Ricardo
Energy & Environment

Recent Findings from Real World Vehicle Emissions Monitoring from UK measurements

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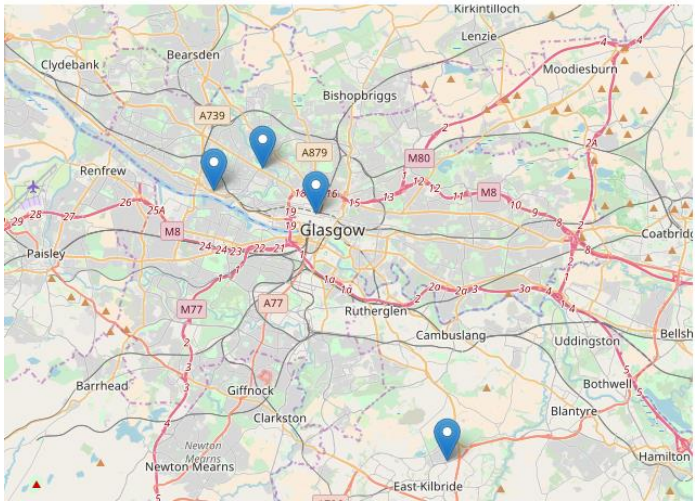
Introduction and Aims

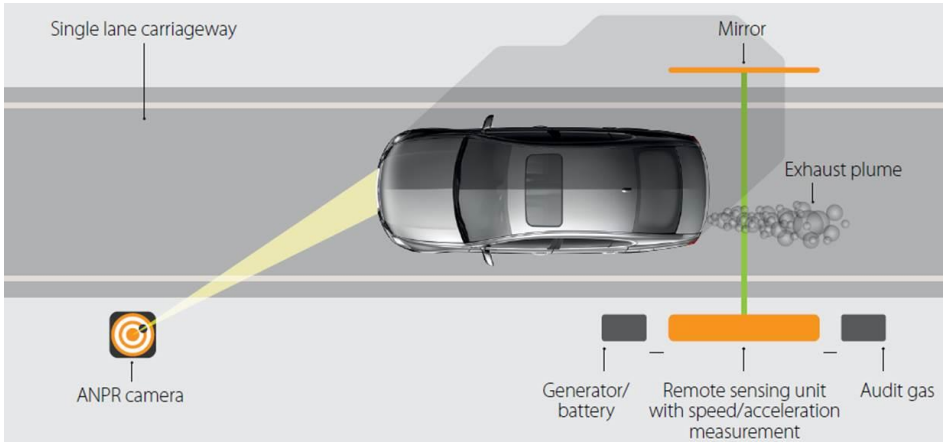
- Present evidence from vehicle emissions monitoring we have undertaken over a period of 6 months at locations across UK
  - Focus on NOx (and PM)
  - Emissions reductions
  - Vehicle characteristics and environmental factors which affect emissions from vehicles

- Provide a link between inventory emission factors and real world emissions factors from vehicle emissions monitoring, implications for modelling and assessment



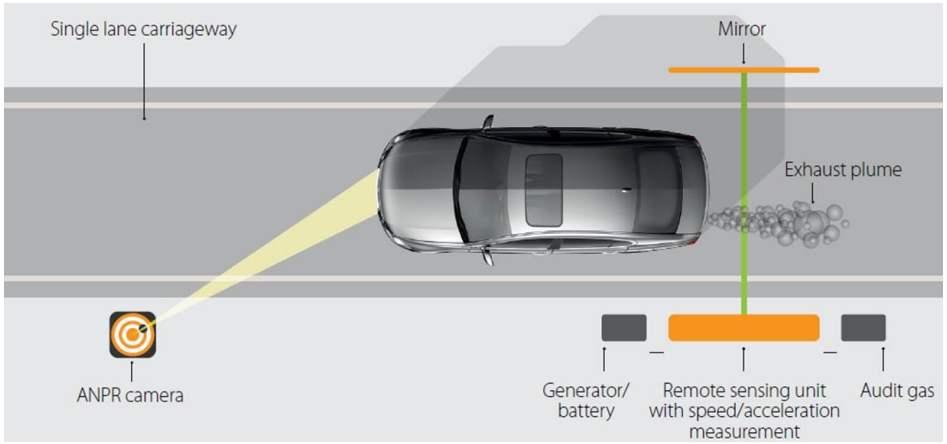
Vehicle Emission Measurements

- Three main ways of measuring vehicles emissions
  - In the laboratory like the Ricardo VERC
  - Portable Emission Measurement System (PEMS)
  - Vehicle emission remote sensing
- The three techniques are highly complementary, but:
  - Remote sensing can provide data that is closely aligned to air quality problems …
  - Measures the whole vehicle fleet
  - Can be used to derive emission factors for use in emission inventories
  - ‘real’ real world in the sense that there is no interference of the vehicle being tested



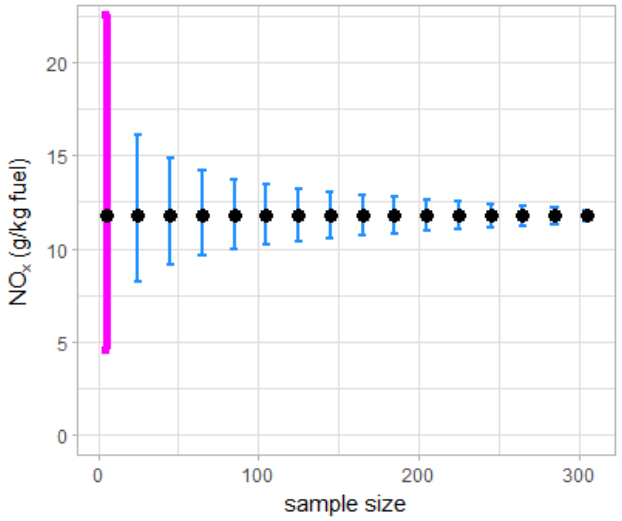
Vehicle Emission Remote Sensing

- We have ~100,000 measurements from 10 different measurement locations across UK from a 6 month trial of a commercial instrument from OPUS
- The technique:
  - UV/Infrared beam to measure emissions – different gases absorb in different wavelength regions
  - Measure NO, NO_2 (hence NO_x), CO, HC, PM and NH_3
  - 100 scans in 0.5 seconds of exhaust plume
  - **Emissions expressed as ratios to CO_2** and through combustion equations, grammes of pollutant per unit fuel (mostly commonly g/kg)
  - Measure speed and acceleration of each vehicle
- Photograph each vehicle to obtain number plate
  - Detailed cross reference with SMMT-derived databases…more than 80 vehicle characteristics, down to the colour of the vehicle!



