Scottish Air Quality Seminar:
Assessing variations in roadside air quality with sampling height
26th March 2015

Introduction

- Study commissioned by the Scottish Government to investigate roadside air quality versus height:
  - Literature Review
  - Sampling
  - Reporting
- Study carried out in Glasgow.
- Sampling methodology.
- Some results.

The Study

"The study will investigate how Air Quality varies with height and aims to:

- ***Determine the relationship between height from pavement and Air Quality.***
- ***Investigate the relationship between mobile and fixed sampling methods.***
- ***Examine diurnal and seasonal variations in Air Quality.***

The outputs will help inform Air Quality policy in Scotland."

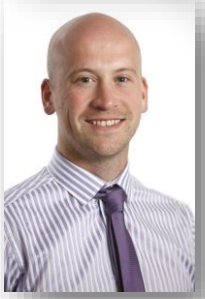
The Team

Ellis Marshall-Padkin

Sam Copsey

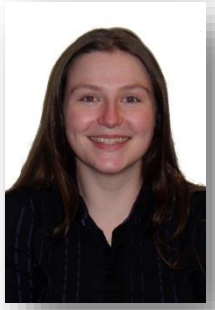
Brian Stacey

Stephen Stratton



David Hector

Stuart Sneddon



Susannah Telfer

Stephen Gray

The Equipment

Species	Sampling Method/Analyser
$PM_{2.5}$ (Automatic)	Lighthouse IAQ 3016 $PM_{2.5}$ analyser
$PM_{2.5}$ (Gravimetric)	Harvard-PEMS + BGI pump (Personal Exposure Monitor)
Black Carbon	Magee MicroAeth AE51
Ultrafine Particles	Philips Nanotracer
NO_2, SO_2, CO and O_3	AQMesh
CO_2	COZIR Optical Sensor
Benzene	Pumped tube sampling
Meteorology	Lufft WS600 (WS+WD+T+H+P+RF)
Video and GPS	Roadhawk
Data Acquisition	Weblogger with 3G telemetry

- The review focussed on but was not restricted to the following types of study:
  - Air quality versus height.
  - Mobile monitoring.
  - Personal exposure.

Findings - Literature Review

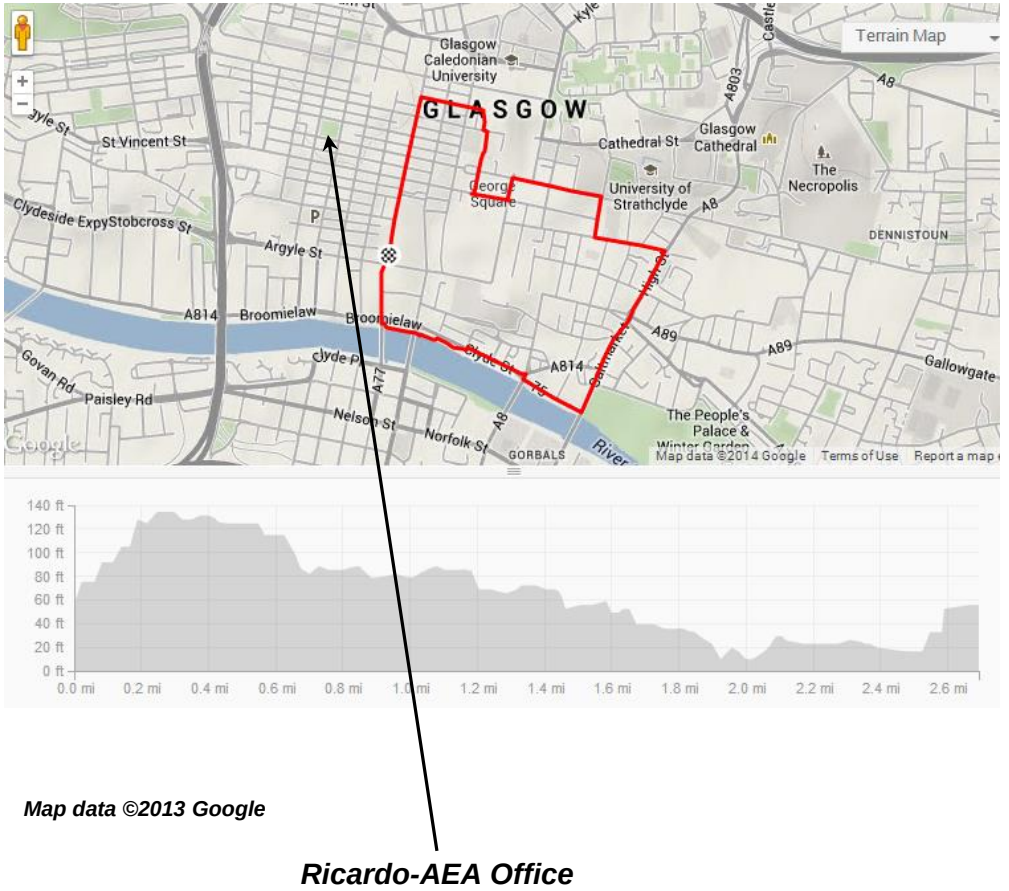
- Research indicates that a pollutant gradient does exist at heights below 3 m above ground level, but that the following factors will affect the vertical profile:
  - Meteorology.
  - Topography.
  - Distance from emissions source.
- No study was found that incorporated mobile sampling with sampling at more than one height.
- Methodology outlined for the study was validated.
- Sampling heights defined as 168 cm above ground level for the average height of an adult above the age of 16 years in Scotland; and 80 cm for a child in a buggy.
- Highlighted problems that we might encounter.

The Location – Why Glasgow?

- Glasgow is Scotland’s largest city.
- Glasgow City Centre combines a variety of urban environments within walking distance.
- Glasgow City Centre is busy, both in terms of road traffic and people.
- Ricardo-AEA Scotland office, Blythswood Square.

Sampling Route

Street name	Description of street on route	Approximate Length of street within study route (miles)
Hope Street	Busy urban canyon orientation south to north (partially restricted to buses and taxes)	0.42
Sauchiehall Street	Urban pedestrian precinct orientation west to east	0.16
Buchanan Street	Urban pedestrian precinct orientation north to south	0.22
St Vincent Street	Busy urban canyon orientation west to east	0.10
George Square	Busy urban street orientation west to east	0.14
George Street	Busy urban canyon orientation west to east	0.14
Montrose street	Busy urban canyon orientation north to south	0.11
Ingram Street	Busy urban street orientation west to east	0.18
High street	Busy urban street orientation north to south	0.21
Saltmarket	Busy urban street orientation north to south	0.34
Clyde Street/Broomielaw	Busy Urban street orientation east to west	0.44
Oswald Street	Busy urban street orientation north to south	0.16



Map data ©2013 Google

Ricardo-AEA Office

- 185 miles covered and 9,840 ft "climbed"…

…over a total of 82 hours.

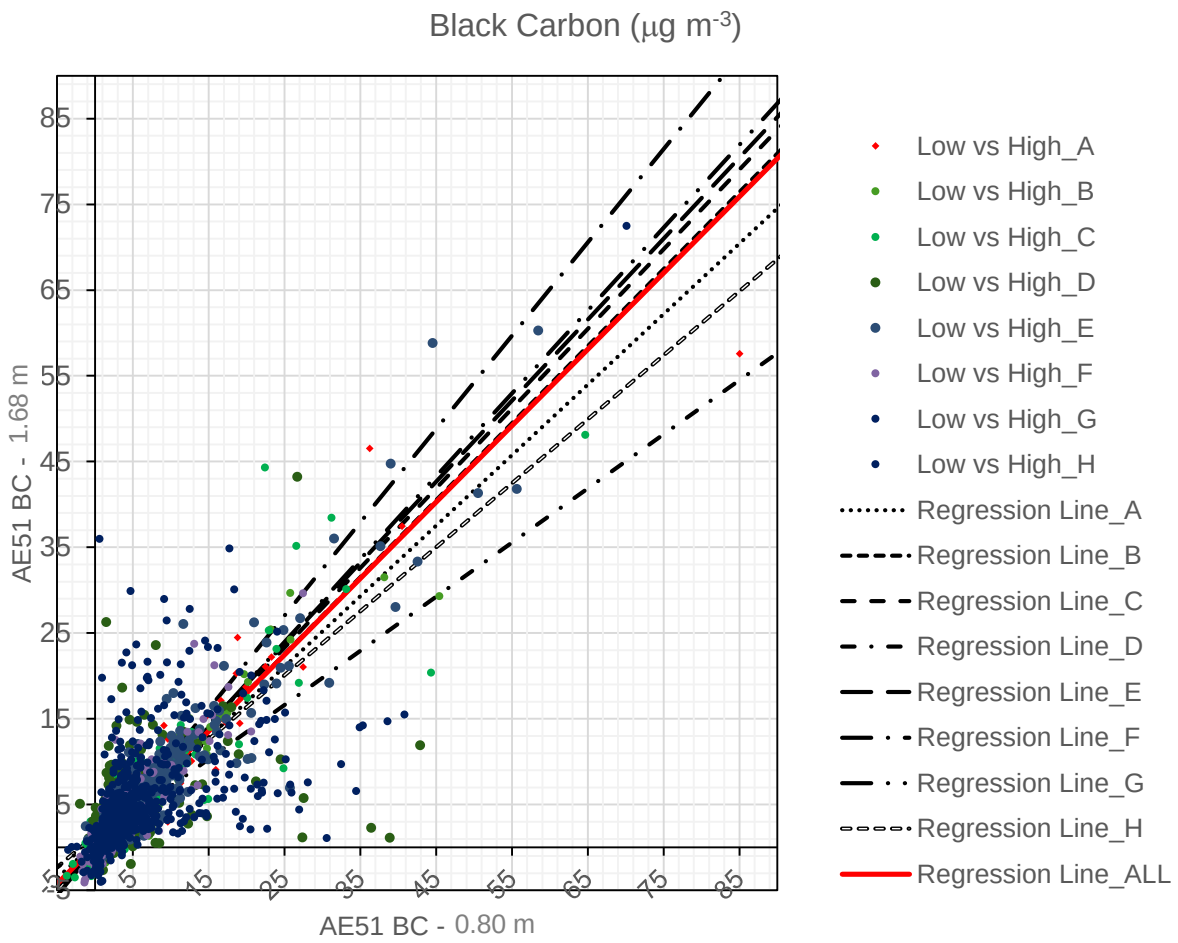
- 2 x 18,575 Calories used.

