MRC-PHE Centre for Environment & Health

Public Health England

MRC Medical Research Council Imperial College London





London's air in flux

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Londonair conference 21st June 2016

Which air pollution management policies are working?

- A large number of policy initiatives are being taken in London, the UK and the EU to improve air quality
 - TfL bus retrofit program, LEZ, EURO classes, etc.
- Difficult to evaluate which policy is working best / at all since we don't have intervention vs control.
- Why not look for the places where air pollution is improving fastest to find the best policy package?

EURO emission standards for passenger cars, g/km							
Tier	Date	СО	NOx	PM	P [#/km]		
Diesel							
Euro 1†	Jul-92 2.	.72 (3.16)	-	0.14	-		
Euro 2	Jan-96	1	-	0.08	-		
Euro 3	Jan-00	0.64	0.5	0.05	-		
Euro 4	Jan-05	0.5	0.25	0.025	-		
Euro 5a	Sep-09	0.5	0.18	0.005	-		
Euro 5b	Sep-11	0.5	0.18	0.005	6×10 ¹¹		
Euro 6	Sep-14	0.5	0.08	0.005	6×10 ¹¹		
		Petrol (Ga	soline)				
Euro 1†	Jul-92 2.	.72 (3.16)	-	-	-		
Euro 2	Jan-96	2.2	-	-	-		
Euro 3	Jan-00	2.3	0.15	-	-		
Euro 4	Jan-05	1	0.08	-	-		
Euro 5	Sep-09	1	0.06 0	.005**	-		
Euro 6	Sep-14	1	0.06 0	.005**	6×10 ¹¹ ***		

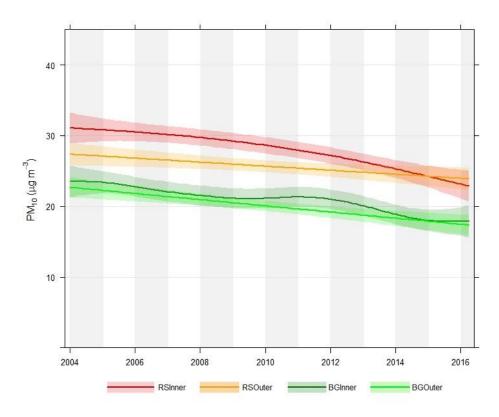


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Which air pollution management policies are working?

- Standard approaches look at single sites of aggregate metrics across an area.
- This is can be subject to preferential sampling and other bias
- Masks heterogeneity.



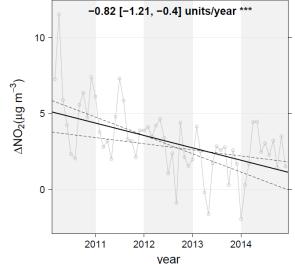
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Methods



- 65 traffic locations in London
- Trends in roadside increments
- (background concentration removed) of air pollutants (Δ)
- > 75% data capture
- Trends calculated between 2005-09 and 2010-14 (inc)
- ΔNO_X , ΔNO_2 , ΔPM_{10} , $\Delta PM_{2.5}$, ΔBC , ΔCO_2
- Trends calculated using the Theil-Sen estimator adjusted for seasonality: trend +/- 95% confidence interval (R-Open-Air, Carslaw & Ropkins)
- Overall trend calculated by meta-analysis (linear random-effects model)
 - more weight is given to sites with less variance (v_i) and more precision $(w_i = 1/v_i)$
- As a 2nd stage **k** means was used to cluster roads by behaviour

Results: trends 2005 - 2009 trends in ΔNO_2

B

trends in ΔNO_x

Trends 2005 - 2009

Lambeth - Brixton Road Redbridge - Fullwell Cross Kensington and Chelsea - Cromwell Road Sutton - Wallington Barnet - Taily Ho Corner Croydon - Purley Way Islington - Holloway Road Brent - Ikea Havering - Romford Greenwich - Blackheath Croydon - George Street Greenwich - Al206 Burage Grove Greenwich - Backey Town Hall Ealing - Acton Town Hall Hounslow - Chiswick High Road Greenwich and Bexley - Falconwood Tower Hamets - Nile End Road Crystal Palace - Crystal Palace Parade Kensington and Chelsea - Knightsbridge Enfield - Derby Road Lambeth - Christchurch Road Newham - Cam Road Hillingdon - South Ruislip Redbridge - South Woodford Kensington and Chelsea - Kings Road Greenwich - Tirafalgar Road Harrow - Pinner Road Greenwich - Plumstead High Street Hillingdon - Motord Avenue Hillingdon - Altingdon Hospital Ealing - Hanger Lane Gyratory Hounslow - Brentford Bromley - Hanwood Avenue Havering - Rainham Lewisham - New Cross Richmond Upon Thames - Castlenau Redbridge - Gardner Close Camden - Swaftesbury Avenue Westminster - Marylebone Road Greenwich - Woolwich Flyover Westminster - Marylebone Road Greenwich - Woolwich Flyover Westminster - Charing Cross Library	Ţ Ţ Ţ Ţ Ţ Ţ Ţ Ţ Ţ Ţ Ţ Ţ Ţ Ţ Ţ Ţ Ţ Ţ Ţ		$\begin{array}{c} -24.67 \left[\begin{array}{c} -30.77 \\ -4.15 \left[\begin{array}{c} -6.67 \\ -0.55 \\ -3.57 \right] \left[\begin{array}{c} -5.83 \\ -3.52 \right] \left[\begin{array}{c} -5.83 \\ -5.83 \\ -1.34 \end{array} \right] \\ -3.52 \left[\begin{array}{c} -5.83 \\ -5.83 \\ -1.34 \end{array} \right] \\ -3.52 \left[\begin{array}{c} -5.83 \\ -5.83 \\ -1.35 \end{array} \right] \\ -2.33 \left[\begin{array}{c} -7.04 \\ -7.04 \\ -2.33 \\ -2.37 $
-40.00	-20.00 0.00 10.00)	
10.00	20.00 10.00	-	