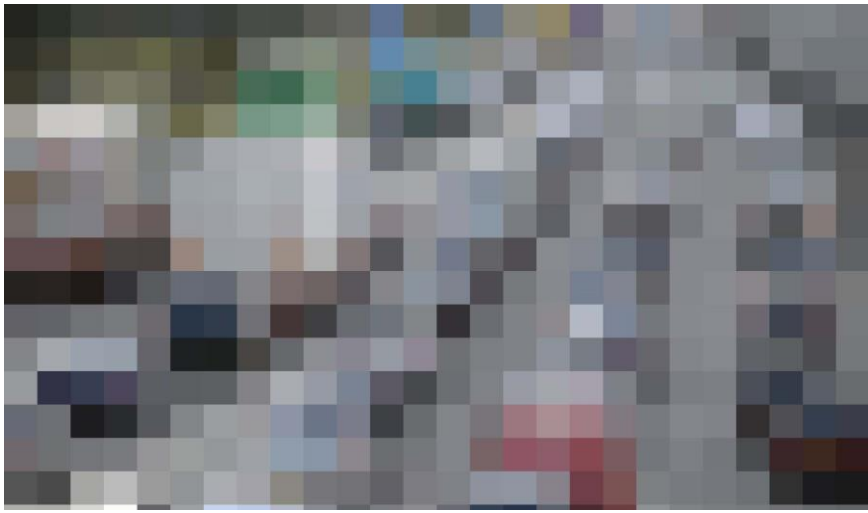
Remote sensing and sample size

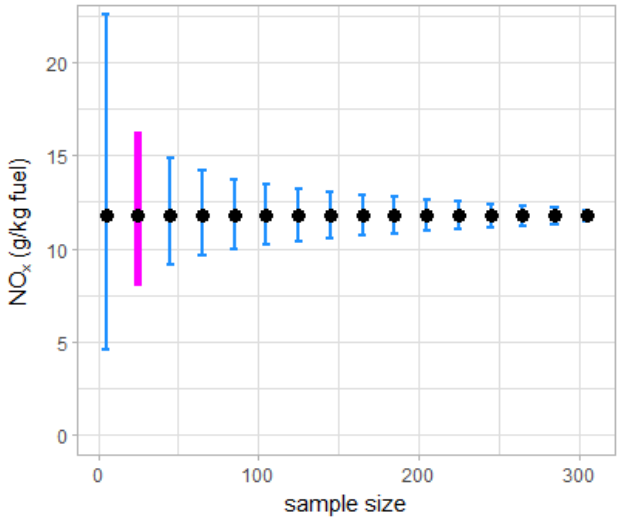
- Consider measurements of 1.6 litre diesel Euro 5 VW Golf
  - Use random sampling to calculate uncertainty (95% confidence interval) as a function of sample size
- 0.56% of the fleet we have measured
- Need to measure **900 vehicles to get sample size of 5** measurements
- Uncertainties driven by:
  - Instrument uncertainty
  - Plume ‘snapshot’ – only part of a drive cycle
  - Driving conditions
  - ‘Real’ differences between vehicles e.g. maintenance, degradation effects
  - Any changes within Euro class
  - Misspecification of vehicle being considered



Remote sensing and sample size

- Consider measurements of 1.6 litre diesel Euro 5 VW Golf
  - Use random sampling to calculate uncertainty (95% confidence interval) as a function of sample size
- 0.56% of the fleet we have measured
- Need to measure **4475 vehicles to get sample size of 25** measurements
- Uncertainties driven by:
  - Instrument uncertainty
  - Plume ‘snapshot’ – only part of a drive cycle
  - Driving conditions
  - ‘Real’ differences between vehicles e.g. maintenance, degradation effects
  - Any changes within Euro class
  - Misspecification of vehicle being considered





Remote sensing and sample size

- Consider measurements of 1.6 litre diesel Euro 5 VW Golf
  - Use random sampling to calculate uncertainty (95% confidence interval) as a function of sample size
- 0.56% of the fleet we have measured
- Need to measure **18000 vehicles to get sample size of 100** measurements
- Uncertainties driven by:
  - Instrument uncertainty
  - Plume ‘snapshot’ – only part of a drive cycle
  - Driving conditions
  - ‘Real’ differences between vehicles e.g. maintenance, degradation effects
  - Any changes within Euro class
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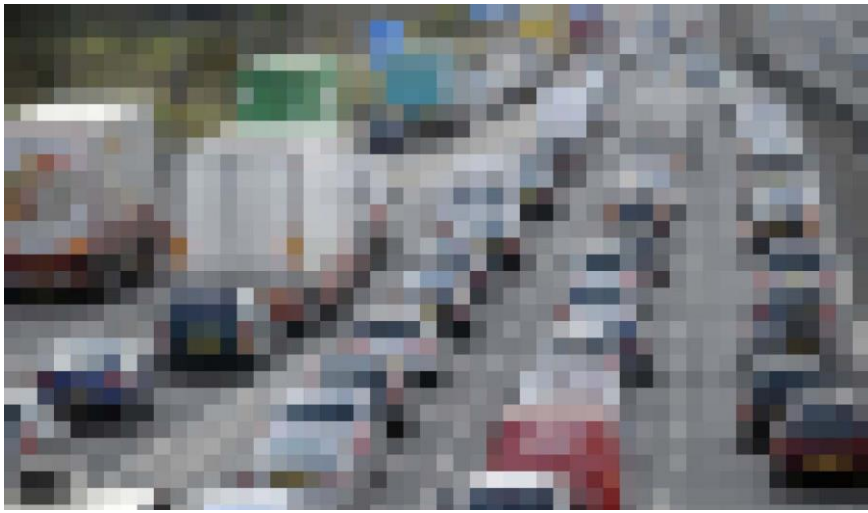

