What have we learnt from 20 years at Marylebone Road?

David Green

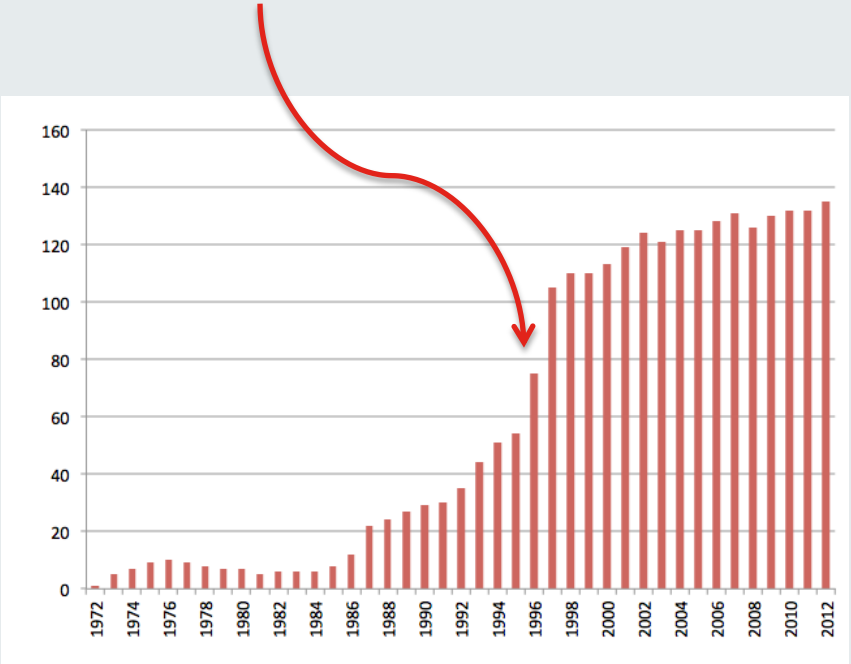
LAQN Seminar 13th July 2017

Where it all began 1996

The brief…

- Department of the Environment
- Widespread expansion of AURN
  - Acceptance that multi-pollutant measurements were required
- Specification
  - 'Establish a fixed air pollution monitoring site in London at the kerbside in a street canyon location'
  - 1-5 metres from kerb
  - a congested canyon street (ideally with more than 25,000 vehicles per day)
  - established in a location at which exposure of the public may occur.

Large – scale expansion of AURN



Number of AURN Sites

Where to put it?

- Where to locate a large (6m) monitoring cabin?
- Possible locations:
  - Marble Arch
  - Southampton Row
  - Marylebone Road
- Marylebone Road best fulfilled brief:
  - Wide pavement
  - Broad street canyon
  - Traffic flow 60-80,000 vehicles per day
  - Hundreds of people queuing outside Madame Tussauds for hours at a time
- Practicalities
  - LA planning permission
  - Highways Agency permission
  - Trial digs, foundations, equipment purchase etc.

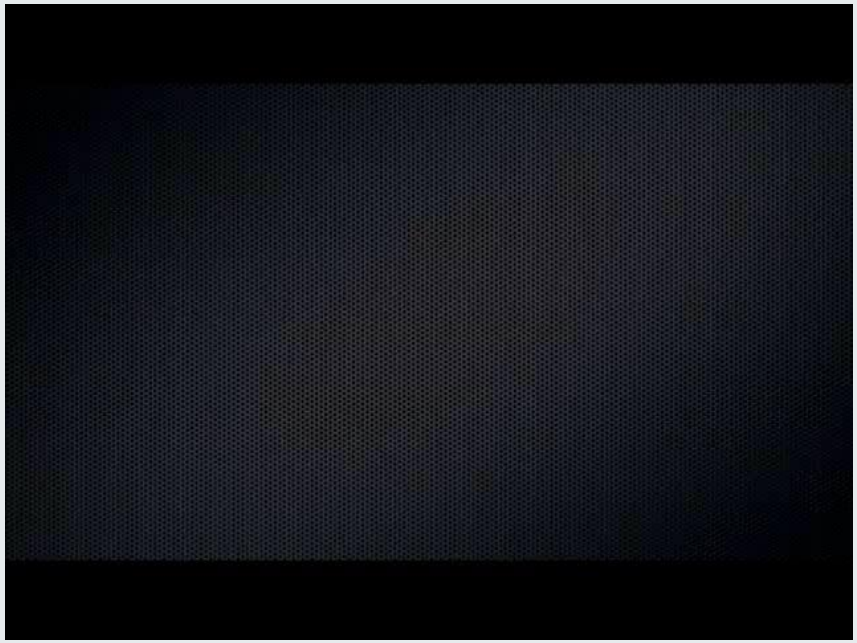
Marylebone Road over the years....

Marylebone Road now

Photo credit: Caroline Teo

What is measured routinely?

- NO_X, NO_2, SO_2, O_3
- Hydrocarbons (30+ ozone precursors)
- PM_{10} & $PM_{2.5}$ mass
  - TEOM, FDMS, reference method
- PM chemical composition
  - Black Carbon
  - Elemental and Organic Carbon
  - Metals (Cd, As, Ni, Pb, Co, Cr, Cu, Fe, Mn, Se & V)
  - PAHs
  - Anions and cations (Na, K, Mg, Ca, NO_3, SO_4, Cl, NH_4)
- Particle size (12-600nm)
- Particle count >7nm
- Meteorology
  - wind speed, direction, T, RH
- Traffic
  - Speed, vehicle class (6 lanes)




Measurements

What makes Marylebone Road a good test bed?

Advantages

- High concentrations
- Test linearity across wide range
- No problem worth limits of detection
- Lots of other measurements
- Plenty of space

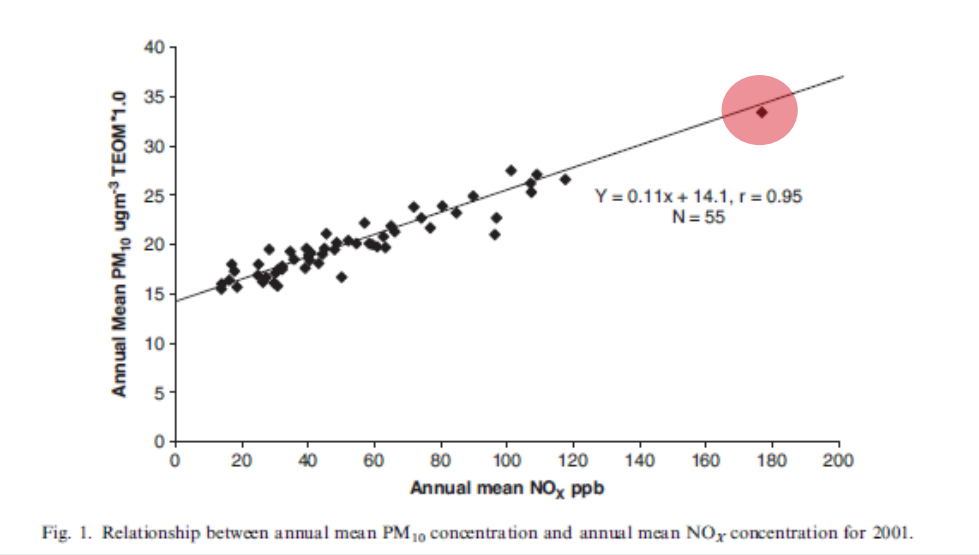


Fig. 1. Relationship between annual mean PM_{10} concentration and annual mean NO_X concentration for 2001.