trend ΔNO_x (µg m⁻³ year⁻¹

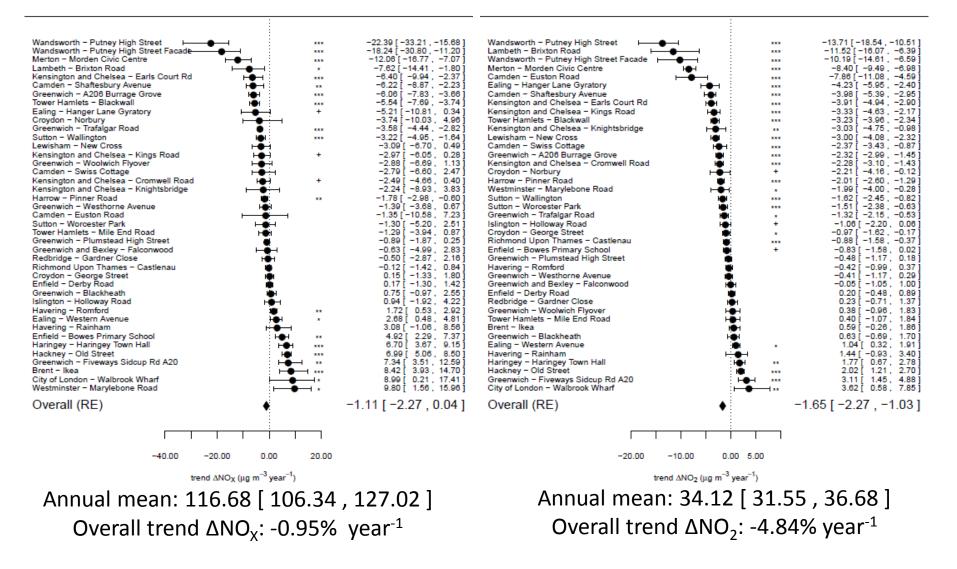
-8.20 [-10.33 , -1.20 [-2.15 , -1.07 [-2.30 , -0.32 [-1.58 , -0.08 [-0.75 , 0.13] -0.96 , Lambeth - Brixton Road , -5.60 , -0.01 *** Redbridge - Fullwell Cross -1.20 -1.07 -0.03 Islington - Holloway Road Kensington and Chelsea - Cromwell Road 0.46 0.63 Croydon - George Street Sutton - Wallington Redbridge – South Woodford Greenwich – Blackheath Croydon – Purley Way Croydon – Norbury Barnet – Tally Ho Corner Haringey – Haringey Town Hall Bexley – Thames Road South ** 1.20 [-0.98 , 2.87 [0.65 , 2.01 Ealing - Hanger Lane Gyratory Greenwich - Westhorne Avenue *** Westminster - Marylebone Road Newham - Cam Road Greenwich - A206 Burrage Grove Kensington and Chelsea - Knightsbridge + Bromley - Harwood Avenue 1.56 1.61 1.62 1.83 1.92 1.93 1.98 2.00 2.03 Kensington and Chelsea - Kings Road ** Ealing - Acton Town Hall *** Greenwich - Trafalgar Road *** Tower Hamlets - Mile End Road *** Hillingdon – Hillingdon Hospital Enfield – Derby Road ** Brent - Ikea * $\begin{array}{c} 0.54\,,\,3.14\,\\ 0.62\,,\,3.52\,\\ 1.27\,,\,2.84\,\\ 1.25\,,\,3.08\,\\ 0.83\,,\,3.62\,\\ 1.34\,,\,3.29\,\\ 0.83\,,\,3.24\,\\ 1.26\,,\,3.19\,\\ 1.27\,,\,3.57\,\\ 1.82\,,\,3.7\,\\ 2.22\,,\,3.39\,\\ 2.30\,,\,3.37\,\\ 1.39\,,\,4.38\,\\ 1.90\,,\,3.67\,\\ 1.97\,,\,4.00\,\\ 1.70\,,\,5.09\,,\,5.09\,\\ 1.70\,,\,5.09\,,\,5.0$ Hounslow - Chiswick High Road ** Redbridge - Gardner Close ** Crystal Palace – Crystal Palace Parade Harrow – Pinner Road 2.04 2.11 2.28 2.31 2.38 2.42 2.45 2.74 *** ** Greenwich – Plumstead High Street Havering – Romford Lambeth – Christchurch Road *** ** *** Greenwich and Bexley - Falconwood *** H H H Richmond Upon Thames - Castlenau *** Bexley - Thames Road North *** 2.80 2.83 2.91 3.05 Hillingdon - South Ruislip *** Westminster – Charing Cross Library Havering – Rainham *** *** Hackney - Old Street *** Greenwich - Woolwich Flyover 3.10 1.70 , 5.09 1.70 , 5.09 1.74 , 4.46 2.44 , 3.96 0.92 , 5.11 3.25 , 5.18 3.70 , 5.86 3.11 Camden - Swiss Cottage *** 3.15 3.38 4.37 4.74 Hillingdon - Oxford Avenue *** Lewišham - New Cross Hounslow – Brentford Camden – Shaftesbury Avenue *** *** Overall (RE) 1.63 [1.25 , 2.01] -1500-10.00 -5.000.00 5 00 10 00

trend ΔNO_2 (µg m⁻³ year⁻¹)