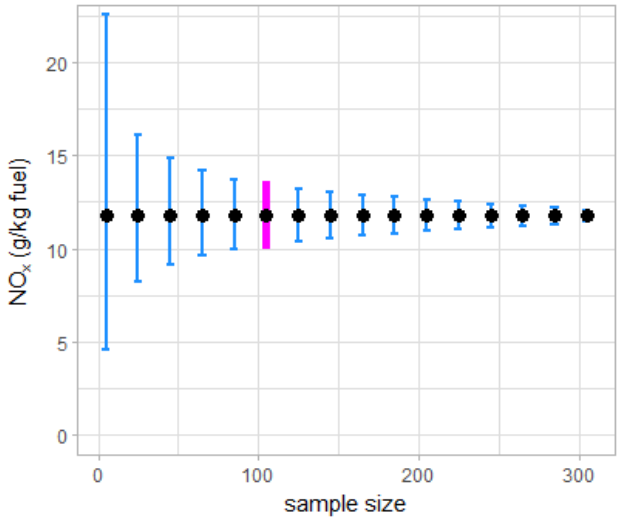

Remote sensing and sample size

- Consider measurements of 1.6 litre diesel Euro 5 VW Golf
  - Use random sampling to calculate uncertainty (95% confidence interval) as a function of sample size
- 0.56% of the fleet we have measured
- Need to measure **35800 vehicles to get sample size of 200** measurements
- Uncertainties driven by:
  - Instrument uncertainty
  - Plume ‘snapshot’ – only part of a drive cycle
  - Driving conditions
  - ‘Real’ differences between vehicles e.g. maintenance, degradation effects
  - Any changes within Euro class
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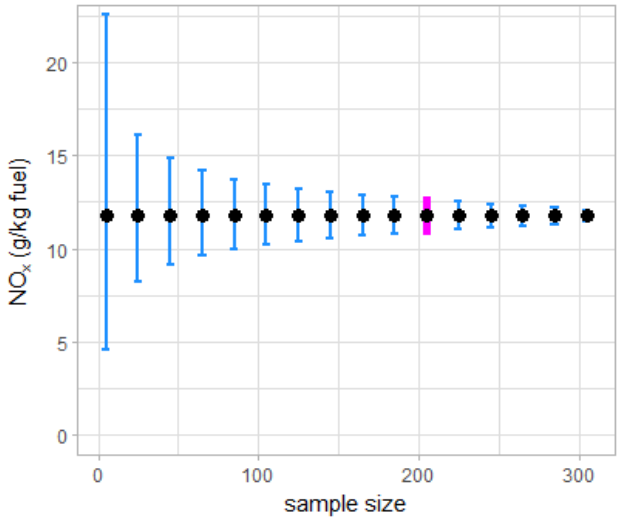
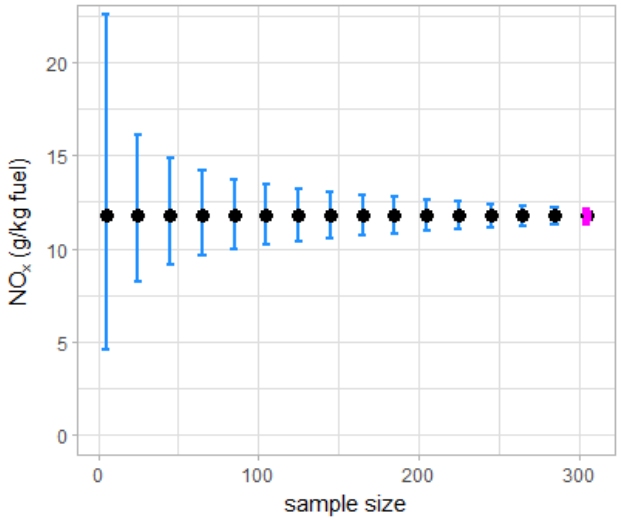


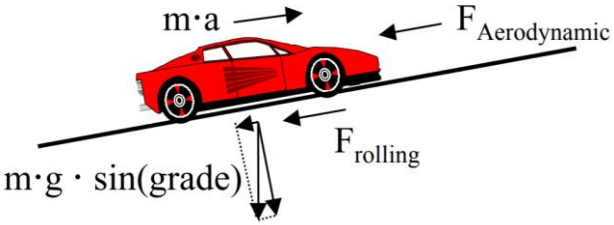
Remote sensing and sample size

- Consider measurements of 1.6 litre diesel Euro 5 VW Golf
  - Use random sampling to calculate uncertainty (95% confidence interval) as a function of sample size
- 0.56% of the fleet we have measured
- Need to measure **58000 vehicles to get sample size of 320** measurements
- Uncertainties driven by:
  - Instrument uncertainty
  - Plume ‘snapshot’ – only part of a drive cycle
  - Driving conditions
  - ‘Real’ differences between vehicles e.g. maintenance, degradation effects
  - Any changes within Euro class
  - Misspecification of vehicle being considered



