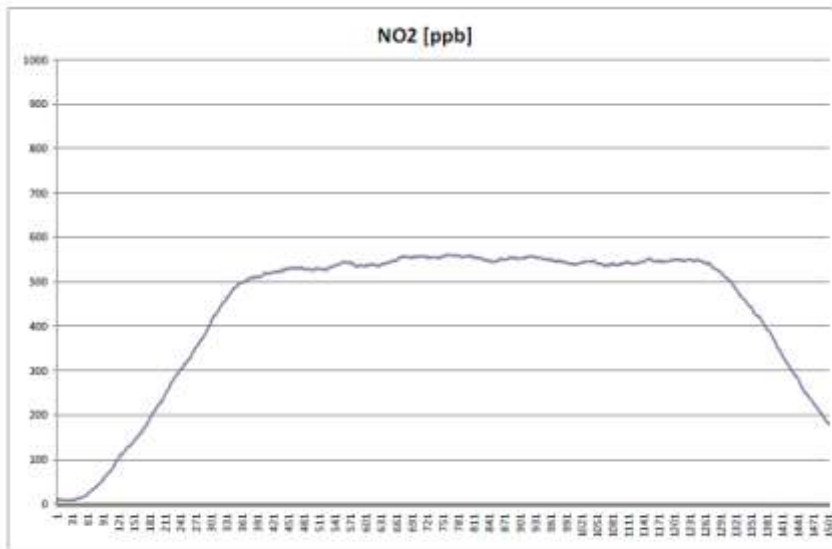


Figure 3 Duvas solving at -500ppb set point

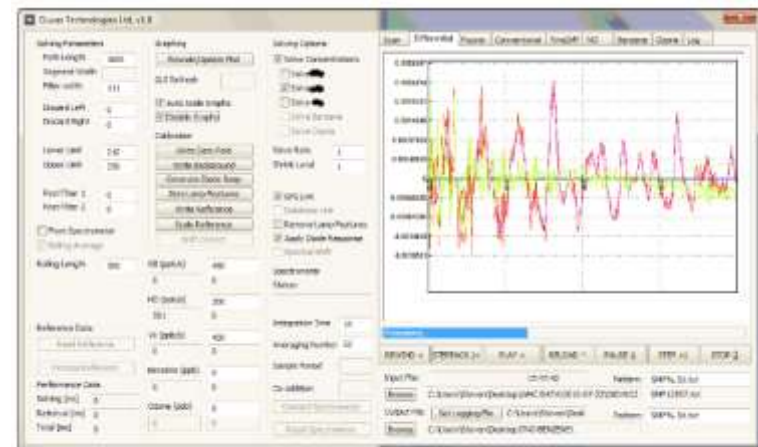
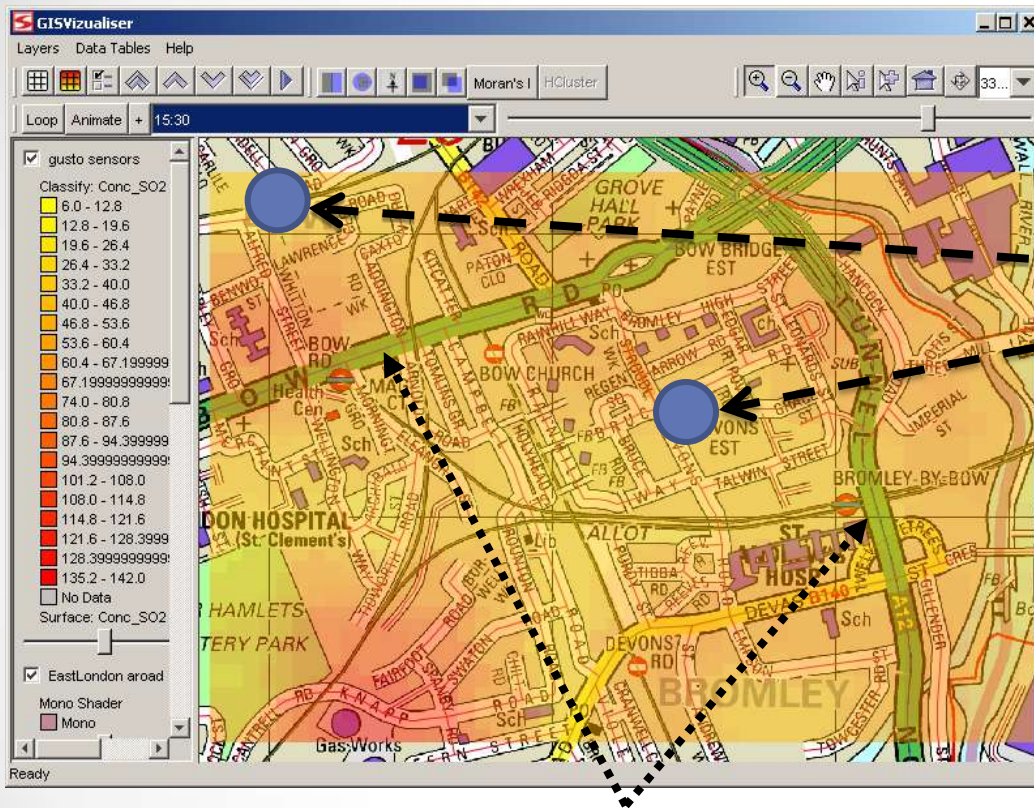