Sampling Regime

- Predetermined route.
- 8 mobile sampling exercise (2 weekend days).
- 6 co-location exercises, sampling at an automatic monitoring site.
- Carried out between Feb-14 and Aug-14.

Mobile Monitoring Video

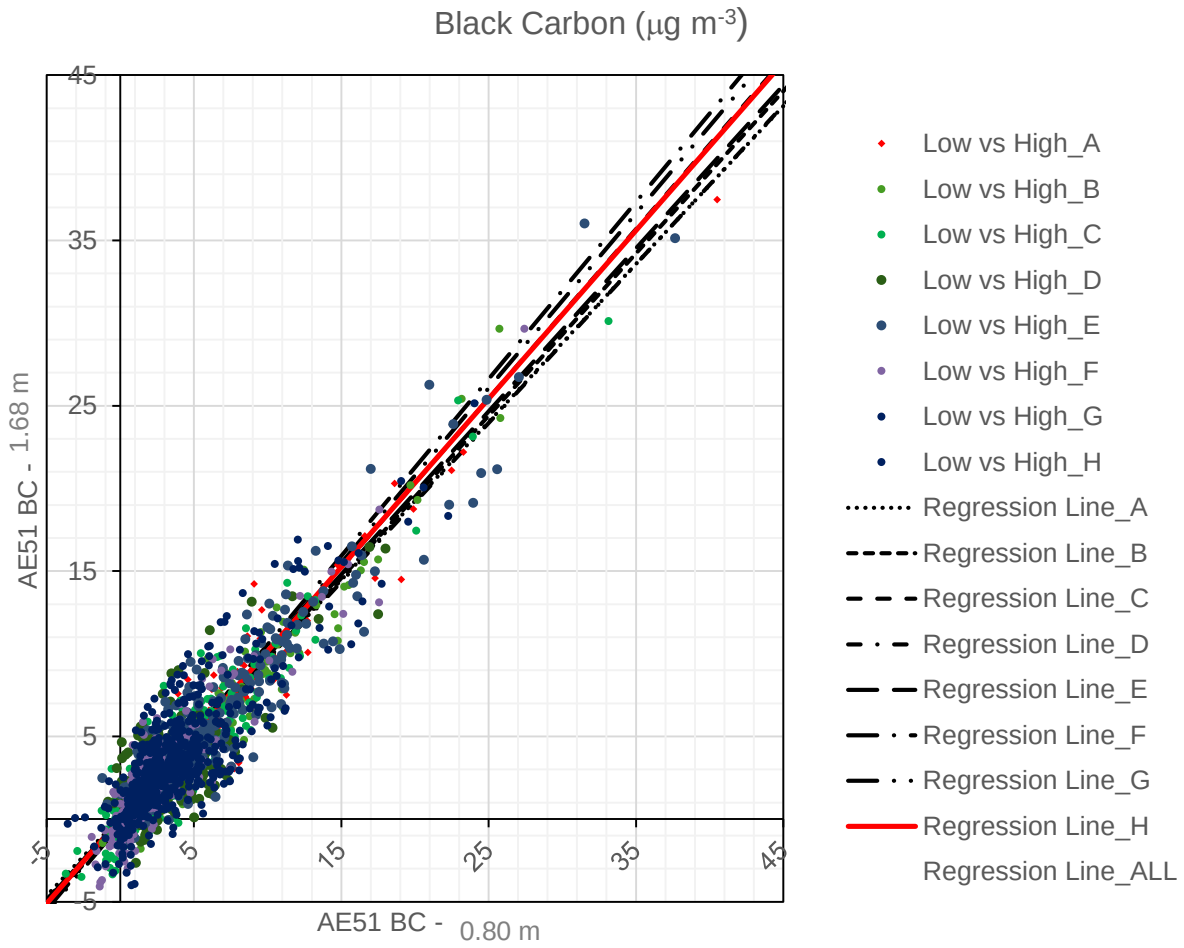
Pollutant Concentrations vs Height Analyses



$y = 0.89x \pm 0.008 + 0.204 \pm 0.052, r^2 = 0.67$

Colocation Data	***Mobile Pollutant vs Height Data***
Orthogonal Regression (y = bx + a)	Orthogonal Regression (corrected HIGH sampler data)
Grubbs' Outlier Test	Grubbs' Outlier Test
Orthogonal Regression	Orthogonal Regression
Correction of HIGH sampler data…	Pollutant vs Height relationship

Pollutant Concentrations vs Height Analyses Continued…



$y = 1.007x \pm 0.006 - 0.101 \pm 0.026, r^2 = 0.87$

Significance criteria:

If $|\boldsymbol{a}| > \boldsymbol{2u_a}$ *then adjust for intercept.*

If $|\boldsymbol{1 - b}| > \boldsymbol{2u_b}$ *then adjust for slope.*

Where:

$a = intercept$
$b = slope$
$u_a = uncertainty\ in\ intercept$
$u_b = uncertainty\ in\ slope$

Colocations

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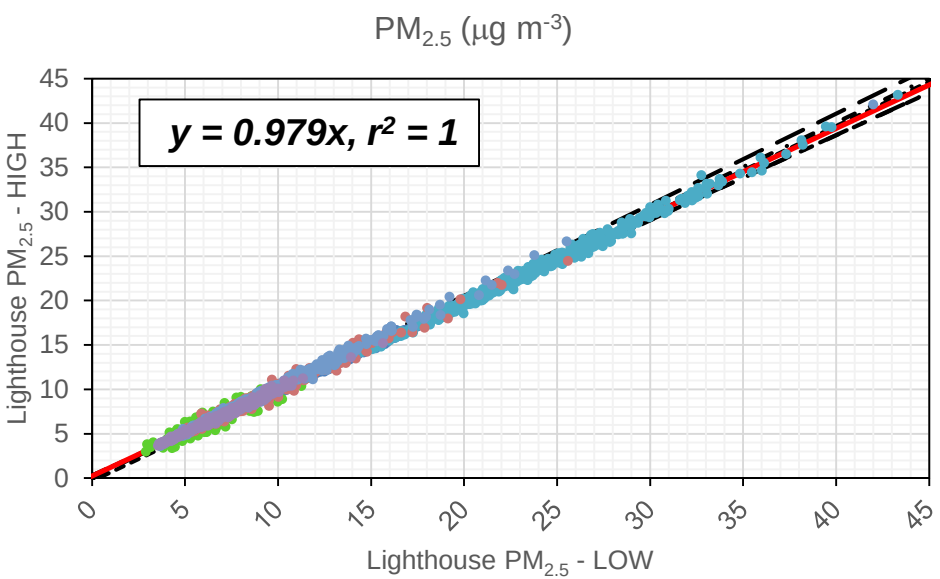