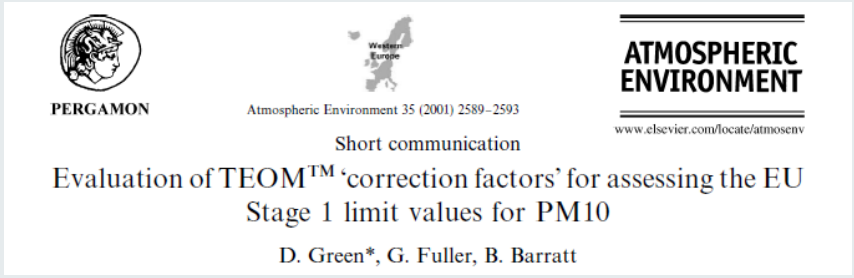
Disadvantages

- Lack of heterogeneity
- Slow moving traffic
- Lots of potential interferences
- NO_X and NO_2
  - High % NOX
  - Rapidly changing concentrations
- Particulate matter
  - High conc of small particles
  - High conc of large particles
- It's also rather dirty…

Fuller, G. W. and D. Green (2006). "Evidence for increasing concentrations of primary PM10 in London." Atmospheric Environment 40(32): 6134-6145.

Accurate measurement of PM_{10} and $PM_{2.5}$

- Reference method daily resolution
- TEOM 15 min resolution
- Advantages in high res for understanding sources
- Reduction in accuracy
- Integral to first assessments of reference method vs TEOM
- Demonstrated deficiencies of uniform 1.3 correction factor



PERGAMON

Atmospheric Environment 35 (2001) 2589–2593

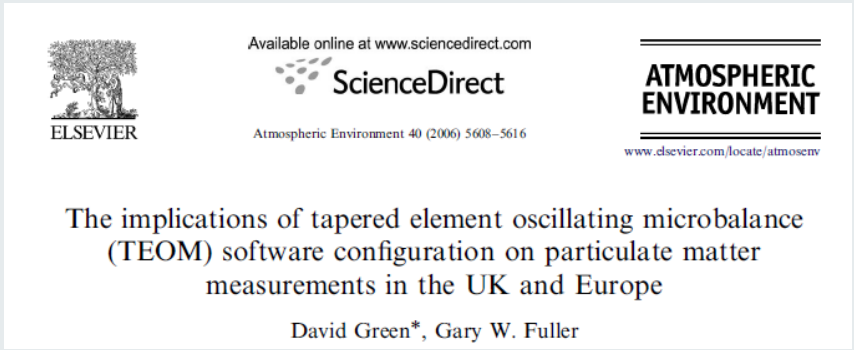
ATMOSPHERIC ENVIRONMENT

www.elsevier.com/locate/atmosenv

Short communication

Evaluation of TEOM™ 'correction factors' for assessing the EU Stage 1 limit values for PM10

D. Green*, G. Fuller, B. Barratt



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Atmospheric Environment 40 (2006) 5608–5616

ATMOSPHERIC ENVIRONMENT

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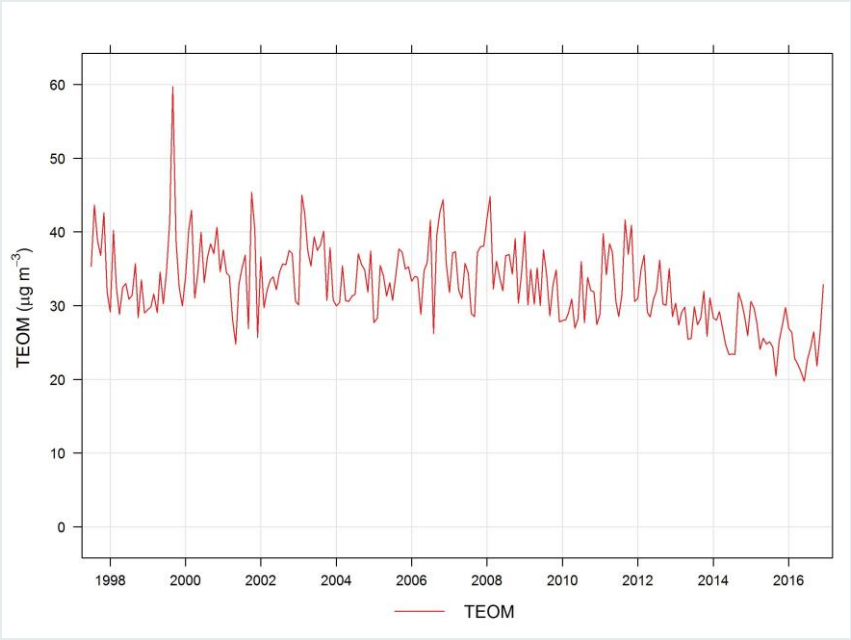
The implications of tapered element oscillating microbalance (TEOM) software configuration on particulate matter measurements in the UK and Europe

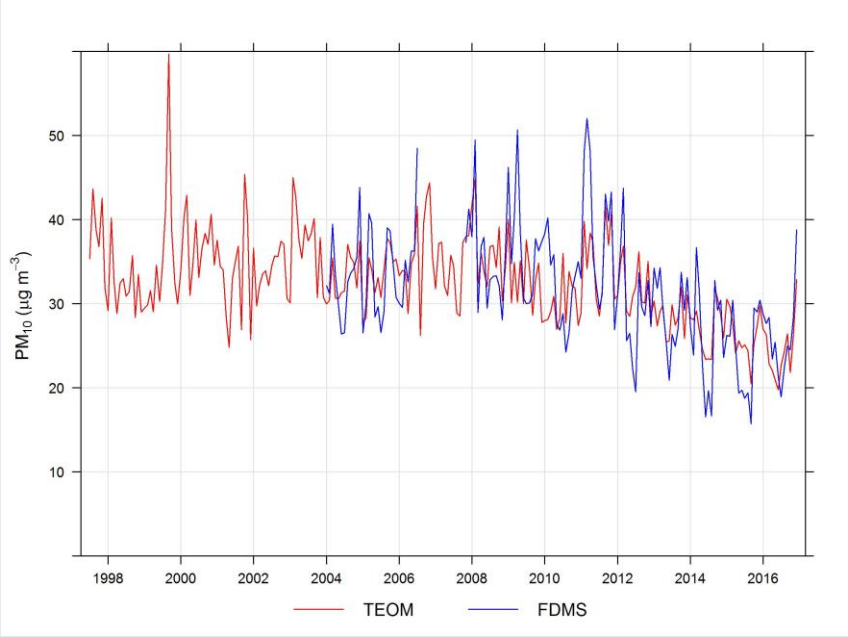
David Green*, Gary W. Fuller

- Continues as one of few remaining TEOM measurements in UK
- Provides continuity through changing measurement methods



