

Air pollution in mainline railway stations

Anna Font[1], Anja Tremper[1], Chun Li[2], Max Priestman[1], Daniel Marsh[1], Michael Woods[3], Mathew Heal[2] and David Green[1]

[1] MRC PHE Centre for Environment and Health, King's College London, UK
[2] Department of Chemistry, University of Edinburgh
[3] RSSB, London

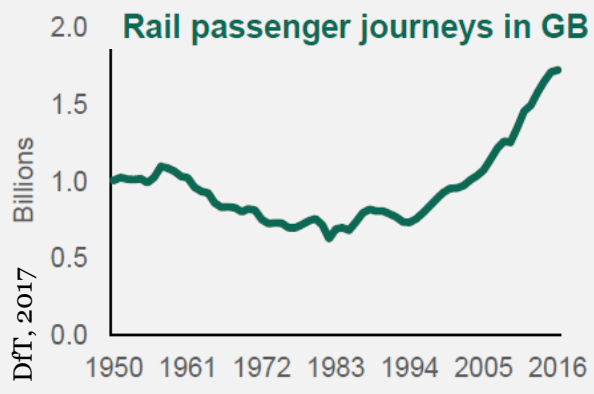
London Air Quality Seminar, 25th June 2019

Rail travel in the United Kingdom

England: 2002 - 16

DfT, 2017

	Trips	Distance	Time
Rail	↑56%	↑23%	↑43%
Car or van	↓13%	↓13%	↓8%
Bus	↓19%	↓14%	↓14%



66% of the rail network in the UK runs on diesel

705 million litres of diesel were used to run the network

ORR, 2017





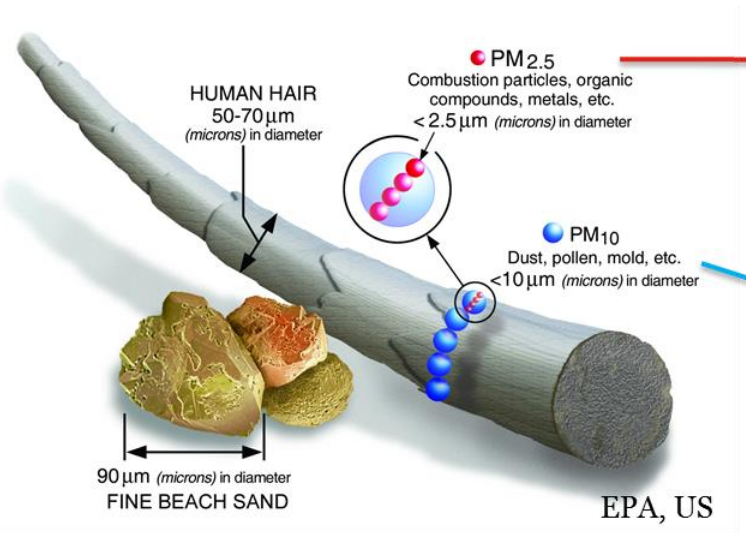
Air pollutants

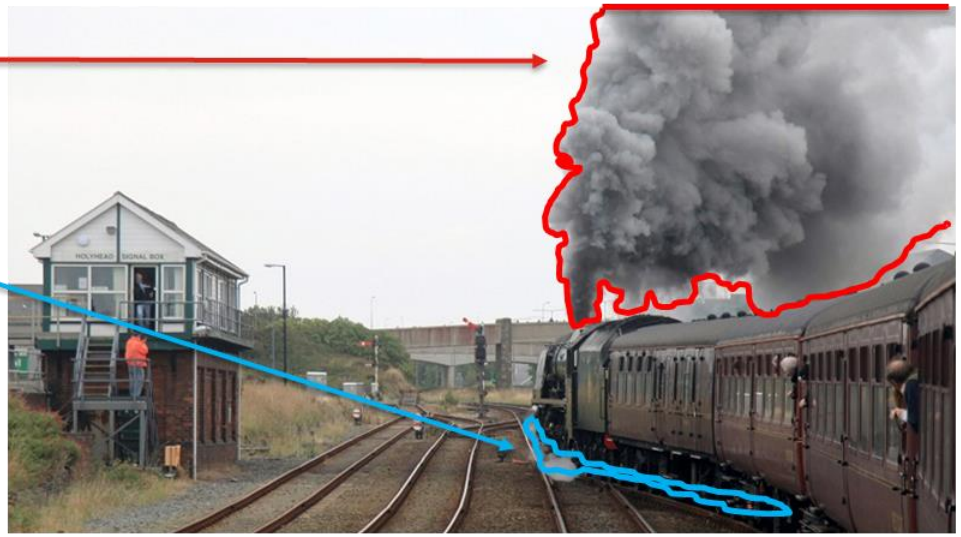
Particulate Matter

PM_{10}: < 10 µm ~ Inhalable Dust

$PM_{2.5}$: < 2.5 µm ~ Respirable Dust

Health effects: ***Respiratory and cardiovascular morbidity*** *(aggravation of asthma, respiratory symptoms, increase in hospital admissions) and* ***mortality*** *(cardiovascular and respiratory diseases)*





Nitrogen Dioxide

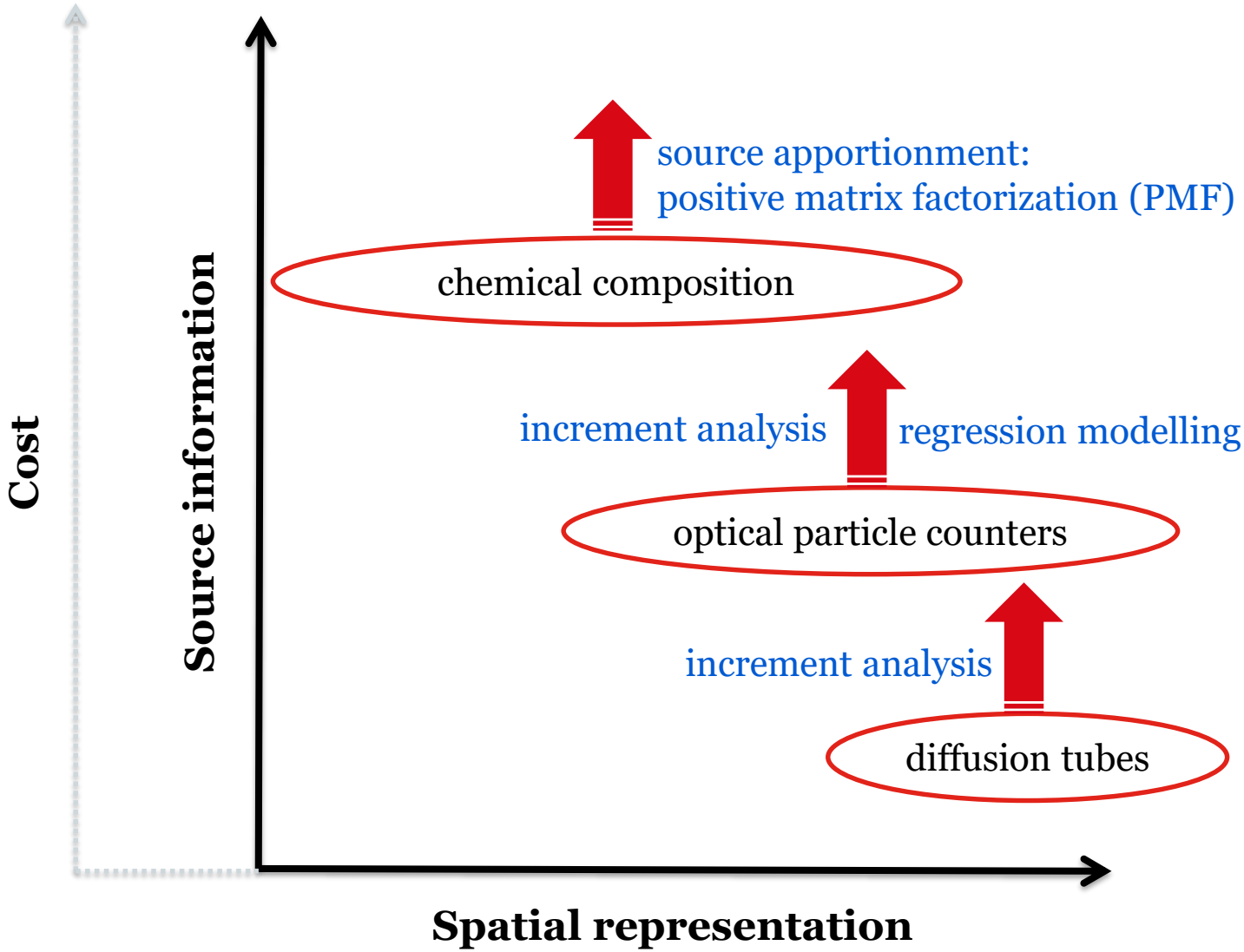
NO_2

Health effects: *NO_2* ***inflames the lining of the lung*** *and* ***reduces immunity to lung infections*** *such as bronchitis. Studies also suggest that the health effects are more pronounced in people with asthma.*

Aims

- To measure the **concentrations of air pollutants** in enclosed stations in the UK
- To characterize the **impact of diesel emissions** in air quality in **two enclosed stations in the UK**
- To **highlight the rolling stock** which **most influenced** the measured concentrations