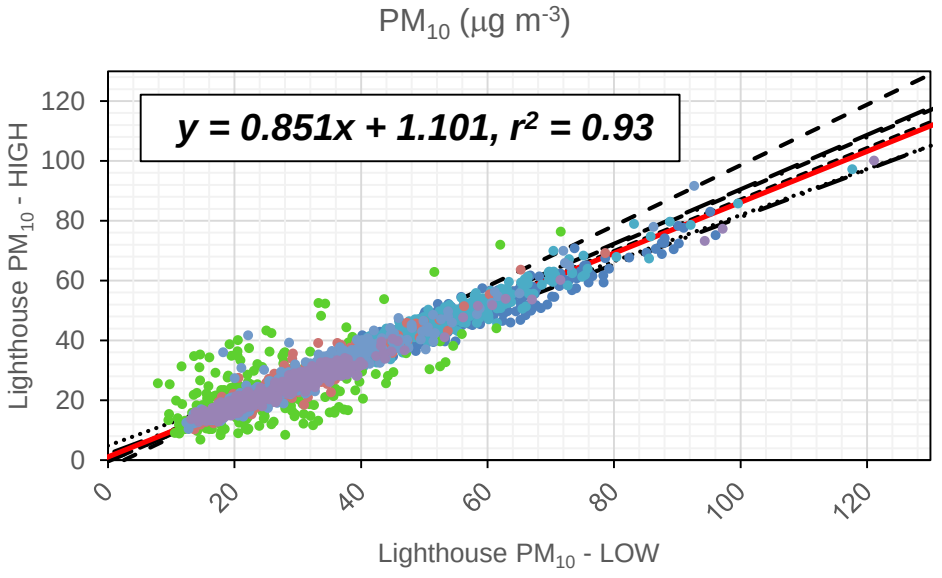

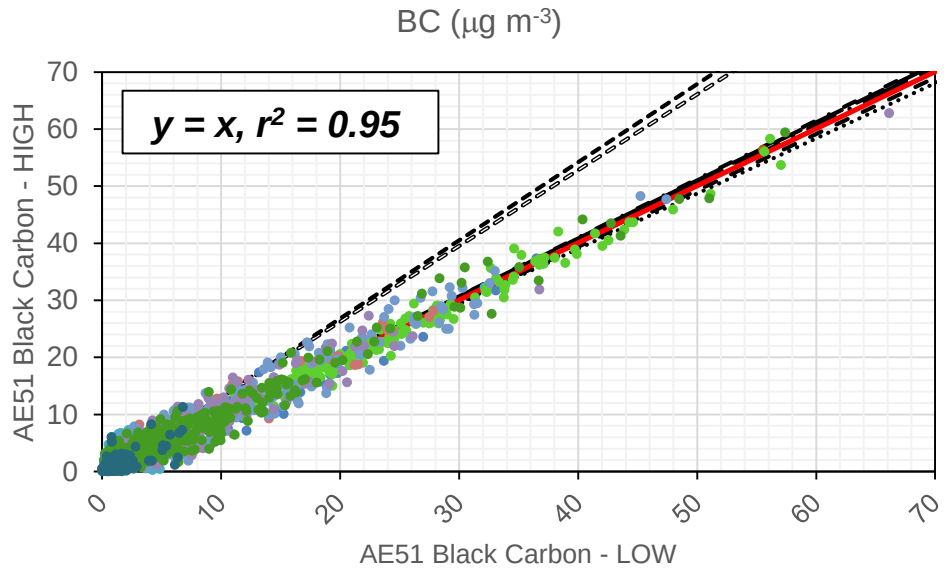

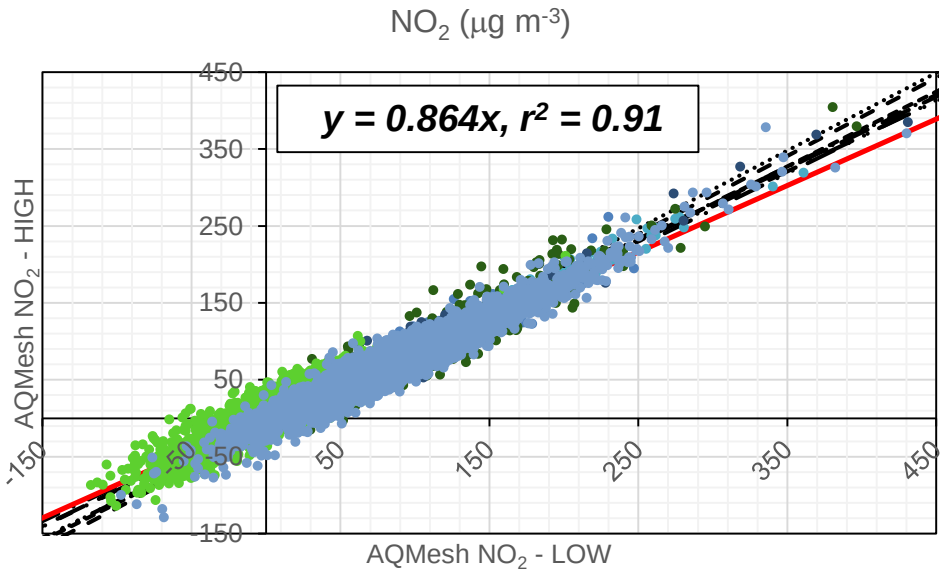

Mobile Runs

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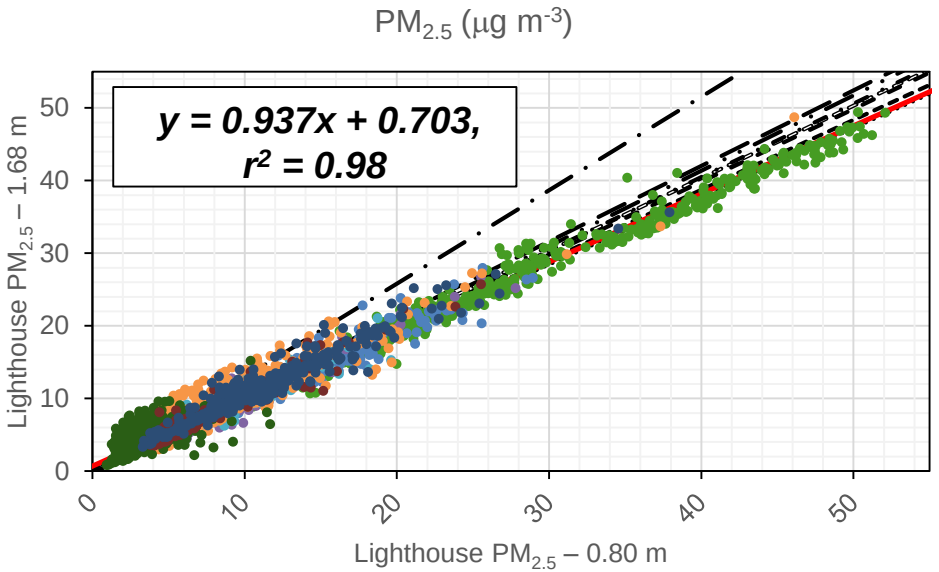