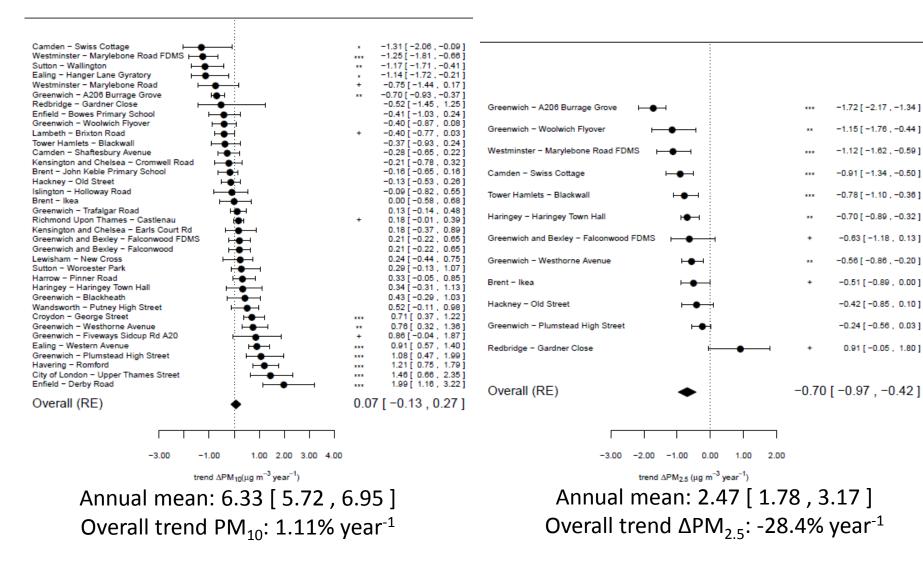
Trends 2005 - 2009

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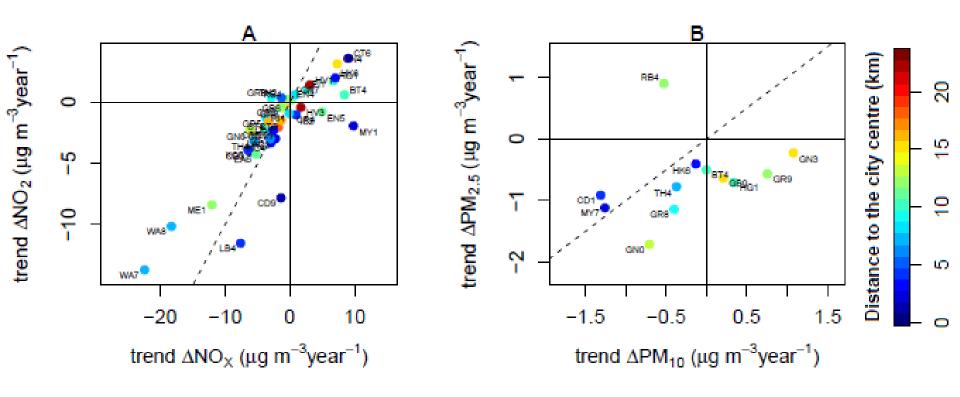
Results: trends 2010 - 2014 trends in ΔNO_x trends in ΔNO_2



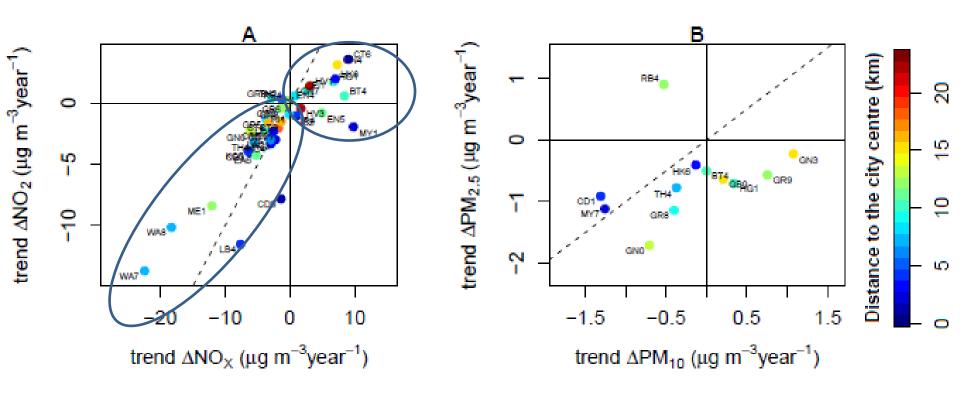
Results: trends 2010 - 2014 trends in ΔPM_{10} trends in $\Delta PM_{2.5}$