Link to inventories: Real world emission factors

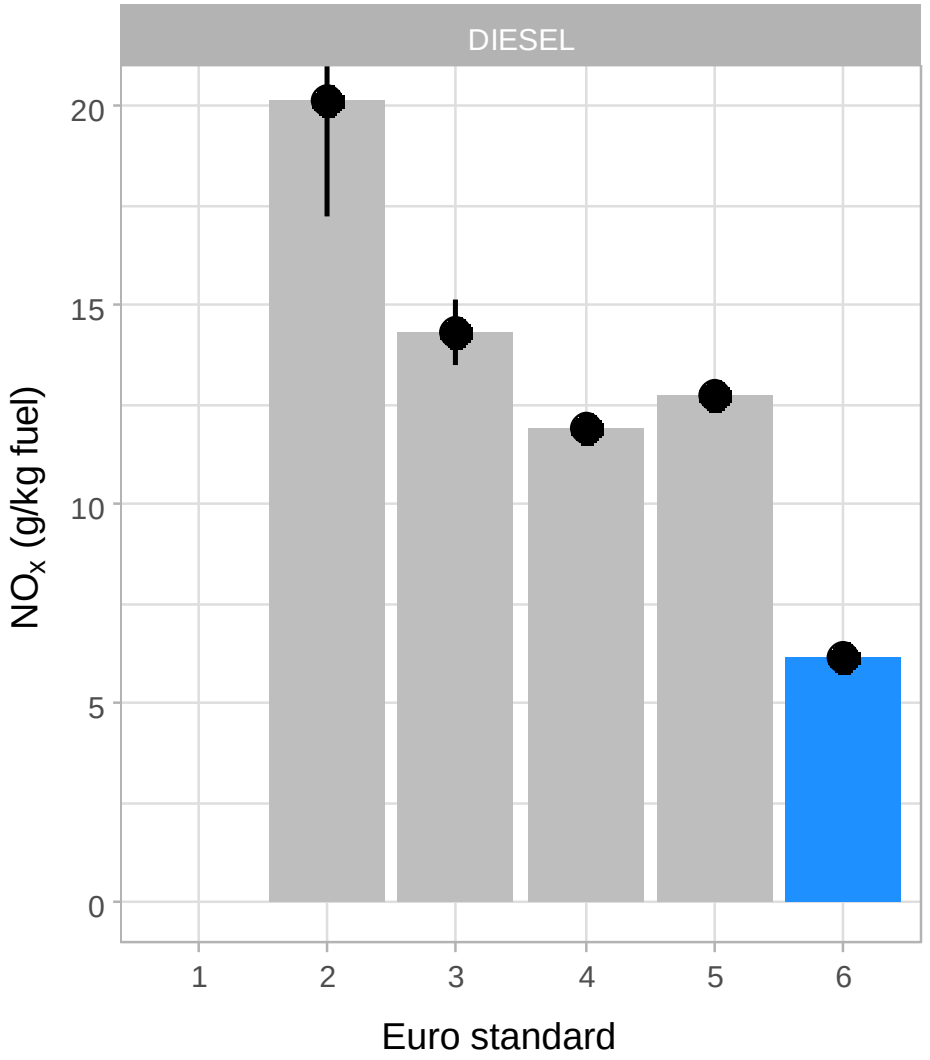
- Remote sensing provides ratios of pollutant to CO_2 from which g per kg fuel estimates of emissions can be made
- Inventories provide emission factors in g per km
- Use a vehicle power model to calculate real world g per km emission factors from remote sensing data
- Remote sensing data can be directly aligned with COPERT emission factor categories
- Can go ***beyond*** COPERT emission factor categories
  - Road gradient
  - Acceleration
  - Temperature
  - Vehicle manufacturer and model
- Informative for air quality modelling and assessment



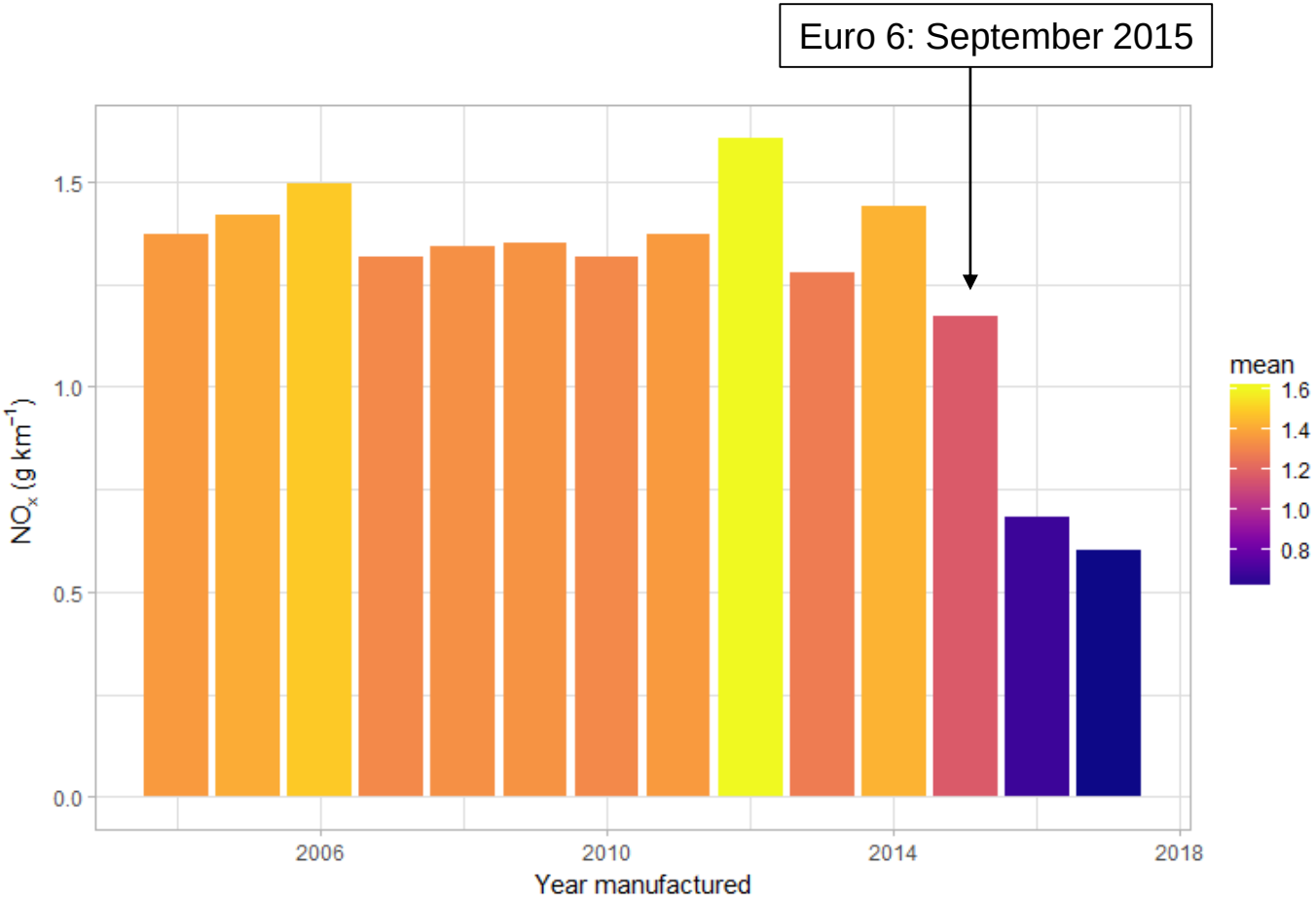
Work in progress: some results will be shown in g per kg fuel, but first results in g per km for diesel cars will be presented

