

KING'S College LONDON

University of London

PM_{10} Measurements – the future



KING'S College LONDON

University of London

PM_{10} Measurements – the future?

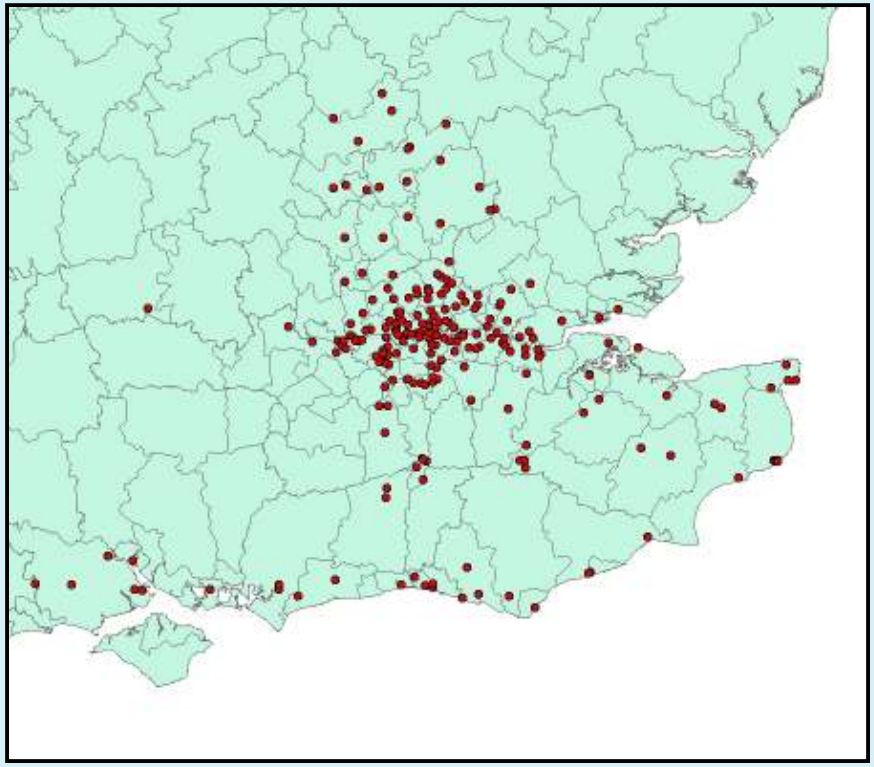
Contents

- Present situation
  - *National PM monitoring*
  - *London and South East PM monitoring*
- Monitoring methods
  - *Intercomparisons*
  - *Equivalence trials*
- London FDMS monitoring
- FDMS Model Development
- Future?
  - *Report PM_{10} reference equivalent concentrations*

UK PM Monitoring

- 71 TEOM PM_{10}
- 7 Reference PM_{10}
- 4 TEOM $PM_{2.5}$
- 7 Reference $PM_{2.5}$
- 240 sites analysed by AQEG

London and South East PM Monitoring



	PM_{10}			$PM_{2.5}$
	TEOM	BAM	Gravimetric	All
London	56	12	3	15
Kent	14	6	0	1
Herts & Beds	12	1	0	0
Sussex	9	0	0	0
Other	4	0	0	0
Total	**95**	**19**	**3**	**16**

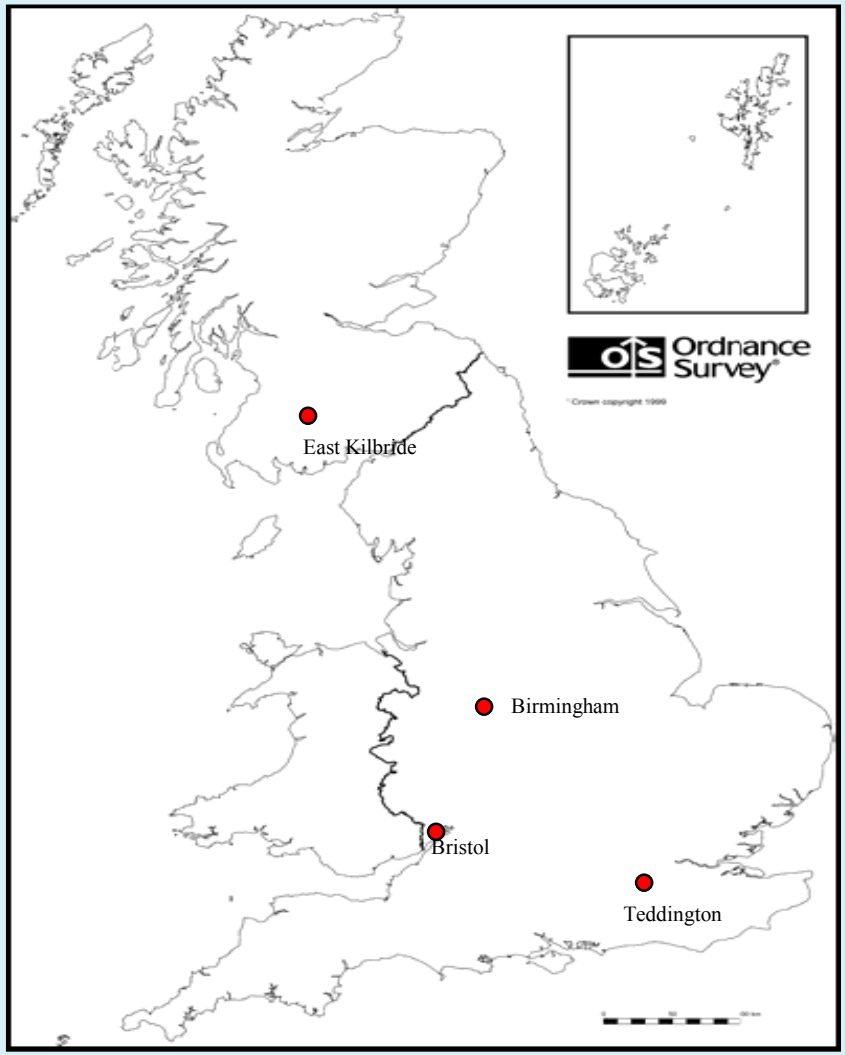
Monitoring methods

- TEOM
  - + *Real time, measurement based on mass, widely used*
  - - *50ºC leads to volatile loss*
- BAM
  - + *Real time*
  - - *measurement by ß attenuation, susceptible to interferences from water*
- Gravimetric
  - + *Reference method, provides sample for subsequent analysis*
  - - *Delay between sampling and measurement, high revenue cost, +ive and –ive artefacts from NO_3, water, organic gases and particles*
- FDMS
  - + *Real time, measurement based on mass, measurement of volatile PM*
  - - *Additional housing requirements*

Intercomparisons

- Lack of reference material for PM_{10}
- EU reference equivalence (EN12341)
  - *Equivalence based on slope and R^2*
  - *Not suitable for automatic instruments*
- Long history of TEOM intercomparisons
  - *Patashnick 1991* → *1.03 + 3 μgm^{-3}*
  - *DEFRA* → *1.3*
- Limited BAM intercomparisons
  - *Marylebone 1999* → *0.82*
- Demonstration of Equivalence from EU
  - *Methodology for comparing automatic methods to the reference method*
  - *Between sampler uncertainty*
  - *Slopes and intercept corrections*
  - *25% expanded uncertainty at the limit value*

UK Equivalence Programme

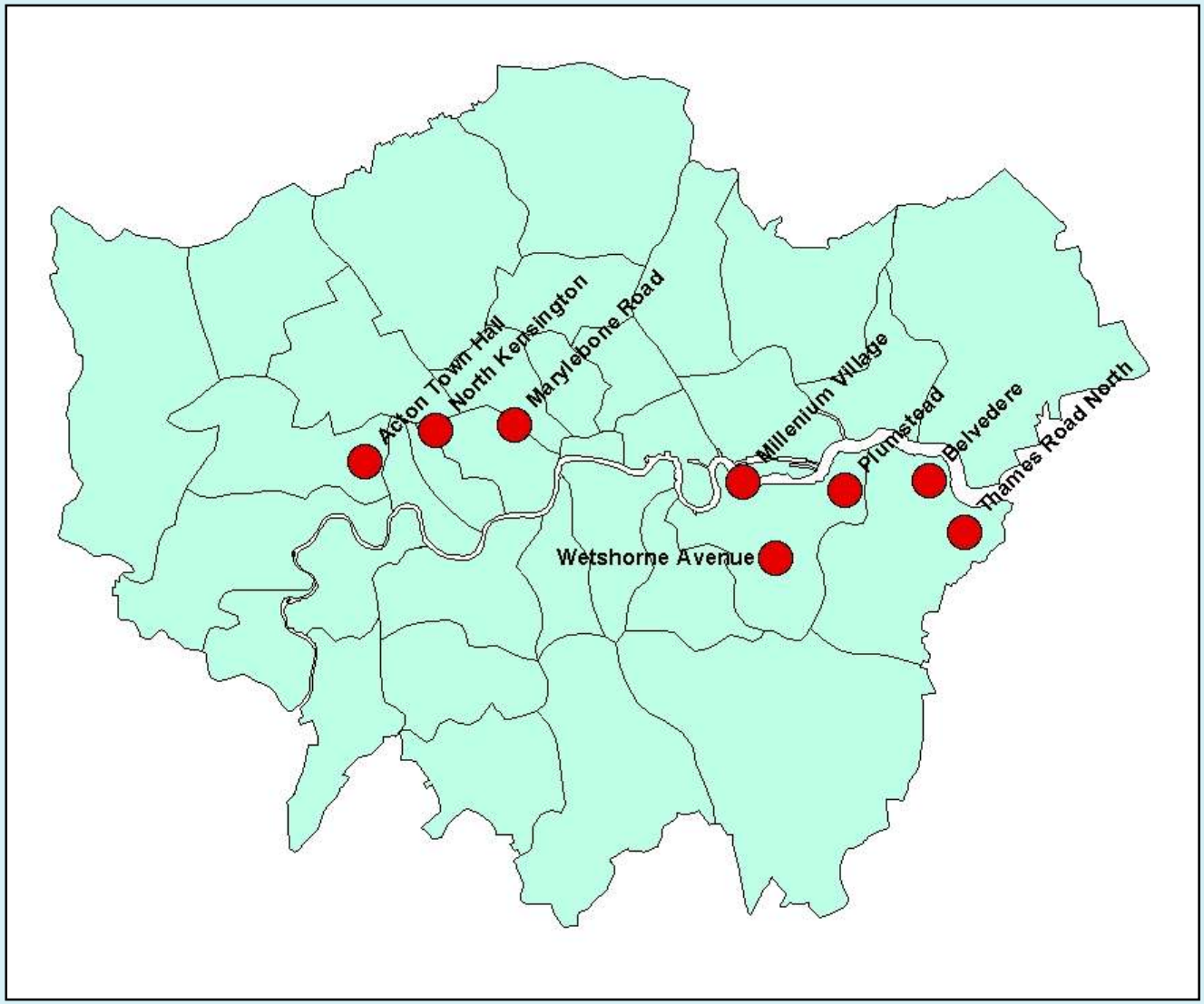


- Bureau Veritas, NPL & AEA
- 2 year study, two seasons in each location
- Partisol 2025, FDMS meet equivalence criteria for PM_{10}
- FDMS met equivalence criteria for $PM_{2.5}$
- BAM met equivalence criteria for PM_{10} after correction factors applied
- TEOM did not meet equivalence criteria for PM_{10}