Comparing pollutant trends 2010 - 2014

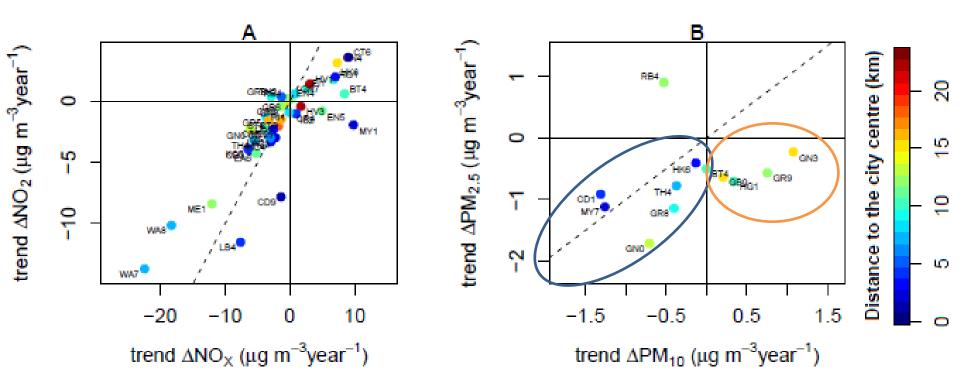


Comparing pollutant trends 2010 - 2014



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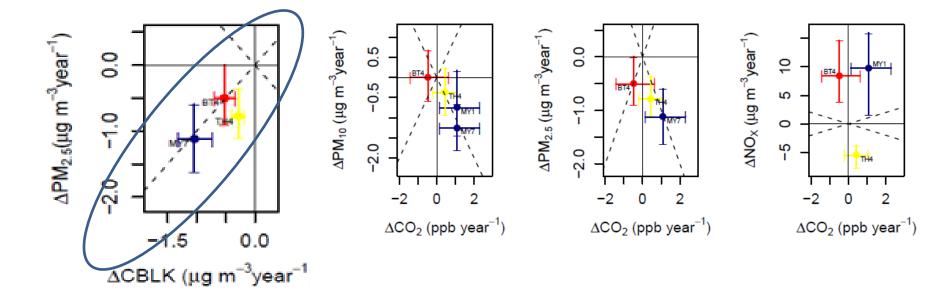
Comparing pollutant trends 2010 - 2014



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Comparing pollutant trends 2010 - 2014 co₂ Black Carbon

	Westminster Marylebone Rd	Brent Ikea	Tower Hamlets Blackwall
$\Delta CO_2 (ppm y^{-1})$	1.08 (0.14, 2.29) [*]	-0.48 (-1.42, 0.64)	0.44 (-0.20, 1.08)
ΔCBLK (μg m ⁻³ y ⁻¹)	-1.04 (-1.32, -0.74)***	-0.53 (-0.70, -0.34)***	-0.28 (-0.39, -0.18)***

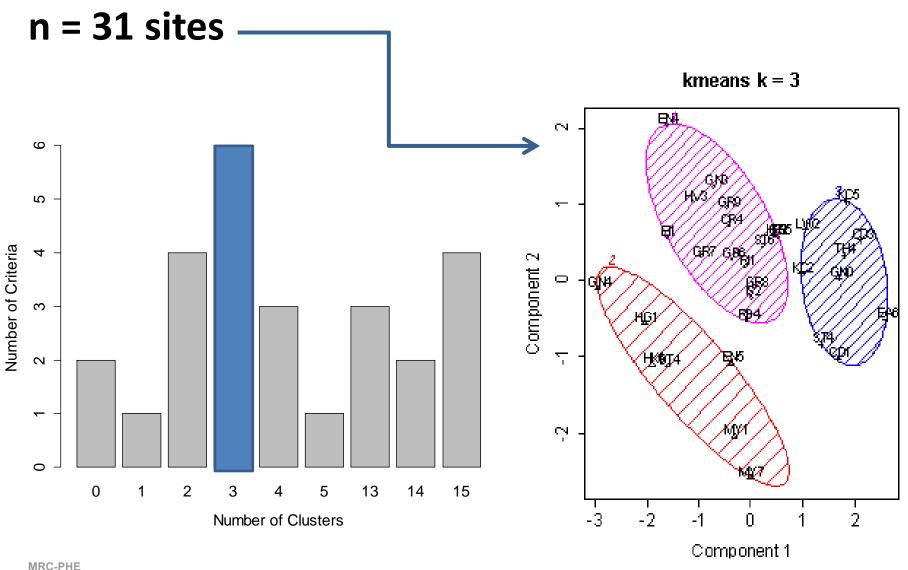


Methods: finding patterns

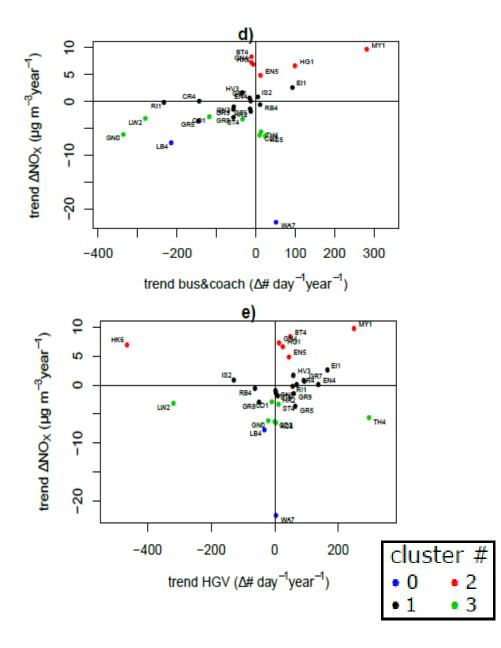
- *K-means* cluster analysis used to group sites with the most similar trends for the time period 2010-2014
- Variables: trends in ΔNO_{χ} , ΔNO_{2} and ΔPM_{10}
- Before clustering , each variable is normalized (mean = 0; variance = 1)
- Exclude Wandsworth Putney High St and Lambeth – Brixton Road (outliers)

