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Mobile multi-species trace vapour sensors for Localised Pollution Monitoring & Mapping

Dr Mark Richards

AAMG Conference 14th – 15th December 2010

aamg

RSC | Advancing the Chemical Sciences

message

Duvas Technologies

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Overview

Urban AQM in Context

Environmental Sensor Networks

Duvas Sensors

Recent Data Collection and Trialing

Summary

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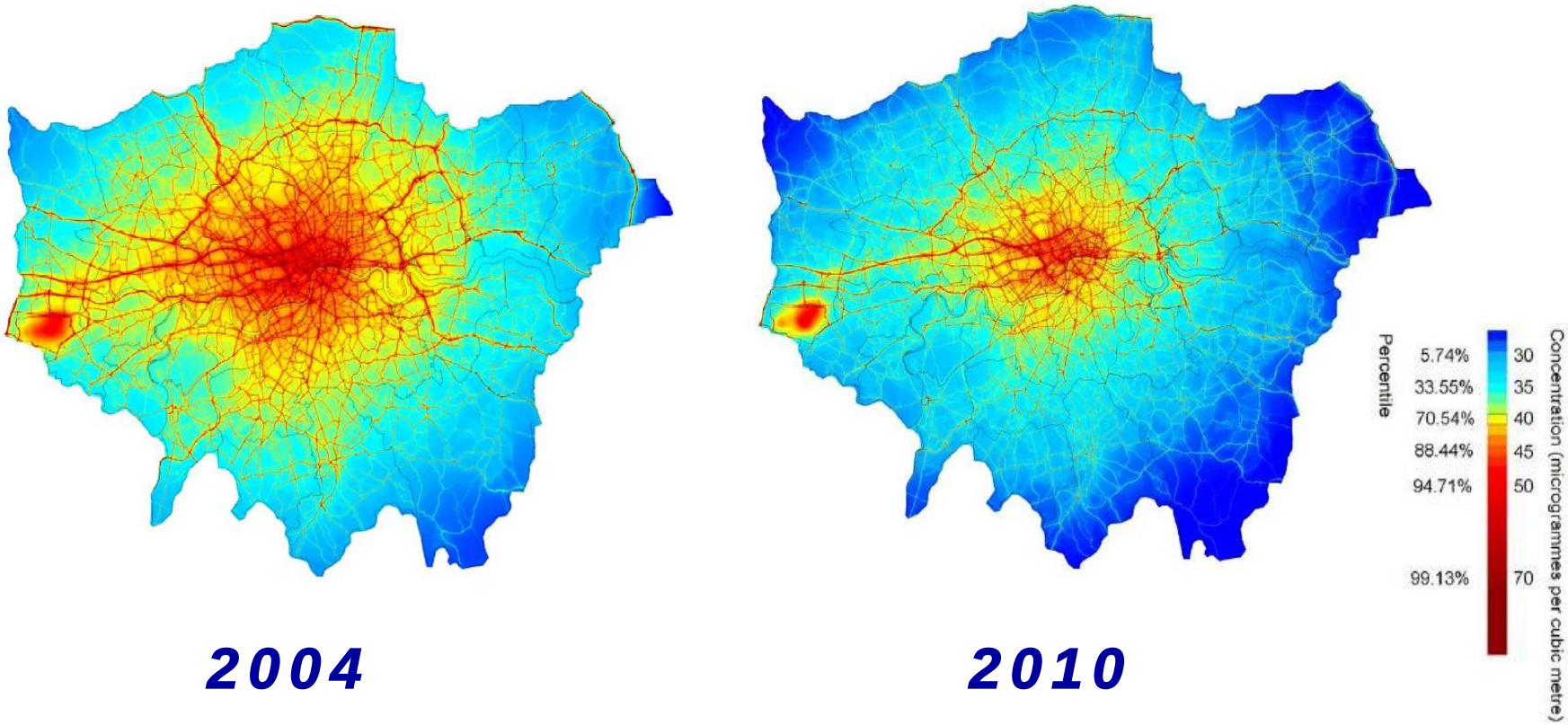
UK Pollution in Context

Urban air quality is improving, but pollution 'hot spots' will remain a key problem

For example, NO_2 in London… we didn't see these improvements?



2004 **2010**

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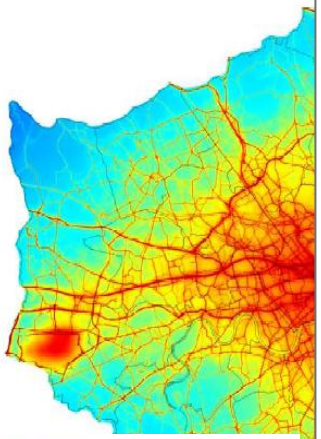
Urban Air Pollution in the News



Compliance based on 2008/50/EC CAFE Directives

UK and 18 other countries failing to meet for 2010

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

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

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

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

Q2 2010 NO2 workshop, Q3 2010 recommendations

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 Prigg
Science Correspondent

LONDON has already breached new EU pollution limits for the entire year – weeks after they were introduced.

Monitoring stations across the capital show that four areas have exceeded the number of times that levels of nitrogen dioxide are allowed to rise above safe levels.

Found primarily in exhaust fumes, NO_2 can harm lung function and cause respiratory problems, especially among children and the elderly.

Simon Birkett, 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 targets, which is a disgrace.

"The Mayor needs to implement a central London low emission zone as soon as possible."

EU rules state that NO_2 monitoring stations, which report levels every hour, cannot exceed 200mg per cube metre more than 18 times in a calendar year. But Brixton Road, Lambeth, has exceeded the limit 140 times, Putney High Street 75 times, Knightsbridge 38 times and Earls Court Road 28 times.

The breaches mean the EU can now take action and impose an unlimited fine on Britain, although it is believed this could take years to progress 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 NO_2."

The Mayor's office admits the 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 values for NO_2 pollution in 2015."

CAPITAL'S WORST POLLUTED AREAS

Four areas of the Capital have already breached NO_2 levels for the year more than the EU's allowed 18 times:

Lambeth	
Brixton Road	140 times
Wandsworth	
Putney High Street	75 times
Kensington and Chelsea	
Knightsbridge	38 times
Kensington and Chelsea	
Earls Court Road	28 times

Source: London air quality network (www.londonair.org.uk)

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Current Typical Criticisms of AQM

- *Existing monitoring technology is out-dated, cumbersome*
- *Local Authorities typically do not want to maintain many monitoring stations nor is there space for additional 'street furniture'*
- *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*

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Research and Development

What do we need?

- ***Compact credible technologies for real-time ambient monitoring***
- ***Multispecies for multivariate analysis and fingerprinting***
- ***Robust deployable sensor network architectures***
- ***Heterogeneous data management to provide quality information***
- ***On-demand modelling and analysis tools***
- ***Supportive datasets to demonstrate the value of sensor networks, and influence policy change***

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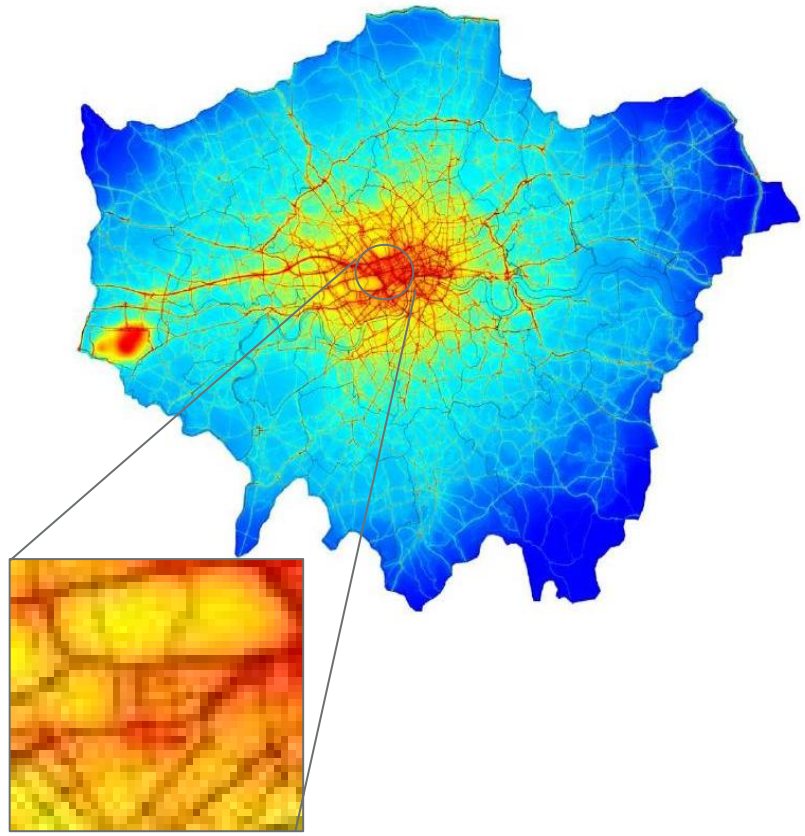
Local 'hotspot' Management

How to design and implement local mitigation?