Current Situation

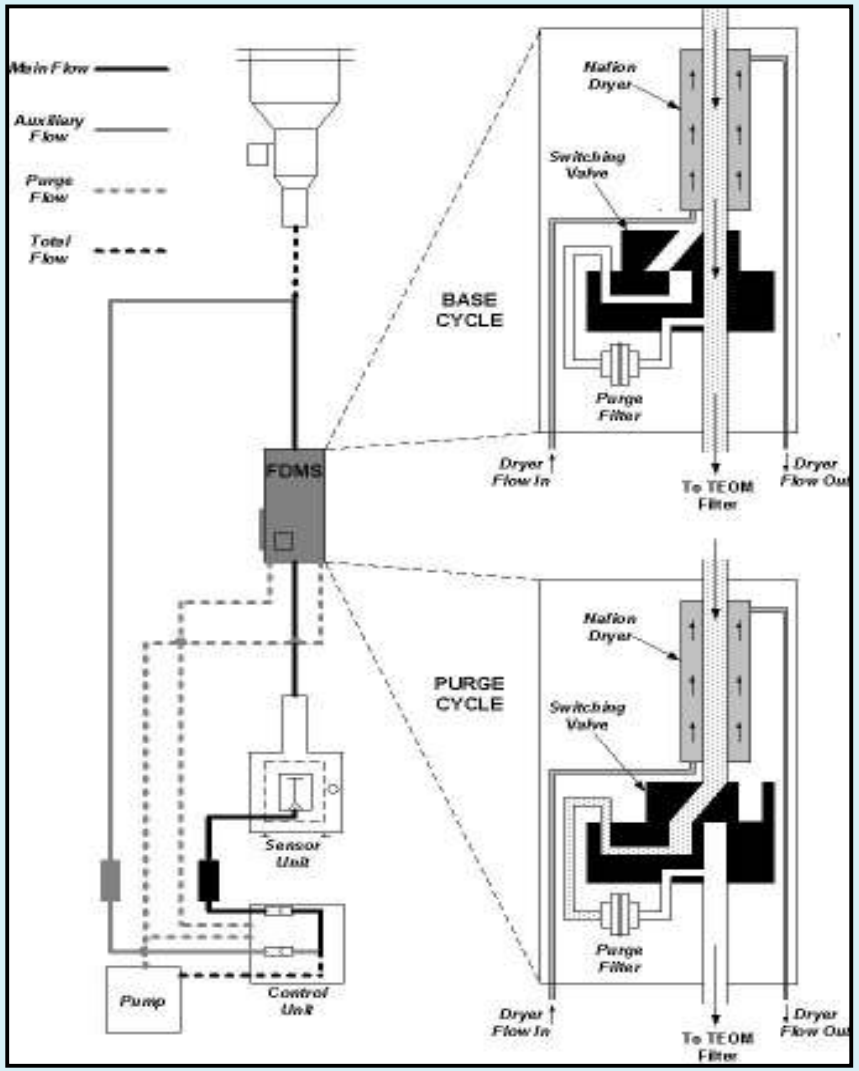
- Defra's advice to Local Authorities using TEOMs
  - *Generally not necessary to replace your TEOM immediately. But when the time does come to replace it, the replacement instrument should be something that meets the equivalence criteria.*
  - *TEOM data multiplied by 1.3 can still be used as an indicative measurement of gravimetric PM_{10} in the interim period*
  - *30-40 daily measurements > 50 μg m^{-3} LAs should consider upgrading*
- Defra's advice to Local Authorities using BAMs
  - *Divide by 1.21 (where measured at STP)*

FDMS monitoring in London



What is the FDMS?

- Filter Dynamics Measurement System
- Add on for the TEOM
- Equivalent to the reference method
- Overcomes the loss of volatile components
  - *Reducing sampling temperature to 30°C*
  - *Uses a diffusion dryer to remove water*
- Two measurement cycles
  - *Measures PM mass* - ***Base Measurement***
  - *Measures PM mass lost due to volatilisation of particles* - ***Purge Measurement***