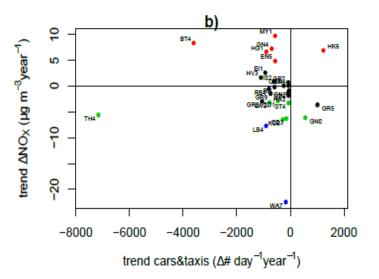


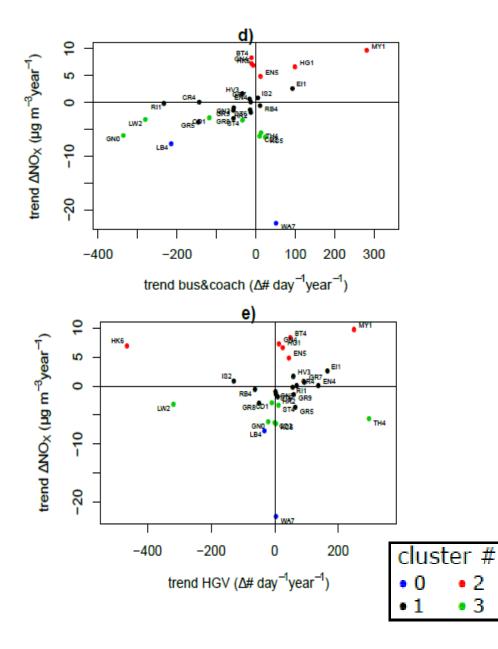
Results: clustering sites

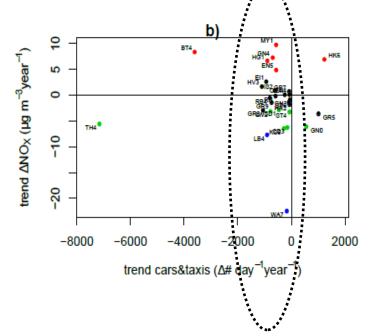


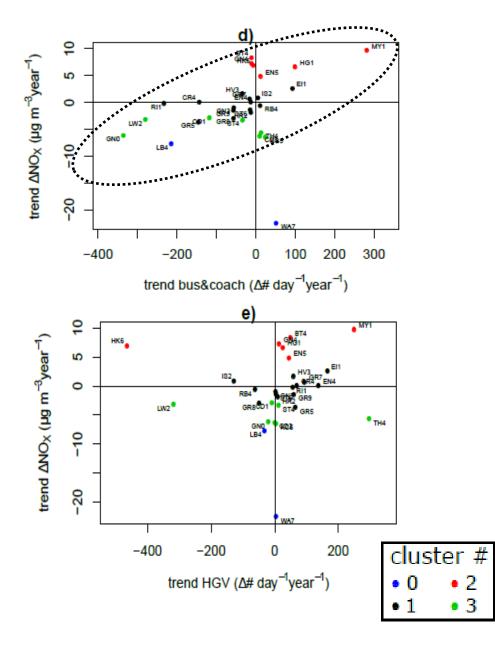
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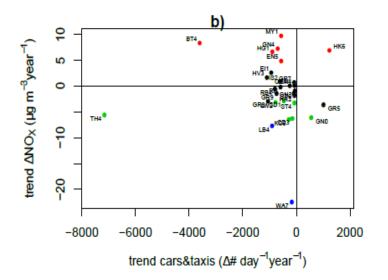