1. ***Use aggregated models to screen for probable emission hotspot locations***
2. ***Deploy mobile sensing to survey the actual distributions***
3. ***Detailed models to assess alternative traffic management***
4. ***Ongoing monitoring to provide feedback***



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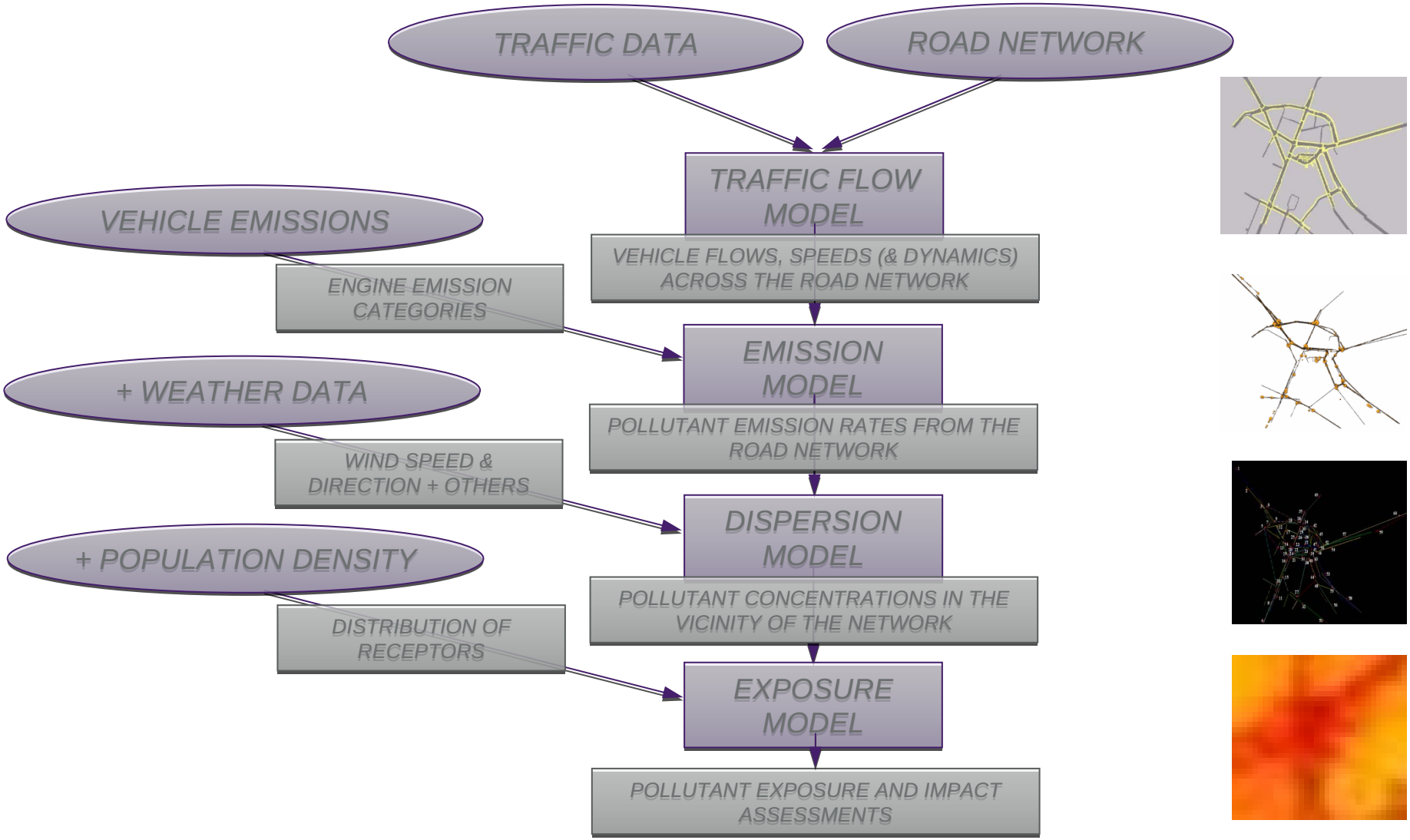
Sensor Data Can Complement Scenario Models



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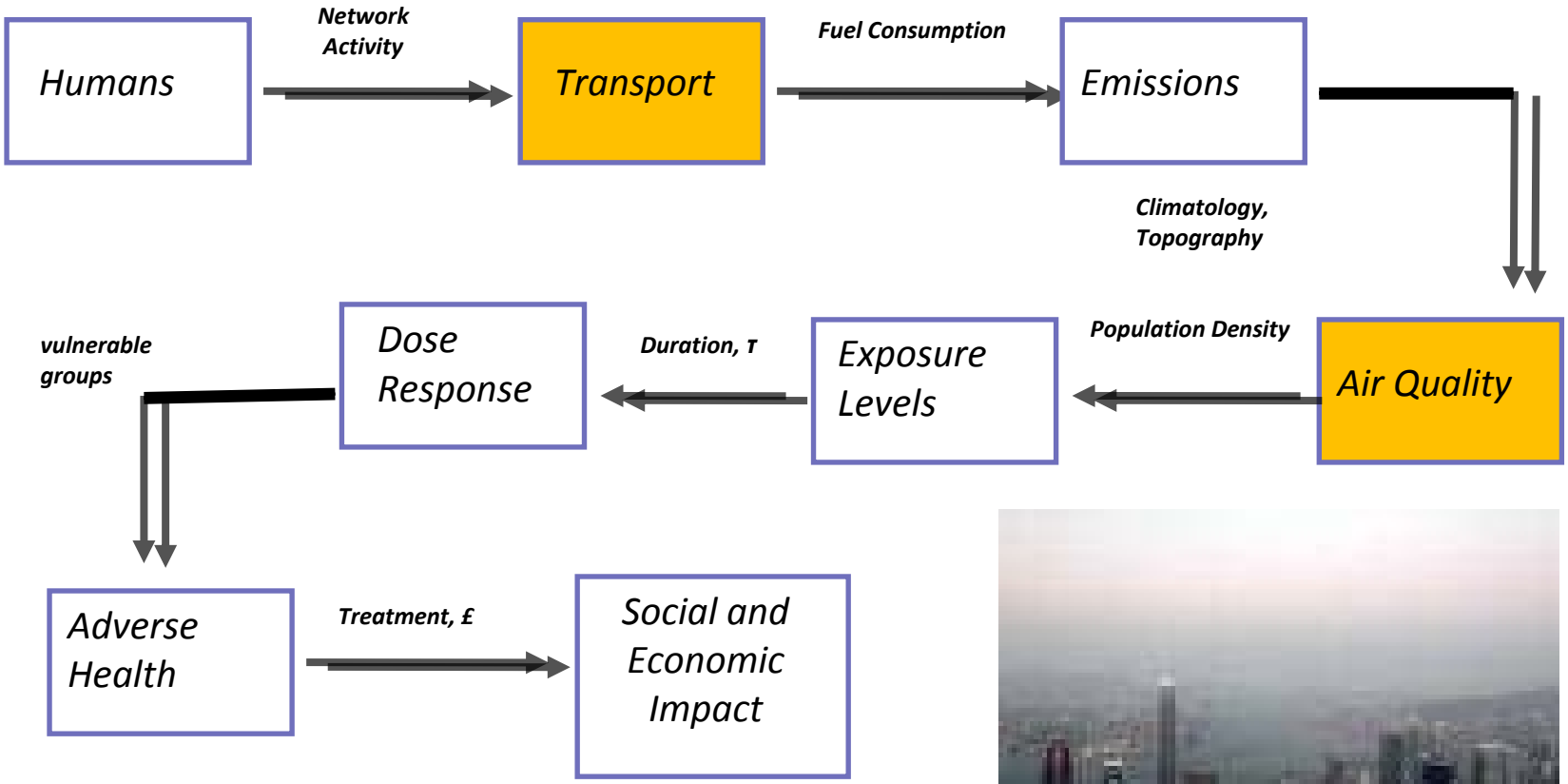
There is a strong link between transport activity and urban air quality



Likely outcomes derived through a combination of data-driven and deterministic modelling

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Mobile sensors were developed during the MESSAGE research programme