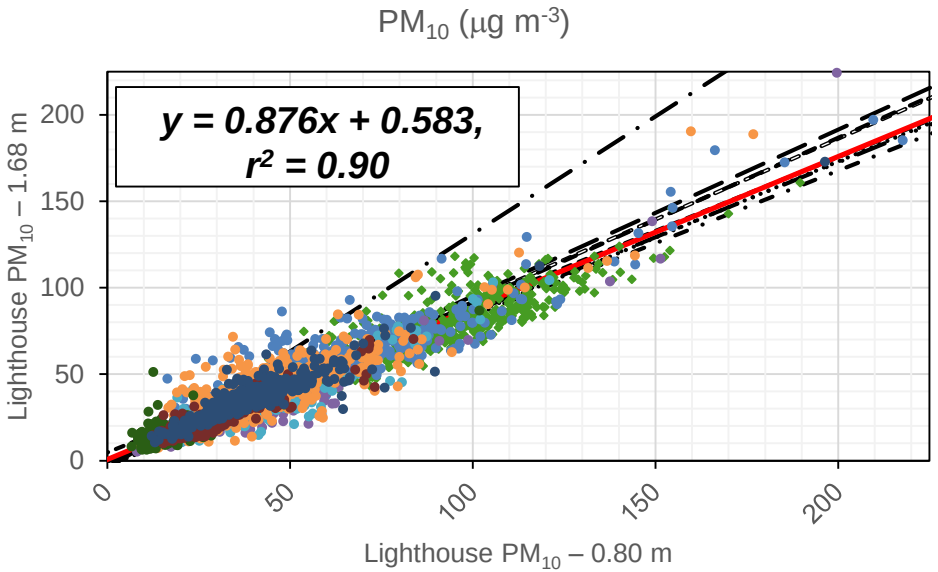

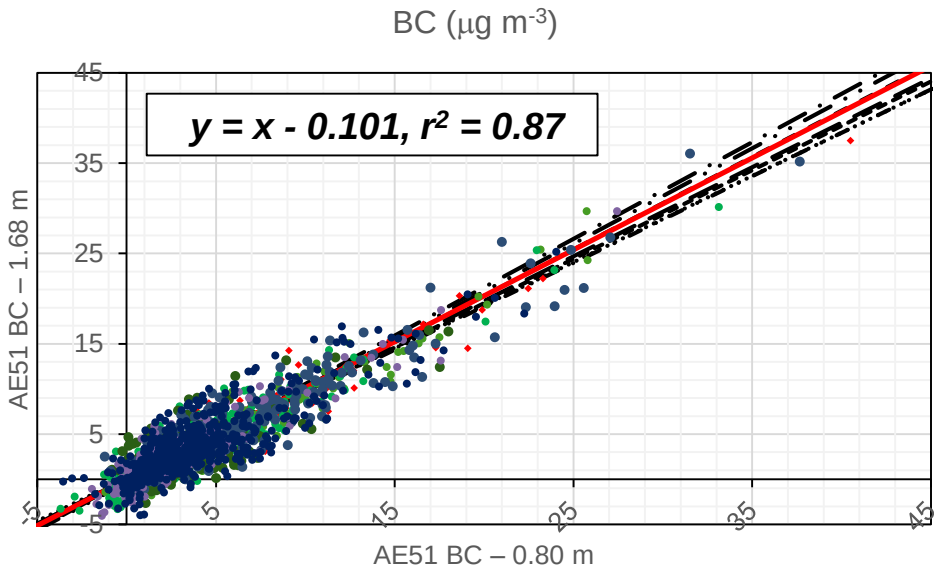

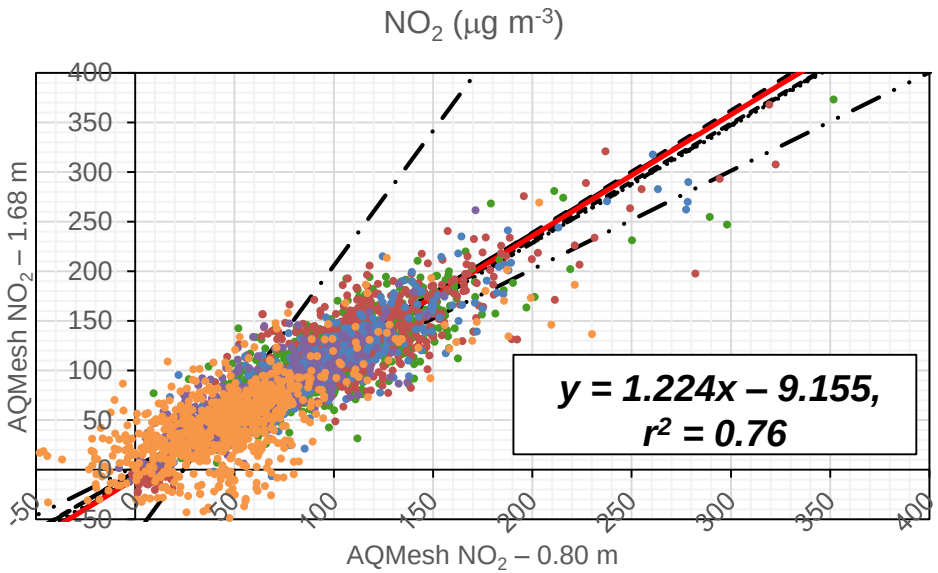

Results: Relationships – Pollutant Concentrations vs Height

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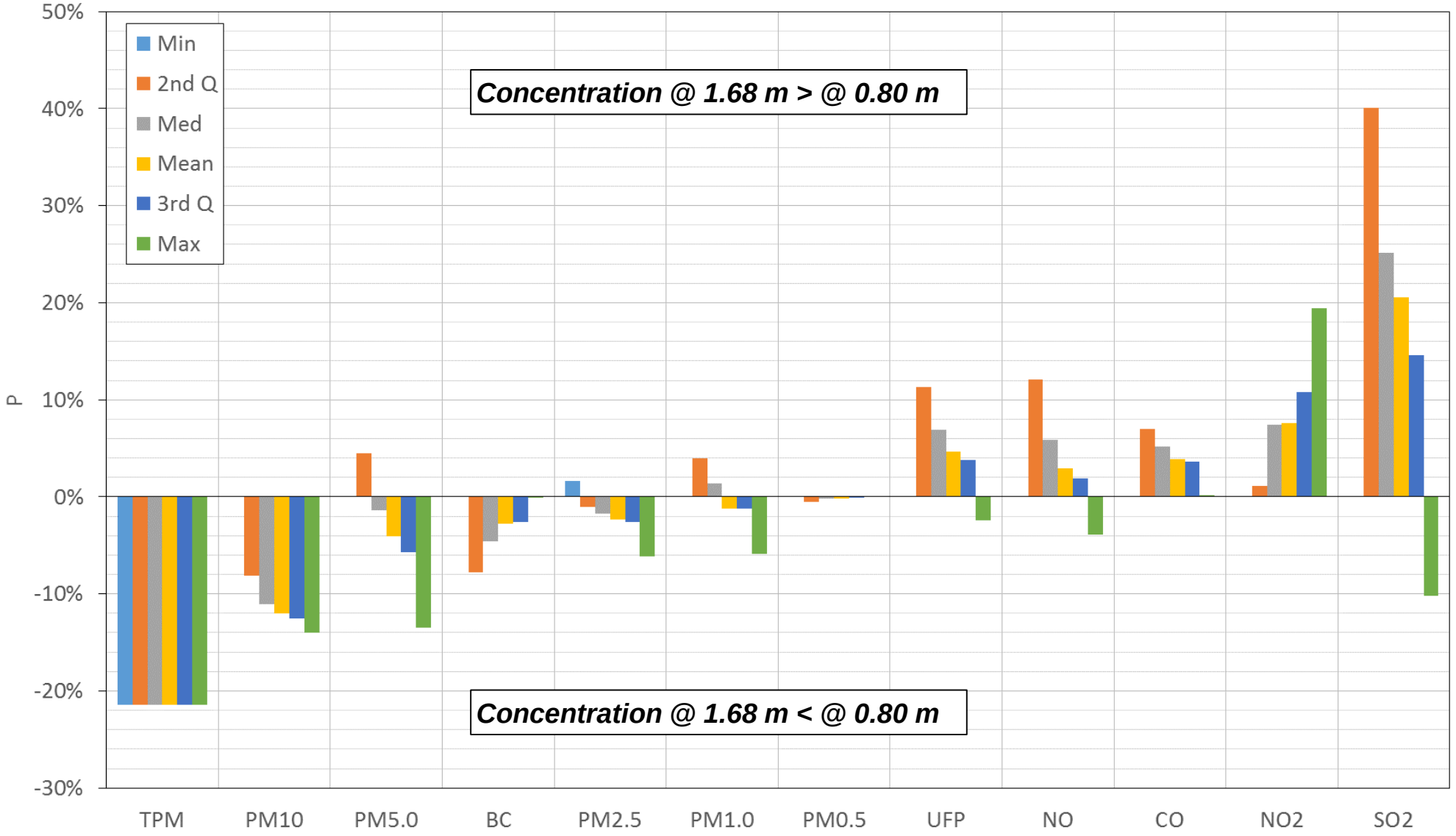
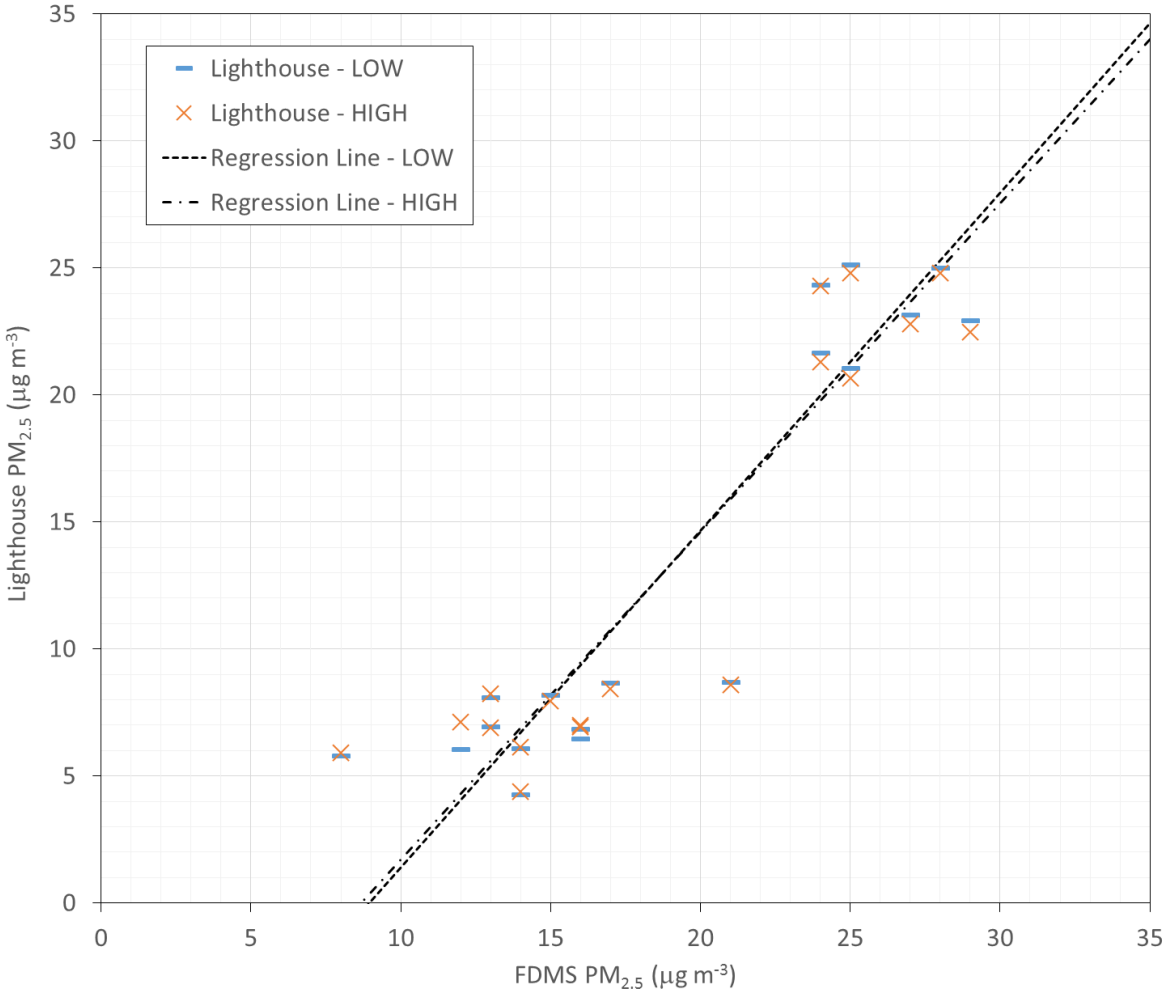
Pollutant	Relationship
Nitrogen Dioxide	$NO_{2\,(1.68\,m)} = 1.224 \times NO_{2\,(0.80\,m)} - 9.155$
Nitric Oxide	$NO_{\,(1.68\,m)} = 0.959 \times NO_{\,(0.80\,m)} + 7.534$
Sulphur Dioxide	$SO_{2\,(1.68\,m)} = 0.866 \times SO_{2\,(0.80\,m)} + 31.274$
Carbon Monoxide	$CO_{\,(1.68\,m)} = CO_{\,(0.80\,m)} + 6.971$
Particulate Matter (diameter = 0.5 μm)	$PM_{0.5\,(1.68\,m)} = 0.995 \times PM_{0.5\,(0.80\,m)}$
Particulate Matter (diameter = 1.0 μm)	$PM_{1.0\,(1.68\,m)} = 0.941 \times PM_{1.0\,(0.80\,m)} + 0.291$
Particulate Matter (diameter = 2.5 μm)	$PM_{2.5\,(1.68\,m)} = 0.937 \times PM_{2.5\,(0.80\,m)} + 0.703$
Particulate Matter (diameter = 5.0 μm)	$PM_{5.0\,(1.68\,m)} = 0.876 \times PM_{5.0\,(0.80\,m)} + 2.452$
Particulate Matter (diameter = 10 μm)	$PM_{10\,(1.68\,m)} = 0.876 \times PM_{10\,(0.80\,m)} + 0.583$
Total Particulate Matter	$TPM_{\,(1.68\,m)} = 0.824 \times TPM_{\,(0.80\,m)}$
Black Carbon	$BC_{\,(1.68\,m)} = BC_{\,(0.80\,m)} - 0.101$
Ultrafine Particles	$UFP_{\,(1.68\,m)} = 0.973 \times UFP_{\,(0.80\,m)} + 1923$
Benzene	$C_6H_{6\,(1.68\,m)} = C_6H_{6\,(0.80\,m)}$