Figure 2 Duvas screenshot at -500ppb setpoint showing NO2 differentials

Product Use-Case Illustration



Portable unit for local
'hotspot' mapping and
monitoring



City buses

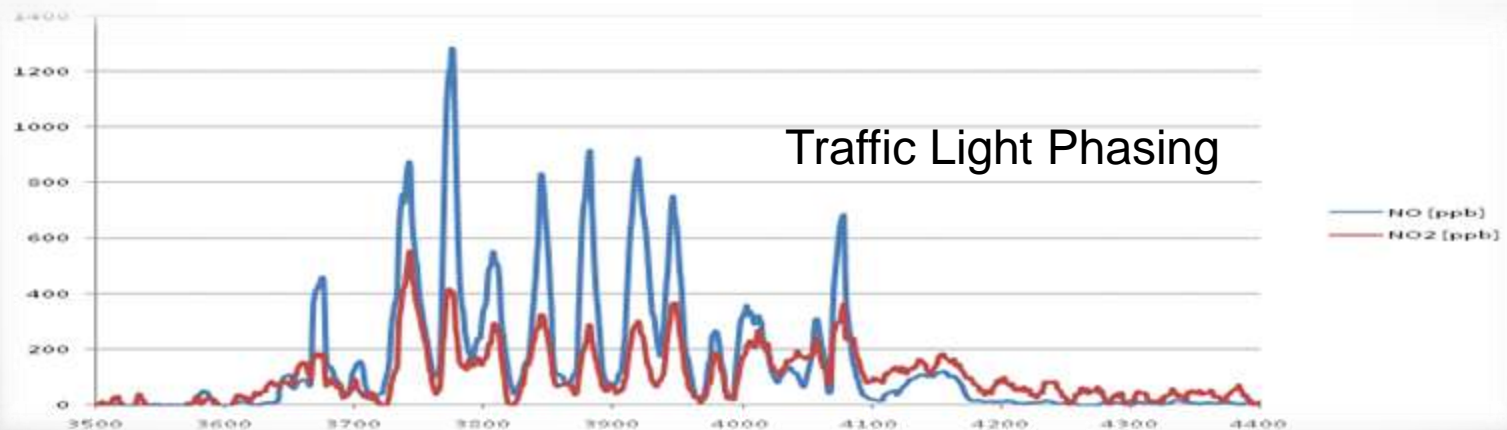