NO_X emissions from diesel passenger cars

- Euro 6 diesel cars emit about 55% less NO_X than Euro 5 cars

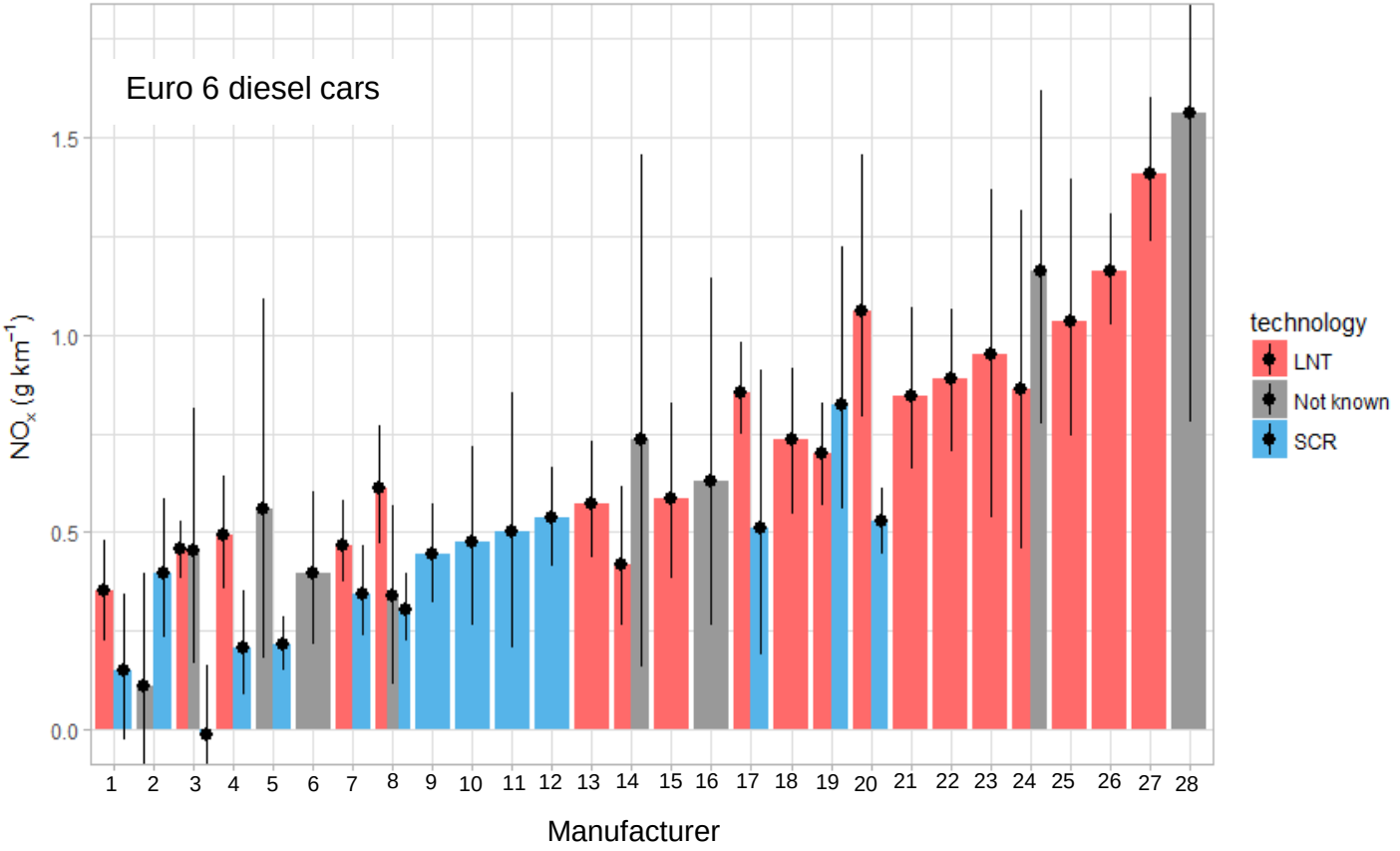


Emissions by year of manufacture for diesel cars



- Clear decrease from 2015 onwards i.e. Euro 6
- Vehicles seem to be improving over time – manufacturers getting better at controlling NO_x