Measurement approaches for source quantification



Diffusion tubes – NO_2

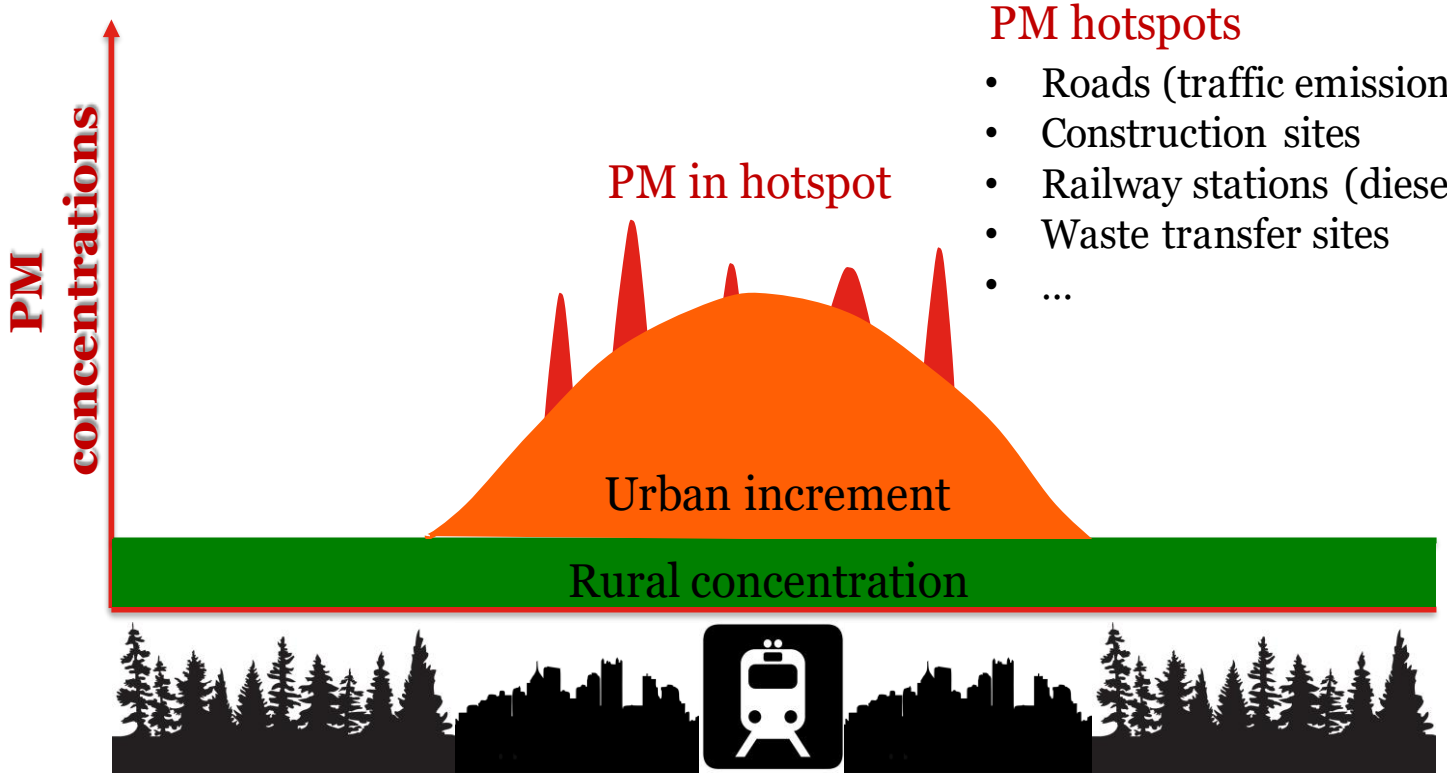
- Tubes exposed to railway air for 2 – 4 weeks
- 3 replicates for every site /exposure period
- Analysis in the laboratory

Osiris Optical Particle Counters (OPCs) – PM_{10} & $PM_{2.5}$

- On-line measurements
- A posteriori correction for loss of volatile PM (heated inlet)
- Measured @15 minute-resolution but reported at hourly

Railway Stations in the context of urban environments

LENSCHOW APPROACH

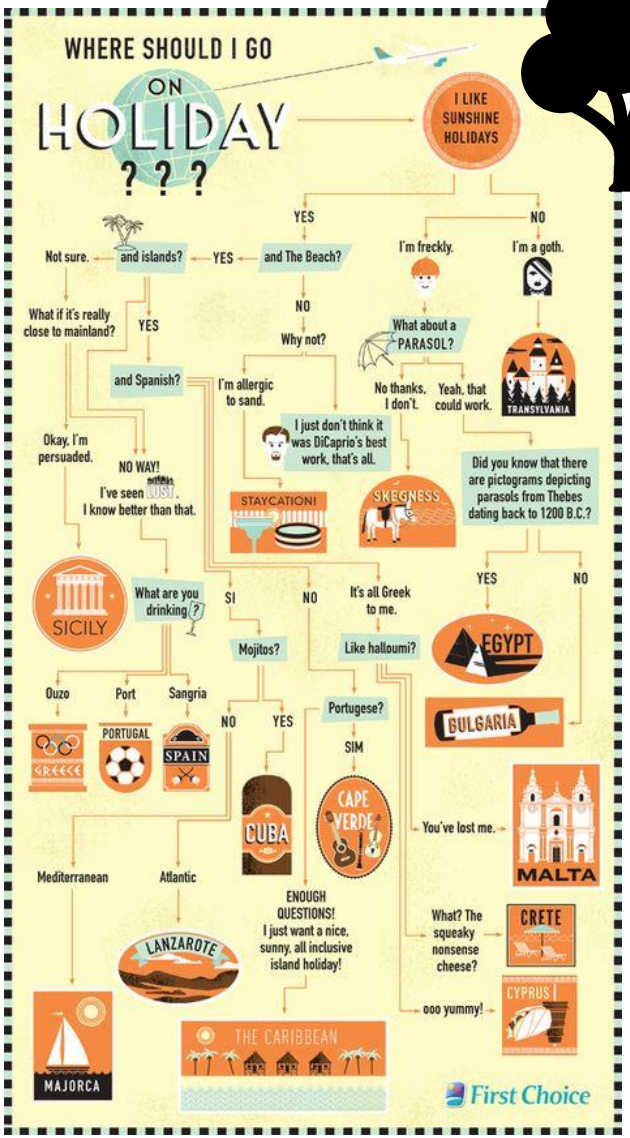


PM hotspots

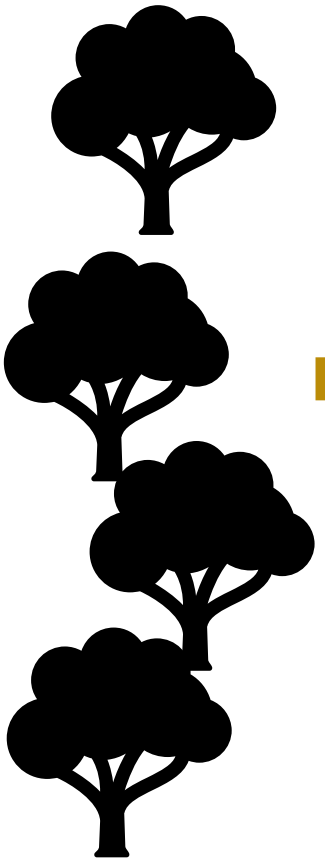
- Roads (traffic emissions)
- Construction sites
- Railway stations (diesel & electric trains)
- Waste transfer sites
- …