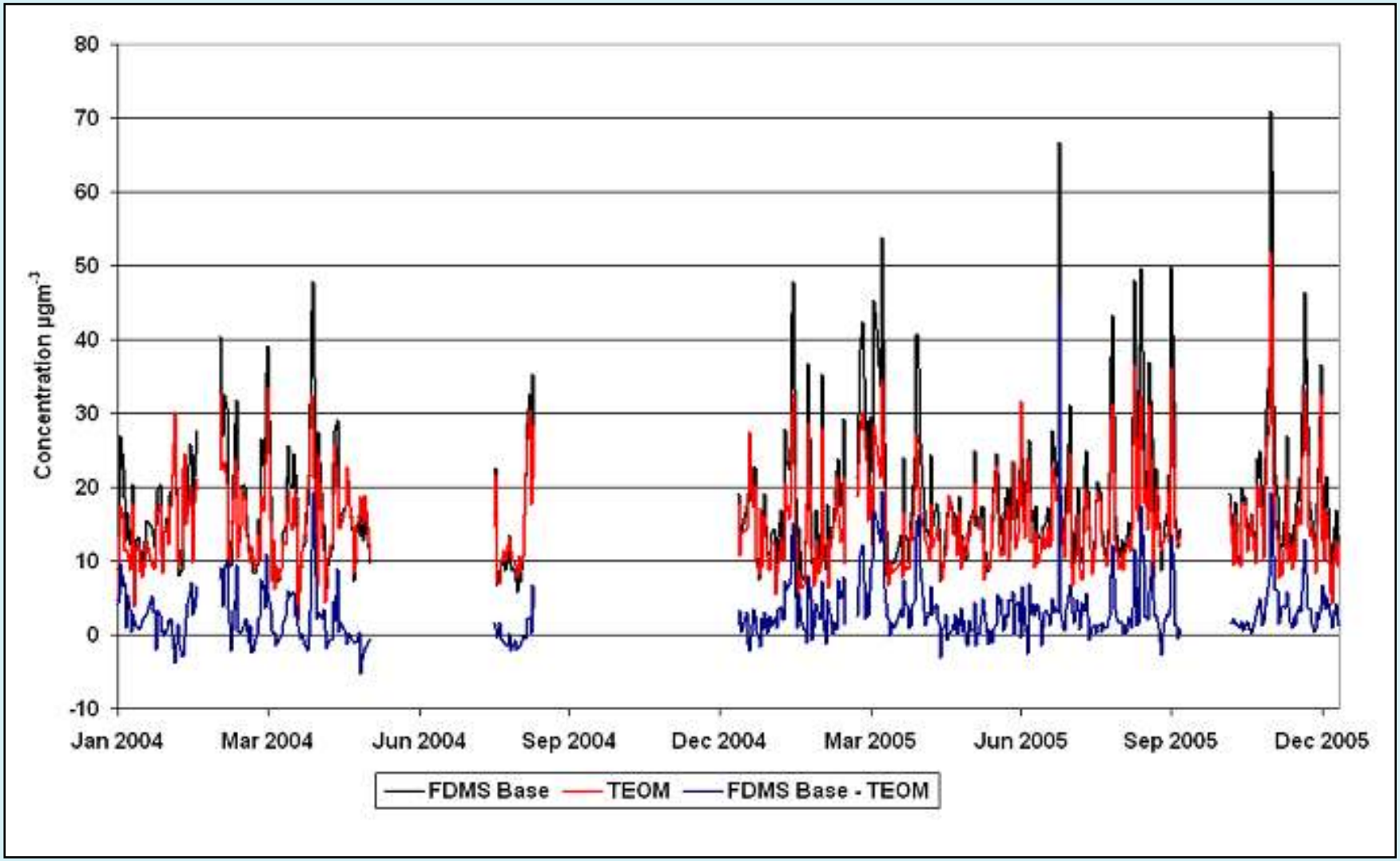


Model Development

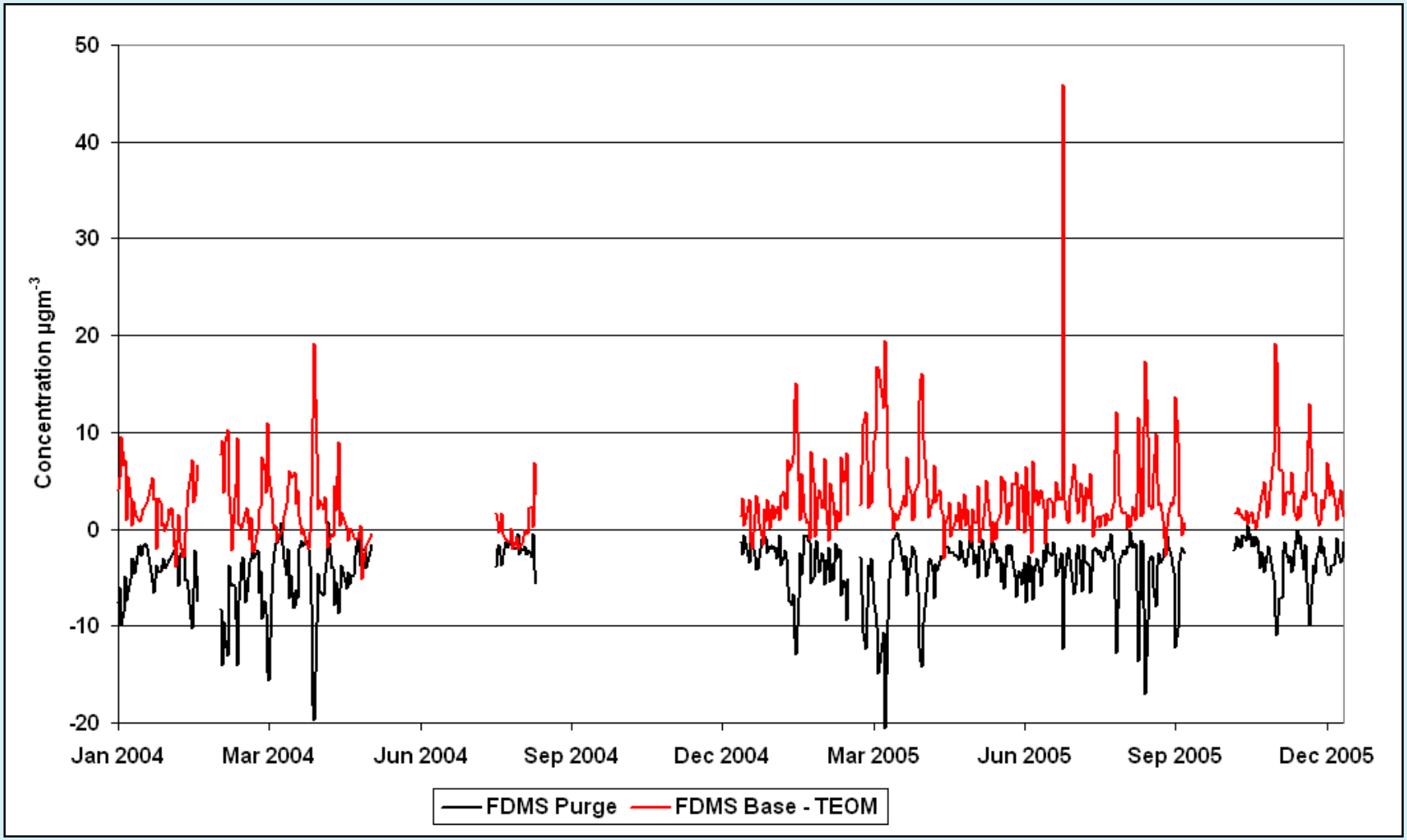
4 key points allow the development of a model to correct the TEOM measurements using a regionally located FDMS instrument.

1. FDMS = FDMS Base - FDMS Purge
2. FDMS = Reference method
3. TEOM - FDMS Base = FDMS Purge
4. FDMS Purge is uniform over a wide area

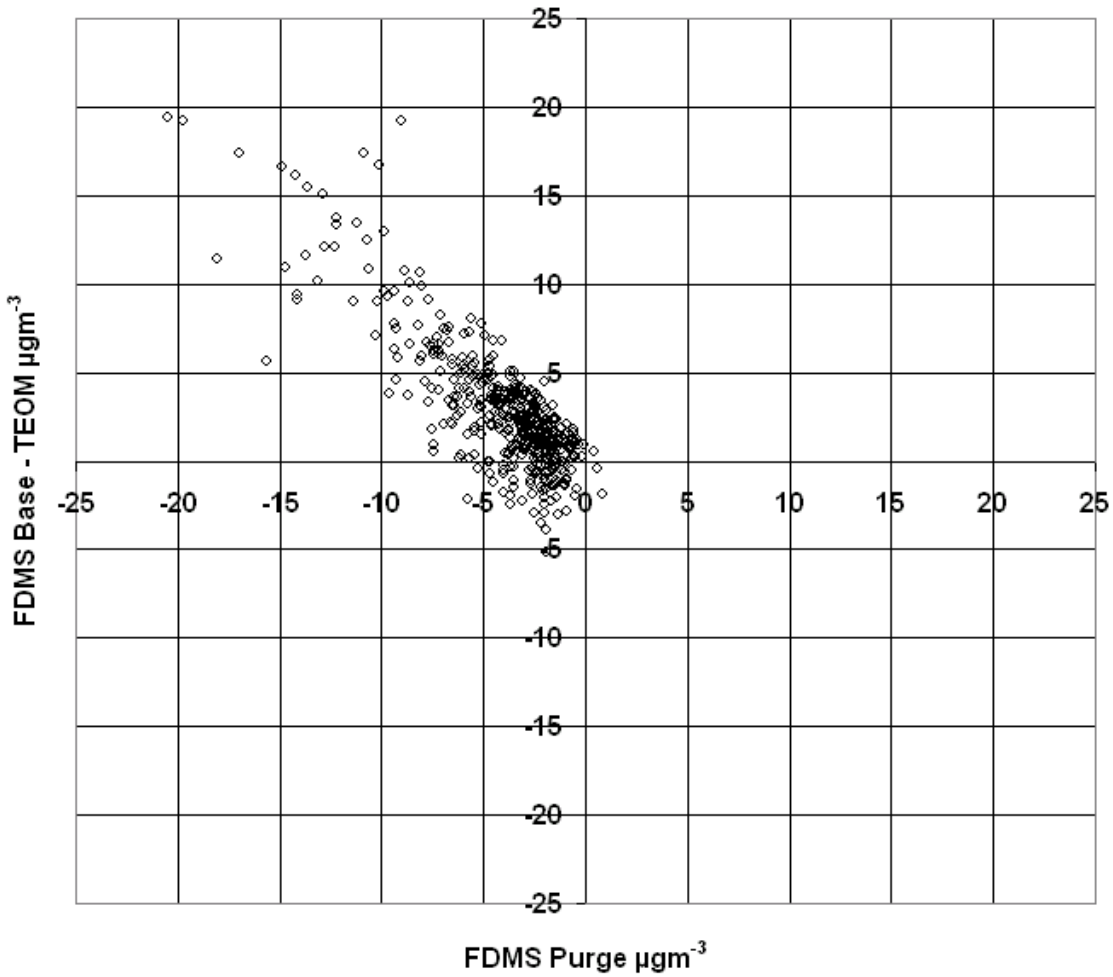
FDMS base vs. TEOM



(FDMS base – TEOM) ~ FDMS purge

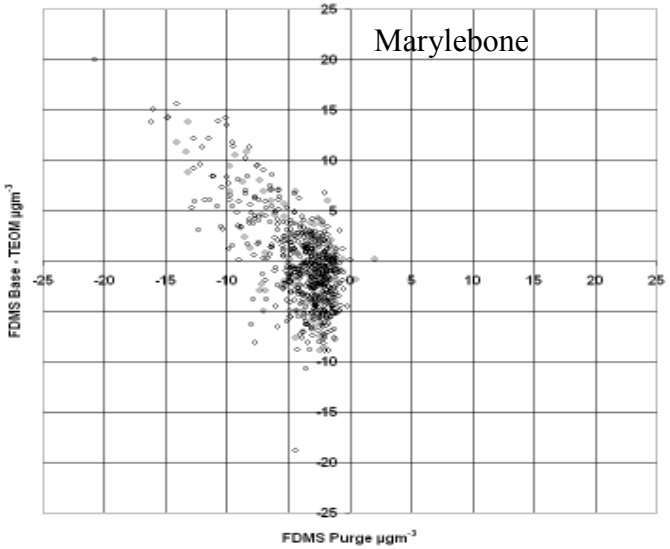


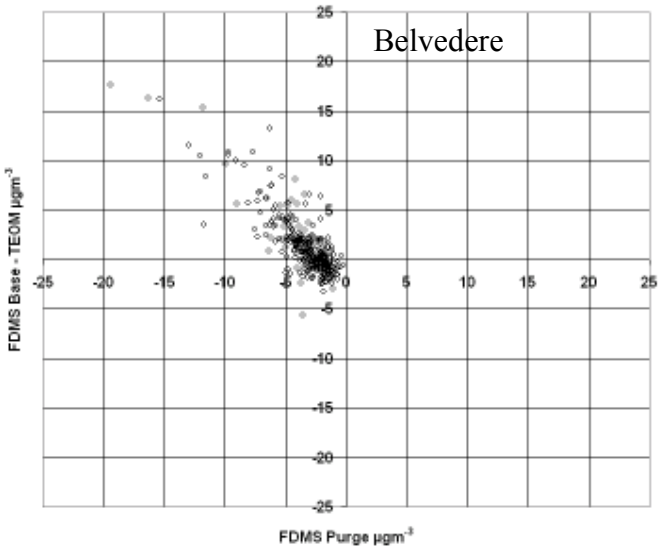
Correlation (1)

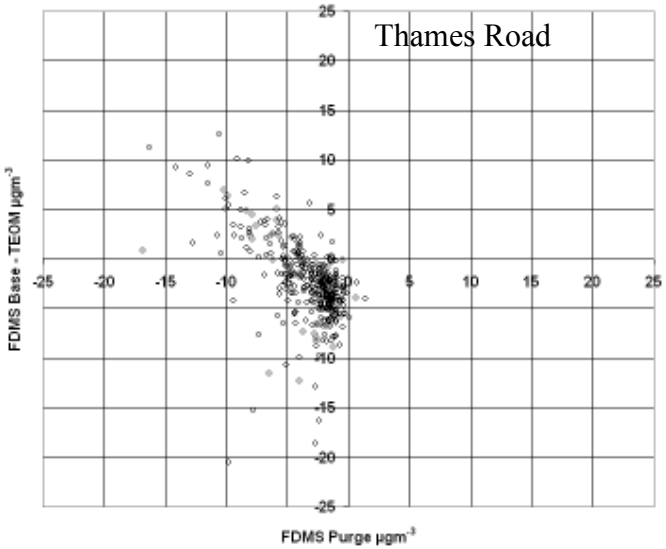


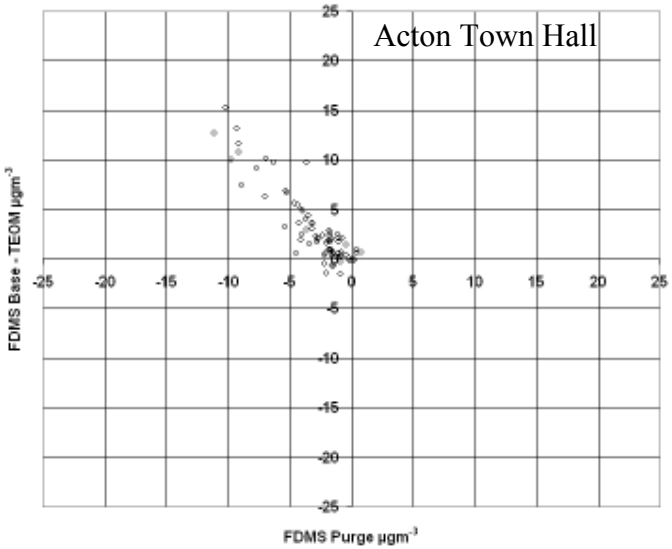
North Kensington

Correlation (2)









Model Development

4 key points allow the development of a model to correct the TEOM measurements using a regionally located FDMS instrument.