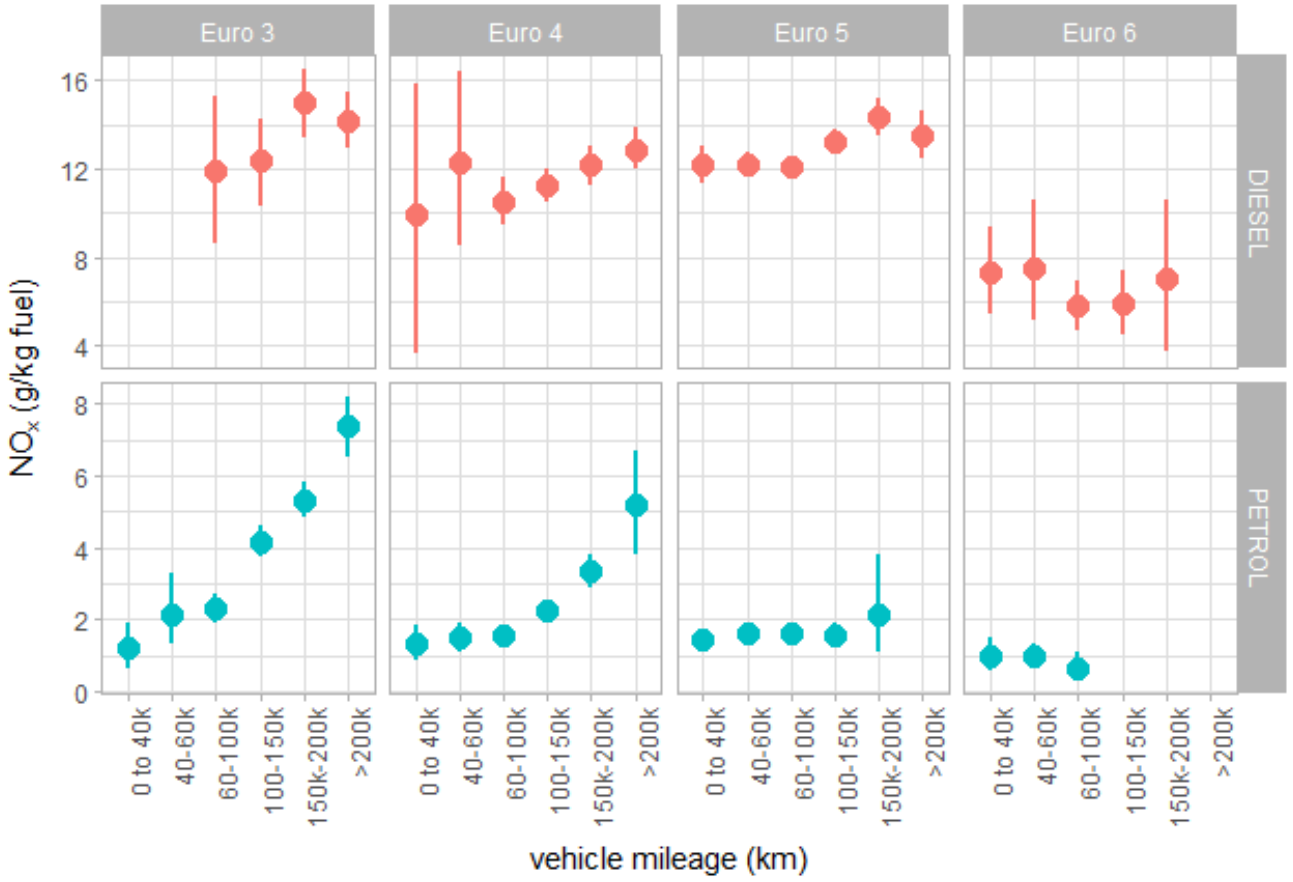
Emissions of NO_x from Euro 6 diesel cars: manufacturer & technology



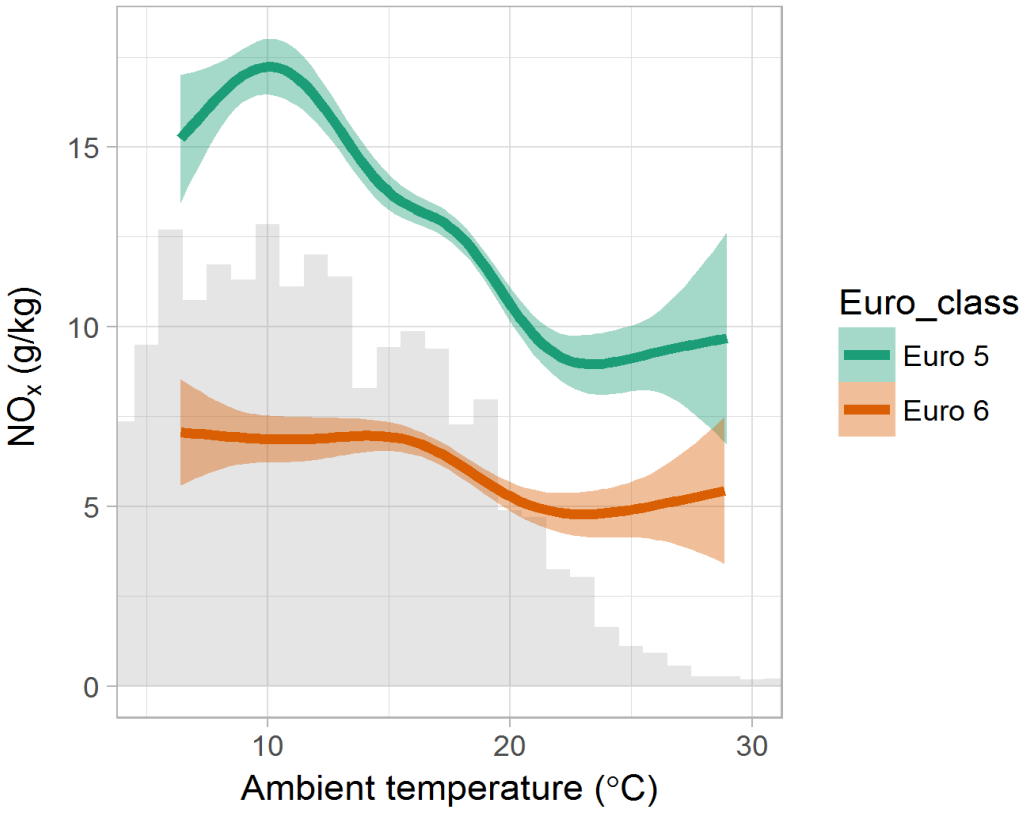
- Considerable range in NOx emissions for different manufacturers
- Generally shows SCR is associated with lower emissions

Effect of vehicle mileage on NO_x emissions – passenger cars

- First time this has been possible!
- Use most recent MOT mileage (> 40,000 cars)
- Little evidence that diesel cars worsen with mileage
- Euro 3/4 petrol cars do worsen with age – consider policies to remove them?
- Provisional results + need to look at interaction between age and mileage…