Taxis, LA, public services

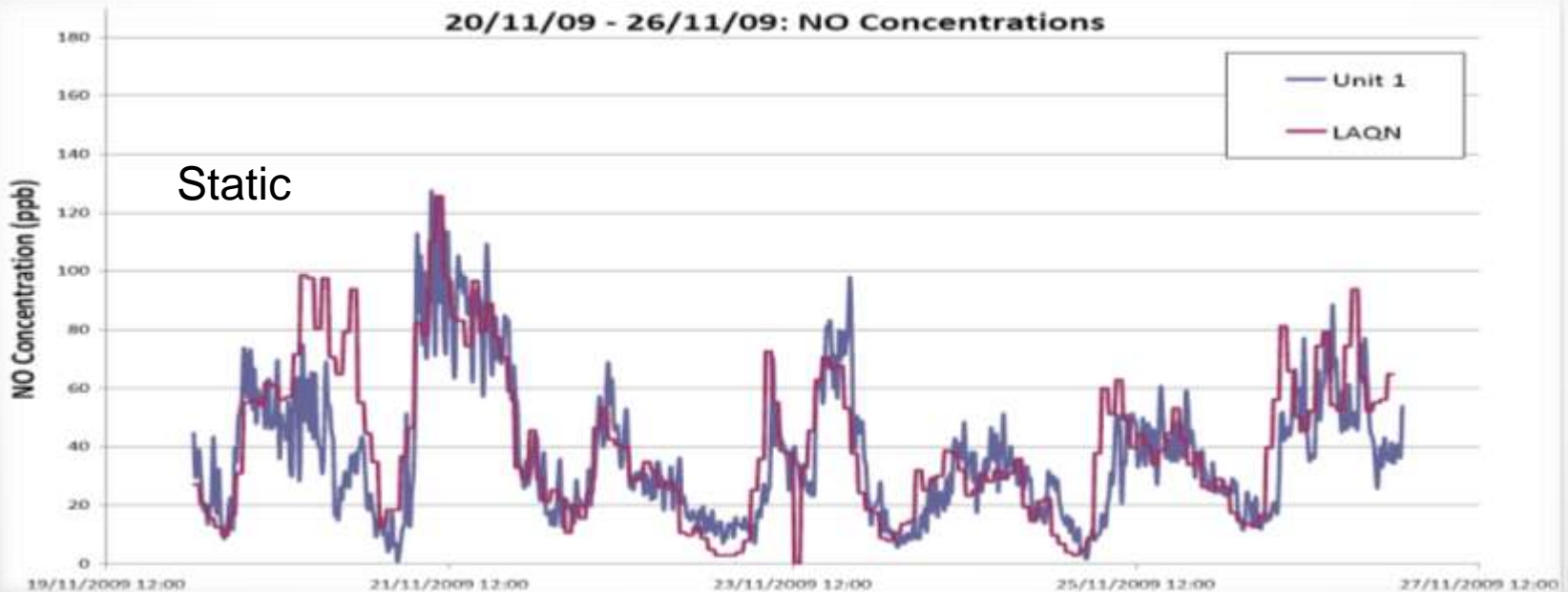
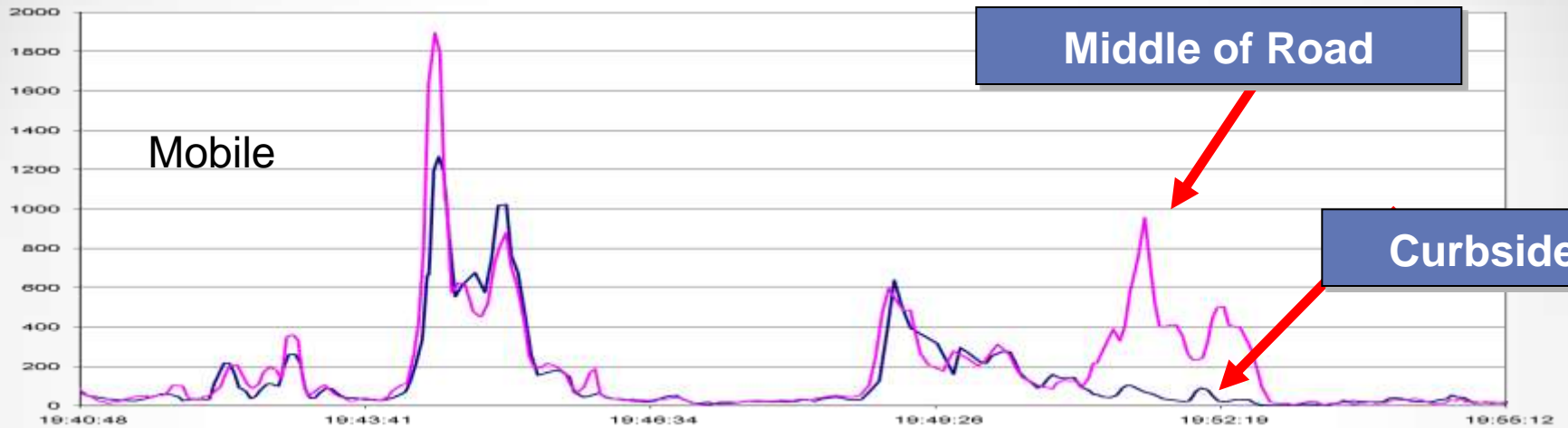
Vehicle-mounted
Mobile unit for
area pollution
mapping from data
measured on route

