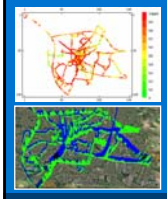
UNIVERSITY OF CAMBRIDGE

# Low-Cost Sensor Units for Measuring Urban Air Quality



**Lekan Popoola**
Department of Chemistry
University of Cambridge
oamp2@cam.ac.uk

Aphasense

message

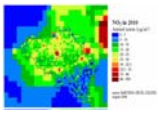
AAMG Conference, 14th October 2010

## Introduction

- Major air pollution events reported include

  Meuse Valley (Belgium) 1930, Great London Smog 1952, Los Angeles (USA)1954, Bhopal (India) 1984 and Tehran (Iran) 2005.....

- As part of mitigation measures several national, regional and local legislation have been enacted (US: The Clear Air Act 1970, EU Air quality directives 1980 and UK National Air Quality Strategy 1997)



➢ Exceedence of national limit $NO_x$

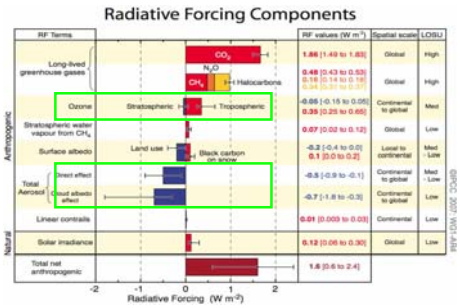
➢ Insufficient temporal and spatial data

UNIVERSITY OF CAMBRIDGE

• D. J. Carruthers *et al. 8th Int. Conf.* Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes.
• F. Fierens *et al.*, 2006. Estimation of the exceedance of the European NO2 annual limit value in Belgian cities and streets during the period 2005 - 2010 – 2015.

2

## Chemistry/climate linkages (IPCC AR4)




UNIVERSITY OF CAMBRIDGE

3

## Mobile Environmental Sensing System Across Grid Environment (MESSAGE)

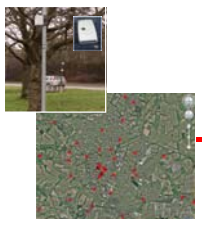
- MESSAGE project (2006 – 2009 ) was aimed at addressing part of this limitations and we at University of Cambridge developed a portable handheld sensor devices.
- Post MESSAGE – development/deployment of static units (2010).
- Sensor units incorporates
  - ➢ electrochemical sensors
  - ➢ Temperature sensor
  - ➢ RH sensor
  - ➢ GPS module
  - ➢ GPRS module

Imperial College London · LEEDS · Newcastle University · UNIVERSITY OF CAMBRIDGE

UNIVERSITY OF CAMBRIDGE

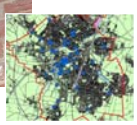
4

## Aim: Development of a low cost gas sensor networks for real time monitoring air quality





???



Yes !!!

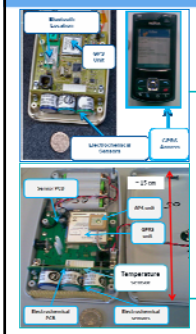
• *Low cost, portable, real-time and better spatial information.*

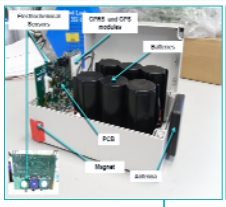
UNIVERSITY OF CAMBRIDGE

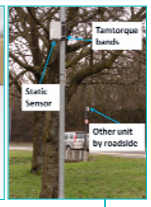
• © 2010 Tele Atlas Image © 2010 The GeoInformation Group © 2010 Infoterra Ltd & Bluesky Image © 2010 Getmapping plc
• © 2010 Google – Map data © 2010 Basarsoft, Europa Technologies, Geocentre Consulting, Tele Atlas , Transnavicom