Results – Percentage Difference



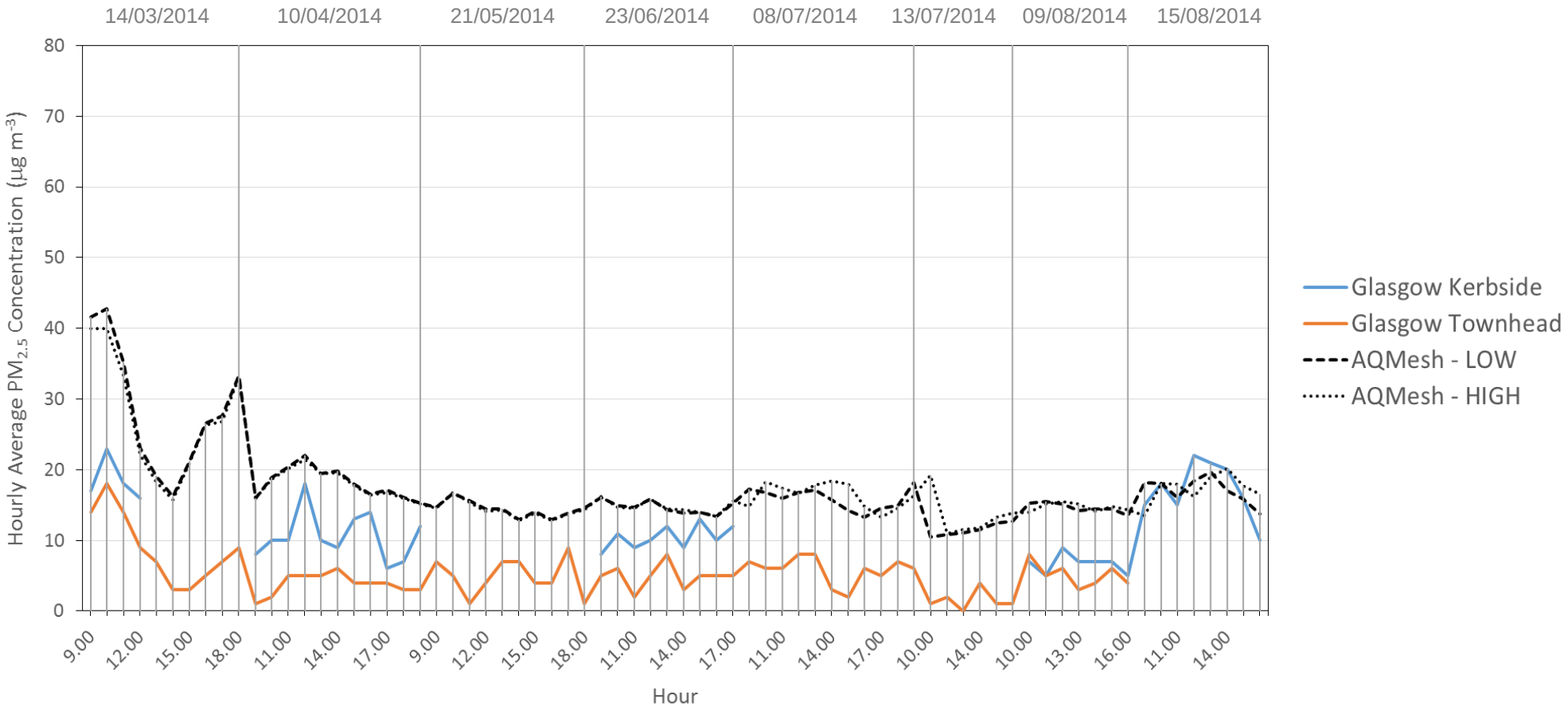
Mobile vs Fixed - Colocation



$$C_{L-Adj} = \frac{C_L + 11.905}{1.329}$$

$$C_{H-Adj} = \frac{C_H + 11.229}{1.293}$$

Results: Mobile vs Fixed Monitoring



Pollutant	1.68 m (µg m^{-3})	0.80 m (µg m^{-3})	Kerbside (µg m^{-3})	Townhead (µg m^{-3})
$PM_{2.5}$	17	17	12	5
PM_{10}	28	31	19	10
NO_2	68	56	63	25