- *3 year project initiated October 2006*
- *Funded jointly by EPSRC and DfT (~£4m), 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 heterogeneous ad-hoc mobile and fixed sensors*

EPSRC

Department for Transport

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Imperial College London | Newcastle University | University of Cambridge | University of Southampton | University of Leeds

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MESSAGE utilised a mobile network of wireless sensors

- Heterogeneous fixed and mobile sensors on infrastructure, vehicles and people
- Sensors communicate via wireless and wired networks
- Positioning via GPS + wireless ranging
- Integration of processing along the data path
- Multiple application studies in different local contexts

EPSRC

Department for Transport

MESSAGE aims to link transport activity with resulting air quality in order to reduce its impact on society

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MESSAGE addressed three key research areas

Field Units

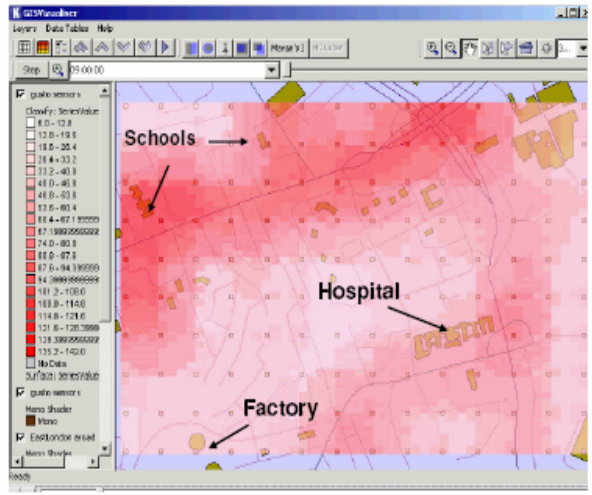
- Sensors
- Positioning
- Communications

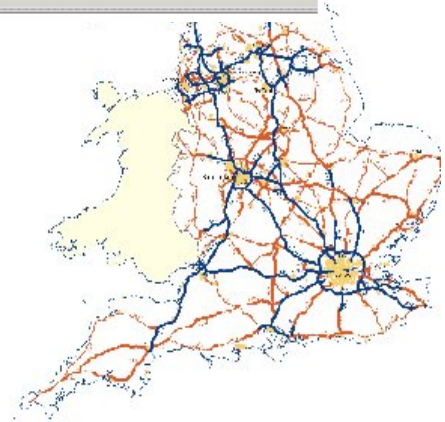
eScience

- Scalability
- Distributed data mining
- Online estimation of pollutant hotspots

Management of transport and environment

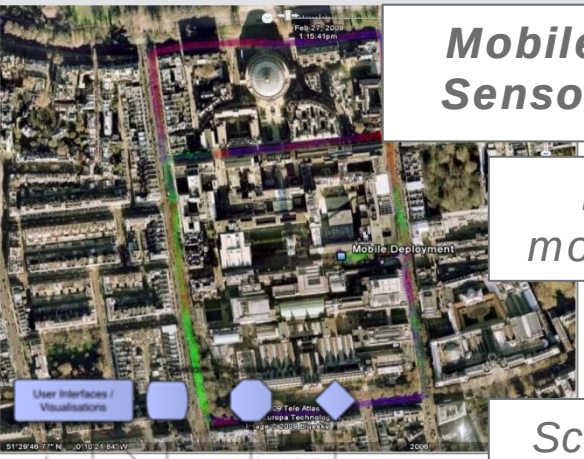
- Traffic management and control
- Traveller information
- Transport Planning activities





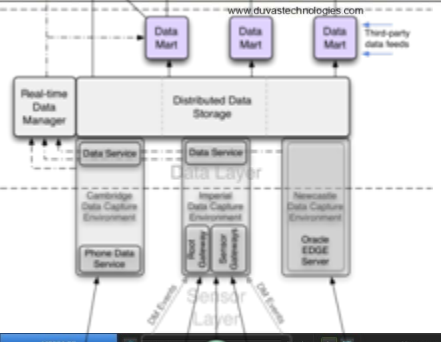
The MESSAGE "System"

Measurement and Modelling

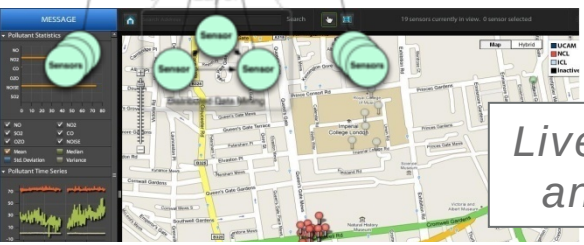


Mobile Wireless Sensor Network

Fixed and mobile sensors



Scalable data-management



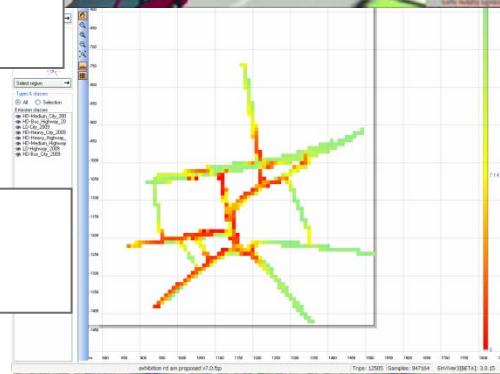
Federated database query

Live display and analysis tools

On-Demand Modelling

Scenario models

Pollutant Emissions



Pollutant Dispersion

Impact Analysis

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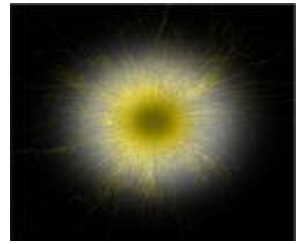
Part of MESSAGE has been commercialised through Duvas Technologies

- *A newly created entity that sits within the Imperial Innovations Incubator that combines the academic and engineering excellence of Imperial College with the commerciality of the real world*
- *The result of 10 years R&D led by Dr John Hassard, the Chairman, and the extensive resources of Imperial College*
- *Jointly owned by Imperial Innovations [Aim Listed] and private capital [MDT] with significant knowledge and strong links with the aviation industry*
- *Duvas have been actively engaging with end-users and other stakeholders in order convert a perceived technological advantage into a commercially viable business model*





Duvas Technologies

www.duvastechnologies.com

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Cross disciplinary inputs

EPSRC
Engineering and Physical Sciences Research Council

dti

message

the GUST project

InforSense

Verdetech Investments

PPARC

NATURAL ENVIRONMENT RESEARCH COUNCIL

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Basis of the Technology

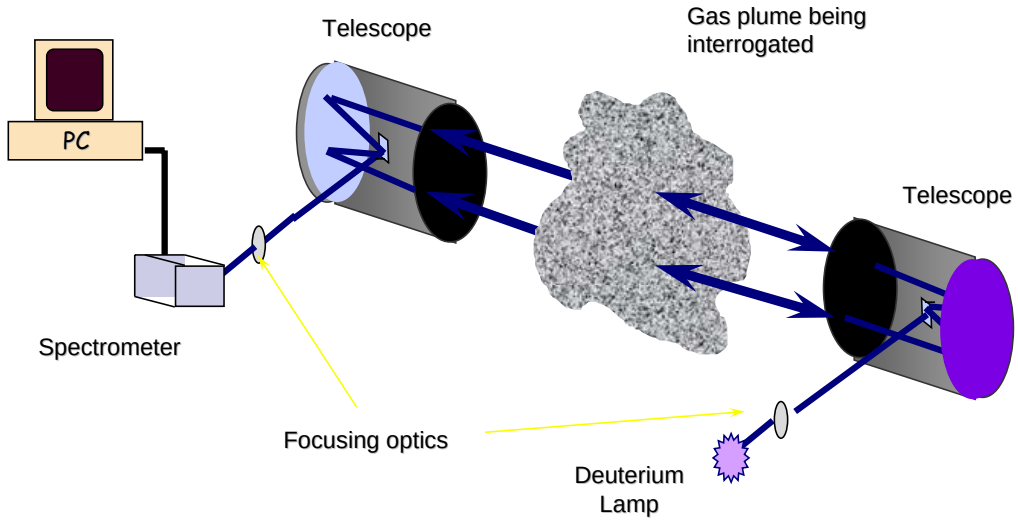
- *Duvas is an acronym for Differential UV Absorption Spectroscopy. It is based on (DOAS) technique used for remote sensing to retrieve volume mixing ratios of trace atmospheric absorbers over long optical paths.*

- *Further stages of noise reduction then take place on the data before the differential spectra are obtained.*

- *Reference spectra for all the species under investigation are then dynamically matched using a sophisticated non-linear algorithm.*