5

## Sensor types- Handheld and static





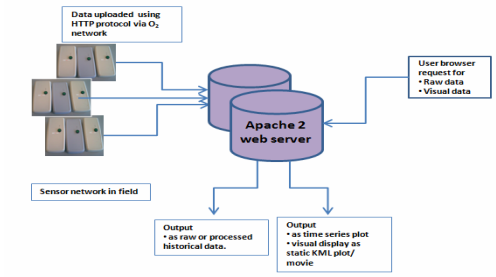

**Handheld units**

**Static units**

UNIVERSITY OF CAMBRIDGE

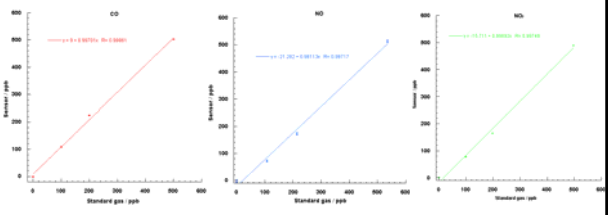
6

## Data mining, transmission and visualisation





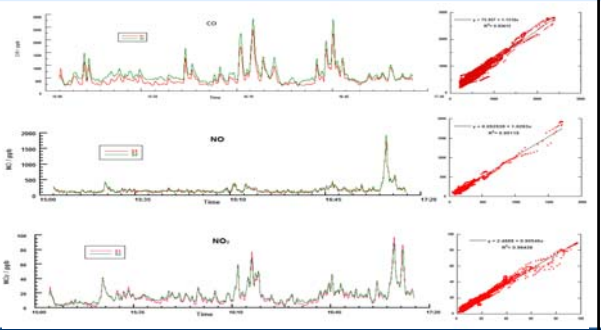

## Laboratory calibration of sensor unit



High selectivity, sensitivity and quantitative response at ppb levels
*(Laboratory conditions, non – ambient concentrations)*



## Sensor reproducibility



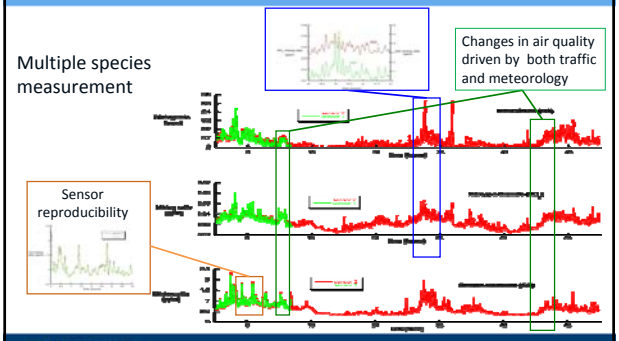


## How reliable are the sensors?

Multiple species measurement

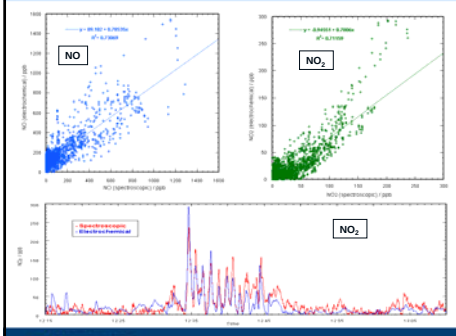
Changes in air quality driven by both traffic and meteorology

Sensor reproducibility





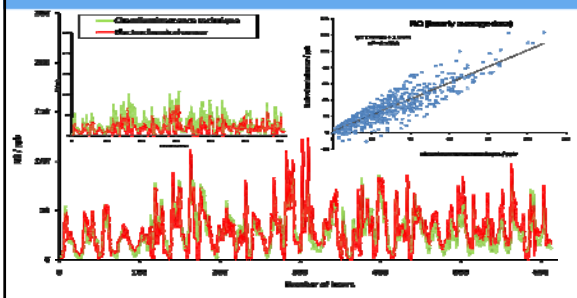
## Comparison with spectroscopic (DUVAS) technique




- Good agreement with spectroscopic technique under ambient conditions.
- Sensor able to "fingerprint" traffic related sources (*selectivity*).
- Generic calibration shown



## Comparison with chemiluminescence technique (scaled data)



- Good quantitative agreement with a roadside monitoring unit over a long period *ca* a month (*temperature corrected)*

## Deployments to date : handheld units



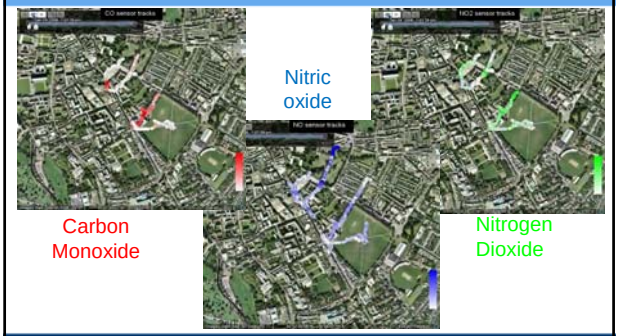



## Cambridge deployment I

- 2 hour deployment (including evening rush hours) 29/01/2009.
- 6 handheld sensors measuring CO, NO and $NO_2$
- Transport mode: walkers
- Zones of interest include park, bus station and traffic junctions.
- Covered approximately 0.7 $Km^2$



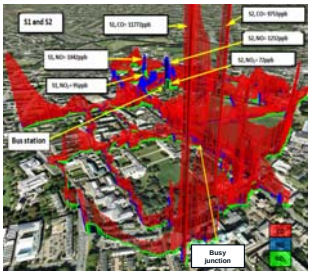
## Multi-species real time mobile measurements of air quality in complex environments