Regression modelling: random-forest

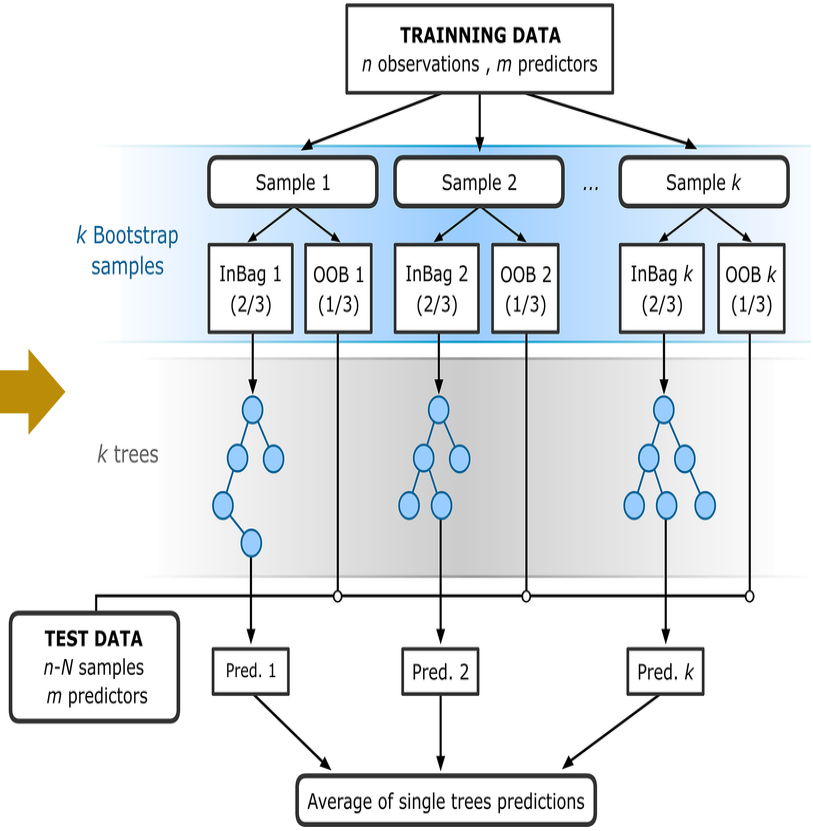
DECISION TREES



MULTIPLE DECISION TREES

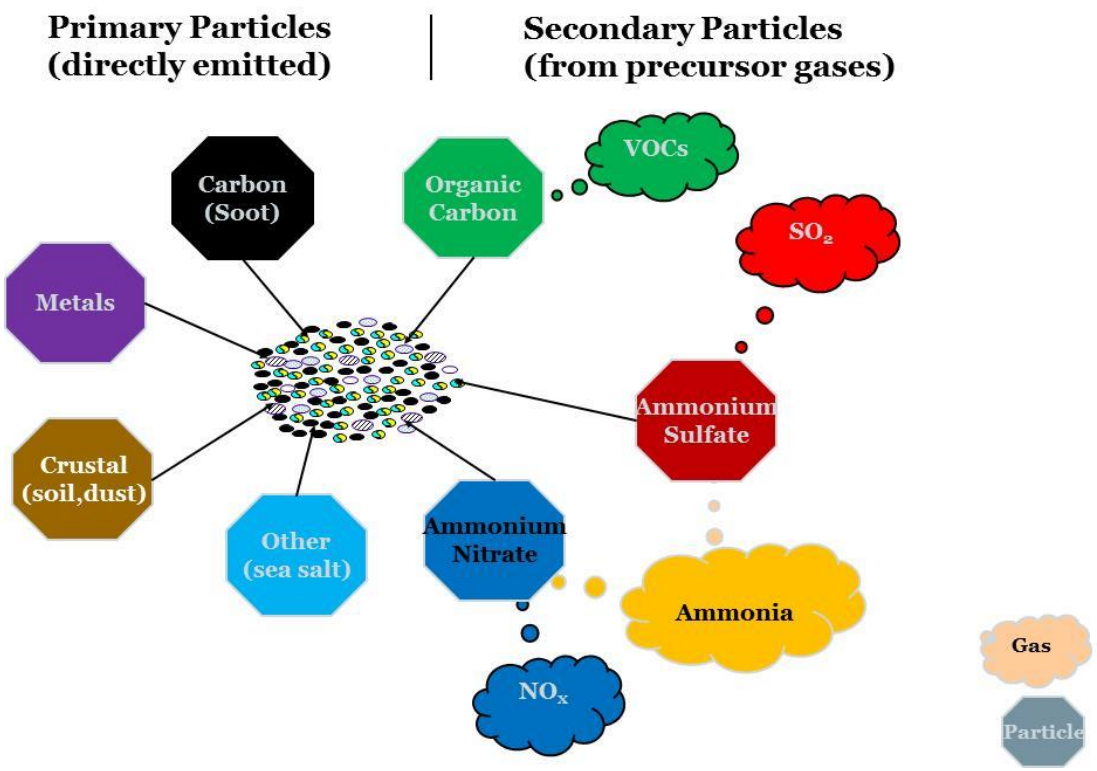


RANDOM FOREST



Rodriguez-Galiano et al., 2016

Chemical composition



6-8 week deployments at each station

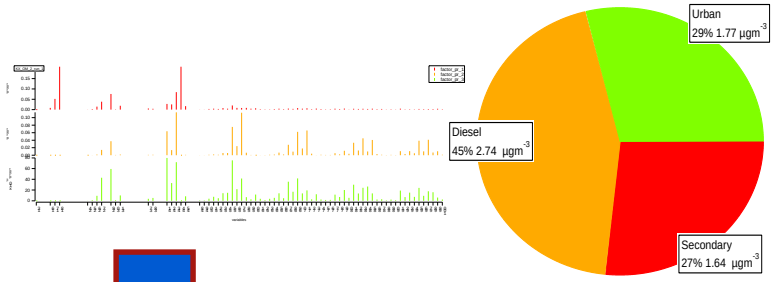
Edinburgh: May – Jul 2018

King's Cross: Jul – Oct 2018

Source apportionment: Positive Matrix Factorization

Organic Aerosol m/z

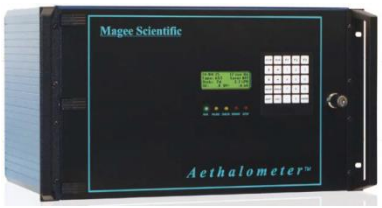
PMF



PMF 1

Factors

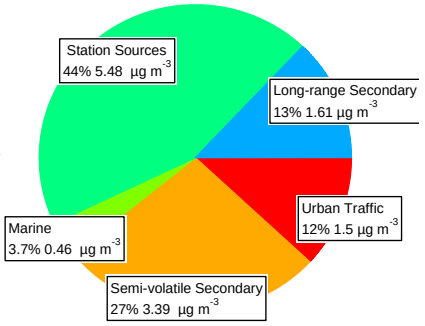
XRF - elements



Elemental Carbon

Inorganic Aerosol

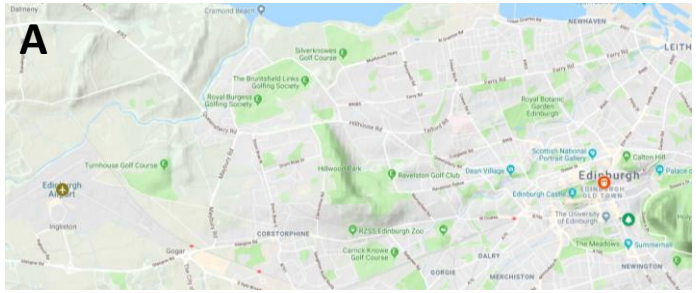