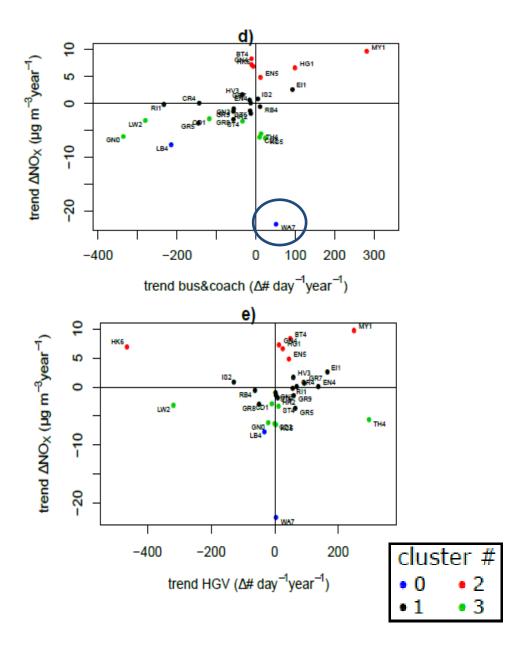


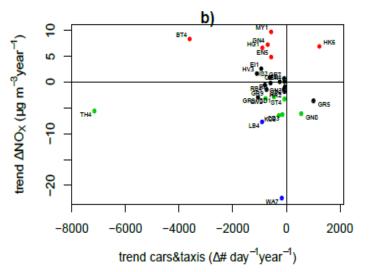


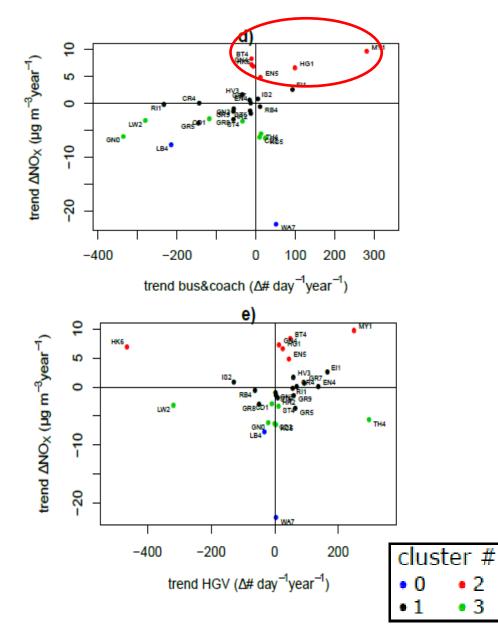


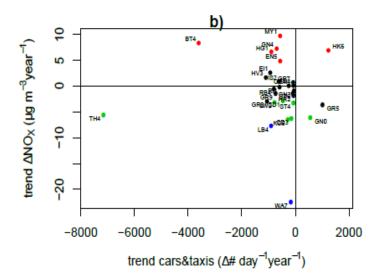


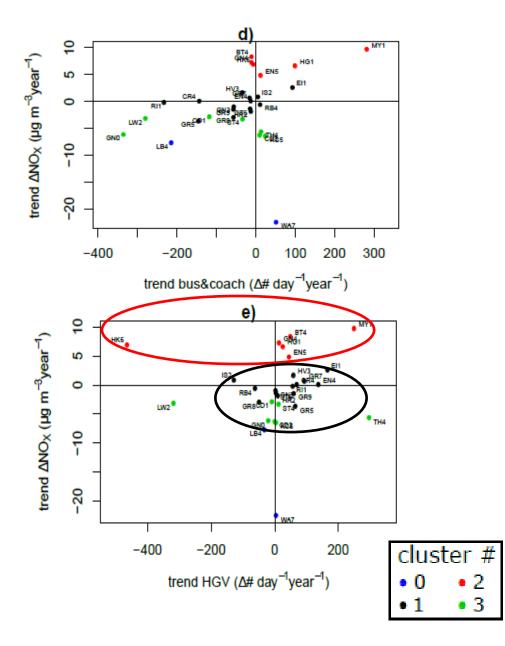


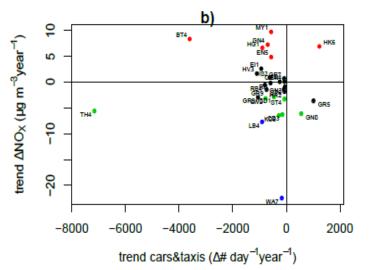


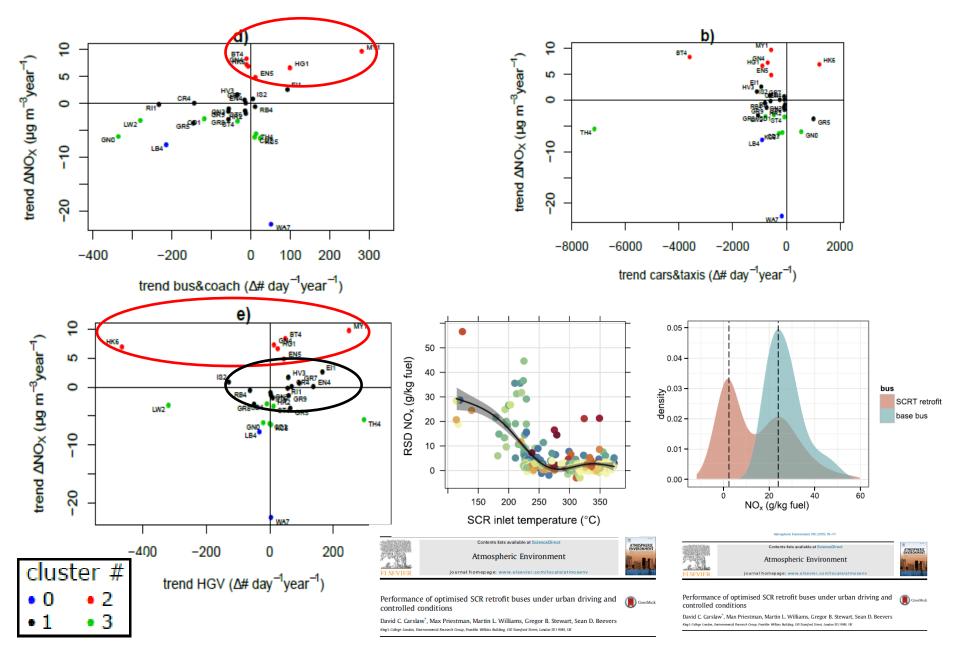


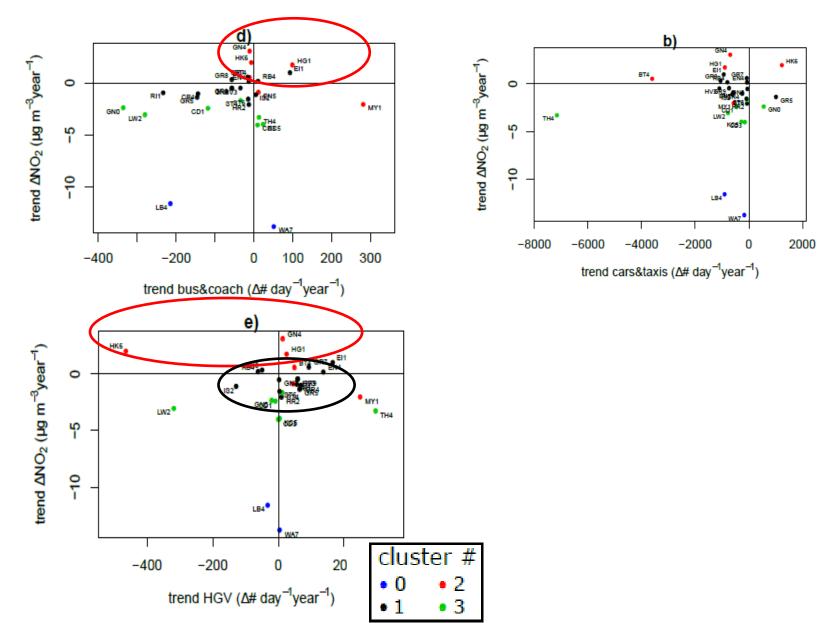








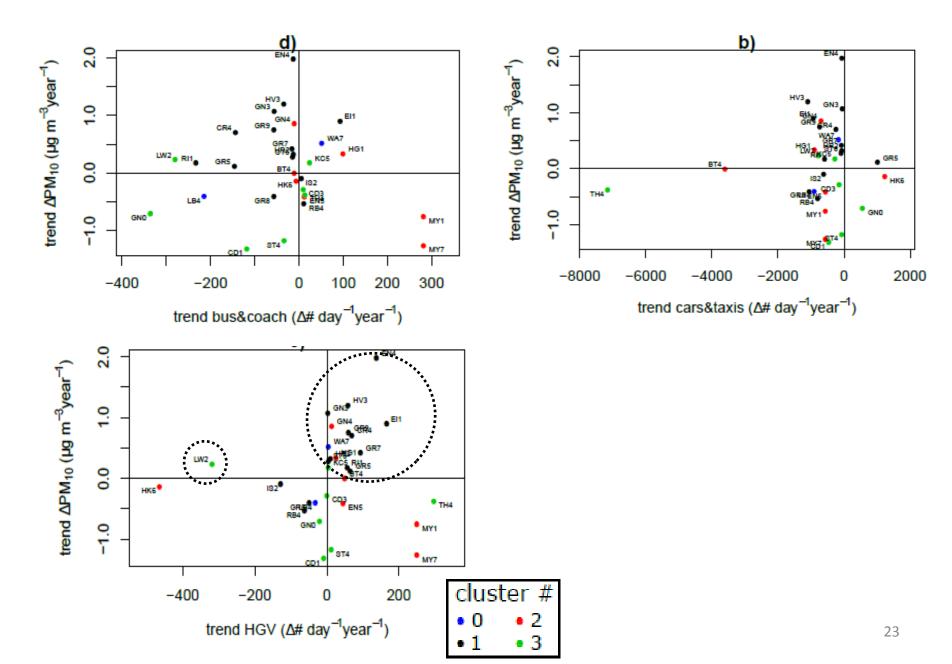


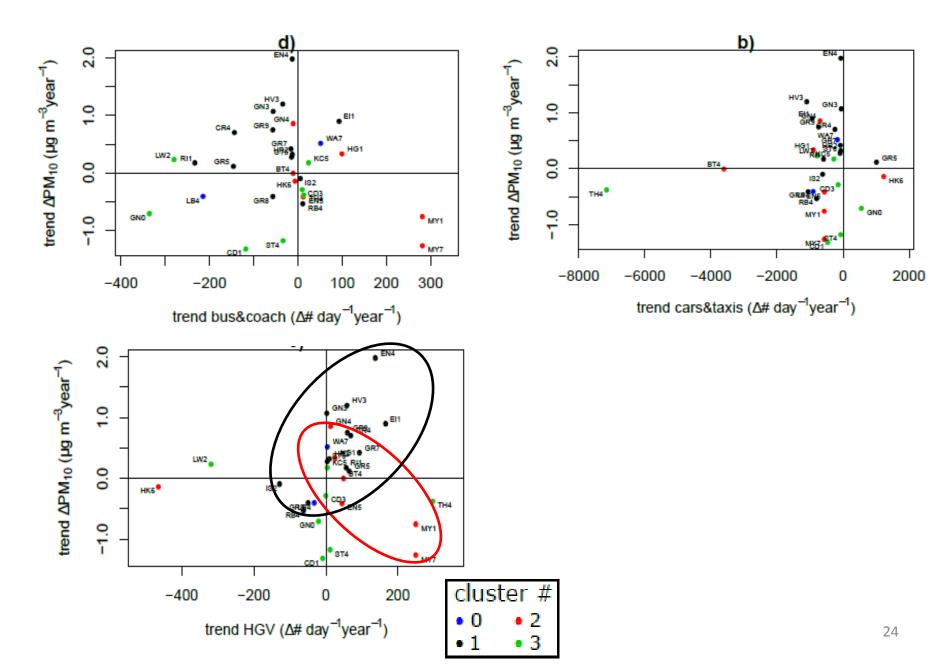


NO₂ - Time to compliance at 2010-2014 rate?

Previous performance is not necessarily a predictor of future performance... These are roadside increment only – see background trend too

cluster #	0	1	2	3
Ν	2	15	7	9
trend ΔNO _x (µg m⁻³ year⁻¹)	-14.70 [-29.16, -0.23]	-0.41 [-1.45, 0.64]	6.66 [5.51, 7.81]	-4.52 [-5.62, -3.43]
mean ΔNO _x 1 st year (μg m ⁻³)	385.74 [279.09, 492.39]	58.98 [47.81, 70.16]	<u>118.51</u> [77.97, 159.05]	135.86 [103 36, 168.36]