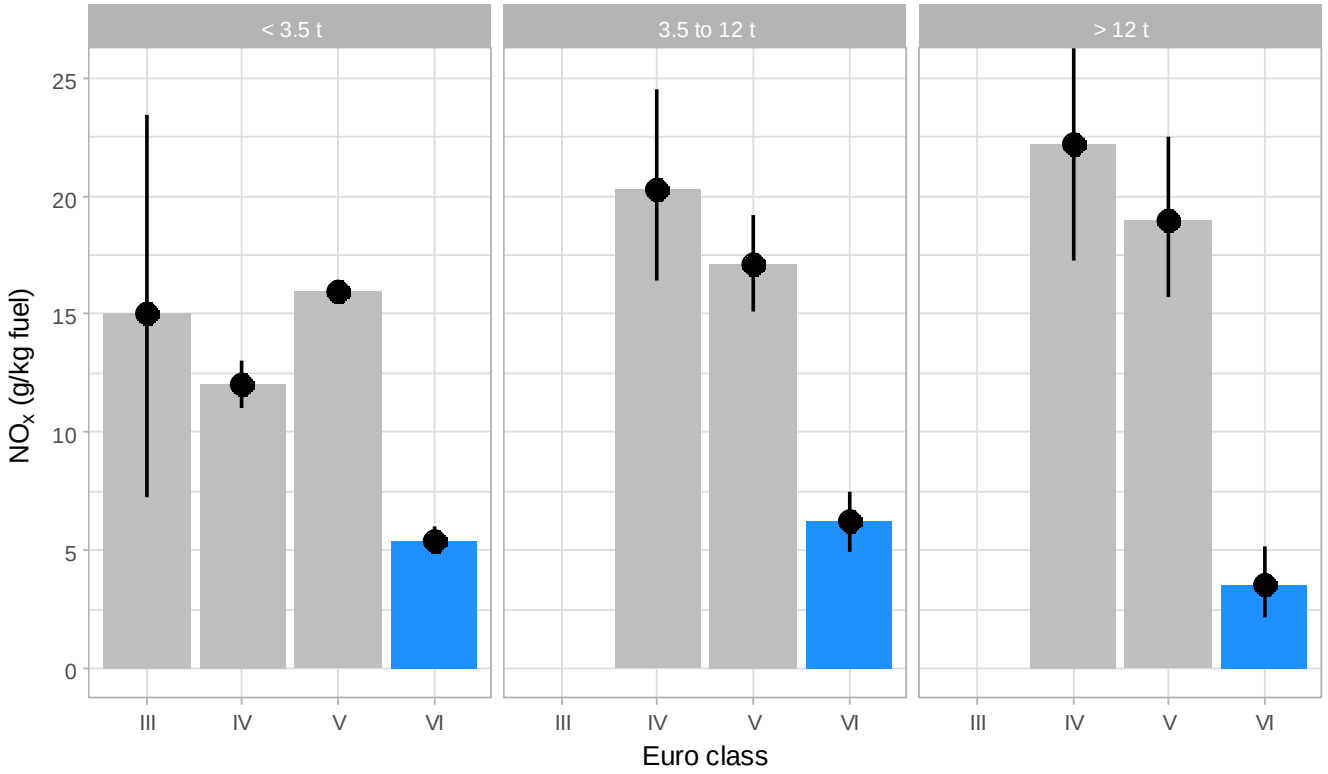
Effect of ambient temperature



- Increased emissions under lower temperatures
- Important for air quality
- Inventories used in air quality modelling and assessment do not include temperature effects