PMF

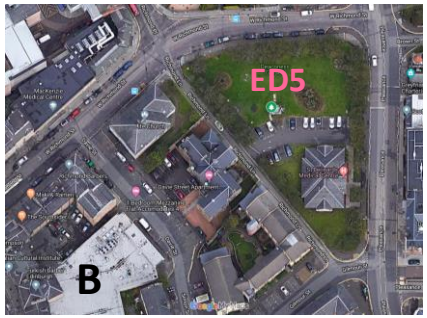


PMF 2

Source related concentrations:
Urban traffic, Station sources, Secondary, Marine

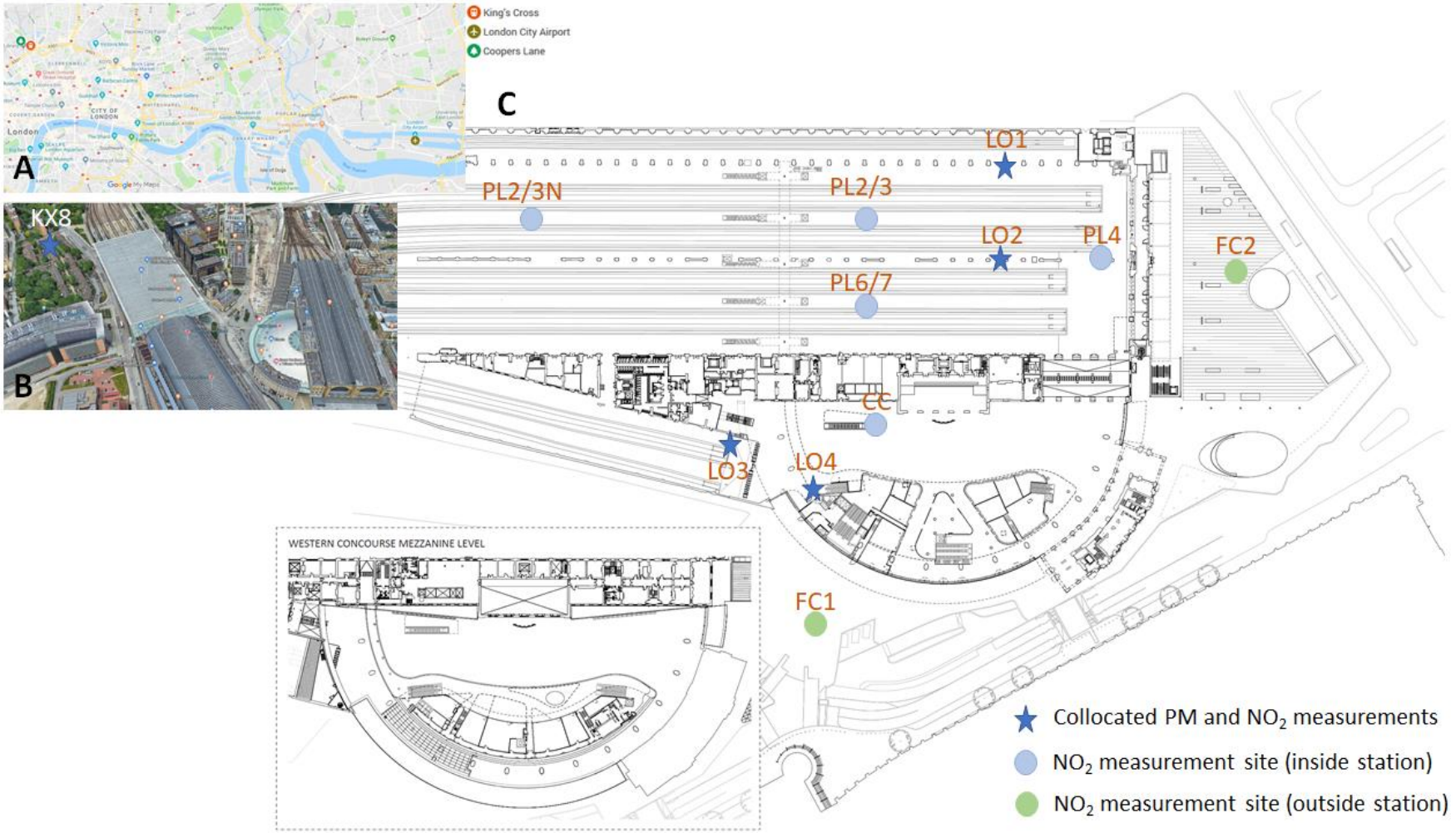
Edinburgh Waverley





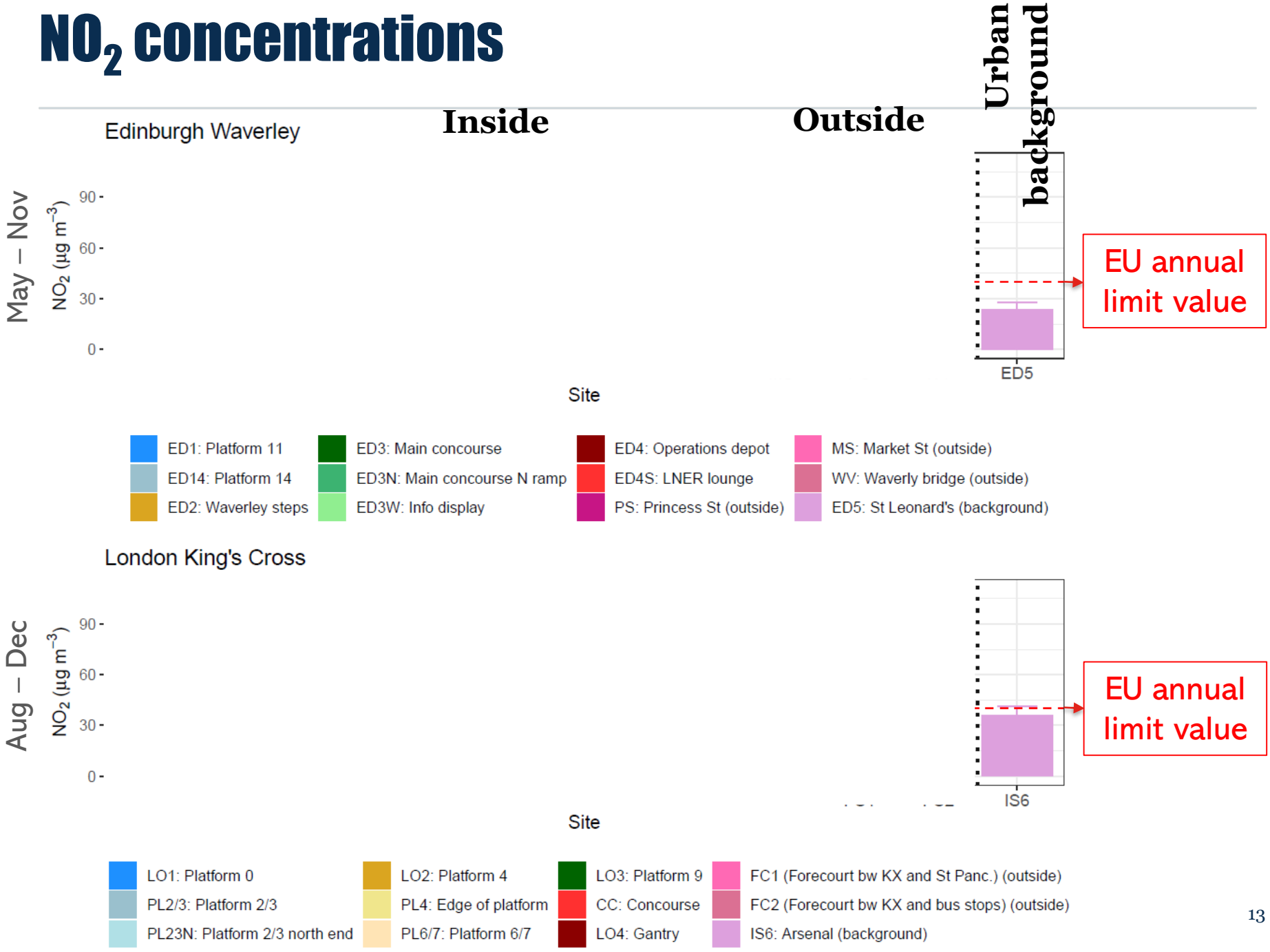
- Through station
- ~ 830 trains / day (Jul – Nov '18)
- ~59% run on diesel
  - *83%: Sprinter Diesel Multiple Units (DMUs)*
  - *6% High Speed Trains (HSTs)*
  - *5% 220/221 (Voyagers)*

London King's Cross

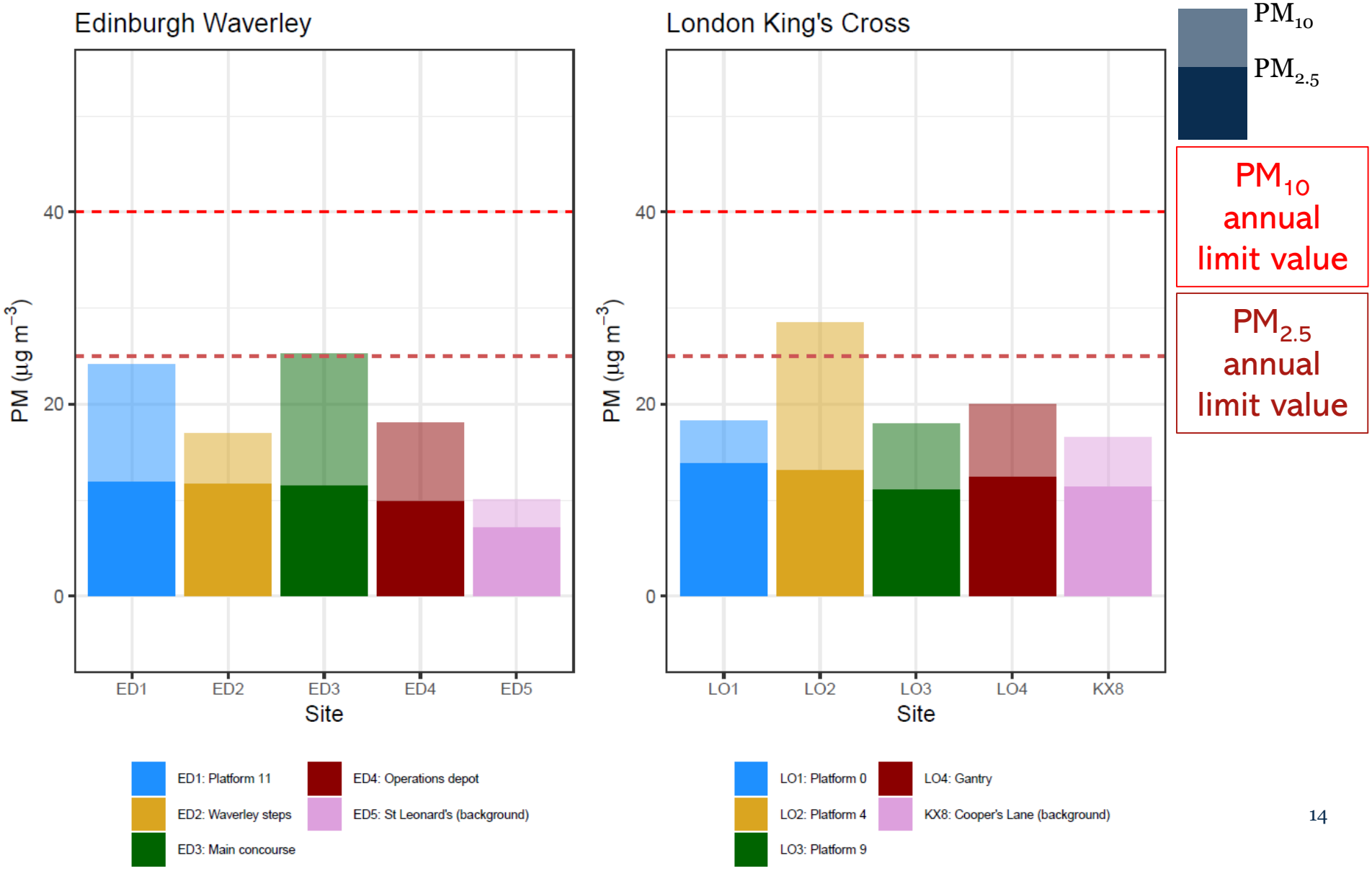


- Terminal station
- ~ 420 trains / day (Jul – Nov '18)
- ~18% run on diesel: *62% High Speed Trains (HSTs); 33% Class 180 Adelante*