Mobile & Static Dataset

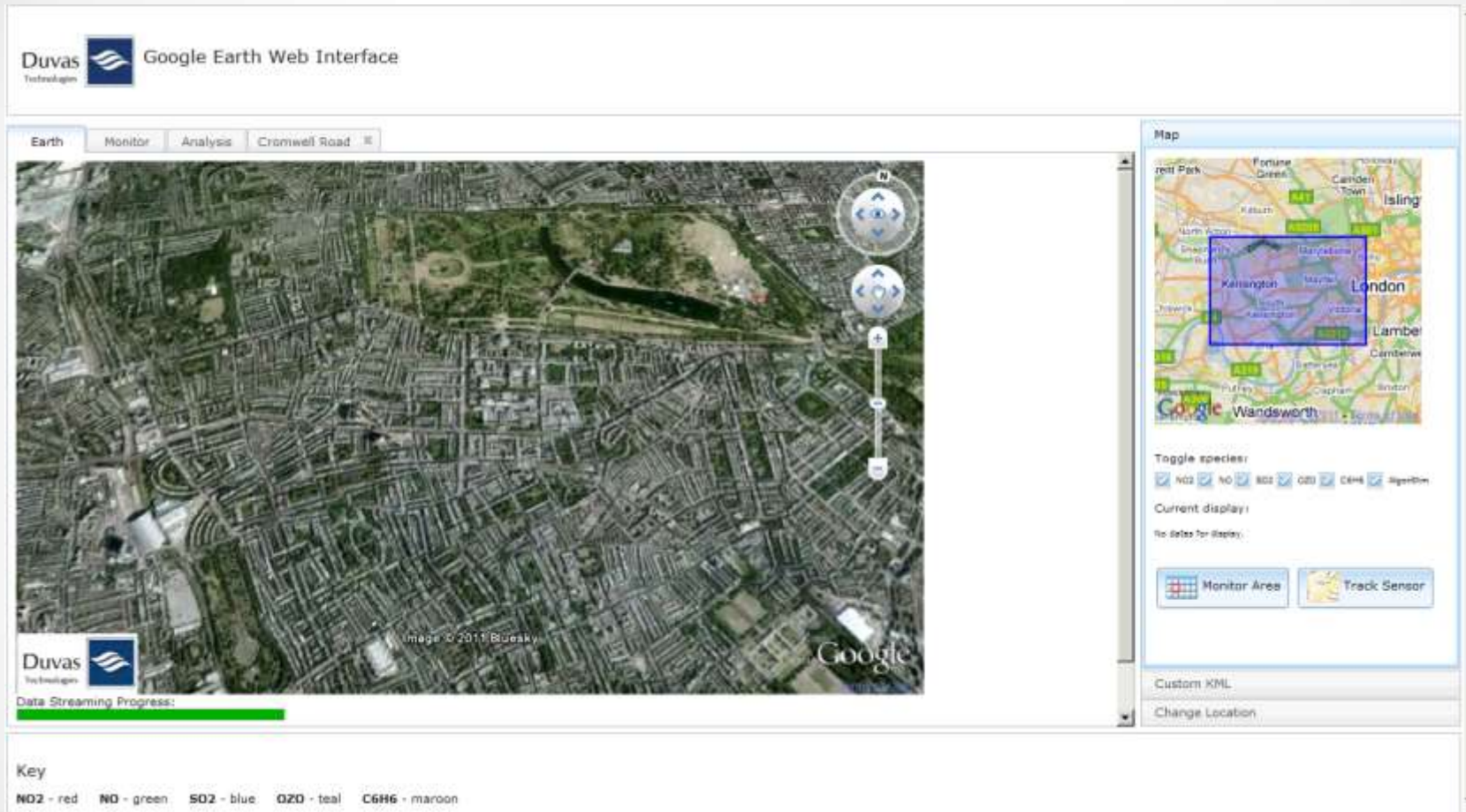
Levels of Nitric Oxide/Dioxide



Spatial Information and Accuracy



Concentrations on Google Maps



DUVAS LIVE

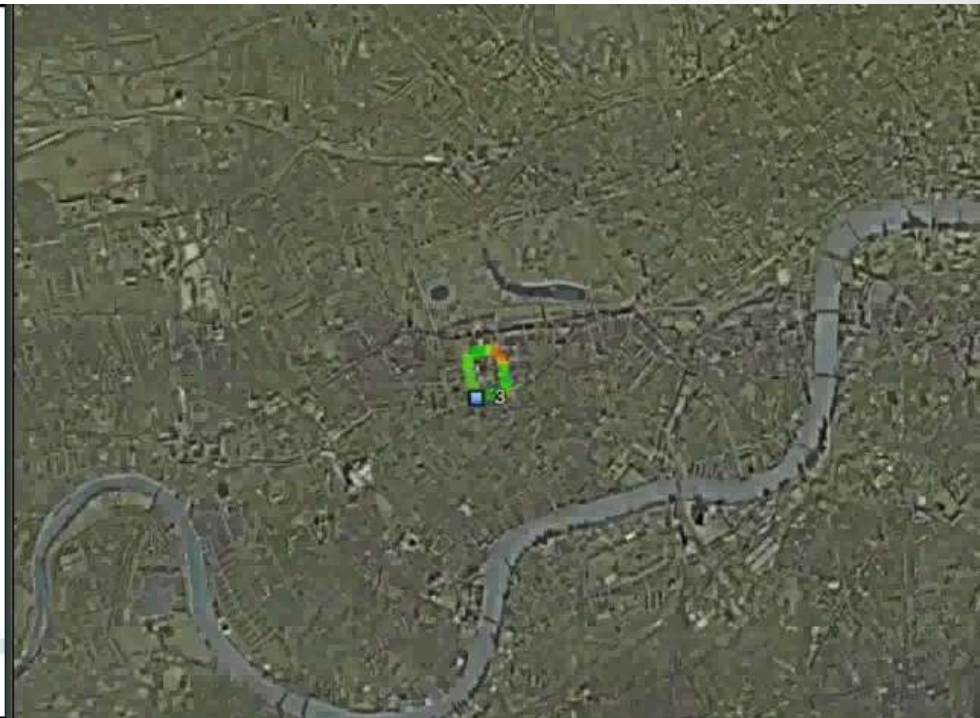

Video

Air Quality Index (AQI) NO