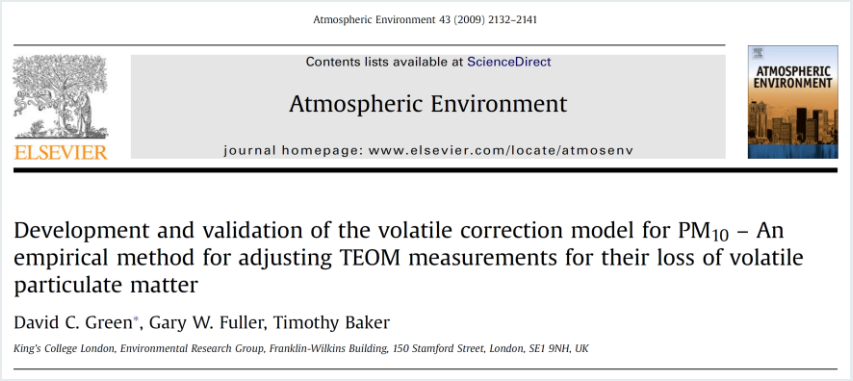
Introduction of FDMS

- First roadside measurements of FDMS in UK
- Provided reference equivalent comparisons to TEOM and filter based methods
- Changed our understanding of long-range transport episodes containing volatile ammonium nitrate
- Highlighted problems with filter type used in reference methods



Development of Volatile Correction Model (VCM)

- VCM corrects TEOM Measurements so that they are reference equivalent
- VCM required relationships between TEOM, FDMS and reference method
  - Derived UK Equivalence sites
- Testing was needed at a wide range of sites
- Uniformity of FDMS volatile PM measurement needed
  - Across geographical range
  - Site type
- Fundamental understanding of FDMS volatile PM measurements



Atmospheric Environment 43 (2009) 2132–2141

Contents lists available at ScienceDirect

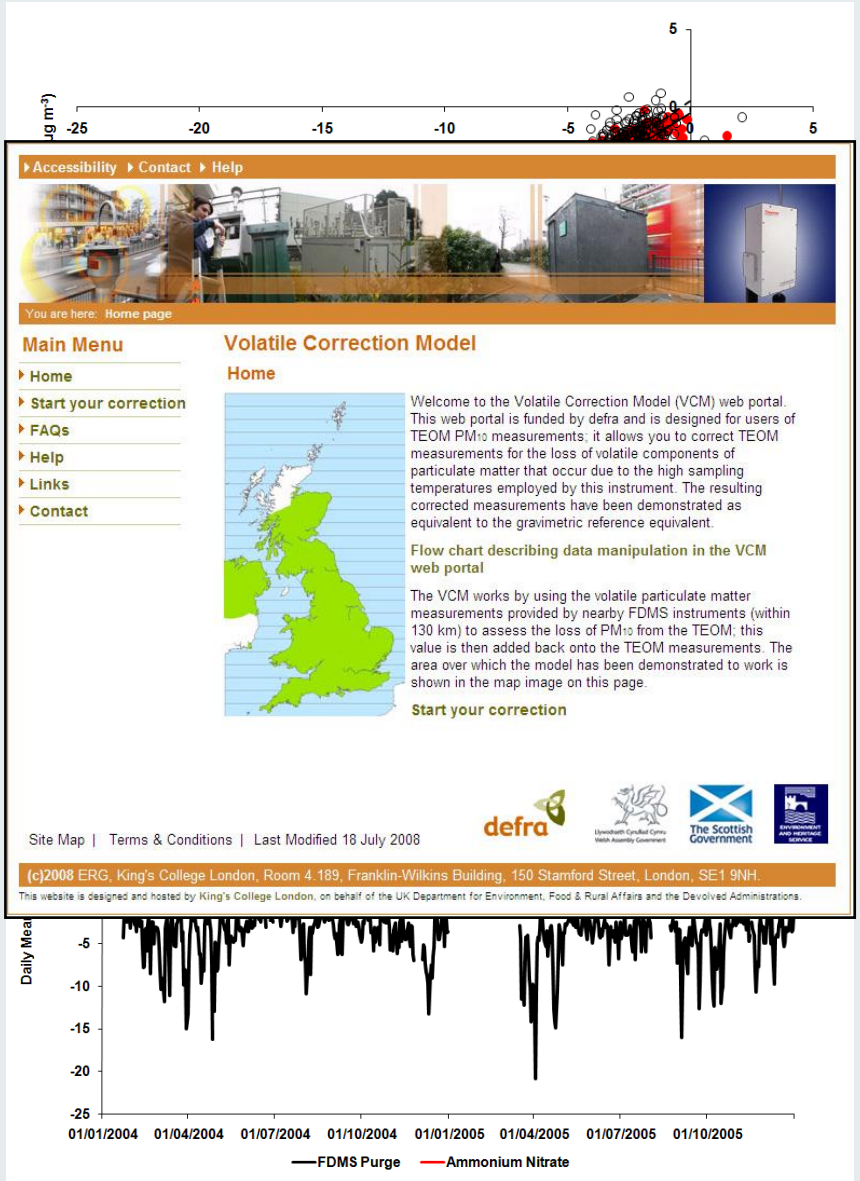
Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Development and validation of the volatile correction model for PM_{10} – An empirical method for adjusting TEOM measurements for their loss of volatile particulate matter