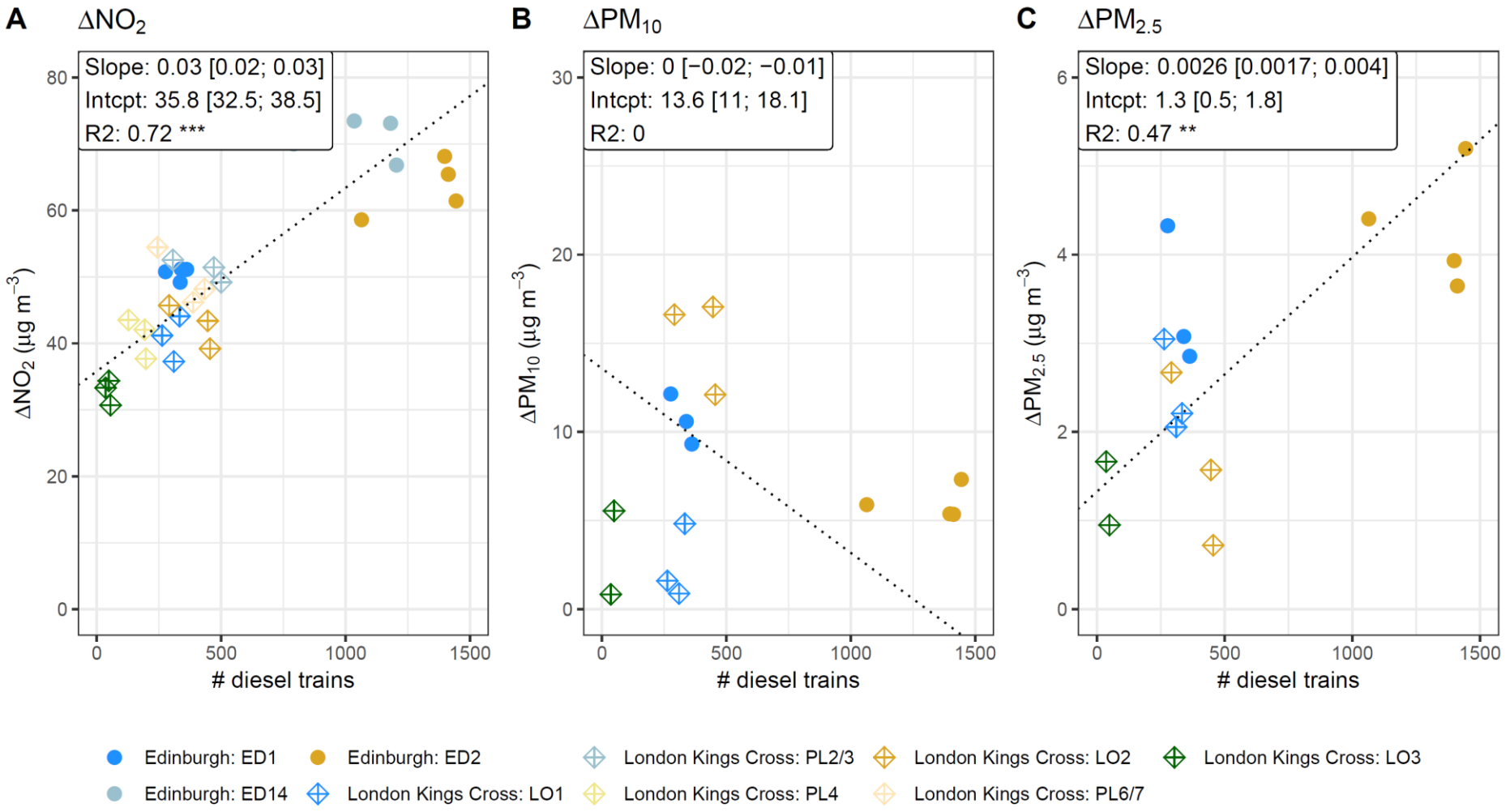
NO_2 concentrations



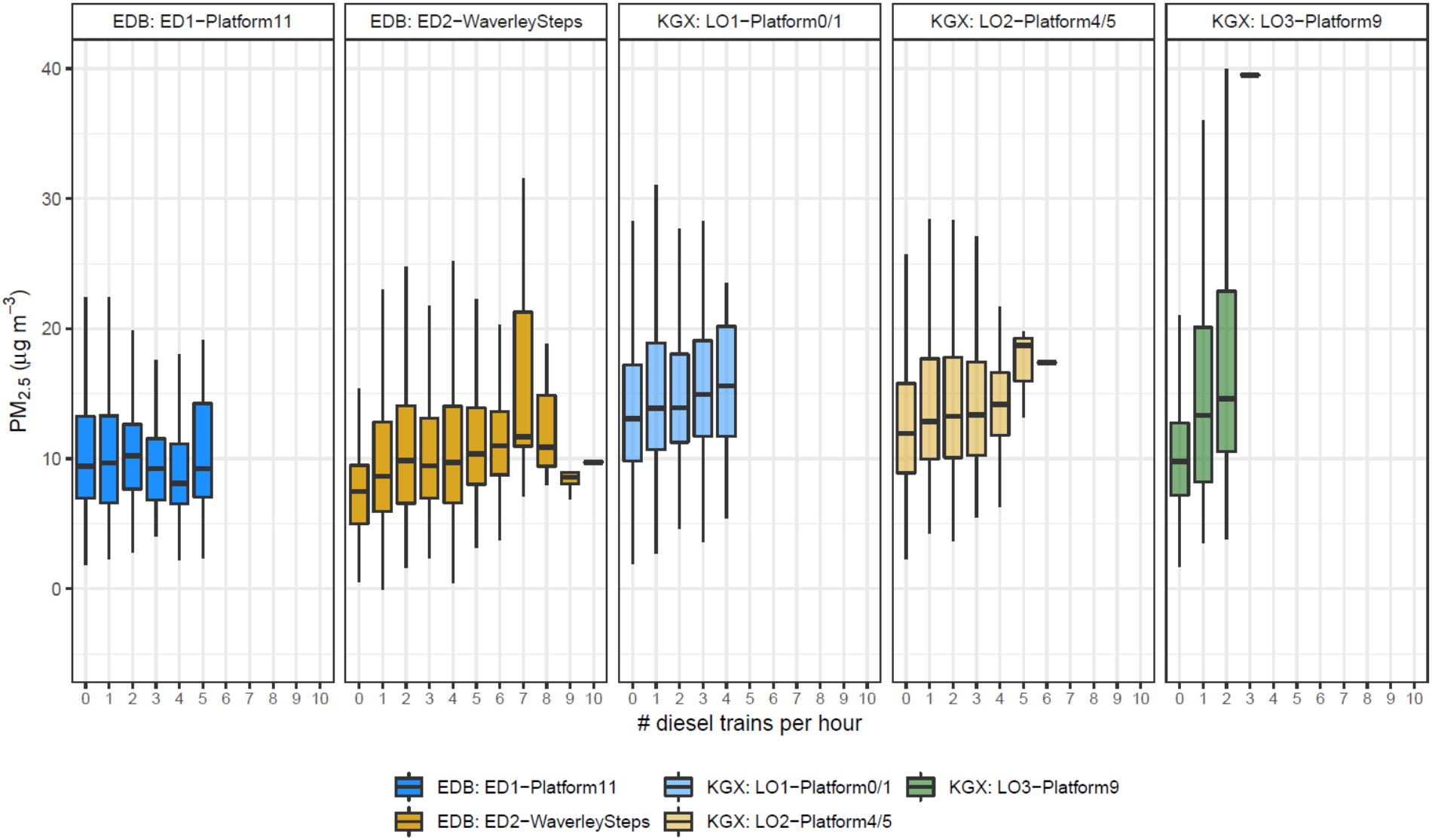
Mean PM concentrations



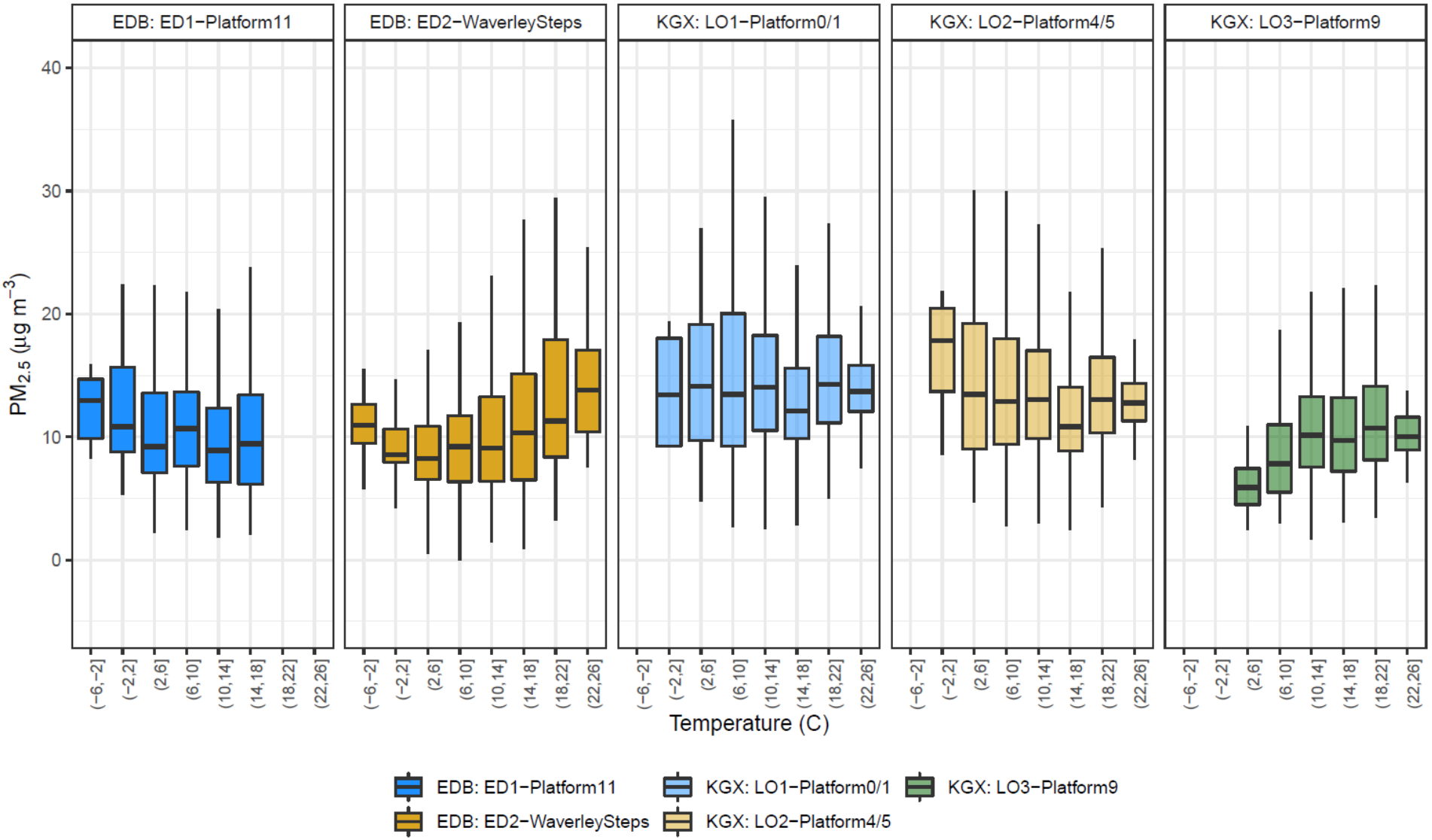
Increments and # diesel trains



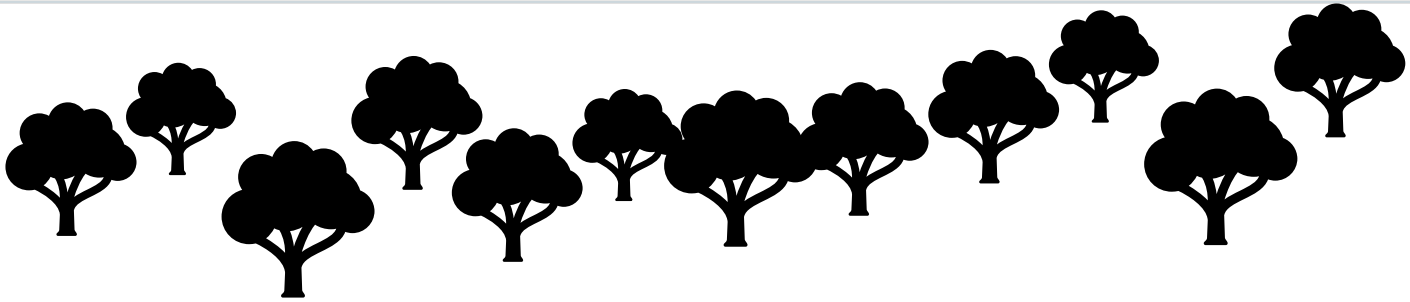
Influence of diesel trains on hourly $PM_{2.5}$



Air quality levels and meteorological variables



Regression modelling: random forest



Dependent variable:

•Hourly PM2.5 concentrations

Predictors (explanatory variables):