Meteorology

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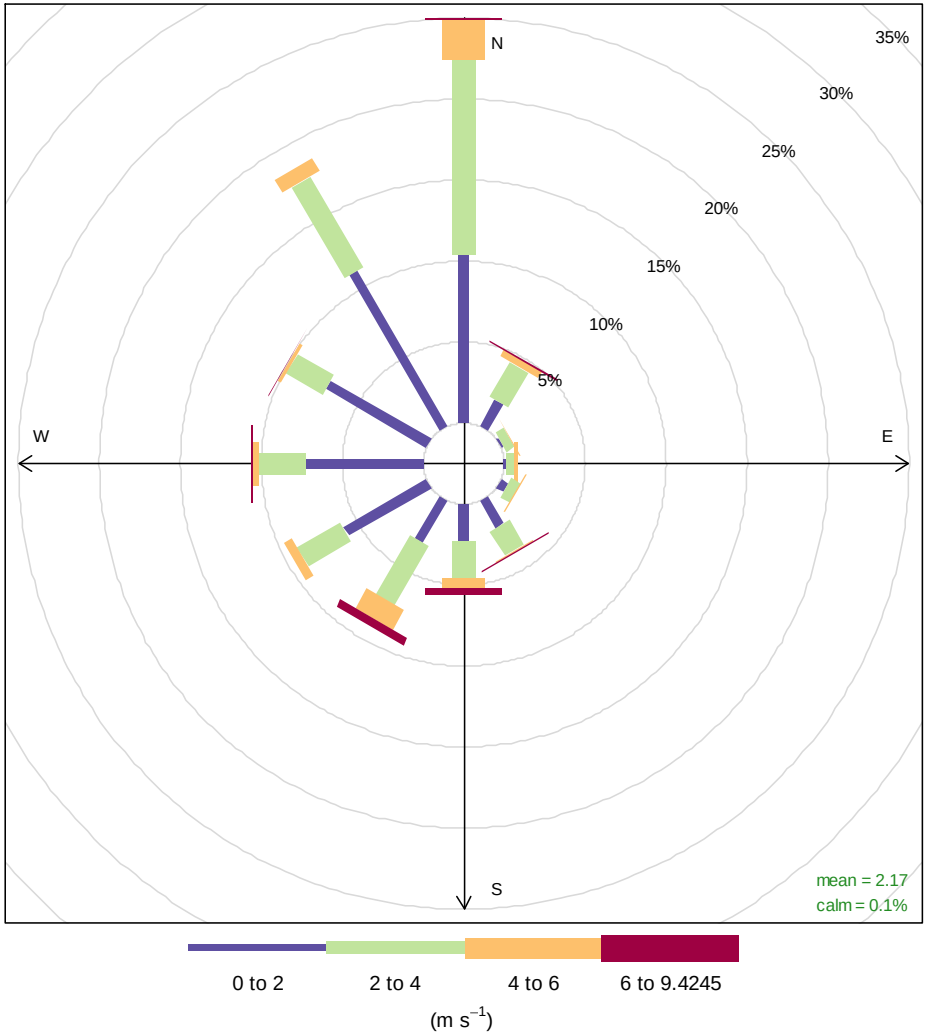
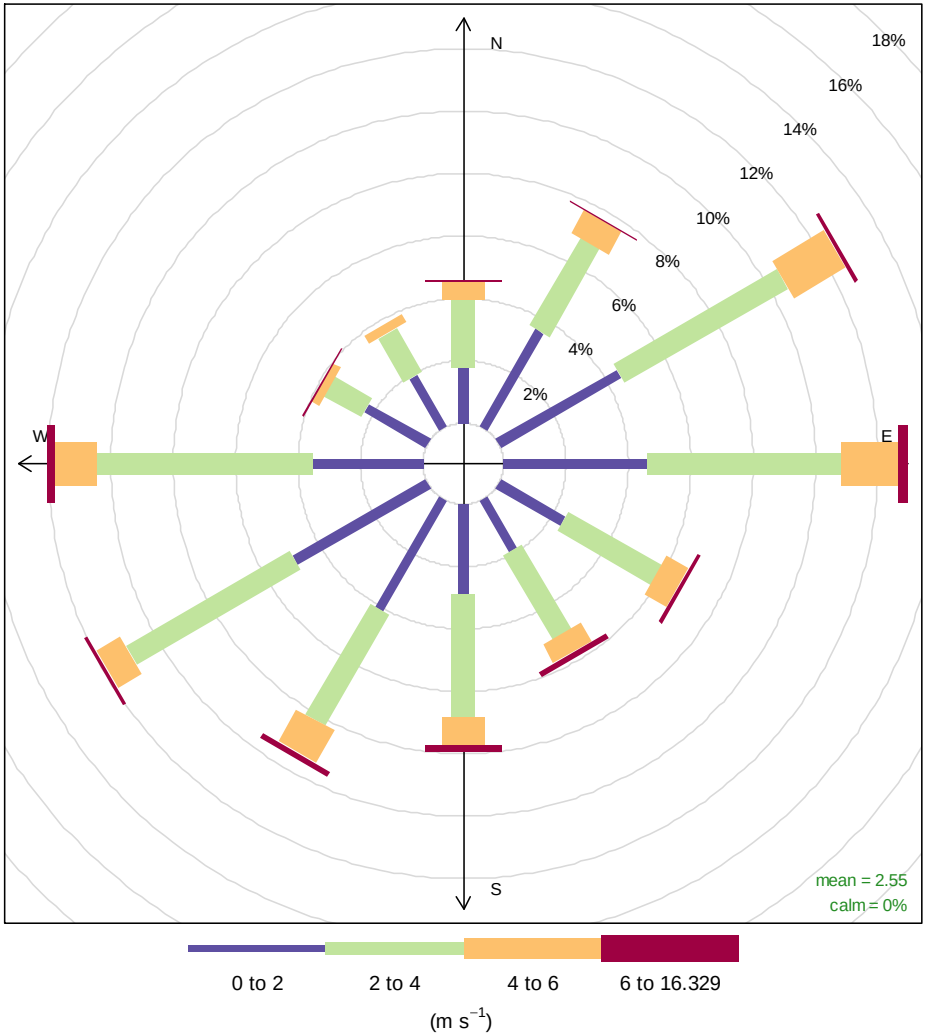
Uncorrected



Frequency of counts by wind direction (%)

Corrected



Frequency of counts by wind direction (%)

Polar Plots

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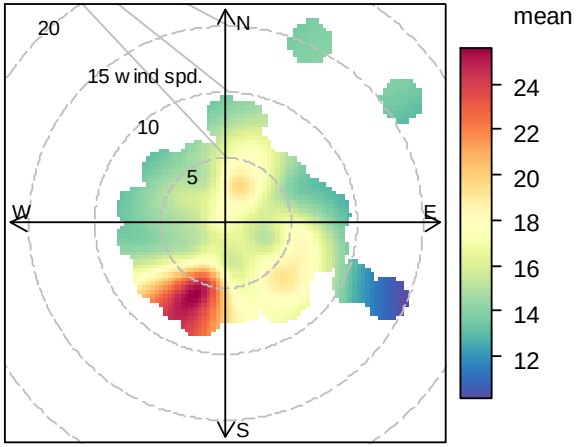
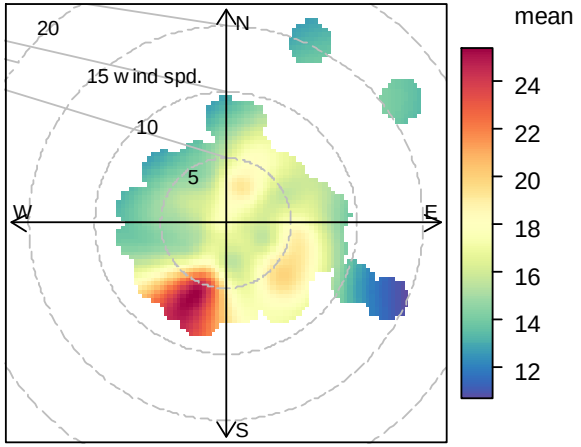
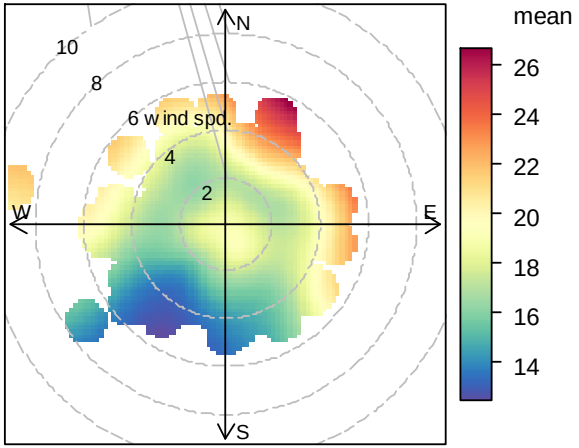
All $PM_{2.5}$ ($\mu g\ m^{-3}$) - 0.80 m



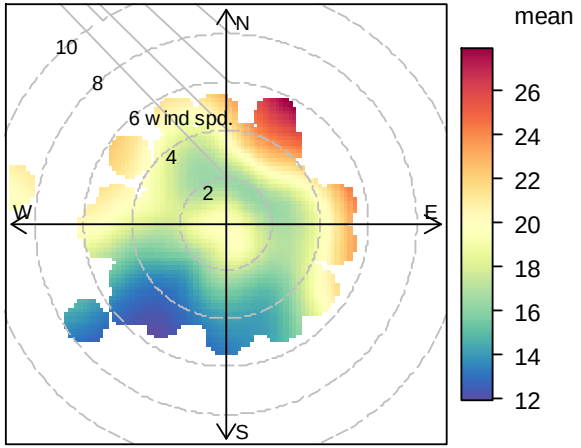
All $PM_{2.5}$ ($\mu g\ m^{-3}$) - 1.68 m