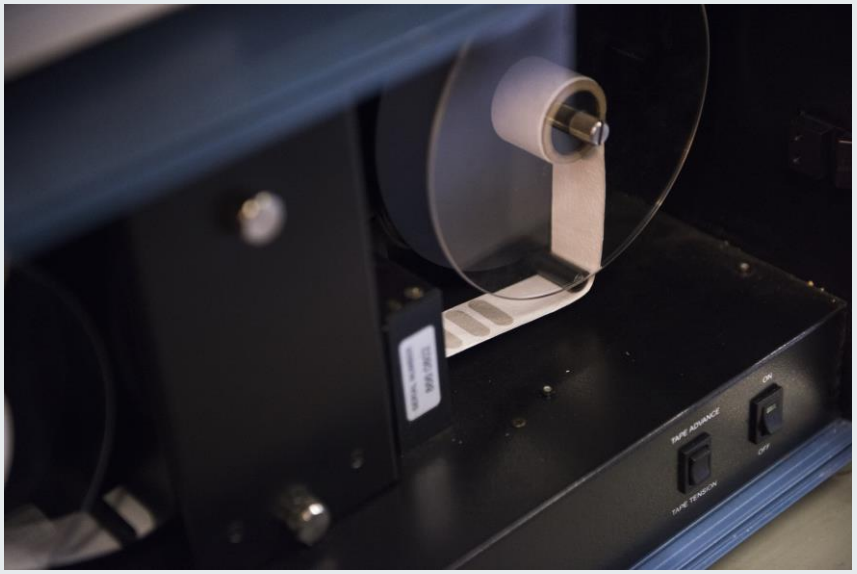
David C. Green*, Gary W. Fuller, Timothy Baker

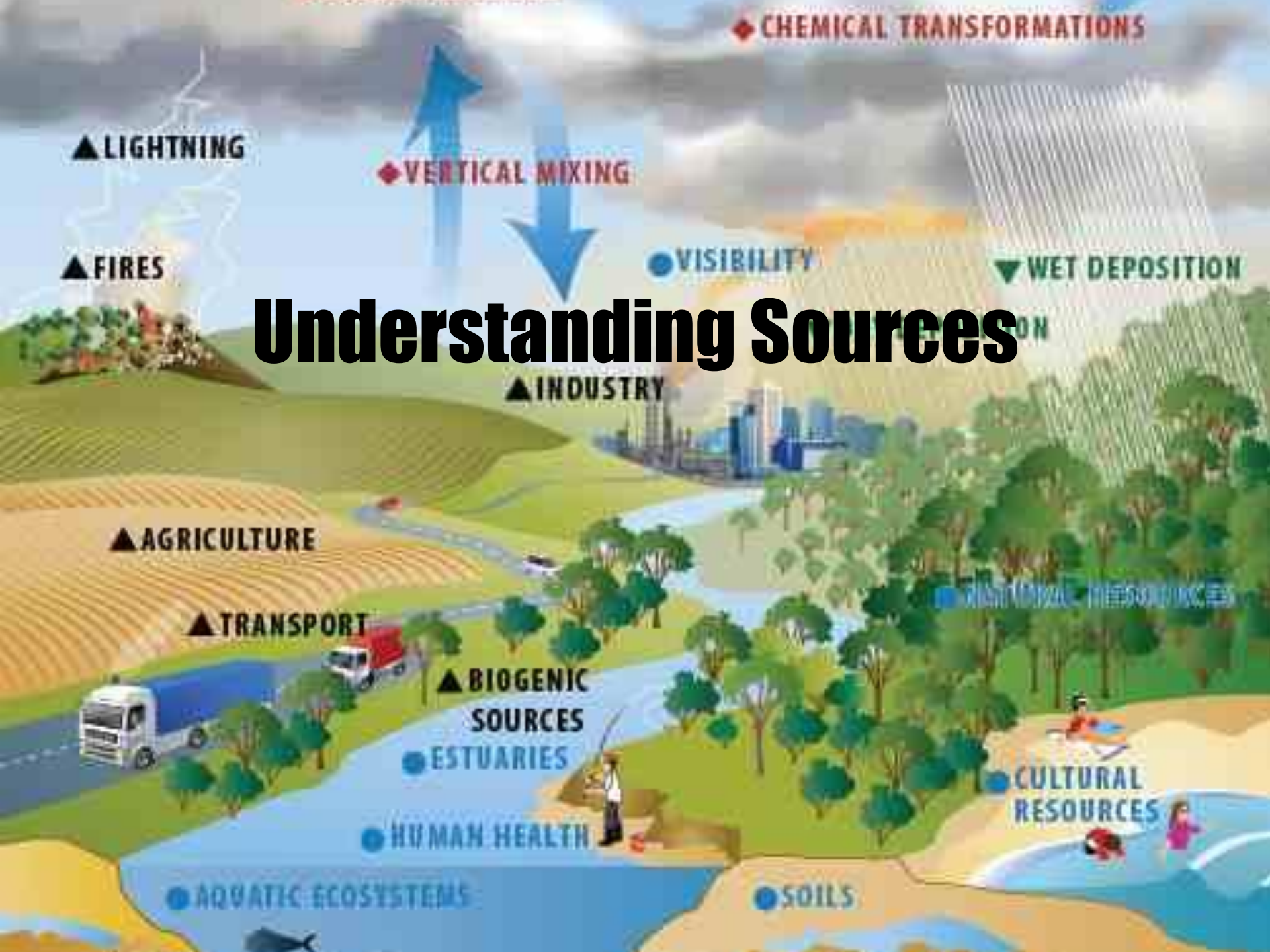
King's College London, Environmental Research Group, Franklin-Wilkins Building, 150 Stamford Street, London, SE1 9NH, UK