1. FDMS = FDMS Base - FDMS Purge
2. FDMS = Reference method
3. **TEOM - FDMS Base = FDMS Purge**
4. FDMS Purge is uniform over a wide area

Model Development

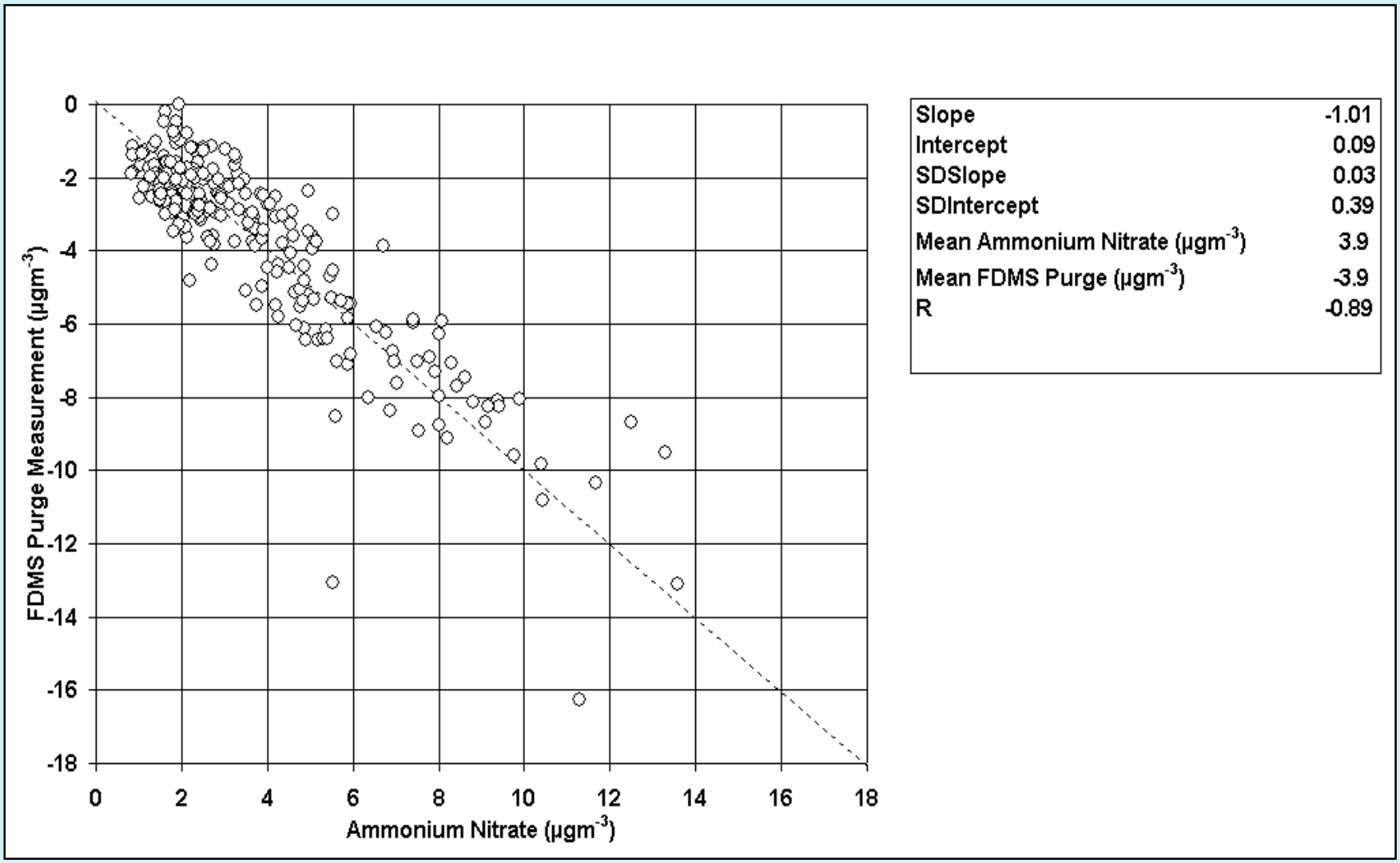
4 key points allow the development of a model to correct the TEOM measurements using a regionally located FDMS instrument.

1. FDMS = FDMS Base - FDMS Purge
2. FDMS = Reference method
3. TEOM - FDMS Base = FDMS Purge
4. **FDMS Purge is uniform over a wide area**

What do we know about the FDMS Purge?

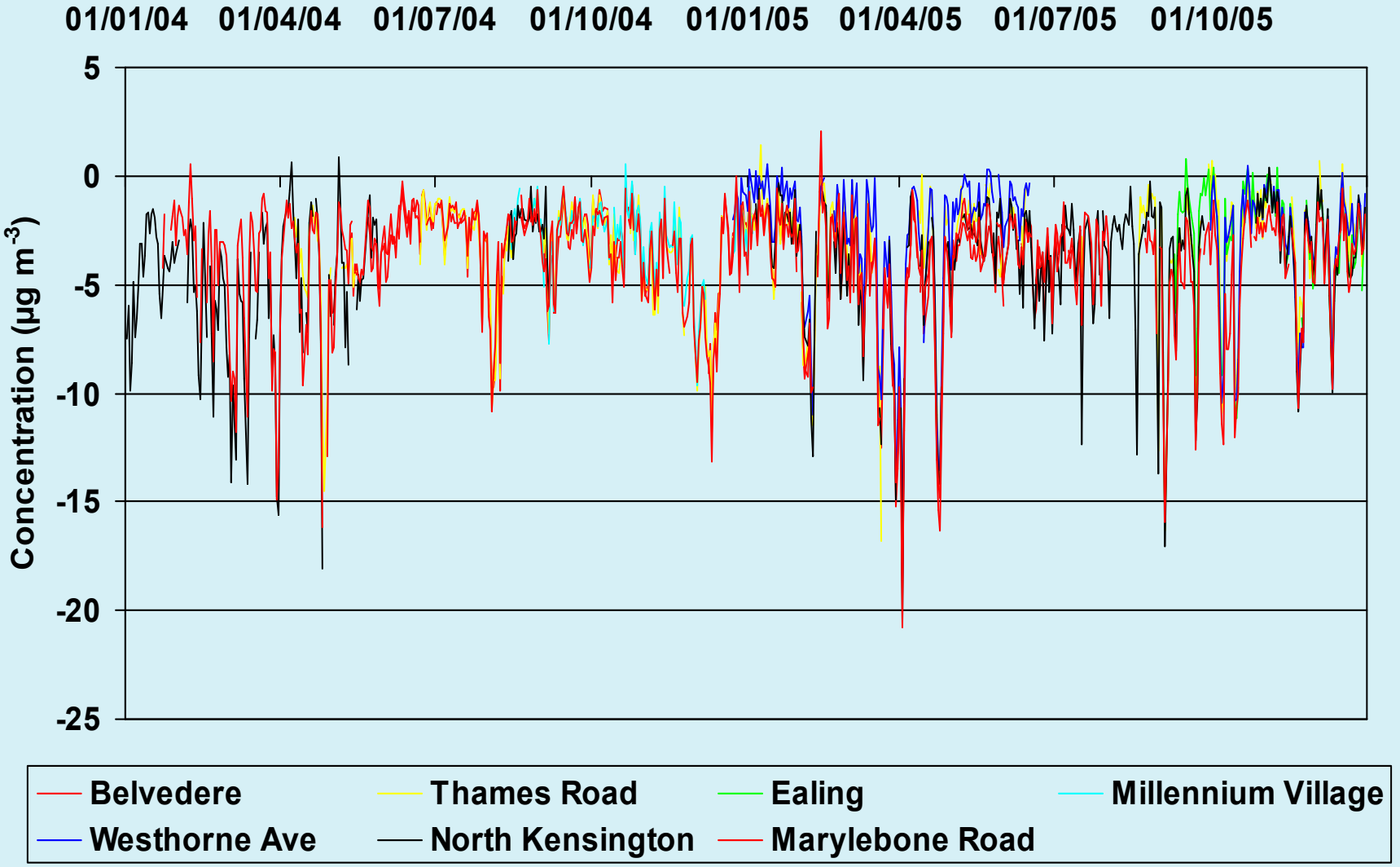
- Measurement made when particle free air is passing over the measurement filter
- Generally negative, indicating loss of mass from the filter
- Sometimes (but rarely) positive, indicating adsorption under some conditions
- Agrees well with mass of ammonium nitrate (*Hering, S. et al., 2004, Wittig, A. E. et al., 2004, Green and Fuller 2005*)
- Ammonium nitrate, being a secondary PM component, is likely to vary little on a regional scale. However, there has been some suggestion of an urban enhancement.

NH_4NO_3 ≈ FDMS Reference (Purge)



Slope	-1.01
Intercept	0.09
SDSlope	0.03
SDIntercept	0.39
Mean Ammonium Nitrate (µgm^{-3})	3.9
Mean FDMS Purge (µgm^{-3})	-3.9
R	-0.89

Daily Mean FDMS Purge Variation



Correlation Matrix

	Belvedere	Thames Road	Ealing	Millennium Village	Westhorne Ave	North Kensington	Marylebone Road
Belvedere	1.00						
Thames Road	0.92	1.00					
Ealing	-	0.90	1.00				
Millennium Village	0.91	0.91	-	1.00			
Westhorne Ave	0.98	0.92	0.96	0.84	1.00		
North Kensington	0.92	0.89	0.92	0.74	0.96	1.00	
Marylebone Road	0.95	0.90	0.87	0.93	0.95	0.91	1.00

Model Development

4 key points allow the development of a model to correct the TEOM measurements using a regionally located FDMS instrument.