Hope St $PM_{2.5}$ ($\mu g\ m^{-3}$) - 0.80 m



Hope St $PM_{2.5}$ ($\mu g\ m^{-3}$) - 1.68 m



Pollutant Correlations

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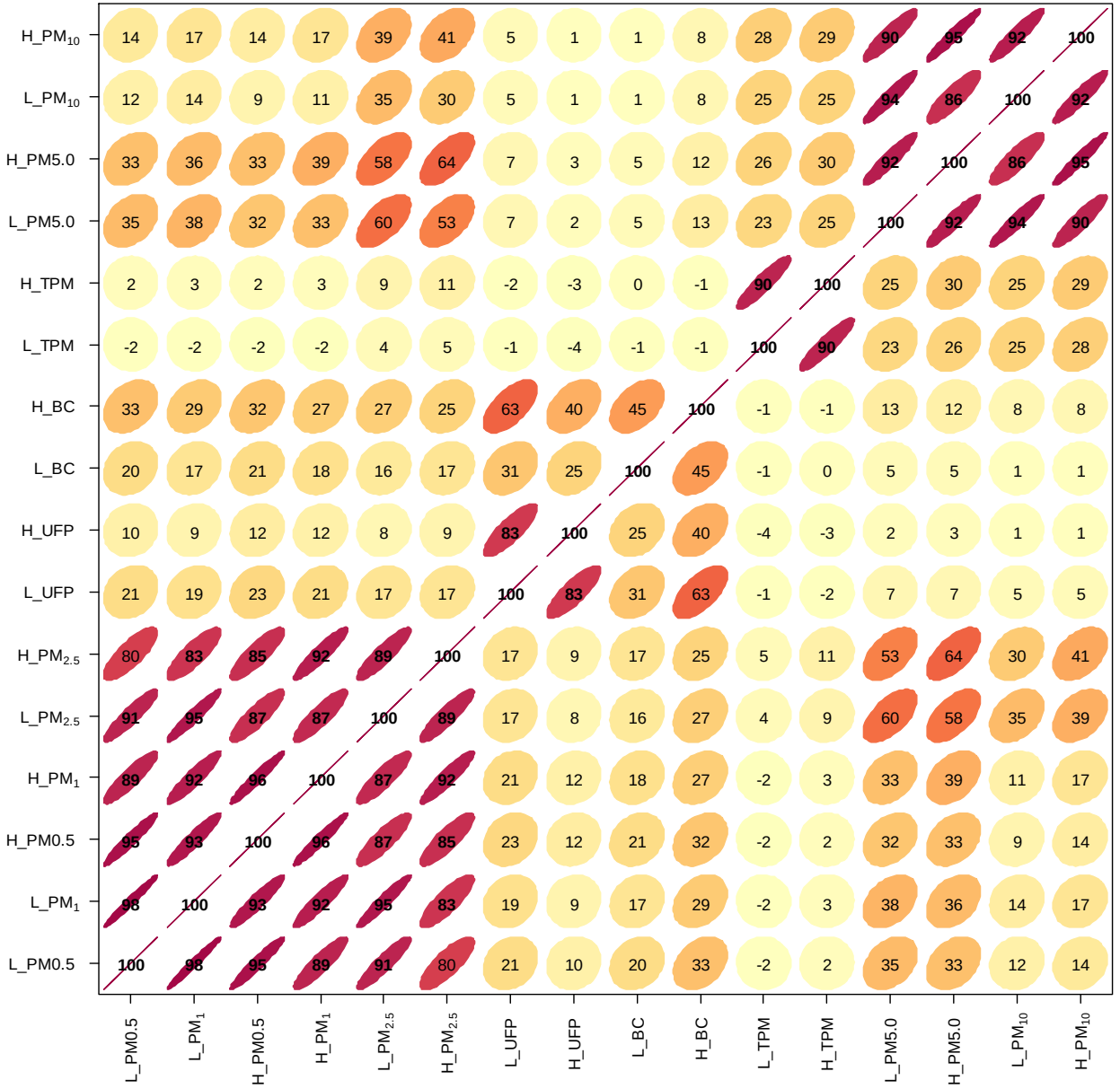
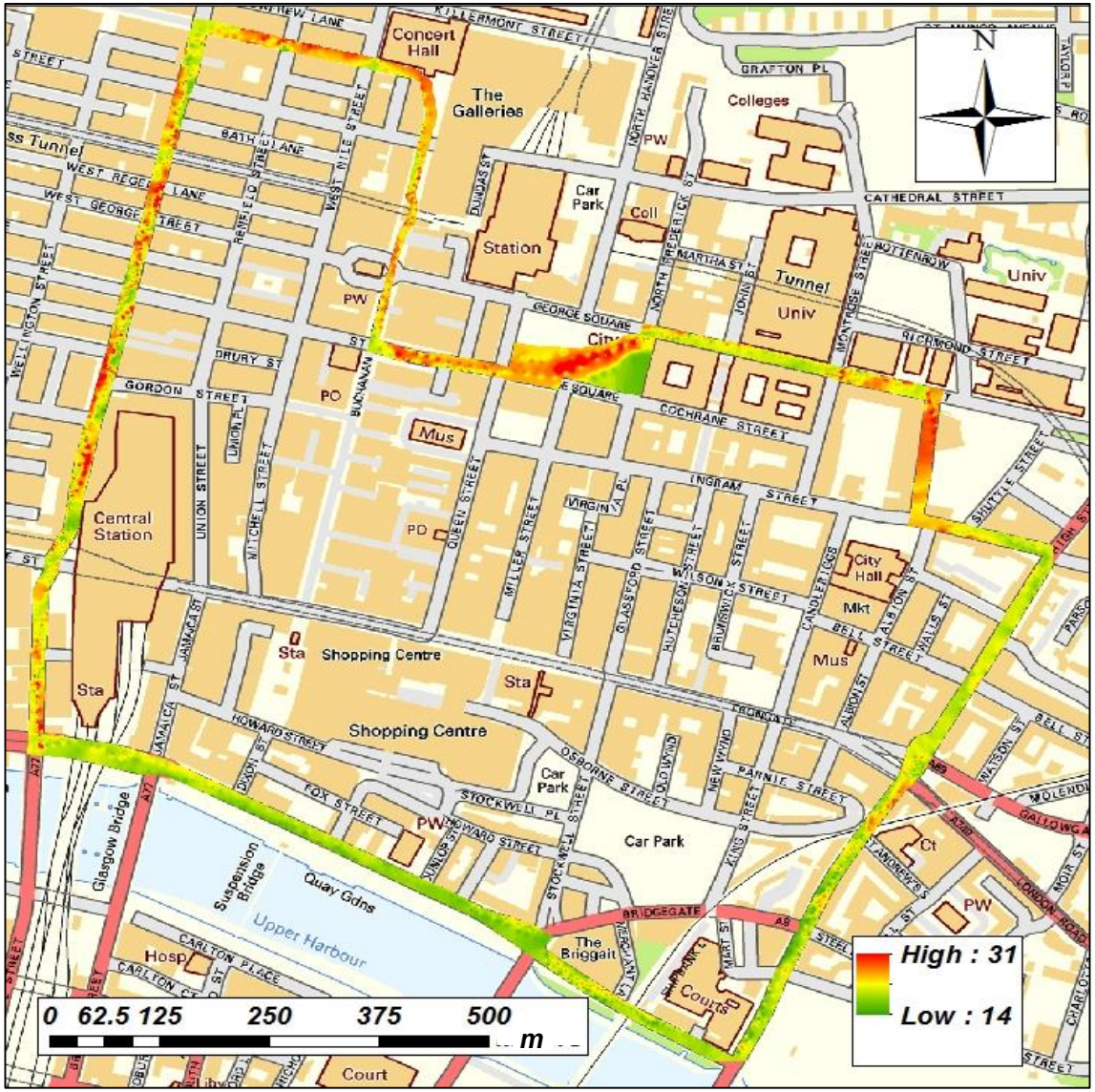


Spatial Distribution - $PM_{2.5}$ ($\mu g\ m^{-3}$)



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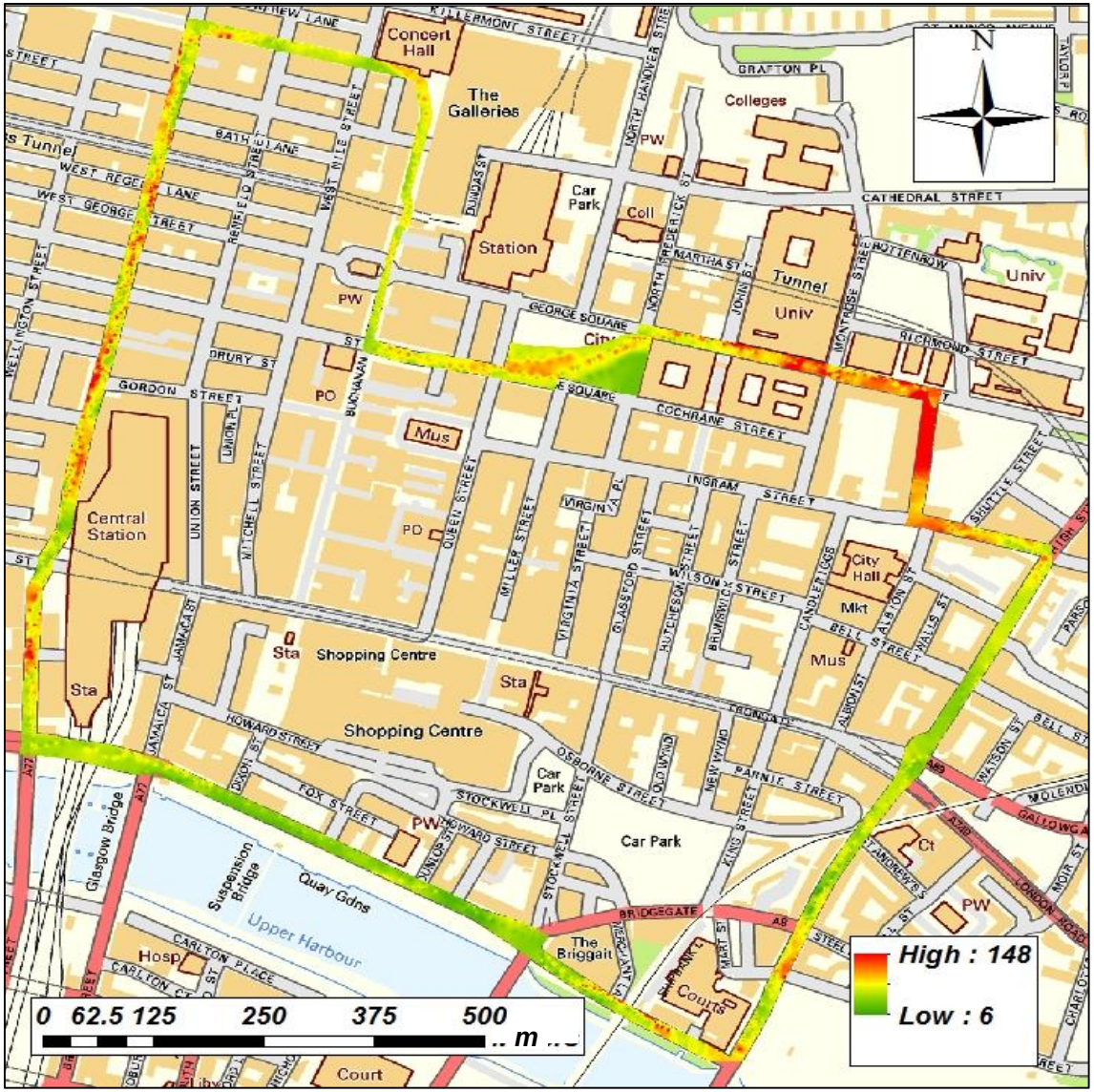
PM_{10} ($\mu g\ m^{-3}$)