- *The **DuvasSolver** utilises a range of statistical analysis tools to aid further noise reduction whilst maintaining real-time sensitivity.*

- *The entire disentanglement process is extremely rapid and takes only a fraction of a second allowing for rapid retrieval updates.*



Open Path Configuration

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

Beer-Lambert Law

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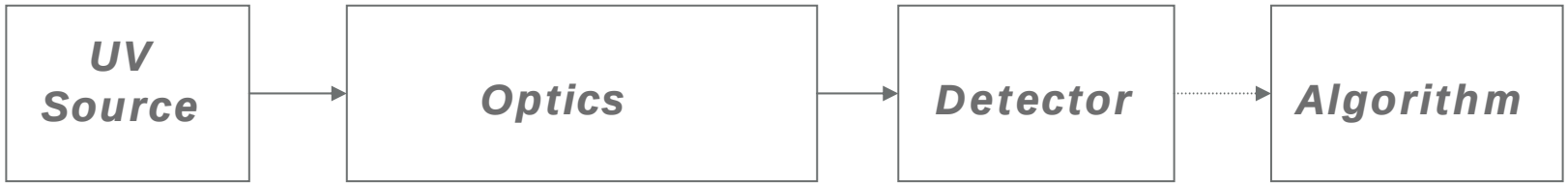
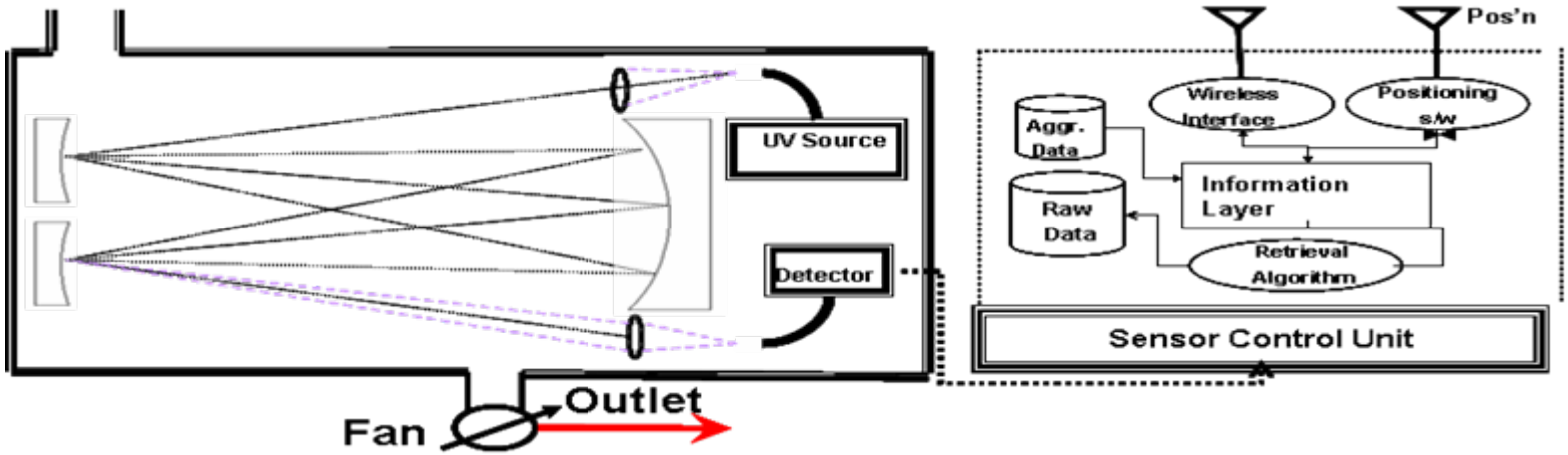
Mobile Sensing Technology



- High throughput UV-DOAS system (~ 1Hz sampling time), continuous flow
- Robust algorithm for multiple pollutant concentration retrievals, on-board processing/comms
- Geared for networking of multiple units within a sensor network
- Can potentially distinguish between different emission products (e.g. aircraft vs. vehicle emission)
- Combines Beer Lambert Law with a Multi-pass White Cell (MWC) optics



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Early Prototyping

What if you could see the air you breathe? Introducing the D1000 Series

It is estimated that around 30% of London school children suffer pollution-related asthma each year, whilst over 5000 people die prematurely of non-smoking related respiratory failure.

Air pollution costs the UK economy millions of pounds per year!

- *Duvas technology can provide measurement of a comprehensive range of gaseous pollutants:*
  - *Primary: NO, NO_2, SO_2, Ozone, and Benzene*
  - *Secondary: Ammonia, Ethylbenzene, Toluene, Formaldehyde, Acetaldehyde, Hydrogen Sulphide,1-3 Butadiene, Isoprene, (p/m/o)-Xylene, Benzaldehyde, Phenol, (p/m)-Cresol, Carbon Disulphide, etc.*
  - *CWA/TIC: Chlorine, Hydrogen Cyanide, Phosgene, Cyanogen Chloride, GB, HD*

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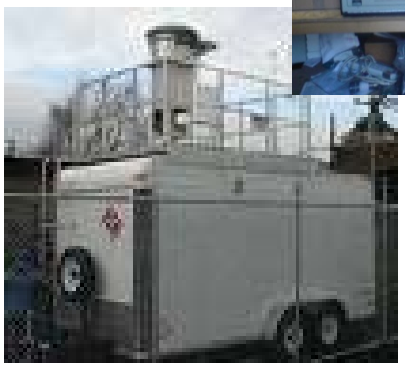
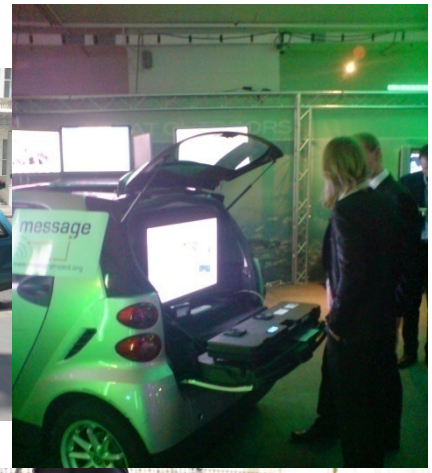
Development Prototype and Testing

Fixed Monitoring Site

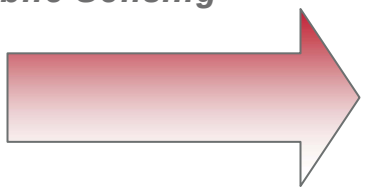


Mobile Monitoring Station

Vehicle-based Monitoring



Mobile Sensing



Portable Monitoring

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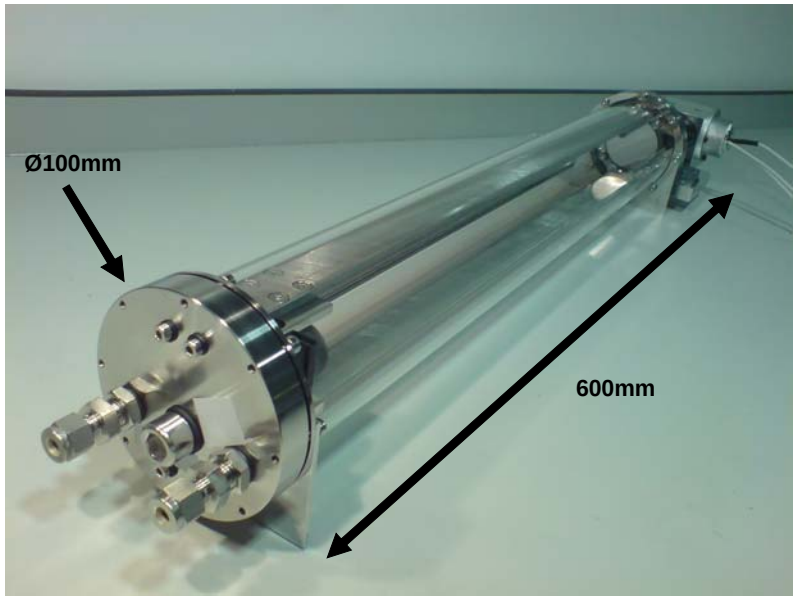
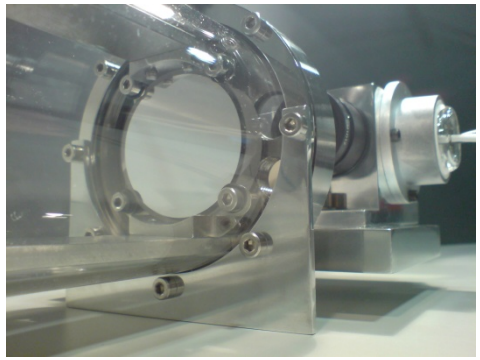
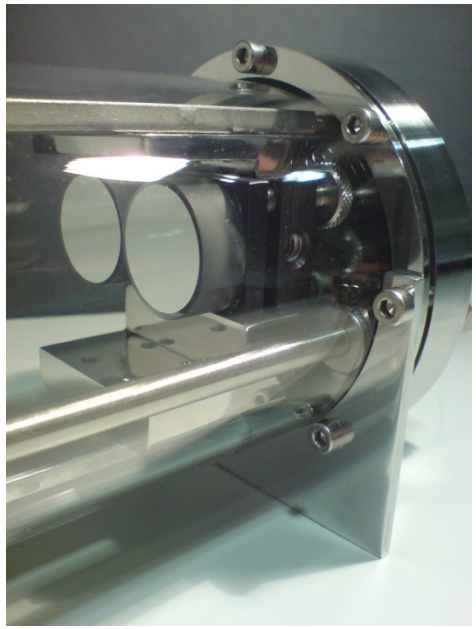
Component Development – Technology Strategy