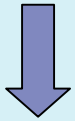
1. FDMS = FDMS Base - FDMS Purge
2. FDMS = Reference method
3. TEOM - FDMS Base = FDMS Purge
4. **FDMS Purge is uniform over a wide area**

Proposed Correction Model

1. $FDMS = FDMSBase - FDMSPurge$

Proposed Correction Model

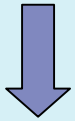
1. $FDMS = FDMSBase - FDMSPurge$



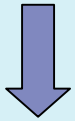
2. FDMS = Gravimetric

Proposed Correction Model

1. $FDMS = FDMSBase - FDMSPurge$



2. FDMS = Gravimetric



$$Gravimetric = FDMSBase - FDMSPurge$$

Proposed Correction Model

$$Gravimetric = FDMSBase - FDMSPurge$$

3. TEOM - FDMS Base = FDMS Purge

Proposed Correction Model

$$Gravimetric = FDMSBase - FDMSPurge$$

3. FDMS Base = TEOM - FDMS Purge

Proposed Correction Model

$$Gravimetric = FDMSBase - FDMSPurge$$

3. FDMS Base = TEOM - FDMS Purge

$$Gravimetric = (TEOM - FDMSPurge) - FDMSPurge$$

Proposed Correction Model

$$Gravimetric = FDMSBase - FDMSPurge$$

3. FDMS Base = TEOM - FDMS Purge

$$Gravimetric = TEOM - 2 \times FDMSPurge$$

Proposed Correction Model

$$Gravimetric = TEOM - 2 \times FDMSPurge$$

4. FDMS Purge is uniform over a wide area

Proposed Correction Model

$$Gravimetric = TEOM - 2 \times FDMSPurge$$

4. FDMS Purge is uniform over a wide area

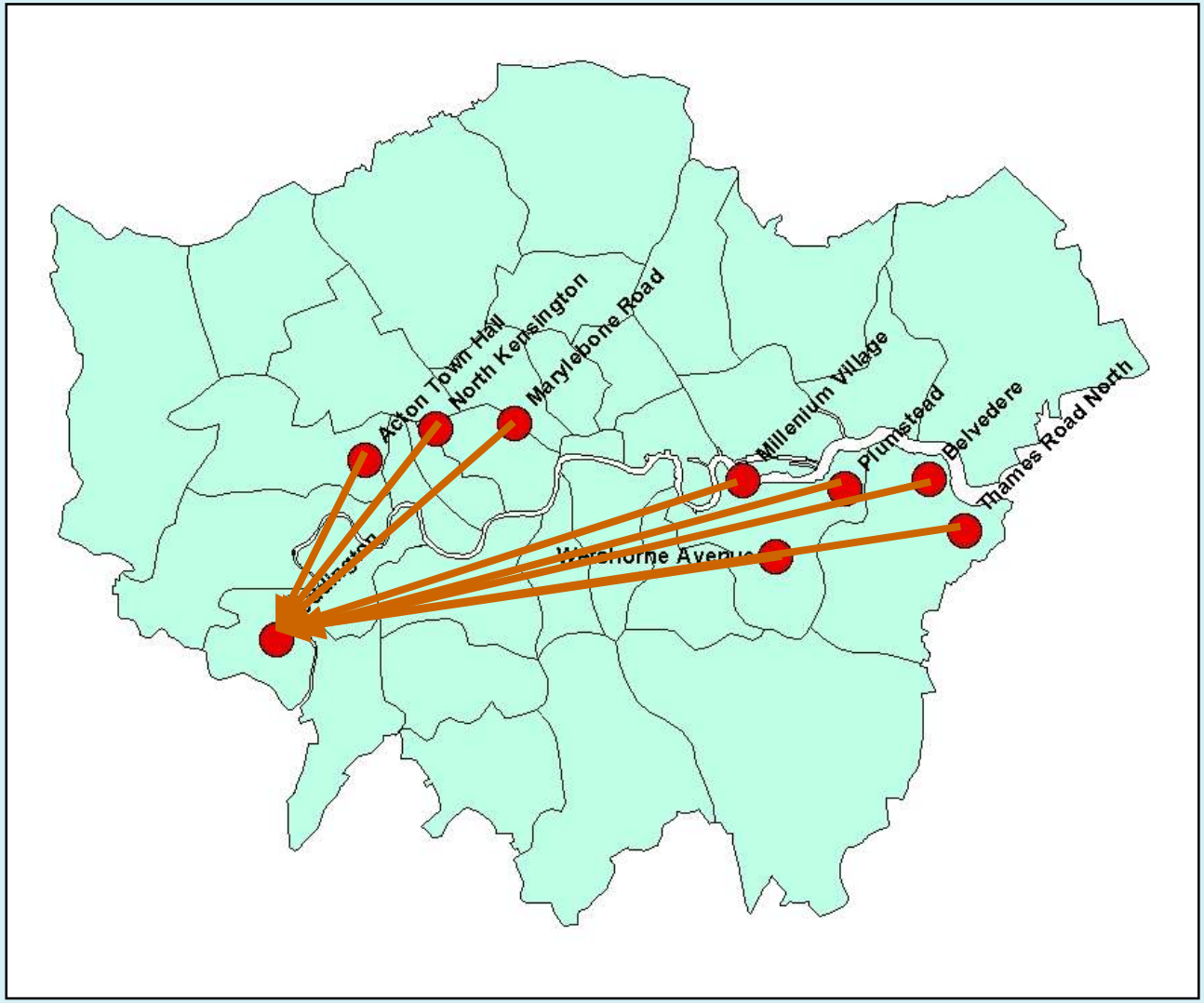
$$Gravimetric = TEOM - 2 \times regionalFDMSPurge$$

Model Testing – Stage 1

$$Gravimetric = TEOM - 2 \times FDMSPurge$$

PM10 KCL TEOM	Dataset	24 hour nbs	ubs	nc-s	r2	Orthogonal Regression Slope (b) +/- ub	Intercept (a) +/- ua	Annual Limit Value of 40 ug m-3 WCM/%	%>50%LV	Daily Limit Value of 50 ug m-3 WCM/%	%>50%LV	(nES,nEC)
Individual Campaigns	Birmingham Winter	75	0.80	47		1.00 +/- 0.05	-0.52 +/- 0.91	7.76	23%	6.20	13%	(1,2)
	Birmingham Summer	70	1.08	39		0.99 +/- 0.03	**2.50 +/- 0.69**	14.40	31%	11.20	18%	(3,4)
	Teddington Winter	85	0.37	33		**0.90 +/- 0.03**	**0.49 +/- 0.78**	19.98	48%	19.84	42%	(2,0)
	Teddington Summer	82	1.00	55		**0.84 +/- 0.03**	**3.32 +/- 0.76**	18.80	38%	20.28	18%	(5,1)
	Bristol Summer	53	1.48	44		**1.07 +/- 0.03**	1.38 +/- 0.78	22.78	50%	20.66	43%	(2,6)
	Bristol Winter	82	1.38	47		**0.93 +/- 0.03**	**4.24 +/- 0.77**	13.32	60%	9.48	38%	(2,2)
	East Kilbride Summer	54	2.65	40		1.09 +/- 0.07	**2.27 +/- 0.66**	**30.20**	5%	**27.70**	3%	(0,0)
	East Kilbride Winter	66	**4.69**	47		1.00 +/- 0.04	**2.43 +/- 0.51**	15.32	17%	12.42	6%	(0,0)
All Campaigns	All Data	1.58	567	352		**0.94 +/- 0.01**	**2.49 +/- 0.29**	13.12	34%	10.64	22%	(15,15)
Annual Limit Value	<20 ug m-3	348	1.59	232		0.80 +/- 0.03	3.90 +/- 0.38	22.66	-	-	-	-
	>20 ug m-3	219	1.56	120		0.87 +/- 0.03	5.38 +/- 0.89	16.48	-	-	-	-
Daily Limit Value of 50 ug m-3	<25 ug m-3	424	1.65	274		0.90 +/- 0.03	2.94 +/- 0.41	-	-	12.08	-	-
	>25 ug m-3	143	1.35	78		0.88 +/- 0.04	4.95 +/- 1.46	-	-	14.42	-	-