trend ΔNO ₂ (µg m ⁻³ year ⁻¹)	-12.82 [-15.85, -9.79]	-0.48 [-0.92, -0.05]	0.81 [-0.52, 2.13]	-2.89 [-3.45, -2.33]
mean ΔNO ₂ 1 st year (µg m ⁻³)	133.68 [127.67, 139.68]	14.06 [10.82, 17.30]	29.95 [18.35, 41.54]	40.91 [31.02, 50.80]
List of AQMSs	WA7, LB4	CR4, EI1, EN4, GB6, GN3, GR5, GR7, GR8, GR9, HR2, HV3, IS2, RB4, RI1, ST6	BT4, EN5, GN4, HG1, HK6, MY1, MY7	CD1, CD3, EA6, GN0, KC2, KC5, LW2, ST4, TH4





Conclusions $-NO_2$

- Roadside sites in London experienced a significant downward trend in ΔNO_x and ΔNO₂ between 2010 and 2014 (-1% and -5% y⁻¹).
- but not all places improved.
- SCR retrofits on Euro 3 buses effective when used intensively
- SCR might not be effective everywhere.
- Changes in ΔNO_x and to a lesser extent ΔNO₂ have some linkage to changes in buses and HGV flows.
 Are policies strong enough?
- Current trends show ~10 to >20 years to LV compliance.
- Hopefully Euro 6 / VI will help.