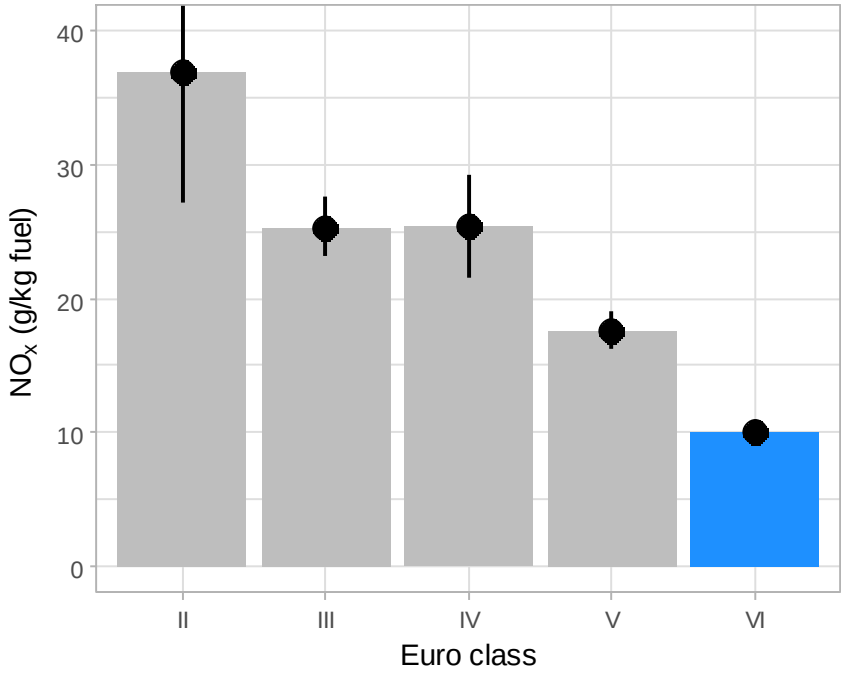
NO_X emissions from vans and HDVs

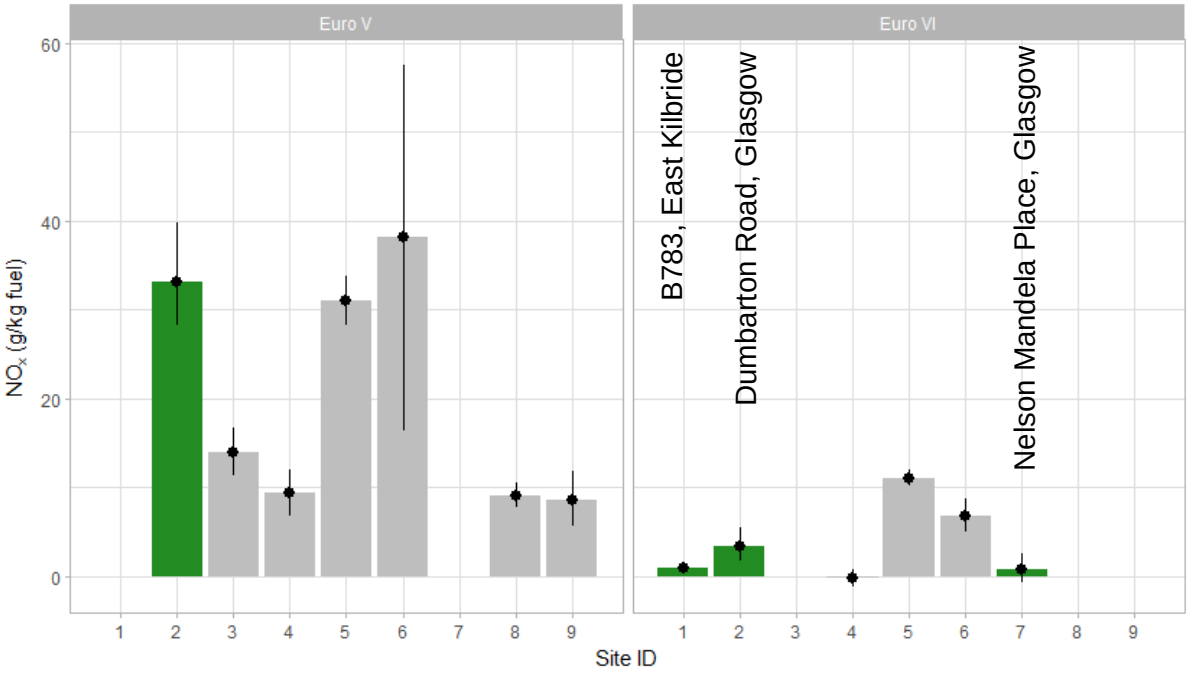
- Euro VI < 3.5 t emit 66% less NO_x than Euro V
- Euro VI <3.5 - 12 t emit 63% less NO_x than Euro V
- Euro VI > 12 t emit 81% less NO_x than Euro V



NO_X emissions from buses

- Euro VI on average 42% less than Euro V
- Local authorities can have very specific bus fleets – different emissions driven by different bus technologies used (and local driving conditions)
- Important for urban areas

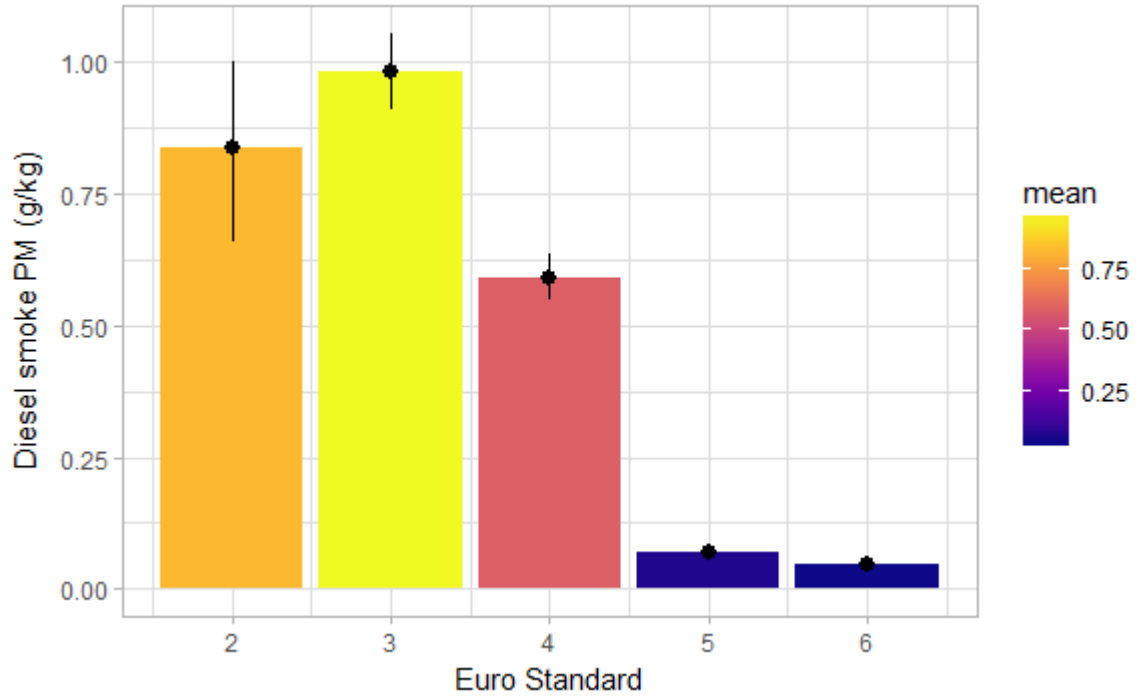




- Measurements in Scotland show good performance of Euro 6 buses in Scotland.

Emissions of PM from diesel cars

- Measure at 250 nm where diesel exhaust (BC) absorbs strongly
- Euro 5 and Euro 6 diesel cars have very low PM emission
  - Consistent with highly effective diesel particulate filters from Euro 5 onwards
  - Some Euro 4 vehicles also had diesel particulate filters
- No evidence of wide spread removal of DPF



Conclusions

- Evidence for considerable reductions in NO_x emissions for most major classes of Euro 6/VI diesel vehicles
  - 40-80% reductions for cars, buses, LGVs and HGVs
  - Vehicle emissions can vary significantly with vehicle properties such as manufacturer and exhaust after treatment technology, vehicle mileage
  - Ambient temperature impacts on emissions

- DPF's have been effective at reducing PM emissions from diesel vehicles

- Can derive real-world emission factors in the same categories as COPERT and going beyond COPERT categories (temperature, manufacturer…)
  - Can inform inventories and air quality modelling and assessment (e.g. CAZ implementation)
  - Further work to compare real world emission factors in g/km to emission factors in inventories

Continued measurements in London

- ICCT project with OPUS and University of York to make 100,000 vehicle measurements in London
  - Double the number of vehicle measurements in database
  - Increase the number of measurements at cold winter temperatures
  - Look for evidence for improvements as staged Euro 6 legislation with RDE test requirements come in

- Intercomparison of OPUS measurements with Denver FEAT instrument operated by University of York
  - Instruments with be collocated for a number of days
  - Validation of measurements

Thank you for your attention!

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