Model Testing – Stage 2

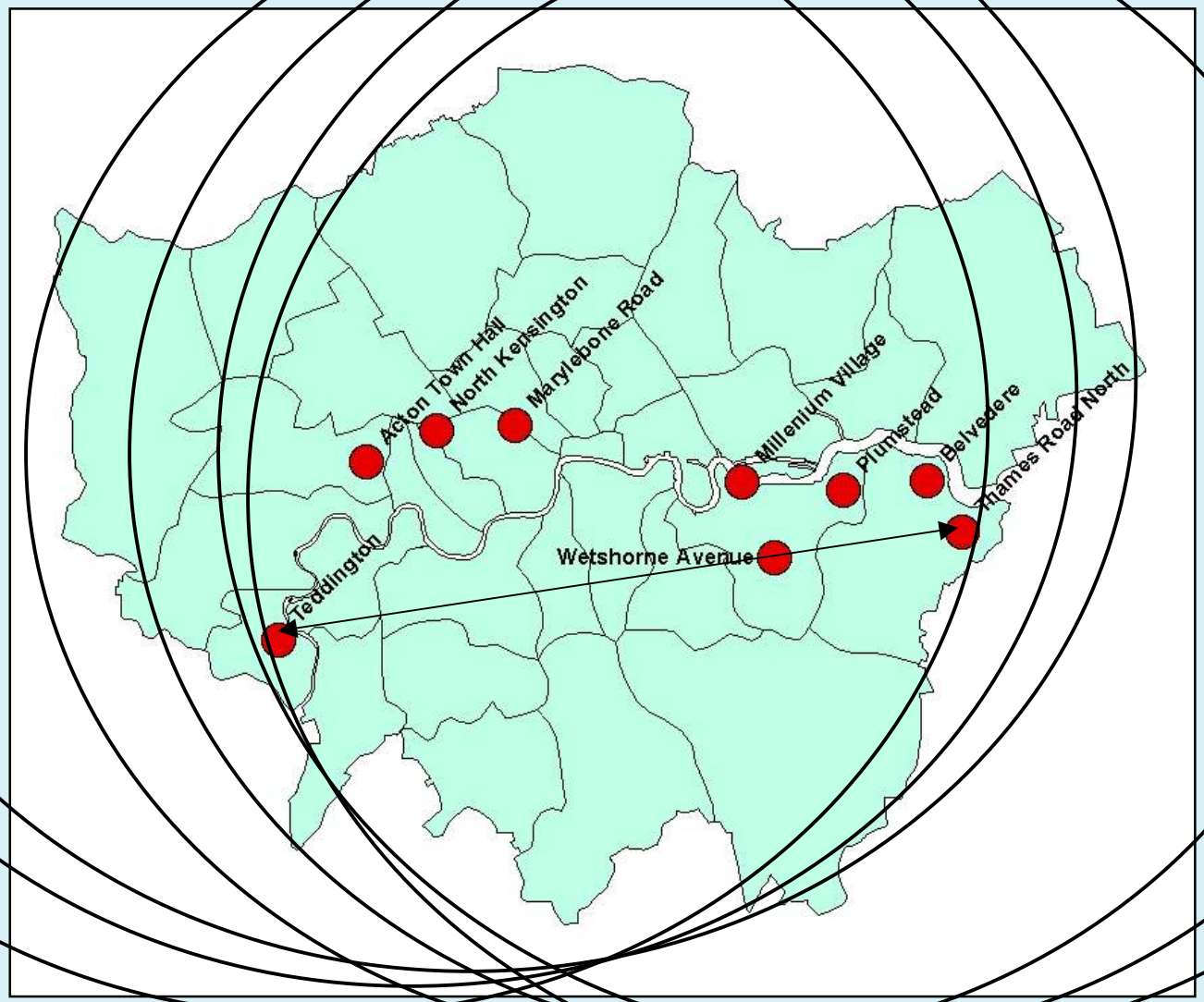


London Equivalence Testing Results

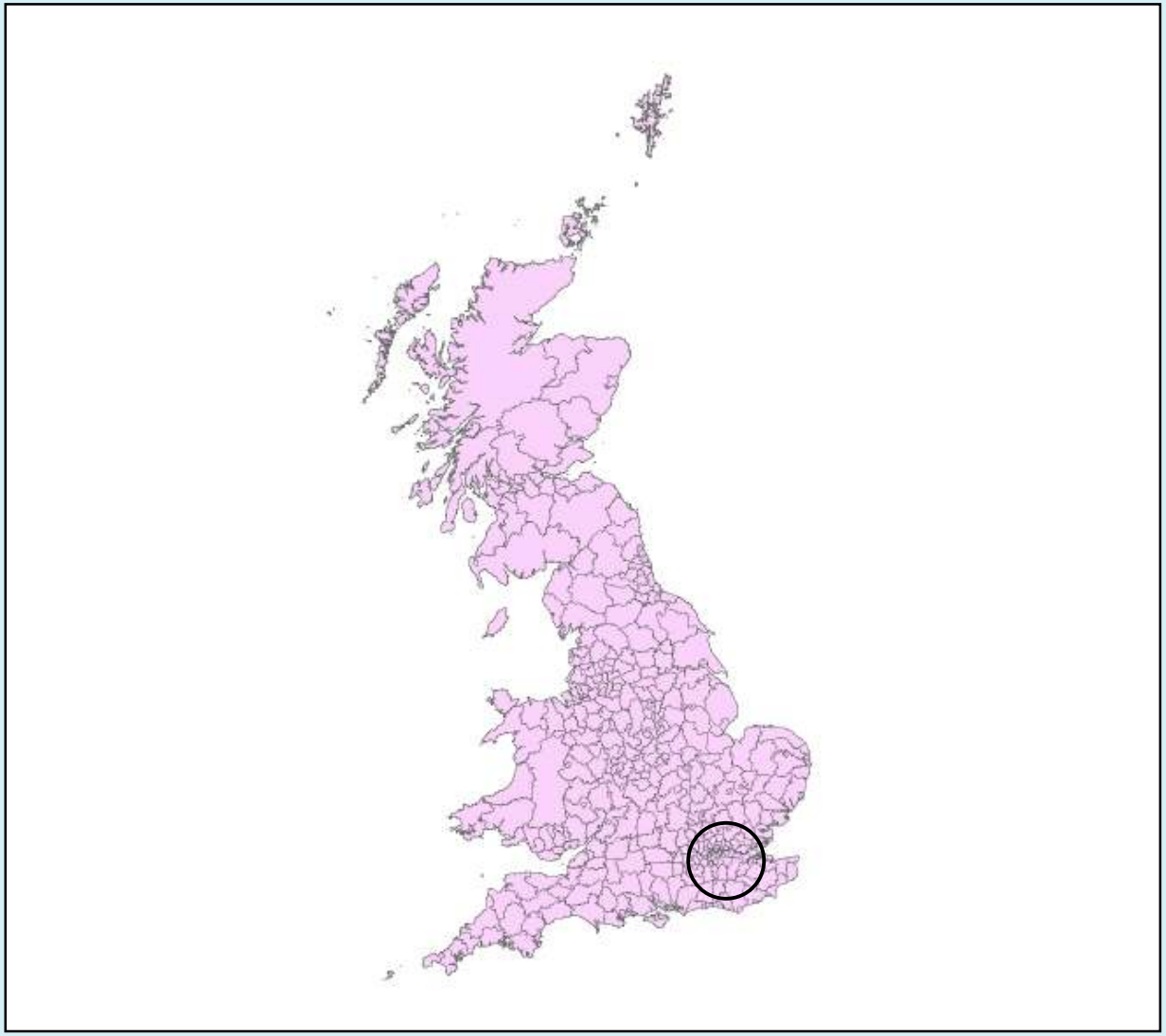
Teddington Winter	85	0.37	33	**0.90 +/- 0.03**	**0.49 +/- 0.78**	19.98	48%	19.84	42%	(2,0)
Teddington Summer	82	1.00	55	**0.84 +/- 0.03**	**3.32 +/- 0.76**	18.80	38%	20.28	18%	(5,1)

Dataset	24 hour		Orthogonal Regression			Annual Limit Value of 4		Daily Limit Value of 50 ug m-3		
	nbs	ubs	nc-s	r2	Slope (b) +/- ub	Intercept (a) +/- ua	WCM/%	%>50%LV	WCM/%	%>50%LV	(nES,nEC)
Kensington Winter	71	0.11	29		**0.84 +/- 0.04**	1.95 +/- 0.99	24.50	34%	**25.41**	17%	(1,0)
Kensington Summer	84	0.15	56		**0.87 +/- 0.04**	**4.44 +/- 0.98**	17.02	45%	16.00	29%	(4,4)
Kensington All Data	155	0.49	85		**0.86 +/- 0.03**	**3.52 +/- 0.80**	19.32	41%	19.06	25%	(4,4)
Marylebone Winter	122	0.10	47		**0.88 +/- 0.04**	**2.26 +/- 1.01**	18.66	57%	18.32	40%	(2,0)
Marylebone Summer	86	0.14	57		**0.86 +/- 0.03**	**4.71 +/- 0.76**	12.38	44%	12.56	23%	(4,4)
Marylebone All Data	208	0.11	104		**0.86 +/- 0.03**	**3.96 +/- 0.63**	16.30	50%	16.78	31%	(6,4)
Belvedere Winter	99	0.12	35		**0.85 +/- 0.04**	**3.25 +/- 1.04**	19.82	49%	20.82	37%	(3,0)
Belvedere Summer	81	0.80	53		**0.90 +/- 0.04**	**5.17 +/- 0.90**	15.44	47%	11.50	30%	(5,4)
Belvedere All Data	180	0.42	88		**0.87 +/- 0.03**	**4.62 +/- 0.75**	16.26	48%	15.16	33%	(8,4)
Thames Road Winter	122	0.10	47		**0.92 +/- 0.04**	0.93 +/- 1.07	19.14	51%	17.56	40%	(3,0)
Thames Road Summer	60	0.44	47		**0.85 +/- 0.05**	**2.55 +/- 1.05**	23.78	34%	23.80	17%	(5,1)
Thames Road All Data	182	0.21	94		**0.88 +/- 0.03**	**1.80 +/- 0.74**	21.18	43%	20.32	29%	(8,1)
Westhorne Avenue Winter	81	0.10	25		0.93 +/- 0.04	**-1.75 +/- 0.82**	23.26	24%	21.18	16%	(0,0)
Westhorne Avenue Summer	62	0.45	50		**0.86 +/- 0.03**	**1.22 +/- 0.72**	23.78	20%	24.14	14%	(5,2)
Westhorne Avenue All Data	143	0.25	75		**0.88 +/- 0.03**	**0.37 +/- 0.59**	24.48	28%	24.06	11%	(5,2)