Conclusion - PM

- ΔPM_{2.5} decreased in 2010-14 (-28%) while PM₁₀ remained constant (~1%) → increase/stabilization of ΔPMcoarse
- ΔPM coarse comes from non-exhaust traffic (resuspension from the road, brake and tyre-wear).
- ΔPMcoarse increasing on faster flowing roads
- We have no policies to control resuspension from the road, brake and tyre-wear apart from vehicle number.
- Comparison with black carbon suggests that the decrease in ΔPM_{2.5} was largely explained by a decrease in traffic exhaust emissions
- (but care needs to be taken with the black carbon trend since only three sites and Davy et al (in prep) shows no trend for two locations in central London).

Conclusions

- New approaches to analysis of the whole population of monitoring sites revealed a clear intra-city variability in trends. We need to check if our polices are working as intended and everywhere
- UK-wide? EU-wide?
- In places the decreased emissions form tailpipe abatement is being undone by increases in bus and HGV flow. Are policies strong enough?
- CO₂ from traffic is not going down as we would hope from policy.
- We need to look in future to see if Euro 6 / VI / CAZ / LEZ is working



Thanks for your attention

Thanks to Transport for London and Greater London Authority for part funding

Part of trends report is available at <u>http://content.tfl.gov.uk/roadside-air-quality-trends-in-london-identifying-outliers-part-1.pdf</u>



MSc Global Air Quality; Management & Science full time cours The full study is in review for *Environmental Pollution*.

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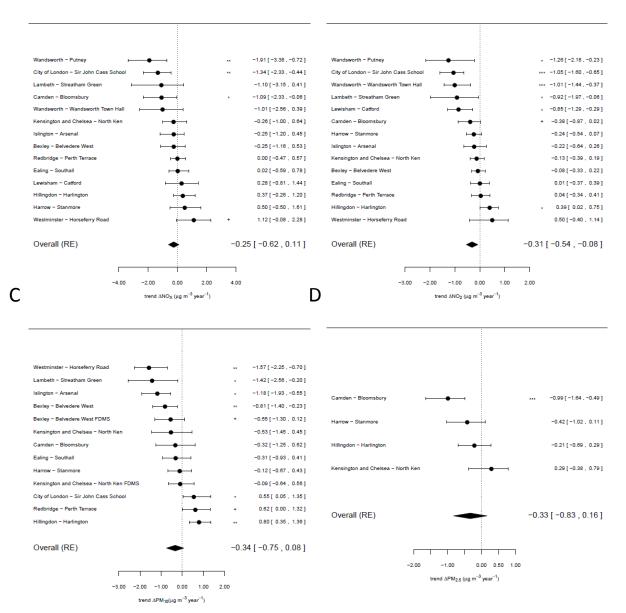
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Results: trends 2010 – 2014 - background

Trends 2010 - 2014

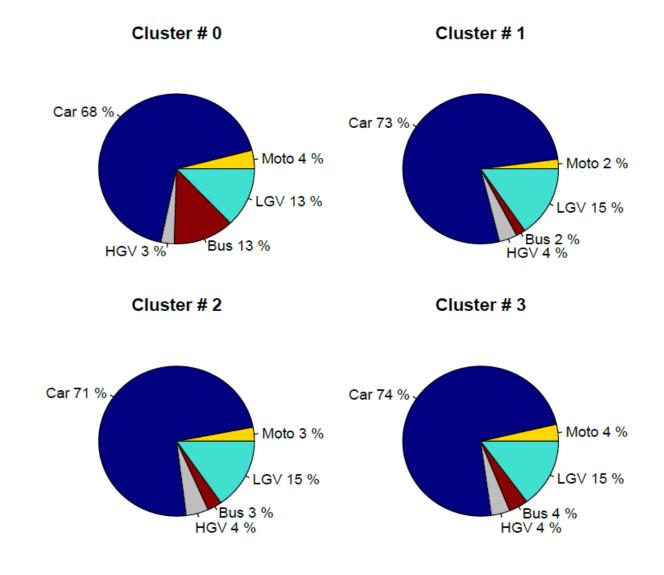
Trends 2010 - 2014

Α



В

But how can we explain the increases?



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Results: clustering sites

- **# 0**: sites in inner London, <u>high streets with lots</u> of buses. Reduction in ΔNO_{χ} and ΔNO_{2}
- **#1**: <u>major roads in outer London</u> with a <u>reduction in ΔNO_2 and $\Delta PM_{2.5}$ while ΔPM_{10} increased therefore coarse PM increased</u>
- **#2**: <u>major multi-lane roads in inner and outer</u> <u>London.</u> Clear <u>increase in their ΔNO_X </u> while <u> $\Delta PM_{2.5}$ clearly decreased</u>; mixed responses in ΔNO_2 and ΔPM_{10}
- #3: mixture of busy roads in inner and outer London. ΔNO_X, ΔNO₂, ΔPM₁₀ and ΔPM_{2.5} decreased