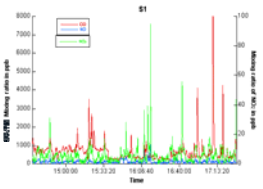







## Results: Temporal and spatial variation in air quality.



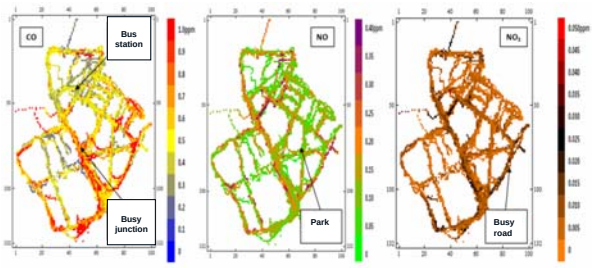



- Urban composition is highly structured, variable, interdependent and complex….
  - ➢High pollution events for NO and $NO_2$ close to bus station.
  - ➢ High CO measurement associated with busy road and junctions e.g. Regent street - Lensfield road junction.





## High temporal data for spatial identification of “hotspots”.






## Cambridge deployment II

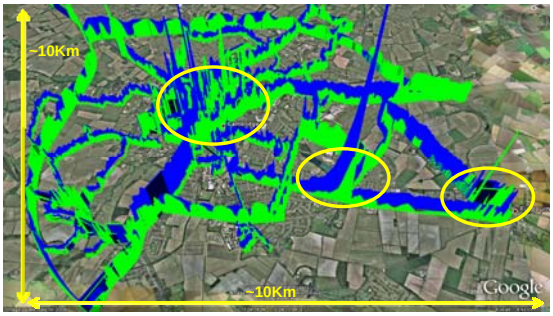
- 3 hour deployment (12/08/2009)
- > 40 handheld sensor units measuring CO, NO, $NO_2$, $CO_2$ and VOC.
- 3 transport mode – walkers, cyclist and vehicles.
- Approximately 100$km^2$ covered.
- > 150, 000 measurements.