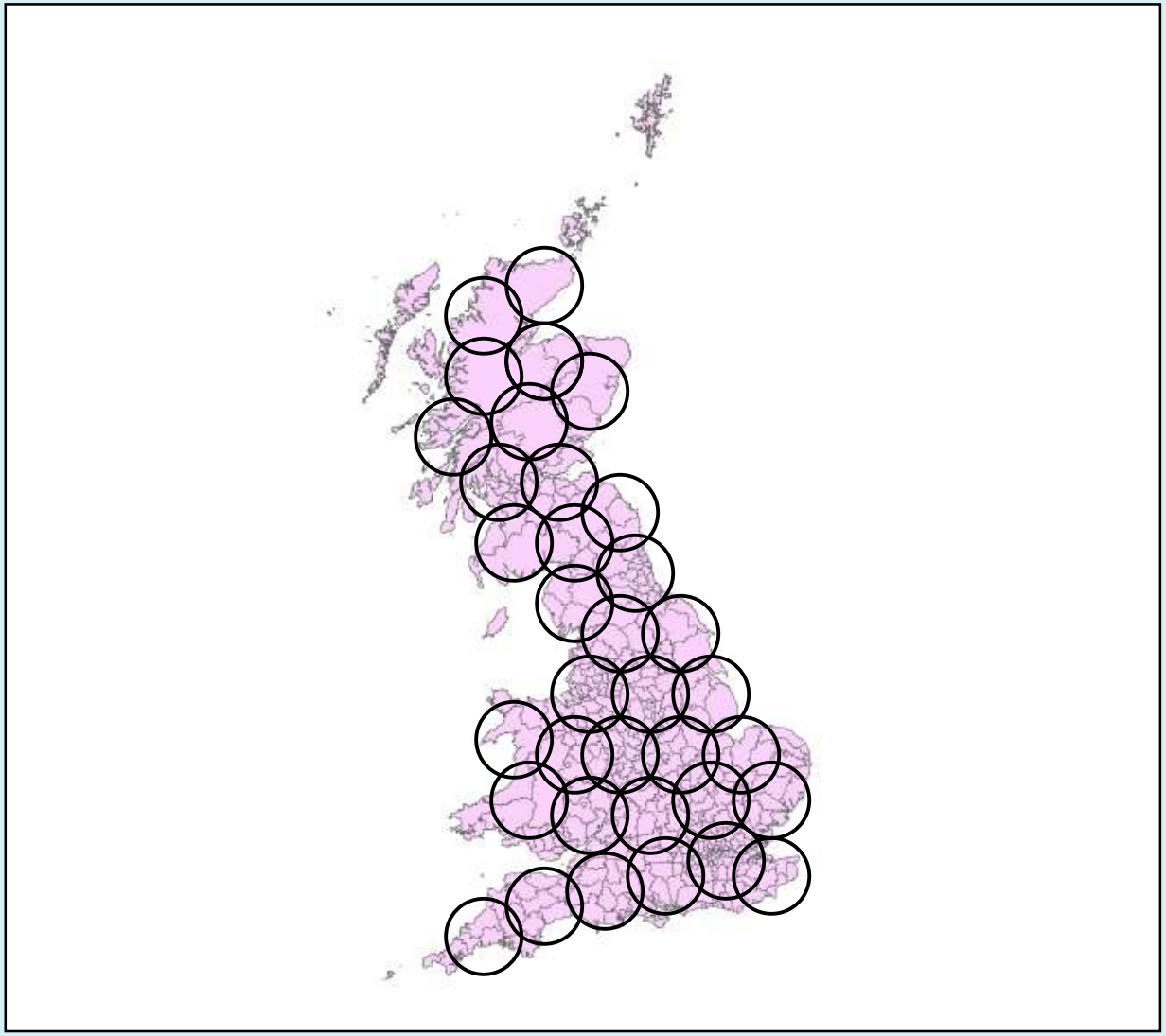
Model Application in London



PM_{10} measurement in the UK

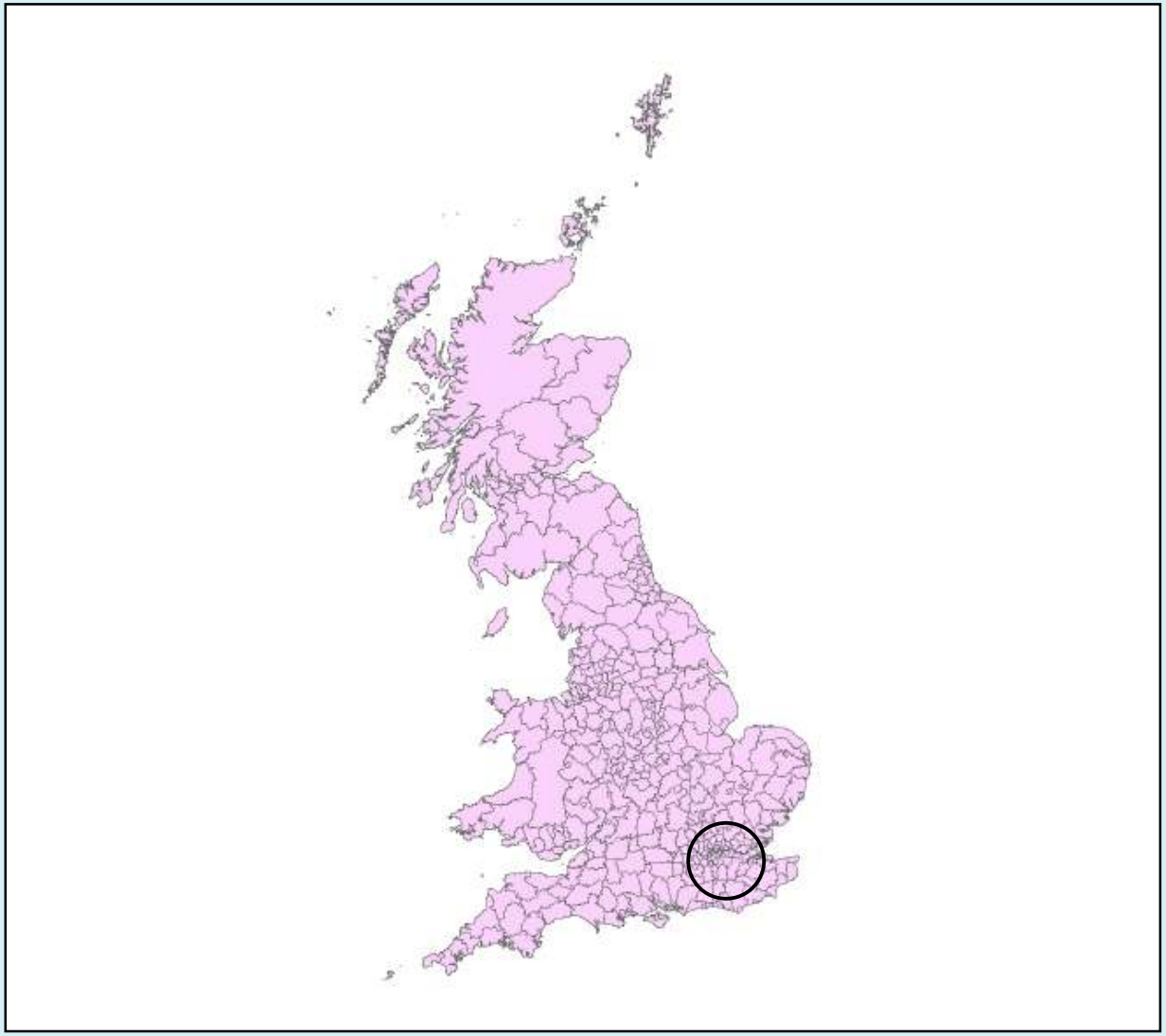


PM_{10} measurement in the UK?

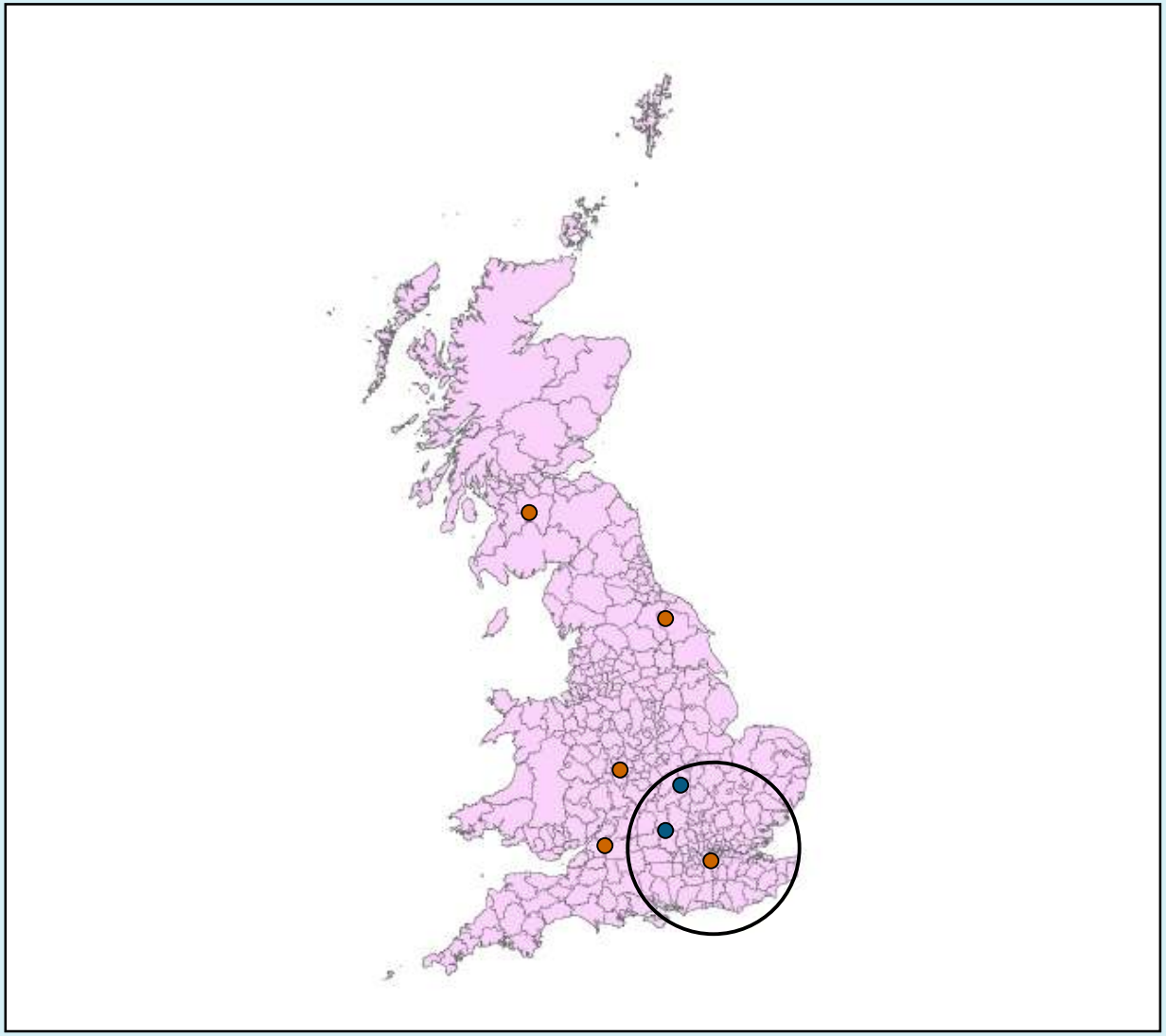


Lots more questions….