- *Modular Component Development*
- *Working towards MCERTs*
- *In-house Automated Test Facility*
- *Technology Testing by NPL*
- *Further testing by TNO/AM*

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Duvas D1000 Sensor

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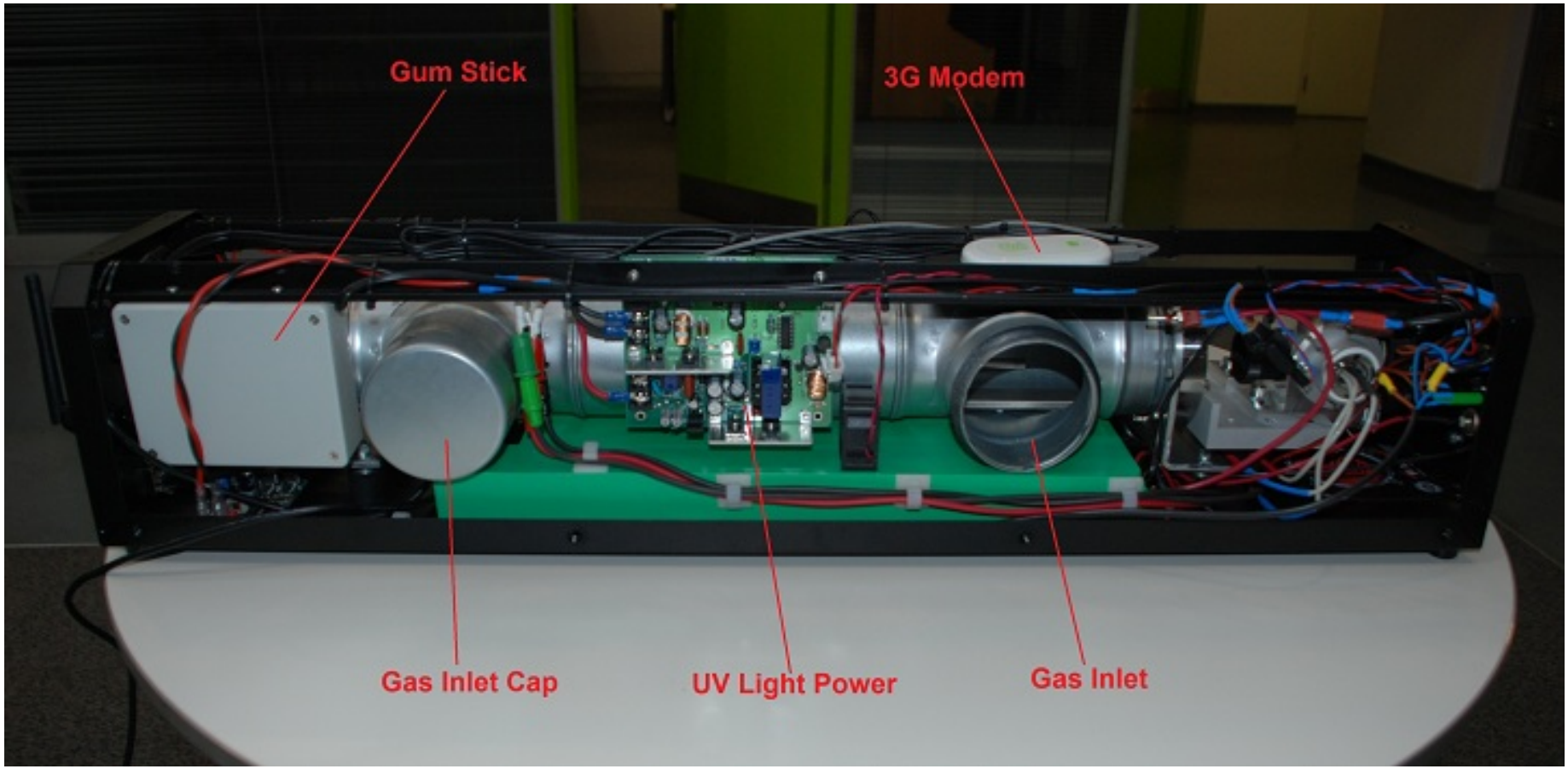
D1000 in-lab Calibration



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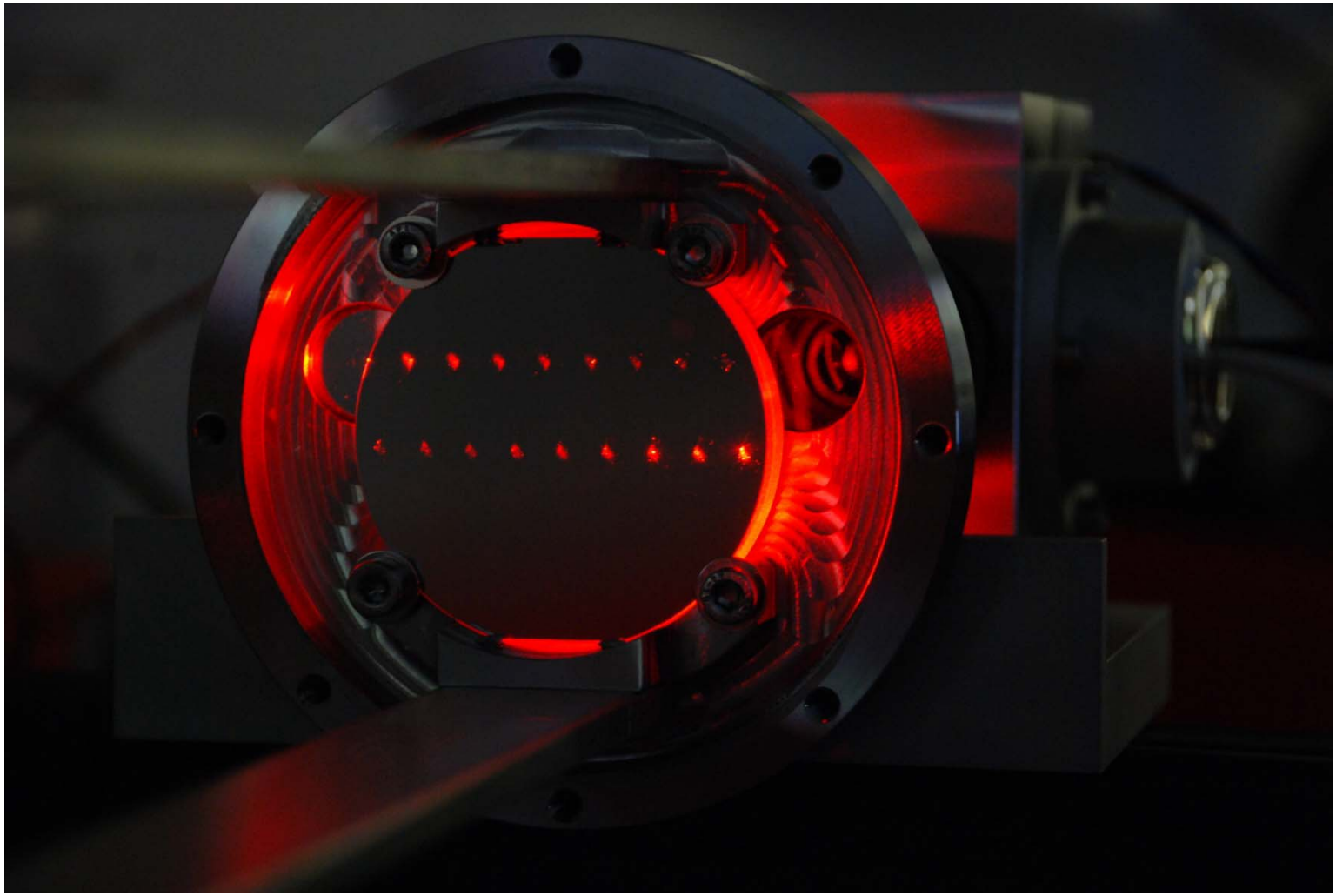
Manufacturing, Alignment