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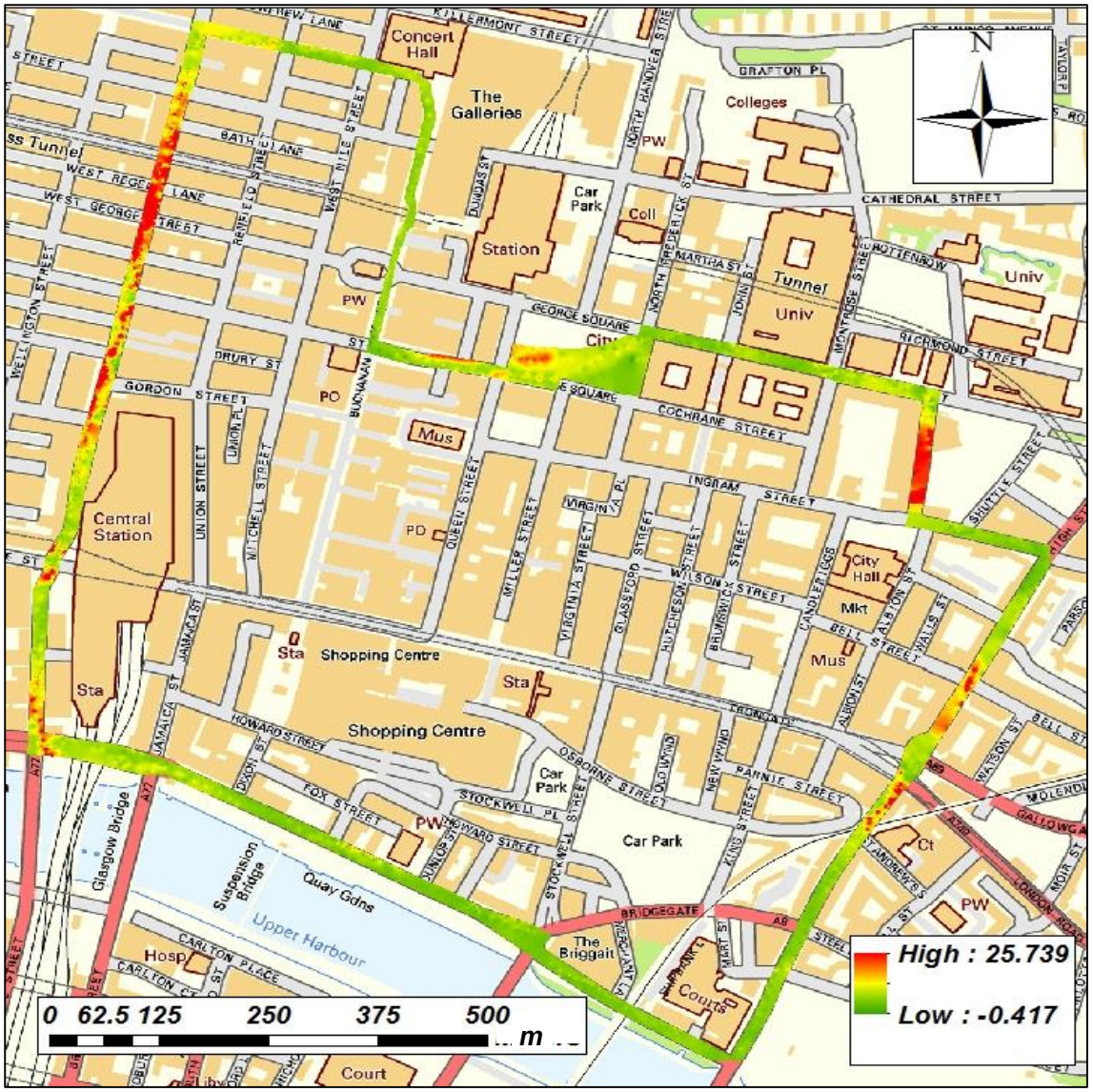
Black Carbon (μg m^{-3})



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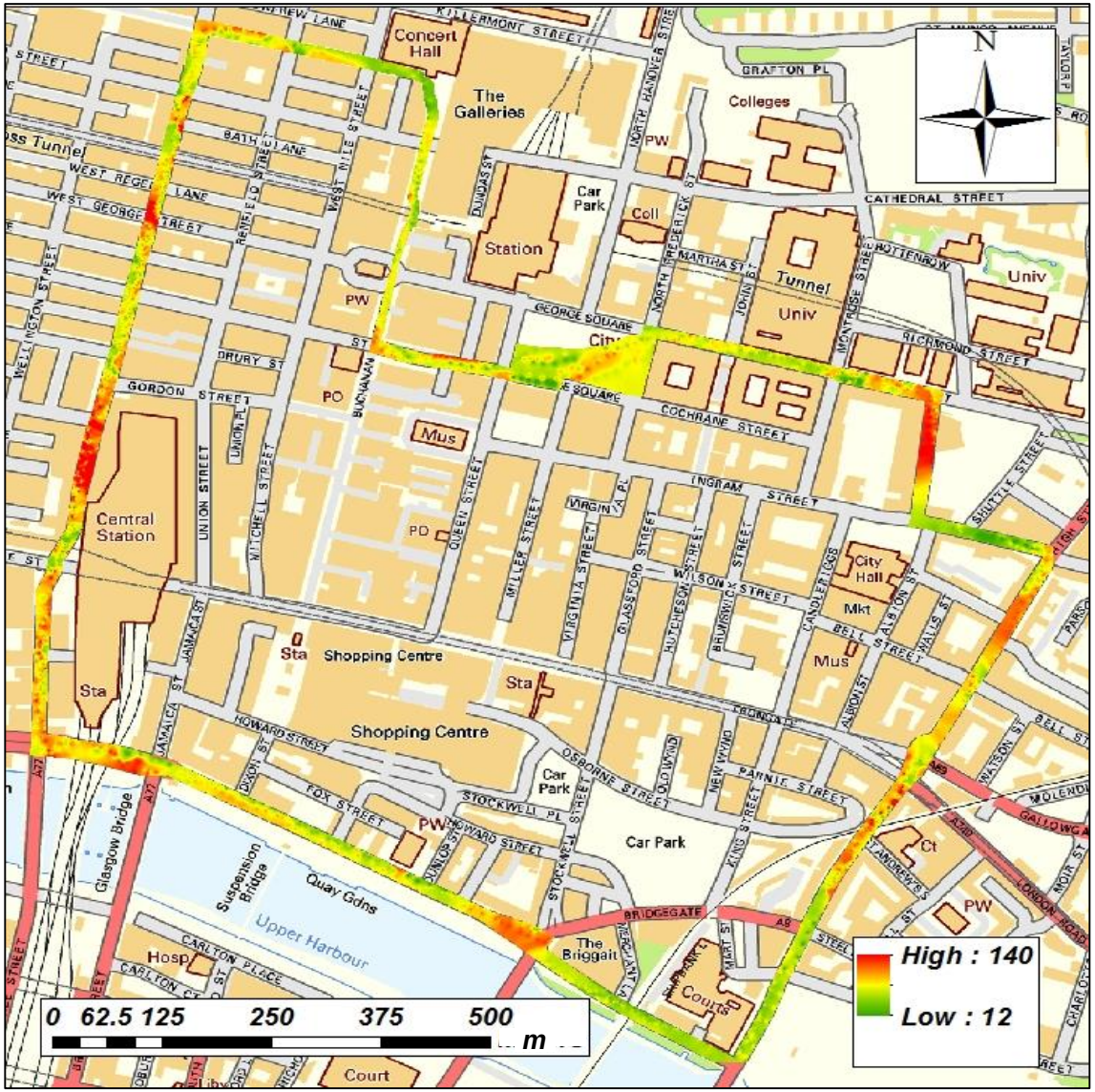
NO_2 (μg m^{-3})



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Finally…

- This type of study, combining mobile monitoring with monitoring at more than one height, has not been carried out before.

- Results indicate that a concentration gradient does exist, but that this is dependent upon a number of factors including:
  - Microenvironment.
  - Met conditions.
  - Pollutant sources.
  - Pollutant.

- Moderate to strong pollutant correlations have been identified.

- Method has proved very useful for characterising the spatial distribution of pollutants, identifying pollution ‘hotspots’.

- Analyses are complete – results due to be published soon.

Acknowledgements

The Scottish Government

AIR MONITORS
Quality - Service - Innovation

RICARDO-AEA

Fife COUNCIL

PERTH & KINROSS COUNCIL

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Comments/ Questions?

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