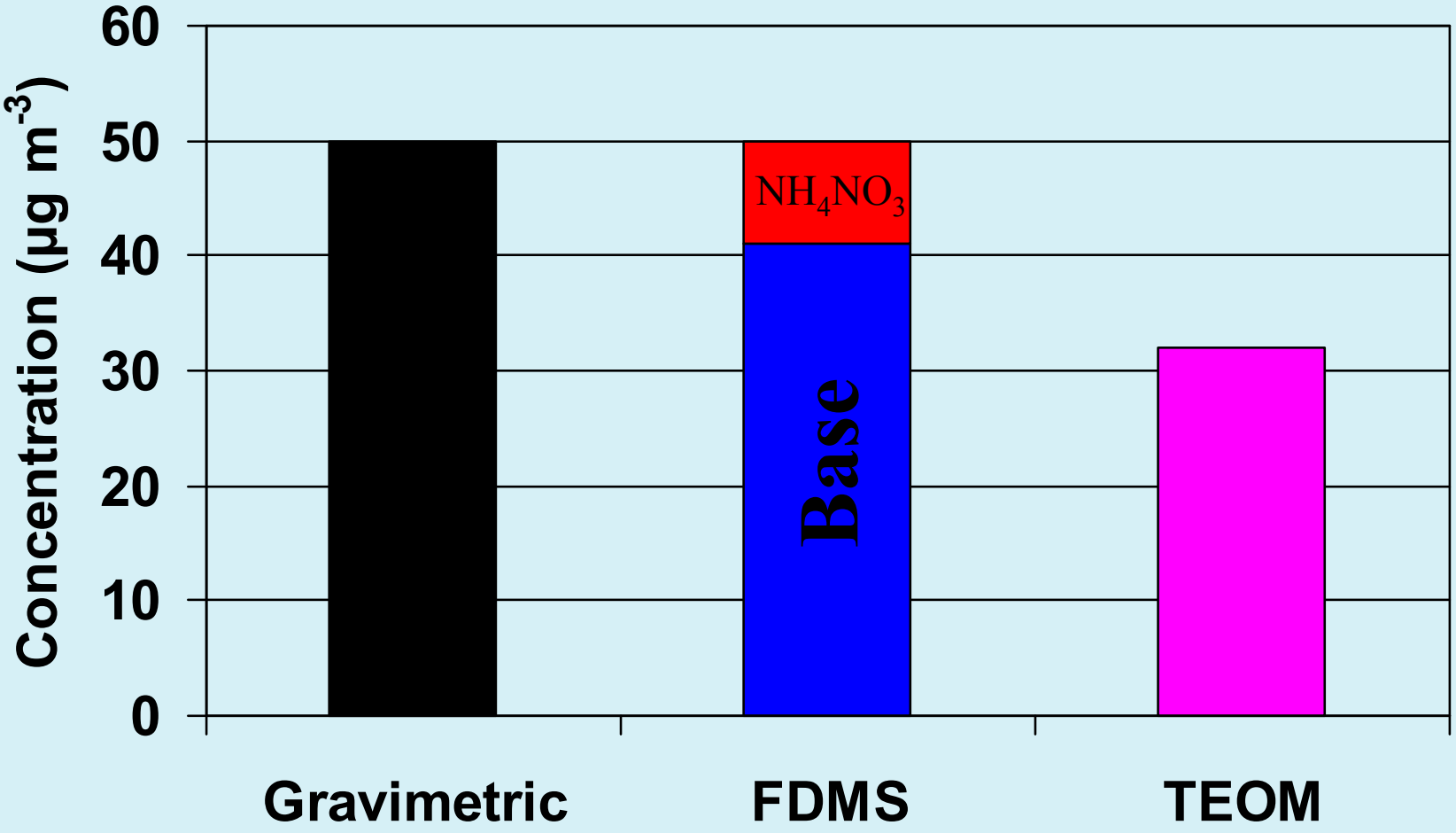
How big is my coverage?



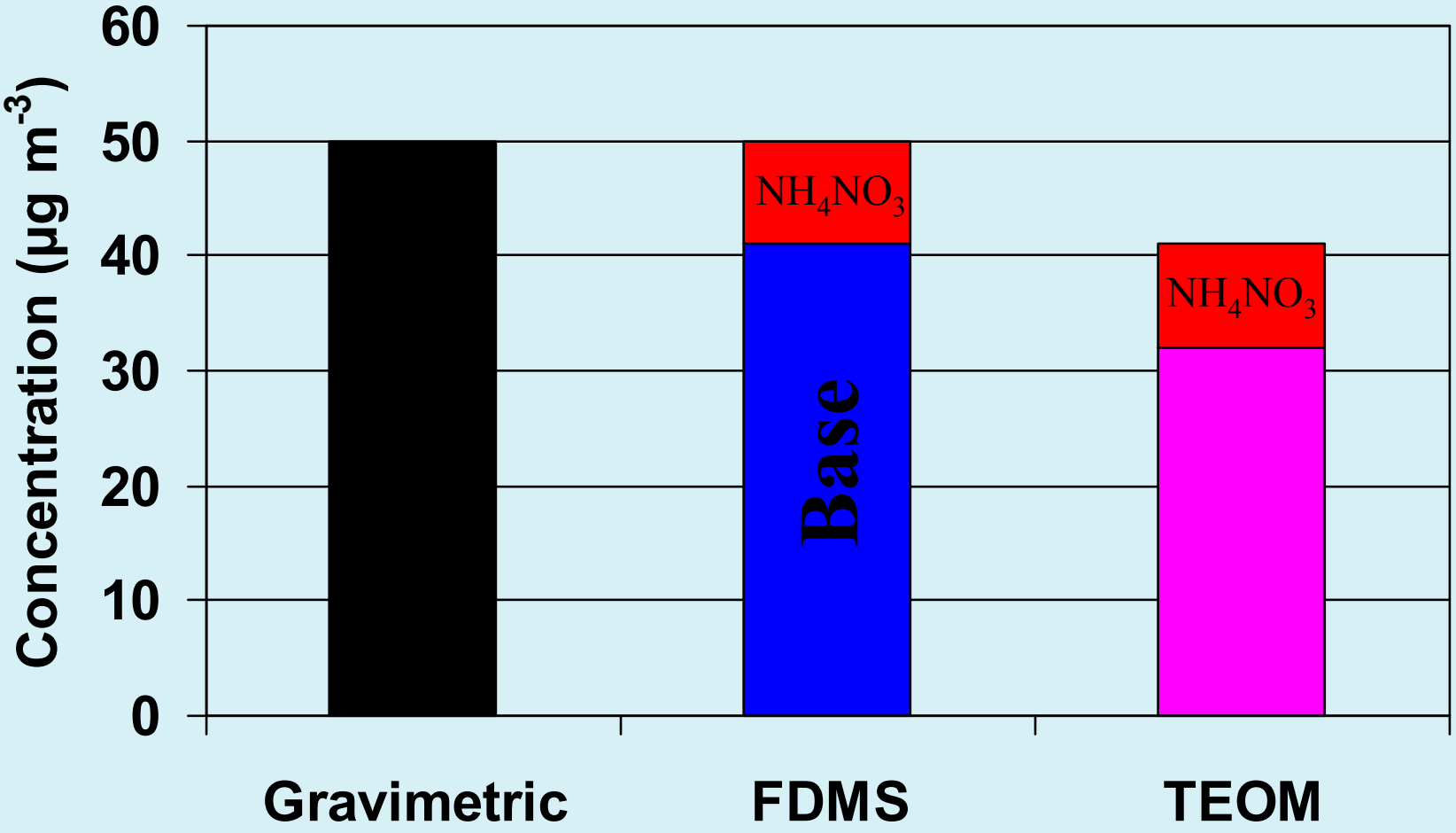
How big is my coverage?



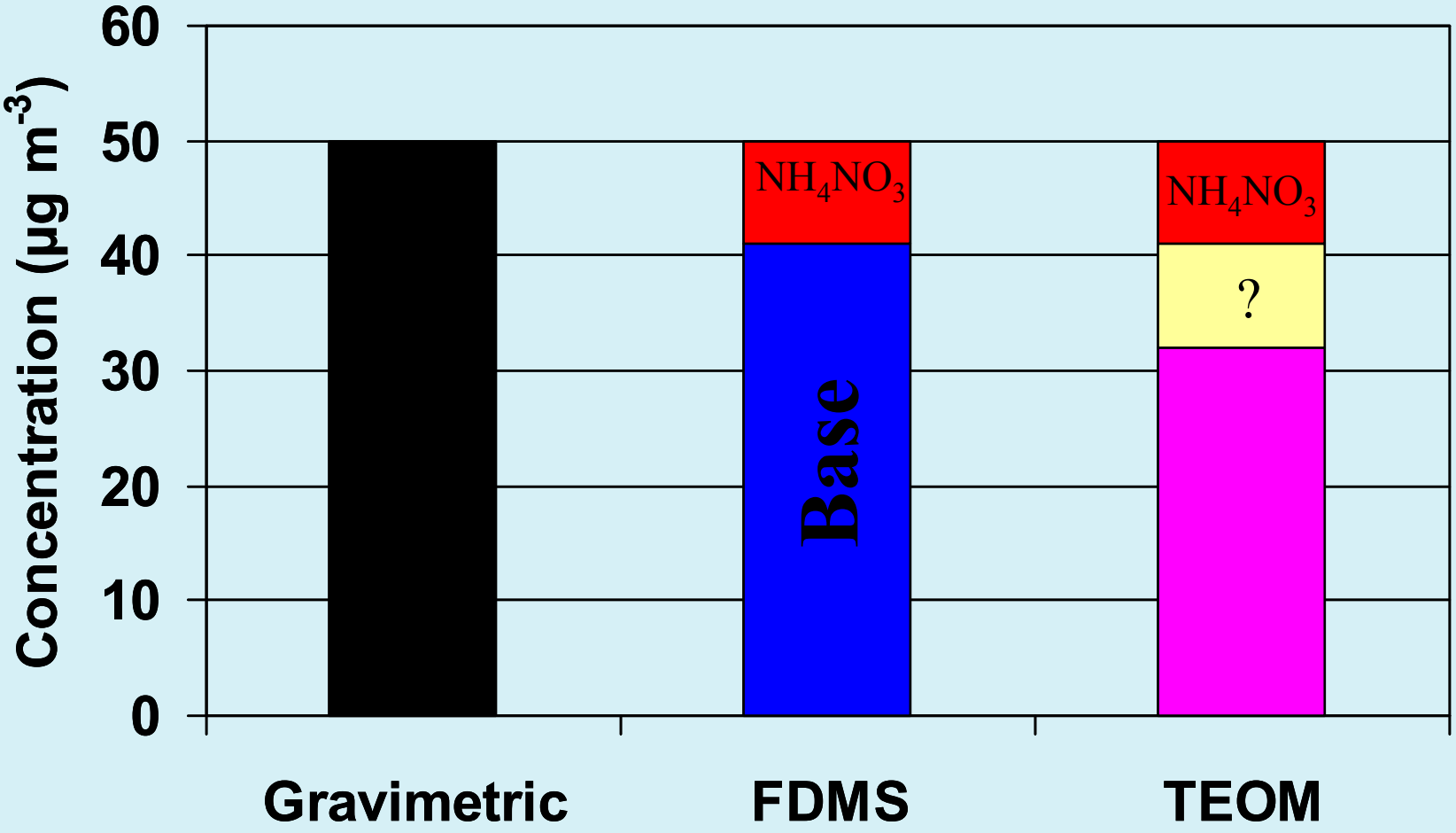
Why does it work?



Why does it work?



Why does it work?



Further Work…

- Further model testing
  - *Geographical extent*
- Underlying mechanisms
- Application in real time
- $PM_{2.5}$

Acknowledgements

- London Borough of Bexley
- London Borough of Greenwich
- London Borough of Ealing
- City of Westminster
- Royal Borough of Kensington and Chelsea
- DEFRA
- Air Monitors

Summary

- PM_{10} monitoring network which reports reference equivalent measurements
  - *Relatively little additional cost*
  - *Gravimetric*
  - *FDMS*
  - *BAM (corrected)*
  - *TEOM (volatile corrected)*