Black Smoke to Black Carbon Measurements

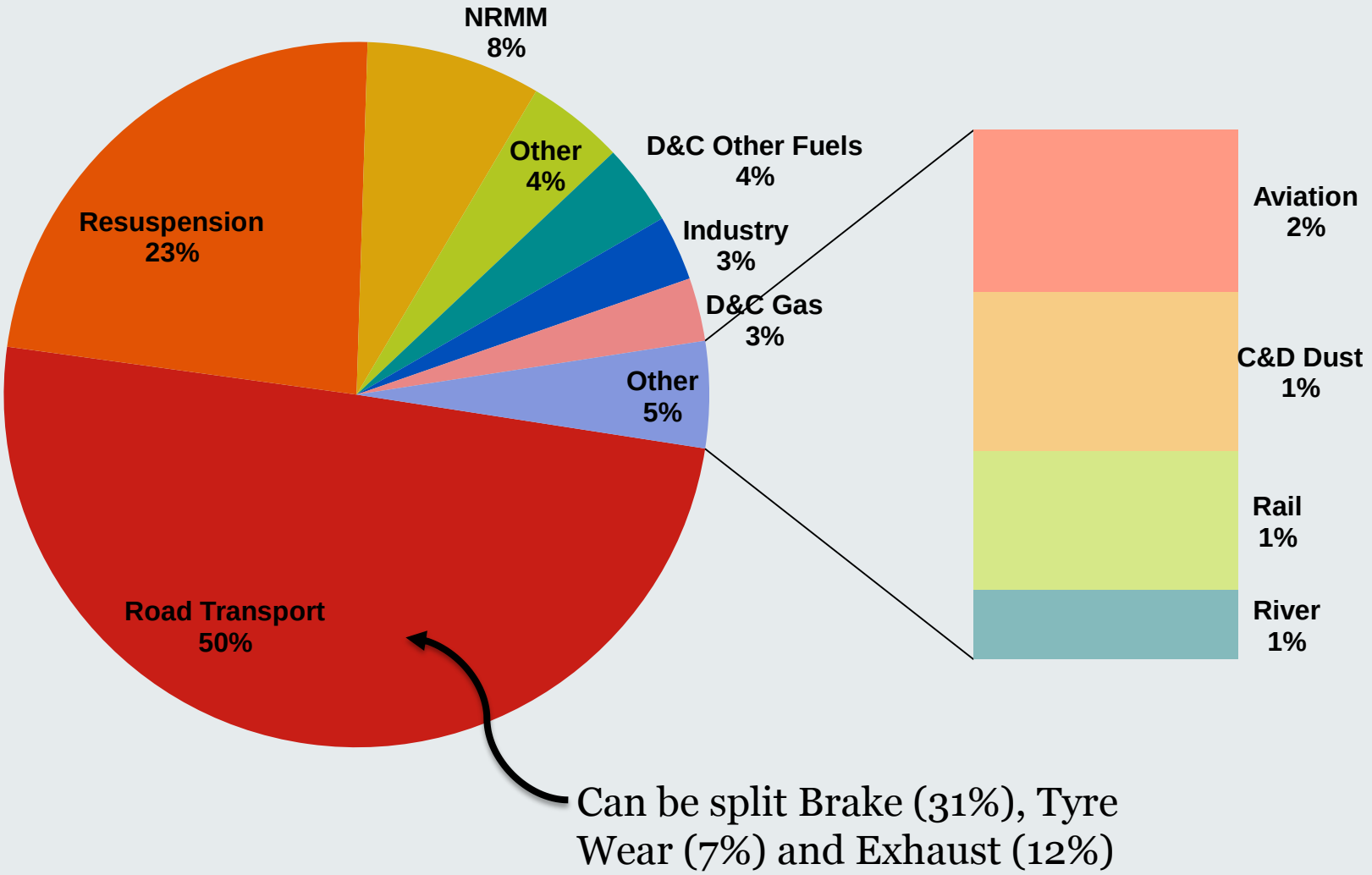
- Prior to 2006 black smoke measured using a bubbler
- Reducing BS concentrations led to measurement < LOD
- 2006 – tested high time resolution techniques
  - SX200 BS technique, MAAP & Aethalometer
- Need to demonstrate ongoing continuity for epidemiological studies
- Led to improved understanding of both traffic and solid fuel burning sources





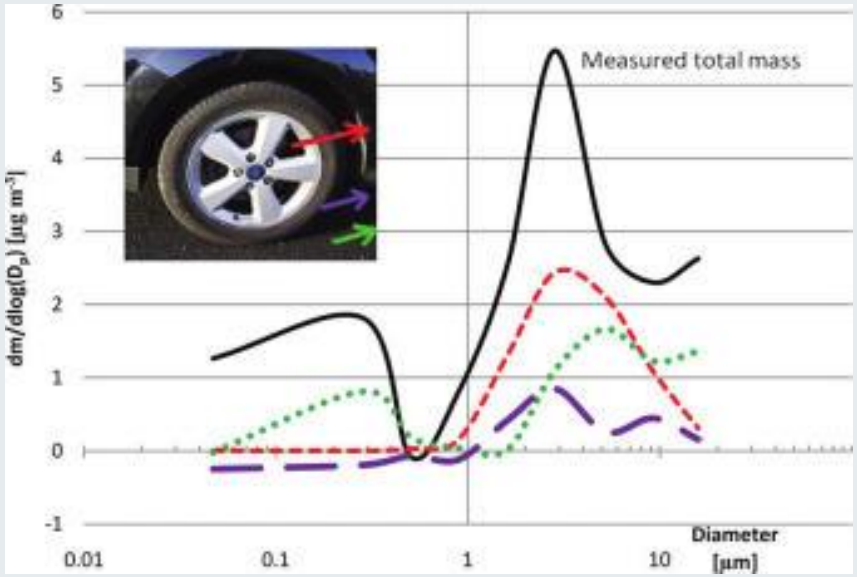
Understanding Sources

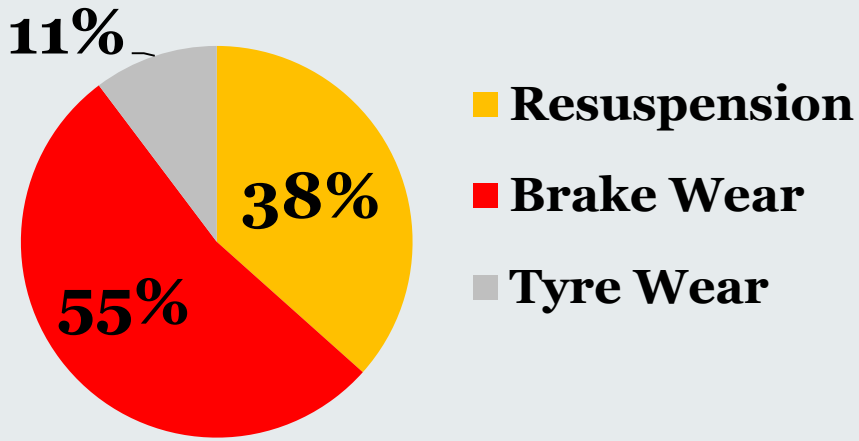
London Atmospheric Emissions Inventory PM_{10}, 2013



Brake Dust, Tyre Wear & Resuspension

- Cascade Impactor
- Size resolved, daily data
- Acid digestion, ICPMS
- Background and Roadside Increment / roadside enhancement
- Key tracers for different sources:
  - Brake wear (Ba)
  - Tyre wear (Zn)
  - Resuspension (Si)
- Applied source multiplication factors based on abundance in source
- Coarse Particles - 0.9–11.5 µm