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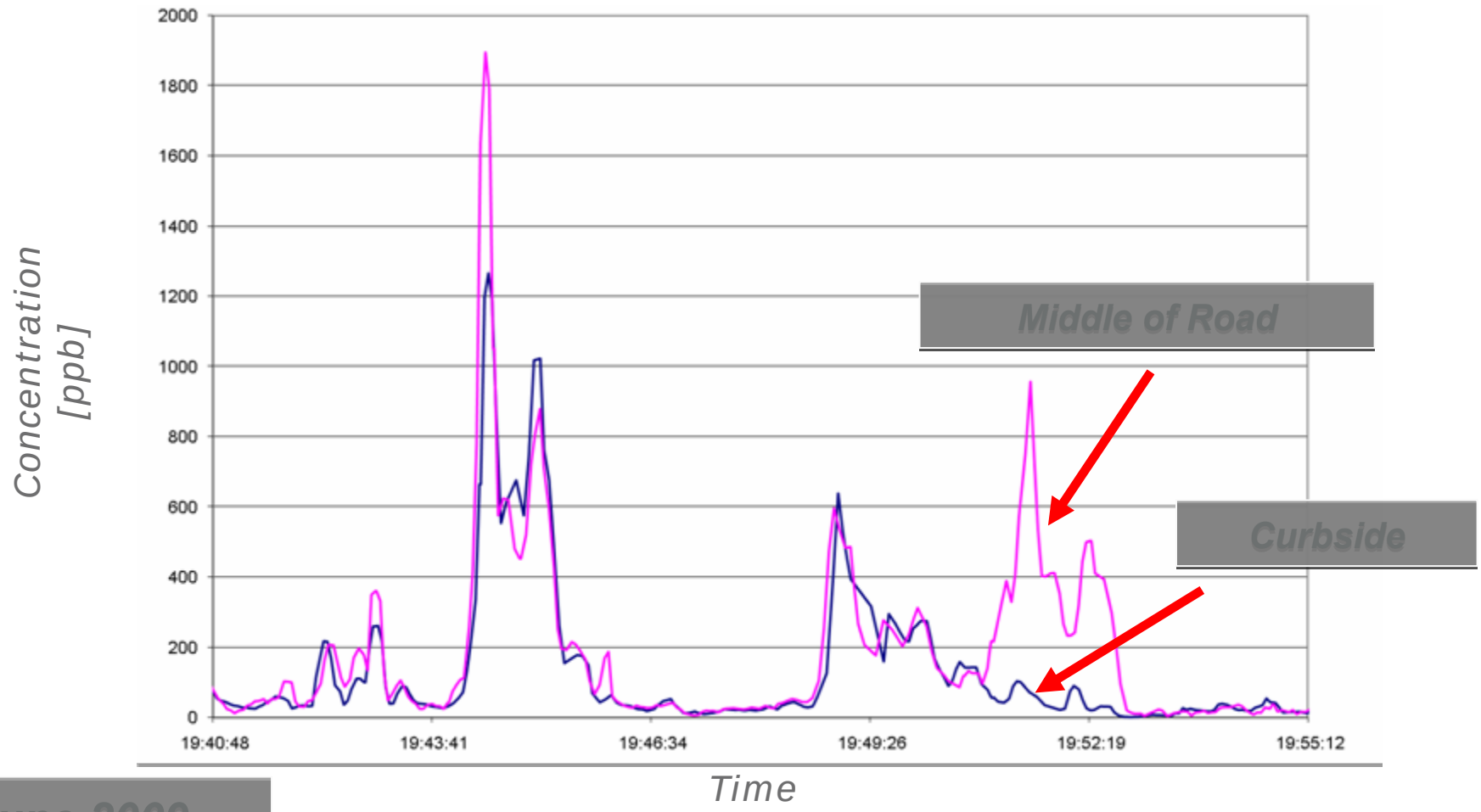
Comparison of Two Portable Units
Walked together, parted temporarily across busy road ~5m



June 2009

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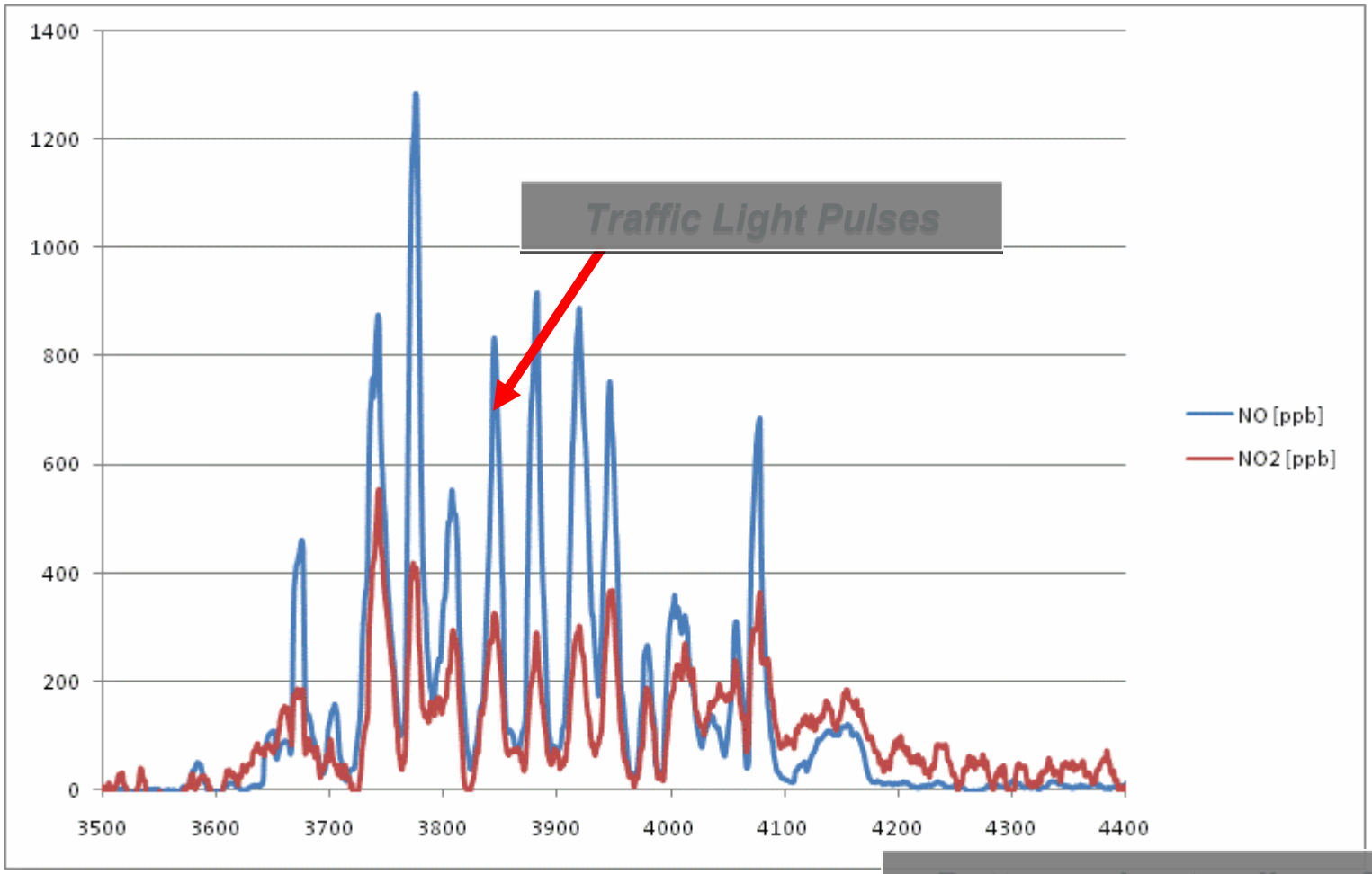
NO/NO2 Back to Back Comparison
Sensor Stationary at Busy Junction