- wind direction
- wind speed
- temperature
- relative humidity
- pressure
- no. diesels trains
- diesel rolling stock
- $PM_{2.5}$ background

Meteorological variables

Train information

PM information

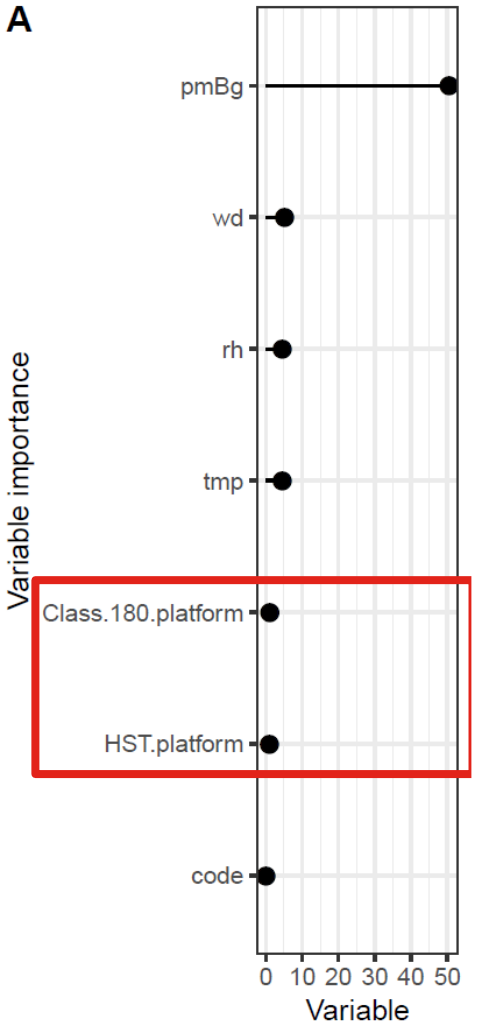
Output

- Rank of the most important variables
- Partial dependency plots

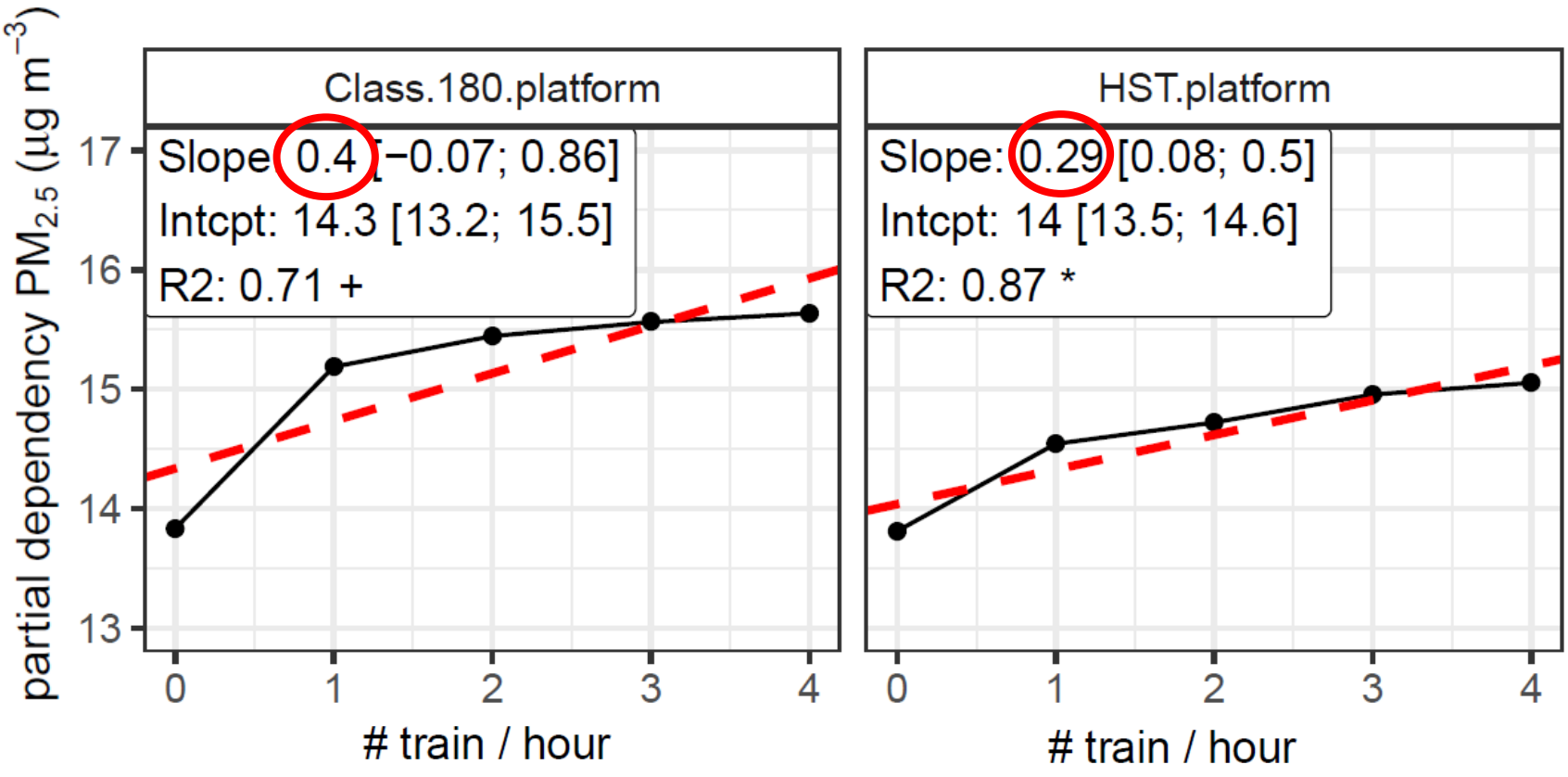
Regression model – King's Cross

$PM_{2.5}$ King's Cross (LO1-Platforms 0/1 & LO2-Platforms4/5 data)