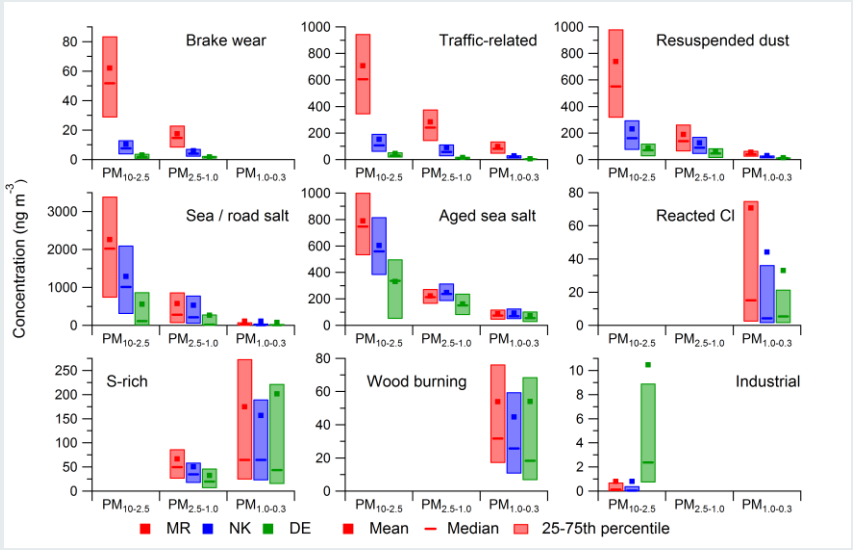


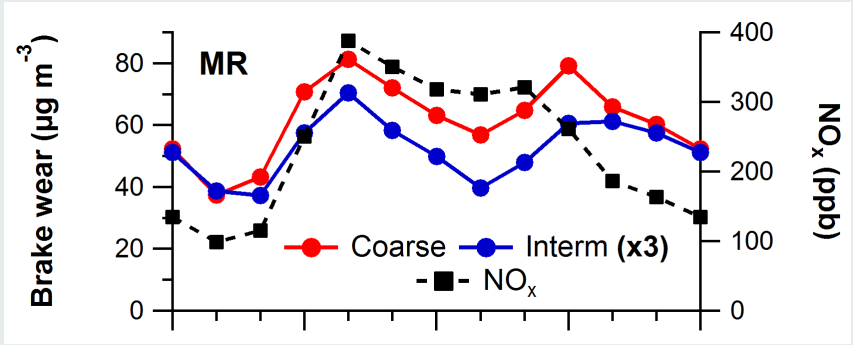


Harrison, R. M., A. M. Jones, J. Gietl, J. X. Yin and D. C. Green (2012). "Estimation of the Contributions of Brake Dust, Tire Wear, and Resuspension to Nonexhaust Traffic Particles Derived from Atmospheric Measurements." Environmental Science & Technology 46(12): 6523-6529.

Measurement and Source Apportionment

- Rural, Background and Roadside
- X-ray fluorescence
- Size and time resolved (2h)
- Wider size range
  - 0.3-1, 1-2.5, 2.5-10 µm
- Source apportionment using PMF
- Traffic coarse factors (2.5-10 µm)
  - brake wear (Cu, Zr, Sb, Ba)
  - other traffic-related (Fe)
  - resuspended dust (Si, Ca)
- Traffic fine factors (0.3-1.0 µm)
  - traffic-related and resuspended dust





Visser et al. (2015). Kerb and urban increment of highly time-resolved trace elements in PM10, PM2.5 and PM1.0 winter aerosol in London during ClearfLo 2012. ACP

Visser et al. (2015). Advanced source apportionment of size-resolved trace elements at multiple sites in London during winter. ACP

Particle Number Reduction

- Over a period of a few months in late 2007 conc reduced by 59%
- Particle number emissions from vehicles were reduced by 65% compared to emissions of NOx
- Coincidental with as the introduction of “sulphur free” diesel fuel
- Consistent with SO4 as condensation nuclei for fresh diesel emissions

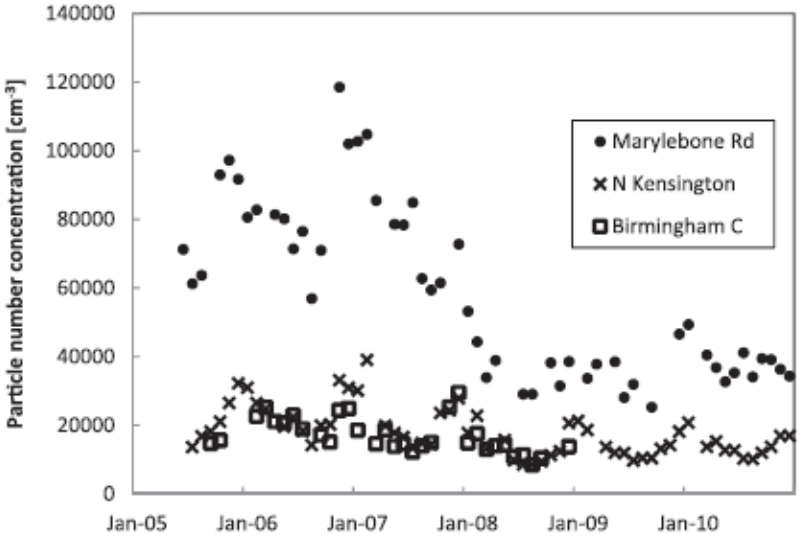


Fig. 2. Monthly mean particle number concentration at three sites.

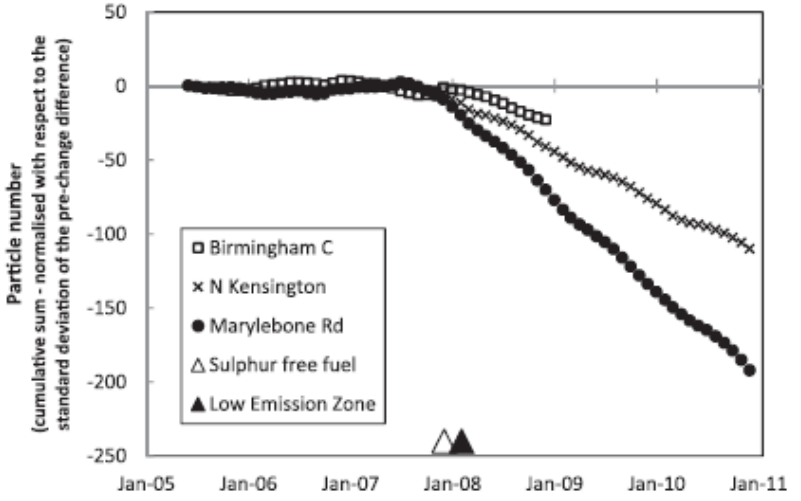


Fig. 3. Normalised monthly cumulative sums of particle number concentration difference. Triangles indicate the introduction of sulphur-free diesel and the LEZ respectively.