June 2009

Better understanding of the nature of high levels

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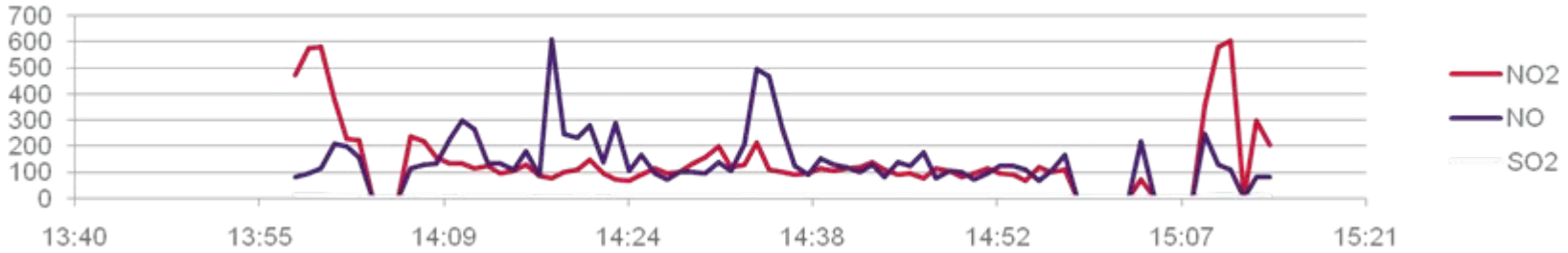
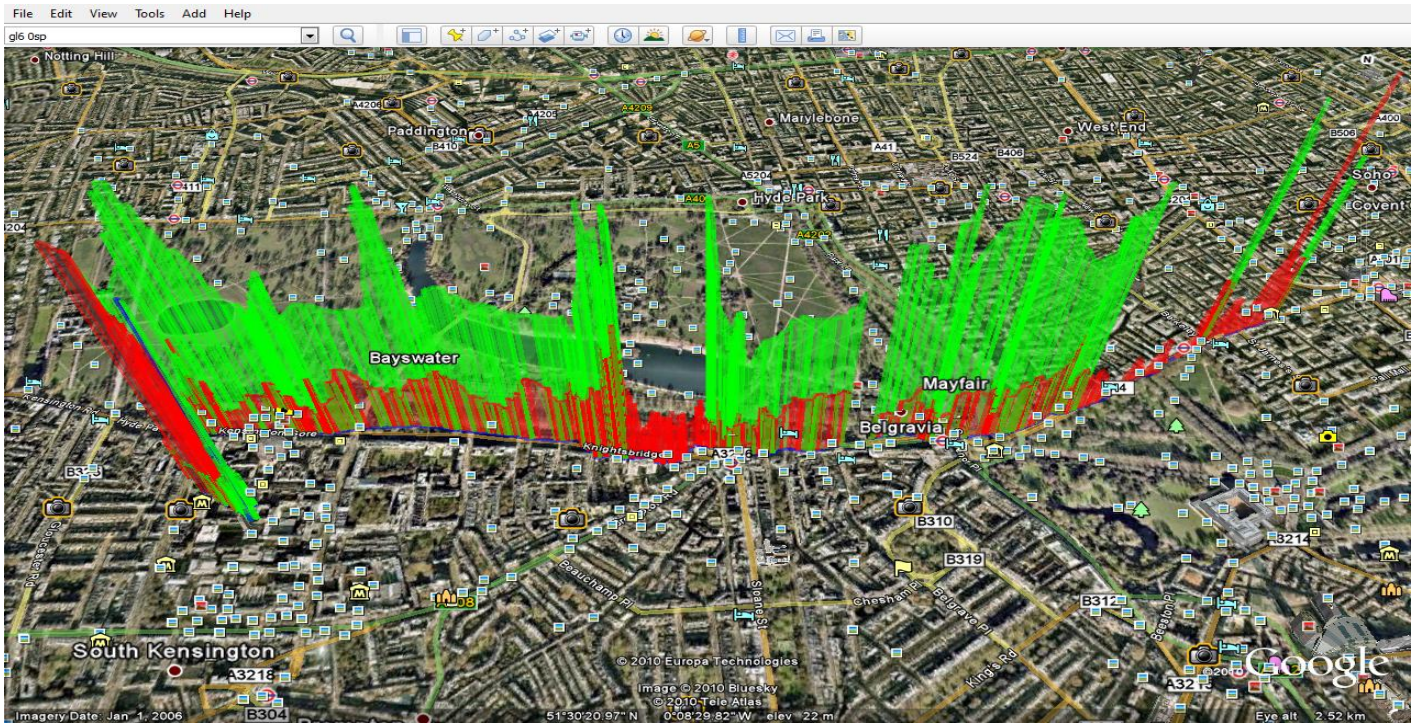
Data – Piccadilly Circus 10/12/2010





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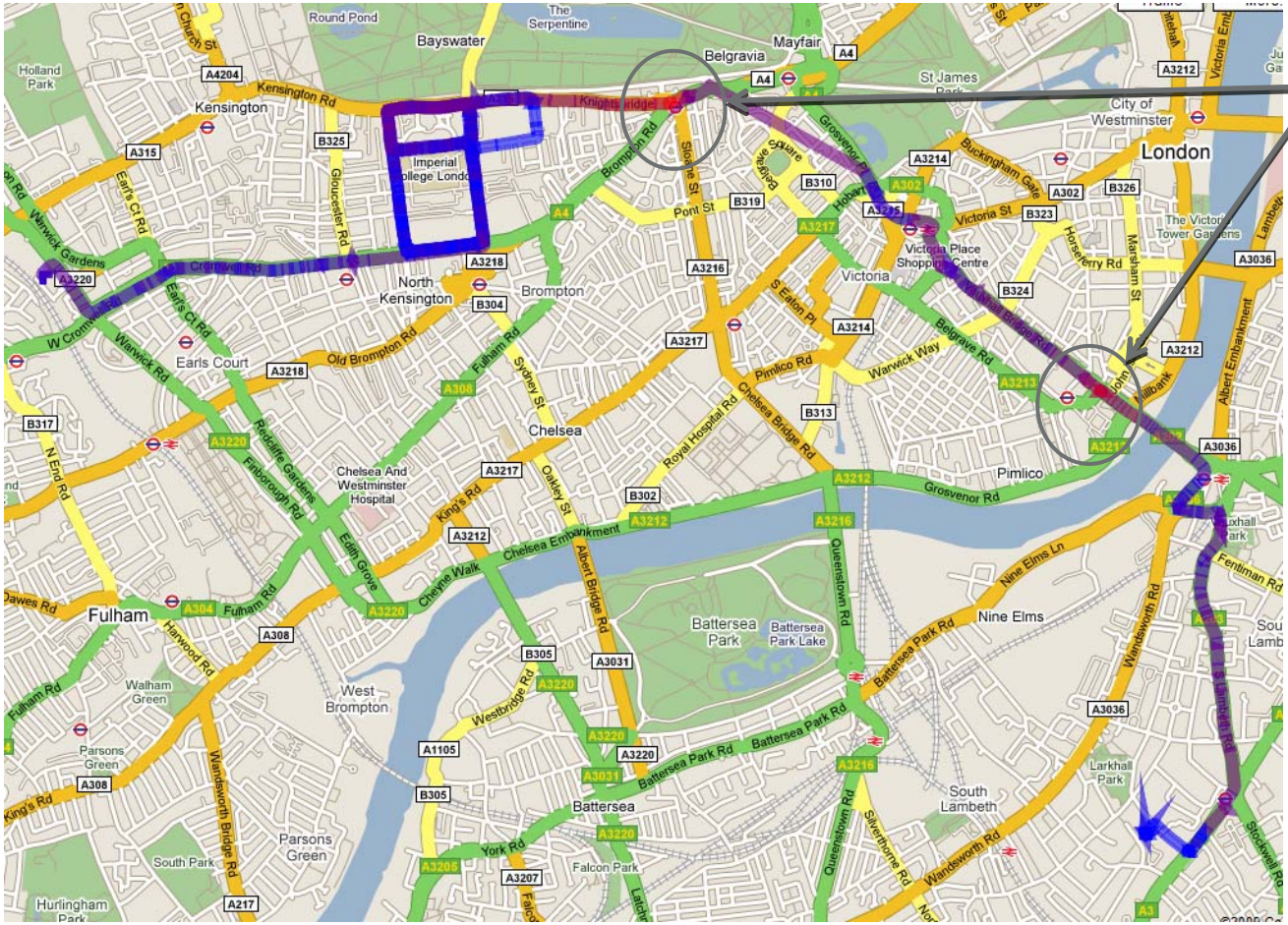
Mobile Drive Dataset - Levels of Nitric Oxide/Dioxide



'Hotspots'

High Levels

Low Levels

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Mobile Sensing – Local Mapping

Imperial College Campus (S.Kensington)

We are now armed with the ability to interrogate urban pollution levels street by street