$R^2 = 0.79$



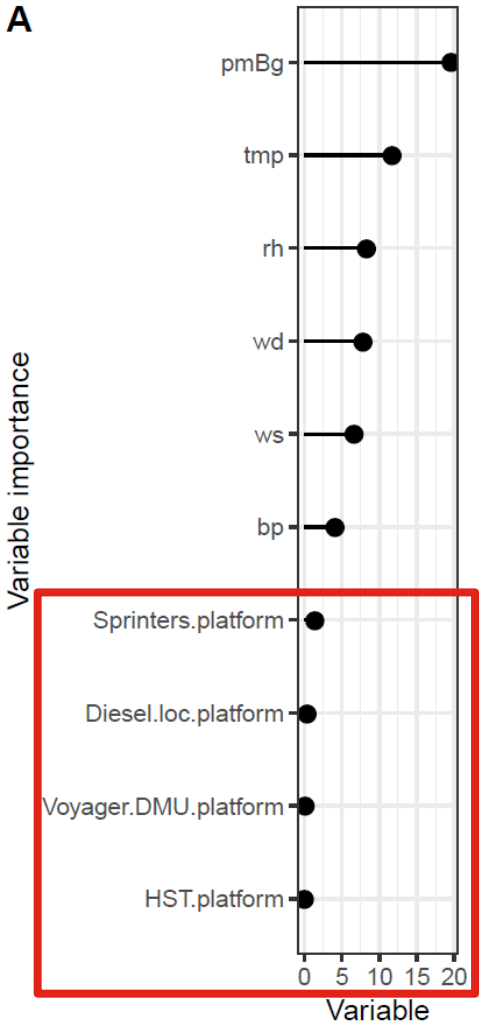
Partial dependencies - King's Cross



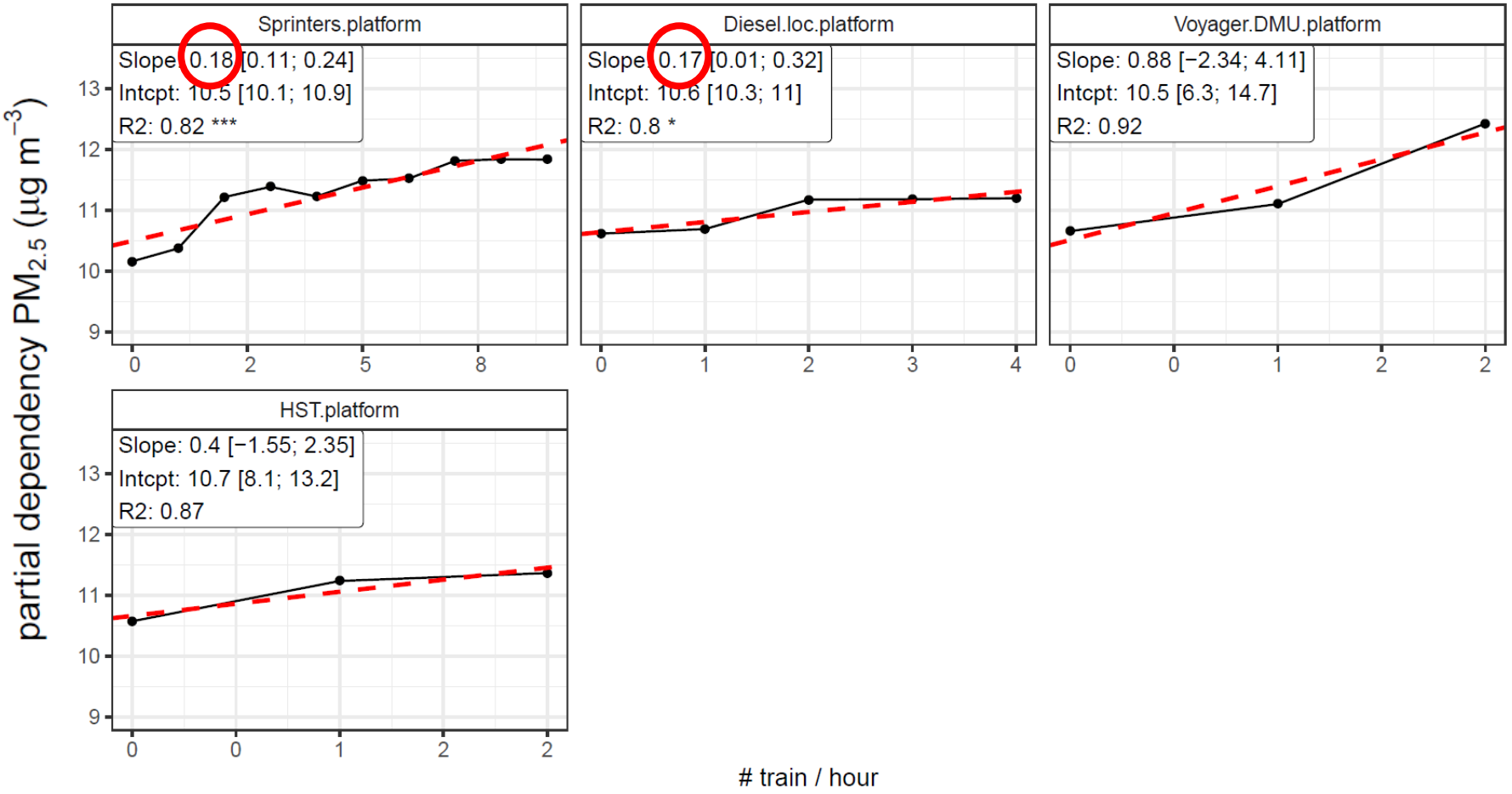
Regression model – Edinburgh Waverley

$PM_{2.5}$ Edinburgh (ED2-Waverley steps)

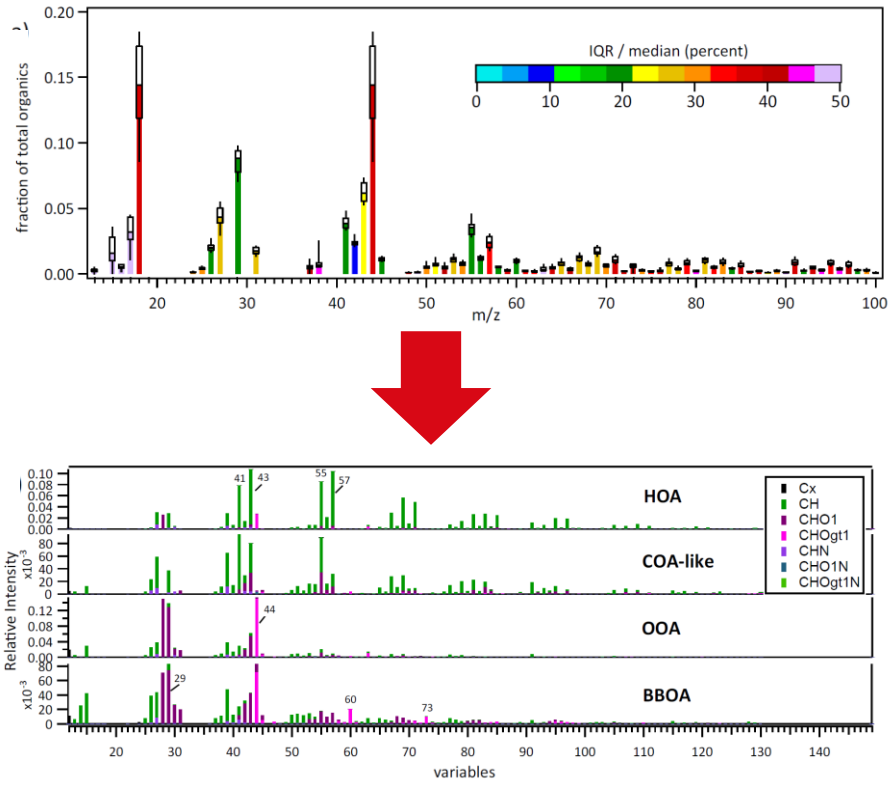
$R^2 = 0.50$



Partial dependencies – Edinburgh Waverley



Source Apportionment of Organic Mass



R. Fröhlich et al.: Intercomparison of ME-2 organic source apportionment

Atmos. Meas. Tech., 8, 2555–2576, 2015

Organic Carbon- three factors at each station

I) **Diesel**-from trains and traffic outside (abbreviated as HOA)

II) **Secondary** – from the wider urban and regional area (abbreviated as OOA)

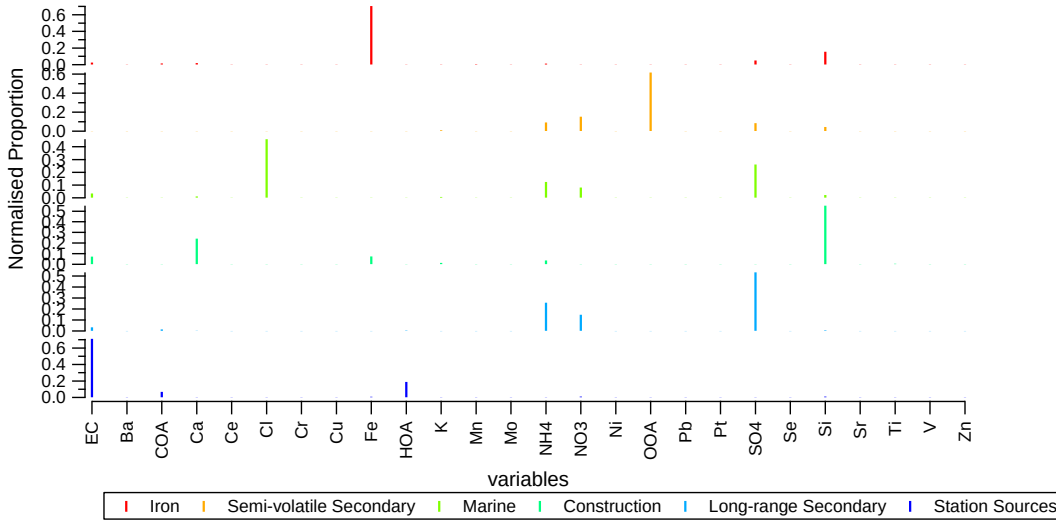
(Edinburgh Waverley only)