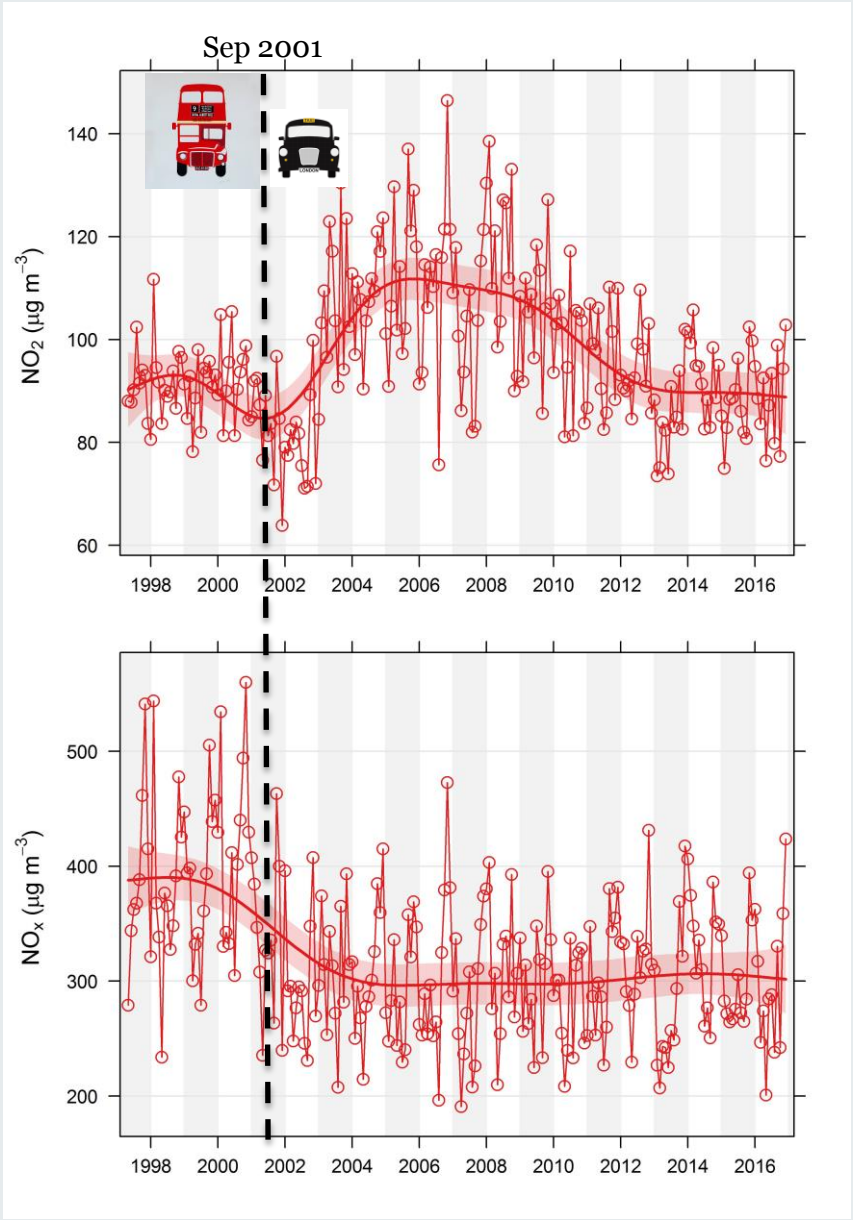
Harrison et al. (2012). "A large reduction in airborne particle number concentrations at the time of the introduction of “sulphur free” diesel and the London Low Emission Zone." **Atmospheric Environment 50 (2012) 129-138**


HEI
RESEARCH REPORT
HEALTH EFFECTS INSTITUTE
Number 155
April 2011
The Impact of the Congestion Charging Scheme on Air Quality in London
Part 1. Emissions Modeling and Analysis of Air Pollution Measurements
Part 2. Analysis of the Oxidative Potential of Particulate Matter (To Be Released in May 2011)
Frank Kelly, H. Ross Anderson, Ben Armstrong, Richard Atkinson, Ben Barratt, Sean Beevers, Dick Derwent, David Green, Ian Mudway, and Paul Wilkinson
Includes a Commentary by the Institute's Health Review Committee

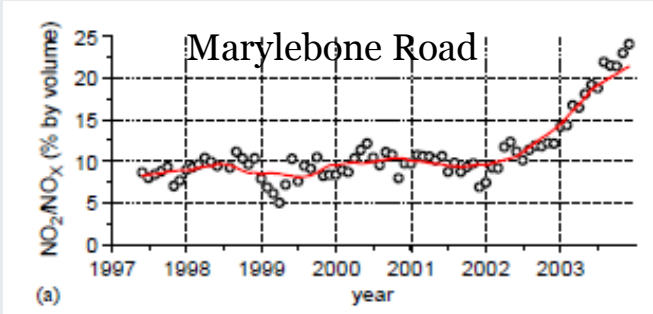

HEI
RESEARCH REPORT
HEALTH EFFECTS INSTITUTE
Number 163
November 2011
The London Low Emission Zone Baseline Study
Frank Kelly, Ben Armstrong, Richard Atkinson, H. Ross Anderson, Ben Barratt, Sean Beevers, Derek Cook, Dave Green, Dick Derwent, Ian Mudway, and Paul Wilkinson

Policy

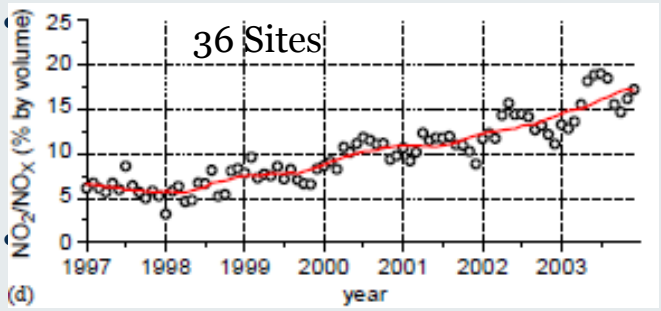
The start of the direct NO_2 emissions story…



- Bus lanes on kerbside lane from Sep 2001
- Increase in bus flows prior to introduction of Congestion Charging Scheme in 2003
  - 79% higher 2003 compared to 1998
- Change in primary NO2 concentrations (previously estimated at 5%)
- Widespread use of DPF in bus fleet



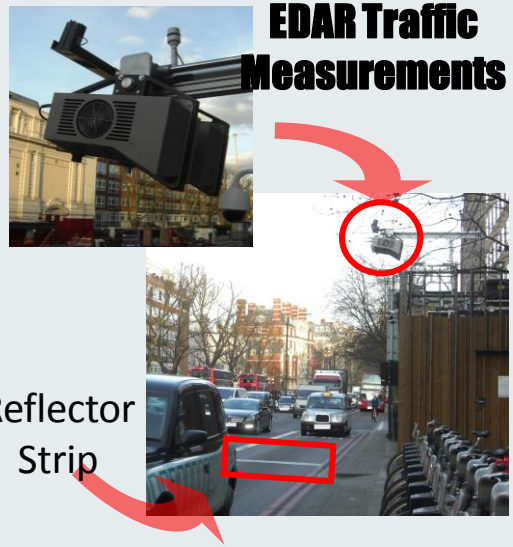
- Increased use of diesel cars
  - 12% in 2000, 20% by 2004