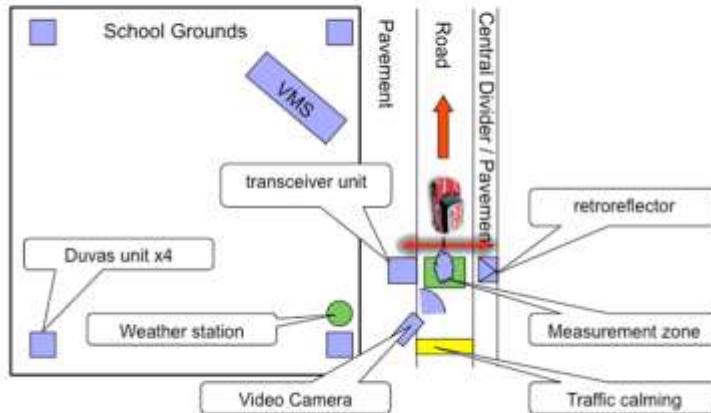
Mobile environmental sensing systems for management of transport and air quality

Field Trial Playback
South Kensington
February 2009



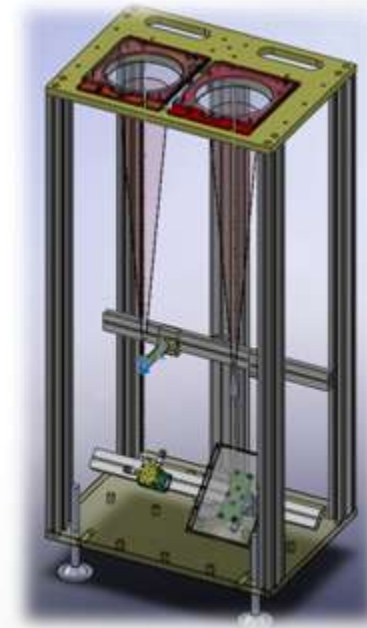
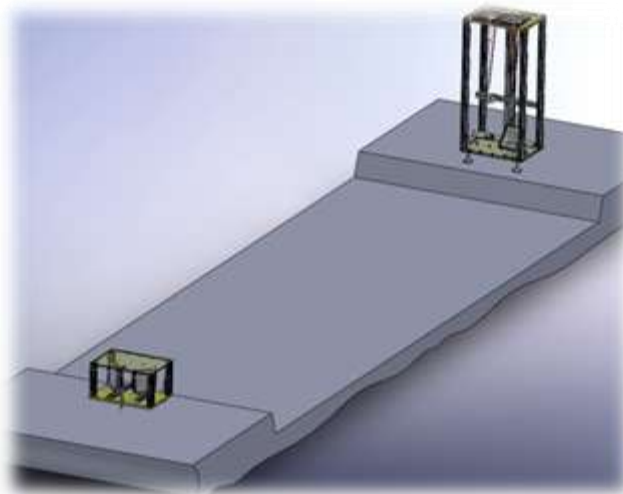
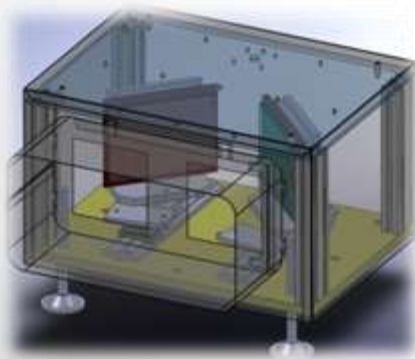
Open Path Development

Proposed Experimental Layout



www.duvastechnologies.com

Duvas
Technologies



Open Path Deployment



Thank You



CARBO  **TRAF**
EUROPEAN FP7 PROJECT

www.airmonitors.co.uk
www.envirologger.com