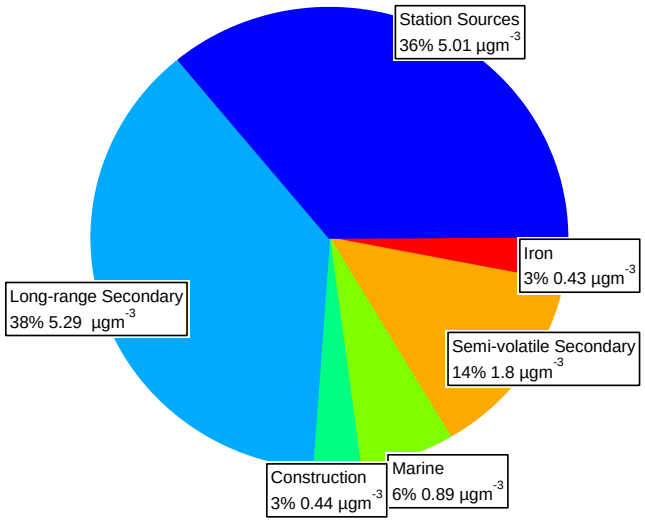
Cooking -from the food hall and other outlets area (abbreviated as COA)

(London King's Cross only)

Urban -from the other urban sources (e.g. cooking, heating) (abbreviated as UOA)

Edinburgh Waverley – $PM_{2.5}$ Source Apportionment

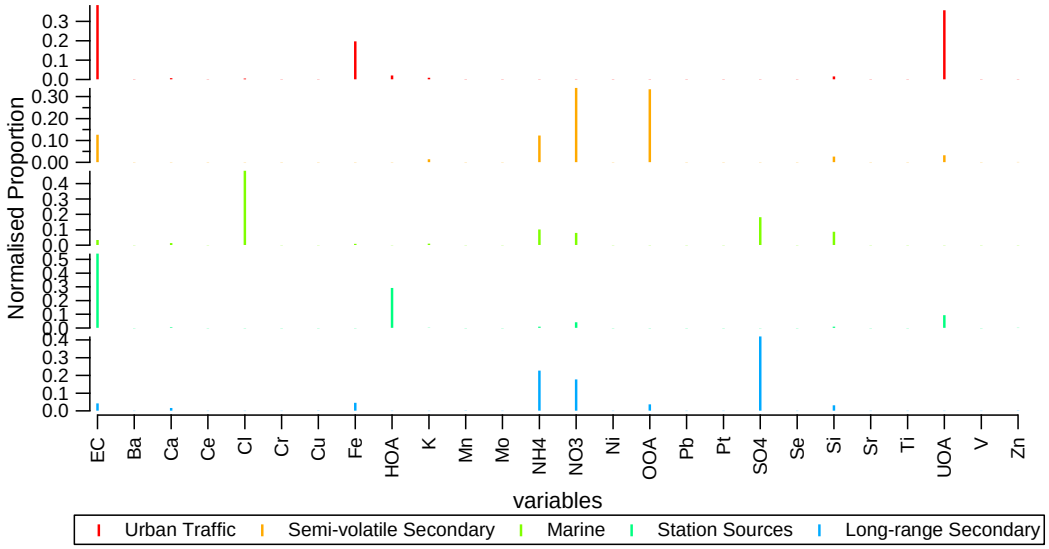


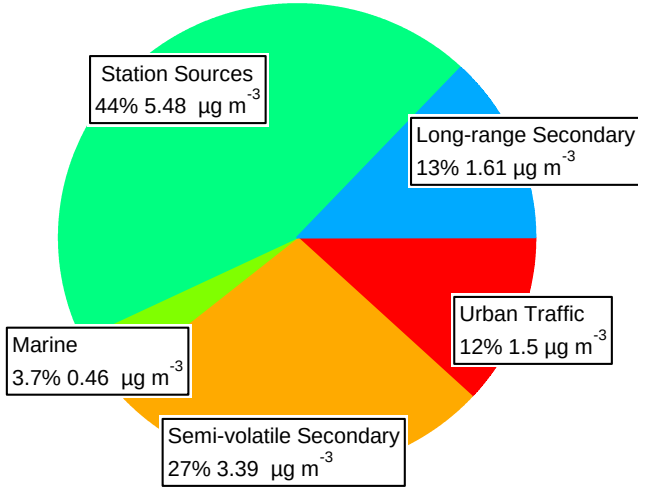


External sources (Semi-volatile Secondary, Marine and Long-range Secondary): **68% of the $PM_{2.5}$**

Internal sources (Station Sources, Construction, Iron): **32% of the $PM_{2.5}$**

London King's Cross– $PM_{2.5}$ Source Apportionment



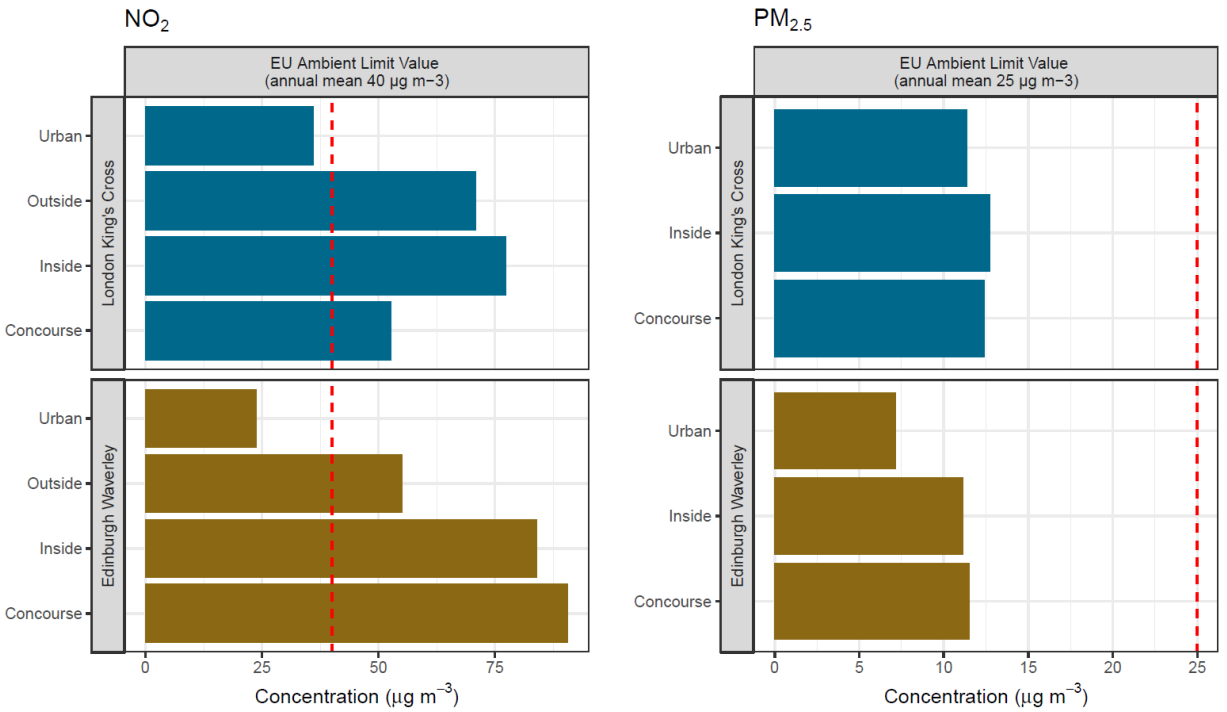


External sources (Urban Traffic, Semi-volatile Secondary, Marine and Long-range Secondary): **66% to the $PM_{2.5}$**

Internal Sources: 34% of the $PM_{2.5}$

Conclusions (Air Pollution in enclosed stations)

- **Mean NO_2** concentrations measured inside **Edinburgh Waverley** and **London King's Cross** was **above** the **40 µg m^{-3}** annual limit value*
- Mean **PM_{10} and $PM_{2.5}$** concentrations **below the annual limit** values* in both stations



Conclusions (NO_2 and PM)

- Overall **station increments** in **NO_2** and **$PM_{2.5}$** concentrations **were higher in Edinburgh** compared to London
- **Locations closer** to the **platforms** generally recorded the **highest concentrations**.
- The **central concourse of Edinburgh Waverley** also recorded **elevated concentrations** and this may be consistent with **stagnation effects due to the central building in the concourse**.
- Station **increments of NO_2** were compared to train timetables and **showed a good correlation with the number of diesel trains**. **$PM_{2.5}$ showed** a **moderate correlation** with the **number of diesel trains**.

Conclusions ($PM_{2.5}$ apportionment)

- **$PM_{2.5}$** concentrations **inside the stations** were **elevated** by up to **5 µg m^{-3}**
  - 30-40% of the background at EDB
  - 20% at KGX
- **PMF analysis** of the chemical composition of $PM_{2.5}$ confirmed the **influence of external sources** and showed that **~40%** of $PM_{2.5}$ was **emitted inside the stations**.
- **Cooking fumes and construction were identifiable in Edinburgh** Waverley

Conclusions (Regression modelling)

- A **regression machine-learning** model was used to explain the **variability in hourly $PM_{2.5}$**, including both train information and meteorological variables. This approach explained a **good proportion** of the **original $PM_{2.5}$** concentrations
- **Urban background concentrations** and the **meteorological conditions had the greatest influence**
- The model showed that priority should be given to the existing program **replacing Sprinters at Edinburgh Waverley** and **Class 180 at London King's Cross**

Thank you

Research supported by RSSB (grant reference T221).
Thanks to Aqueel Juanjua, James Wright and Michael Woods at RSSB. We also thank Russell Preece from Virgin trains.