DEFRA/RBK&C Fixed AQM site

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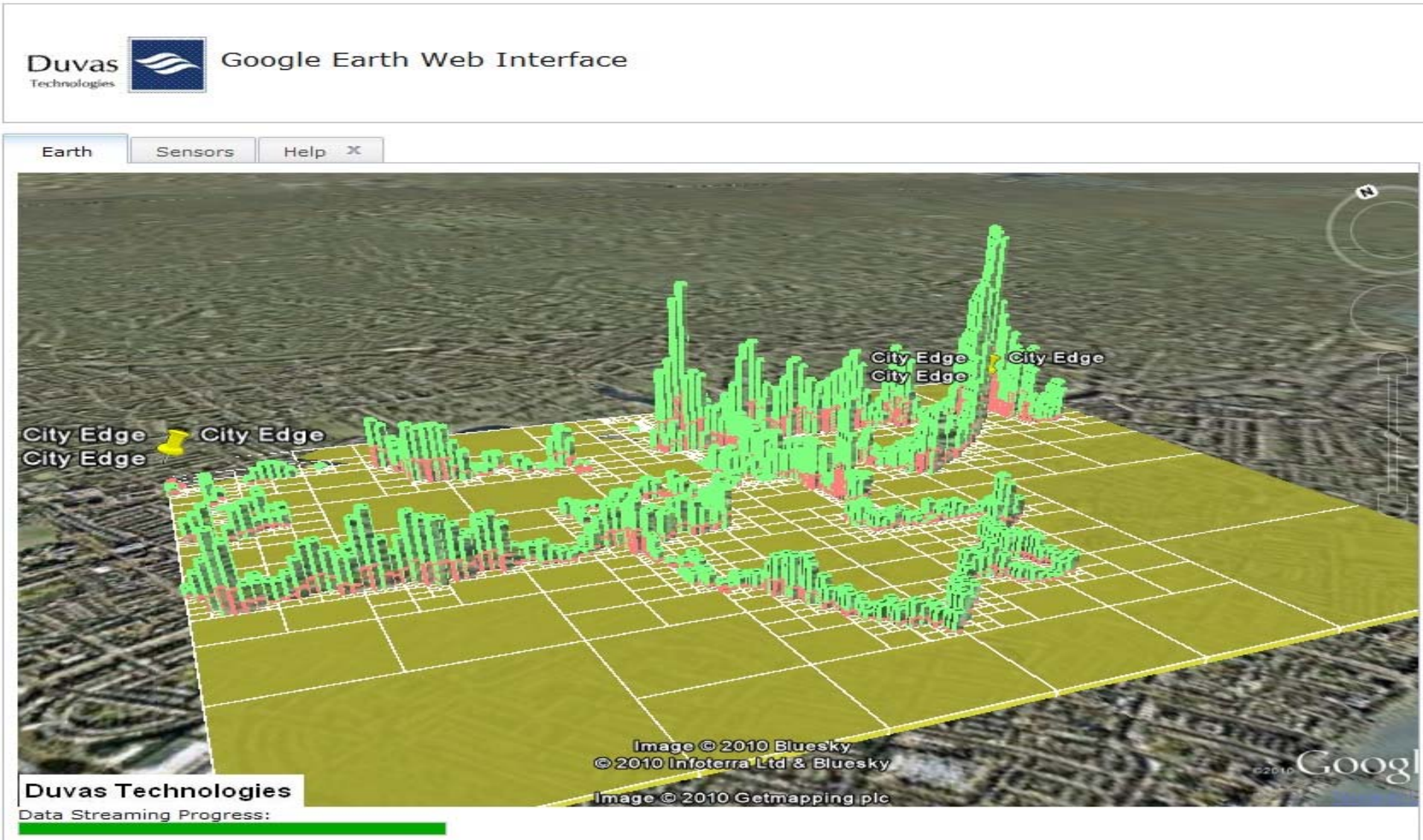
Data Management & City - Wide Mapping



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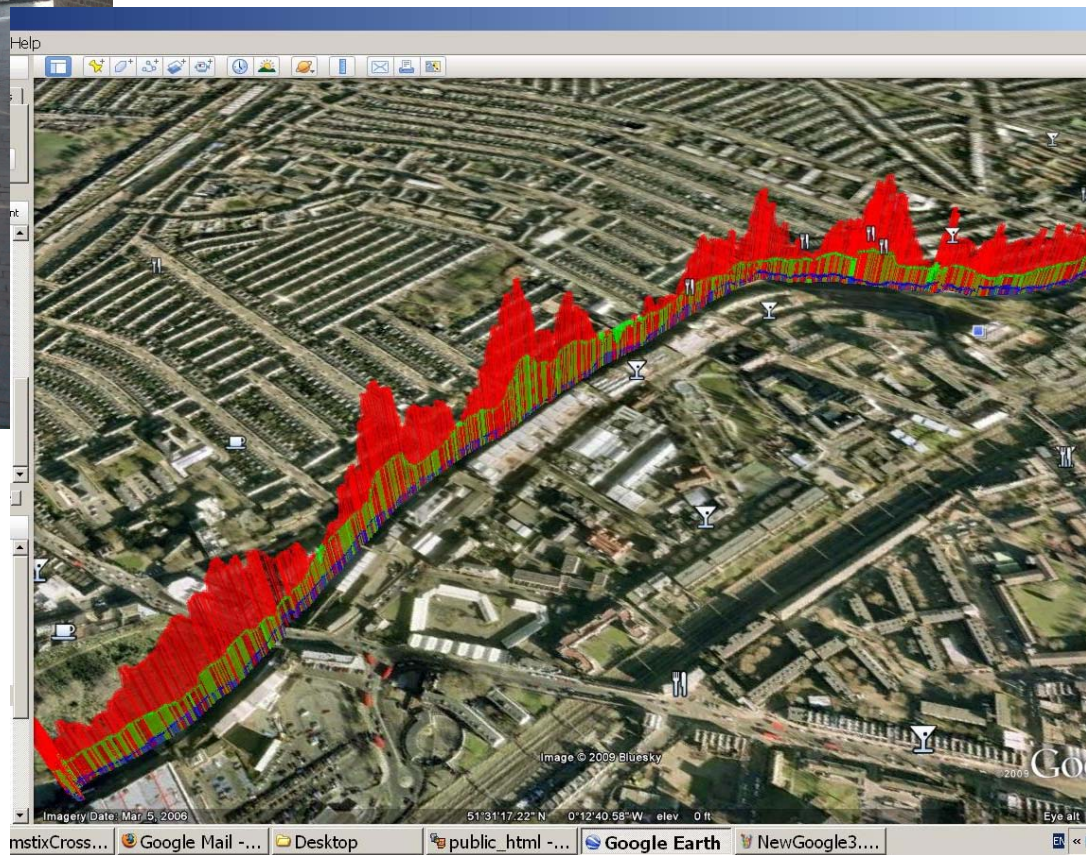
Data Management – Olympic Site Assessment



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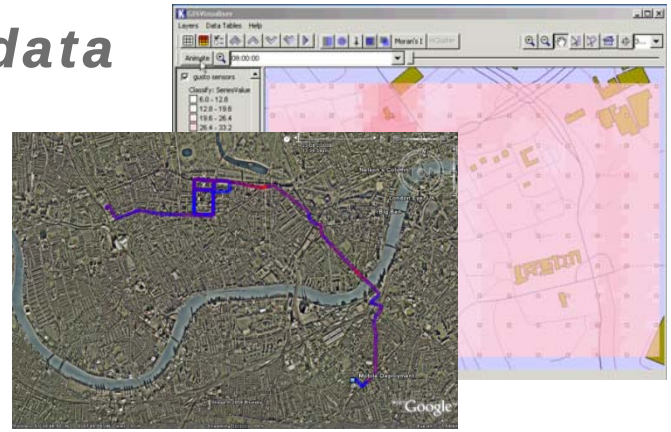
Research Challenges & Policy Implications



Informatics: Mobile data vs fixed point data

Driver exposure vs pedestrian exposure

Pollutant source apportionment

What are the implications on policy?
(Transport, Environmental, Health, Town Planning etc)

What level of public awareness should there be?

Economic affects (house pricing, fines)

Mobile Sensing represents a step-change in pollution sensing methodology

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Further Development Areas

- *Increase Scope and Sensitivity of Sensors*
- *Develop (mobile) Data Validation Protocols*
- *Dynamic Measurement Routines*
- *Data Representation*
- *Anomaly Research for Threat Mitigation*

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Thank you

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Units will be distributed through Air Monitors Ltd and the EUROPA Group

www.duvastechnologies.com *www.Message-project.org*