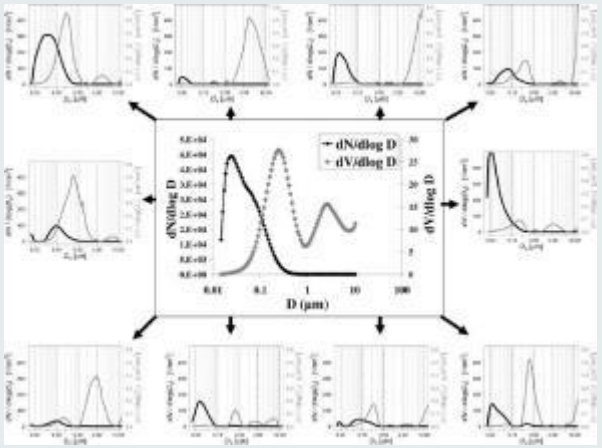
Carslaw et al. (2005)

Here's just a few of the thigs I didn't have time to tell you about…

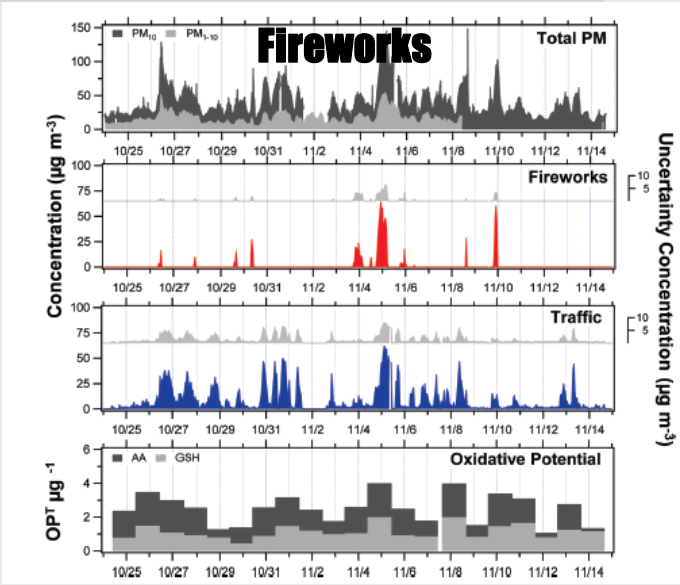
EDAR Traffic Measurements



Source apportionment of Particle Number Distribution

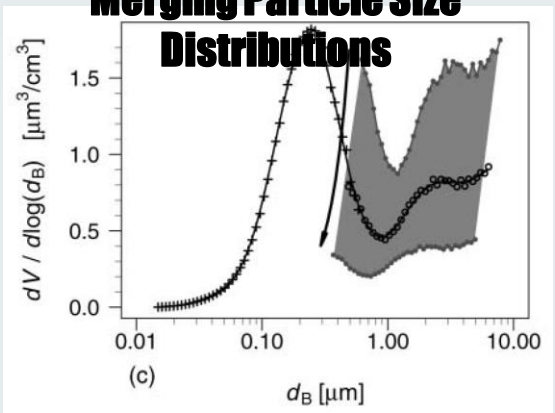


Fireworks

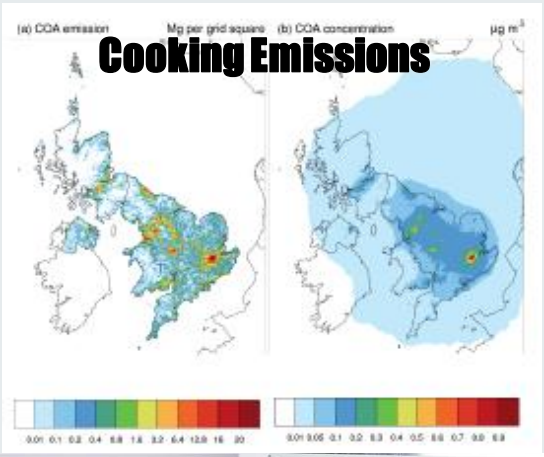


DUST Suppressant Trial 2012

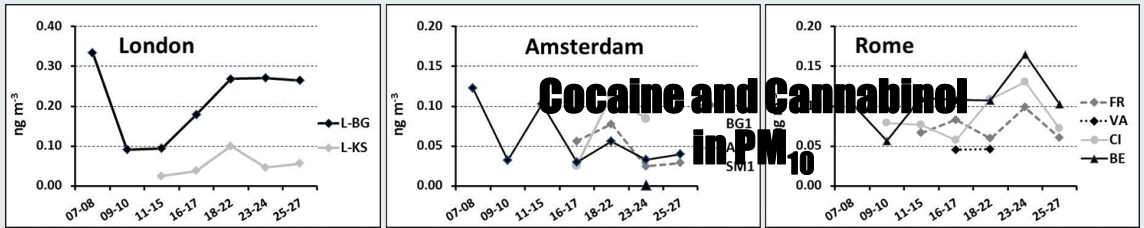
Merging Particle Size Distributions



Cooking Emissions



Cocaine and Cannabinol in PM_{10}



High time resolution measurements of PM Toxicity

What have we learnt?

- Unparalleled contribution to Air Quality in UK
- Has been fundamental in our understanding of emissions from traffic sources
  - Direct NO2 emissions
  - Drop in particle number concentration due to S-free diesel
  - Importance of non-exhaust emissions
- Provides the widest range of measurements of any station in the UK
  - Needed to understand interactions between pollutants
  - Discovery and importance of novel sources e.g. cooking
- Provided an invaluable test location for new measurement techniques

What have we still got to learn?

- How new measurement techniques will perform in heavily trafficked locations
- Further quantification of non-exhaust sources
  - Relative importance of tyre / brake wear and resuspension
- The impact of emissions abatement (e.g. DPF, SCR)
- Changing vehicle fleet – diesel to petrol and importance of secondary organic aerosol formation
- Influence of changing urban sources (e.g. Solid fuel burning, cooking)
- Lots to learn from studies in collaboration with other London and UK and international supersites…

Acknowledgements

Funding Organisations:

- Defra
- Environment Agency
- NERC

Everyone in the Monitoring Team who helps run the site

Especially those who have to spend hours next to Marylebone Rd to keep everything running:

- Ana Beckett
- Anja Tremper
- Andrew Grieve