## Cambridge deployment August 2009





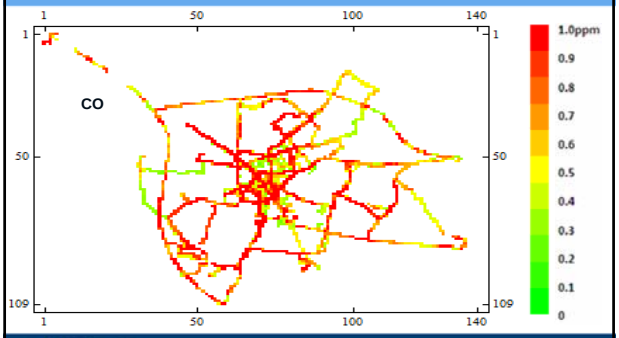

## Cambridge deployment August 2009: $NO_X$: remarkable level of detail.





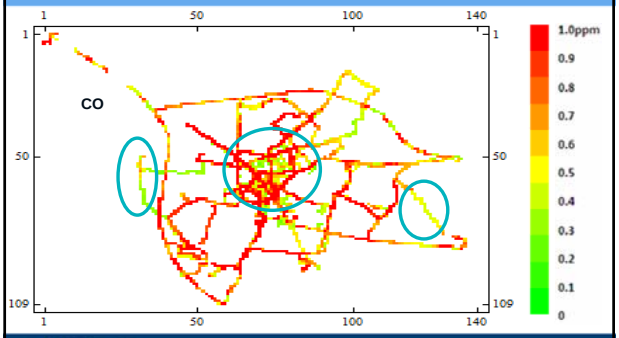



## High spatial information



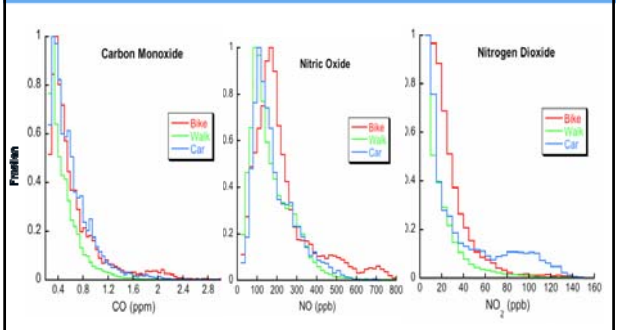



## High spatial information: *low pollution routes?*



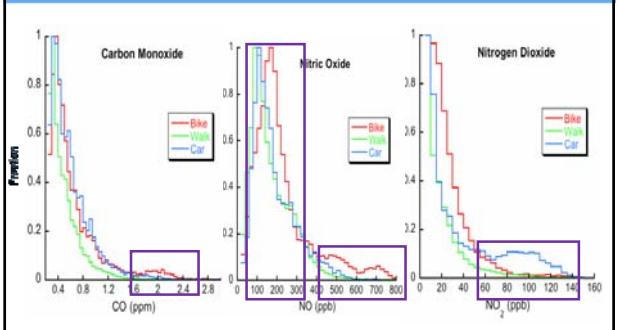



## Data analysis: Statistical ensemble indicating level of exposure

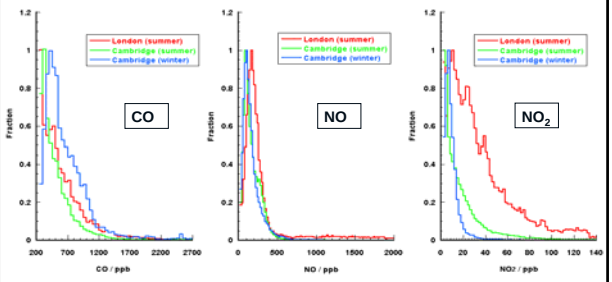





## Data analysis: Statistical ensemble indicating level of exposure



## London (summer) *vs.* Cambridge (summer & winter), 2009




Snapshot of variation in pollution level ……



## Static low cost sensor deployment, Cambridge, UK

>2 month deployment (March-June 2010)

>40 sensors (CO, NO, $NO_2$) , T, RH

Lamp post mounted, GPRS (GPS)

Inner city, mixed urban, rural

>25,000,000 measurements!

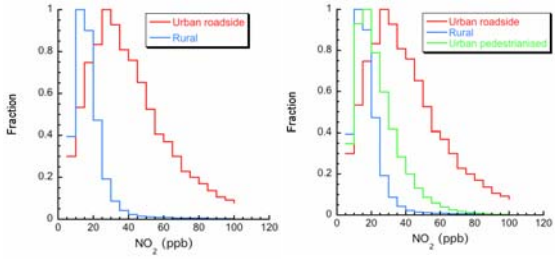


## 47 sensor nodes (CO, NO, $NO_2$) , T, RH in 10 × 10 km





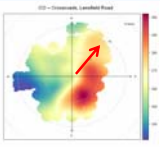

## Pollution spatially heterogeneous: $NO_2$.



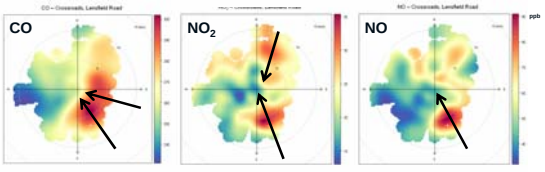

Urban roadside vs. rural (expected) differ, similarly urban site and nearby pedestrian site differ.



## Exploit knowledge of meteorology (wind) for *source attribution*

Bivariate polar plot of concentration as a function of both wind speed and direction help provide information on pollution sources






## Sensor network conclusions (caveat):

Spatial and temporal variability in air quality not captured by low density static detection sites.

High density/mobile sensor network required for:

- describing "real" air quality
- individual exposure
- source attribution

Sensors: individual calibration, baseline correction (T), ……

## Science conclusion (caveats)

•Air quality highly complex for all species in both space and time
• Snapshot of deployments show low density static air quality network is insufficient to describe urban air pollution
• Low cost sensor a better replacement for diffusion tubes.

• Resolution not as good as traditional (chemiluminescence) technique but easier to populate and relatively cheaper.

➢ New measurement paradigm?



## Further work

- Extension to more gas species
  - ➢ $O_3$, $SO_2$, VOC'S
- Particulate matter
  - ➢ $PM_{2.5}$ and $PM_{10}$



## Acknowledgements

**Cambridge Mobile Sensor Team:**

Iq Mead
Olalekan Popoola
Gregor Stewart
Jose Baldovi
Tom Hodgson
Mark Calleja
Matt McLeod
Ray Freshwater
Rod Jones

**Imperial College, London:** Jeremy Cohen & Robin North

**DUVAS Technologies:** Steve Wilkins

**Environmental Department, Cambridge City Council:** Jo Dicks & Anita Lewis

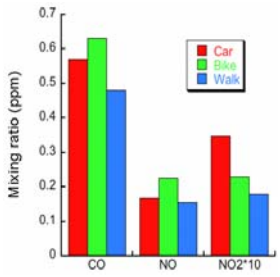
Alphasense

message





## Statistical assessment of mobile A/Q data by transport mode






## Real time detection of point emission sources

Individual aircraft movements evident in sensor network data…