WACL
Wolfson Atmospheric Chemistry Laboratories

UNIVERSITY of York

Assessing New Delhi's vehicle emissions using remote sensing techniques

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Why should we care about vehicle emissions?

- High NO_x emissions in European Cities
- NO_2 concentrations exceeding annual 40 µg m^{-3} health limit
- Bad for public Health (respiratory and cardiovascular dieses)
- Direct emission of NO_x from diesel vehicles major source

Why should we care about vehicle emissions?

- Underestimation of vehicle emissions (standard rolling-road tests)
- Vehicles emitting higher NO_x under real-world driving conditions
- Need for real-world measurements of vehicles

Real-world assessment

Portable emission measurement system (PEMS)

Monitor individual vehicles

Expensive, only get individual car information

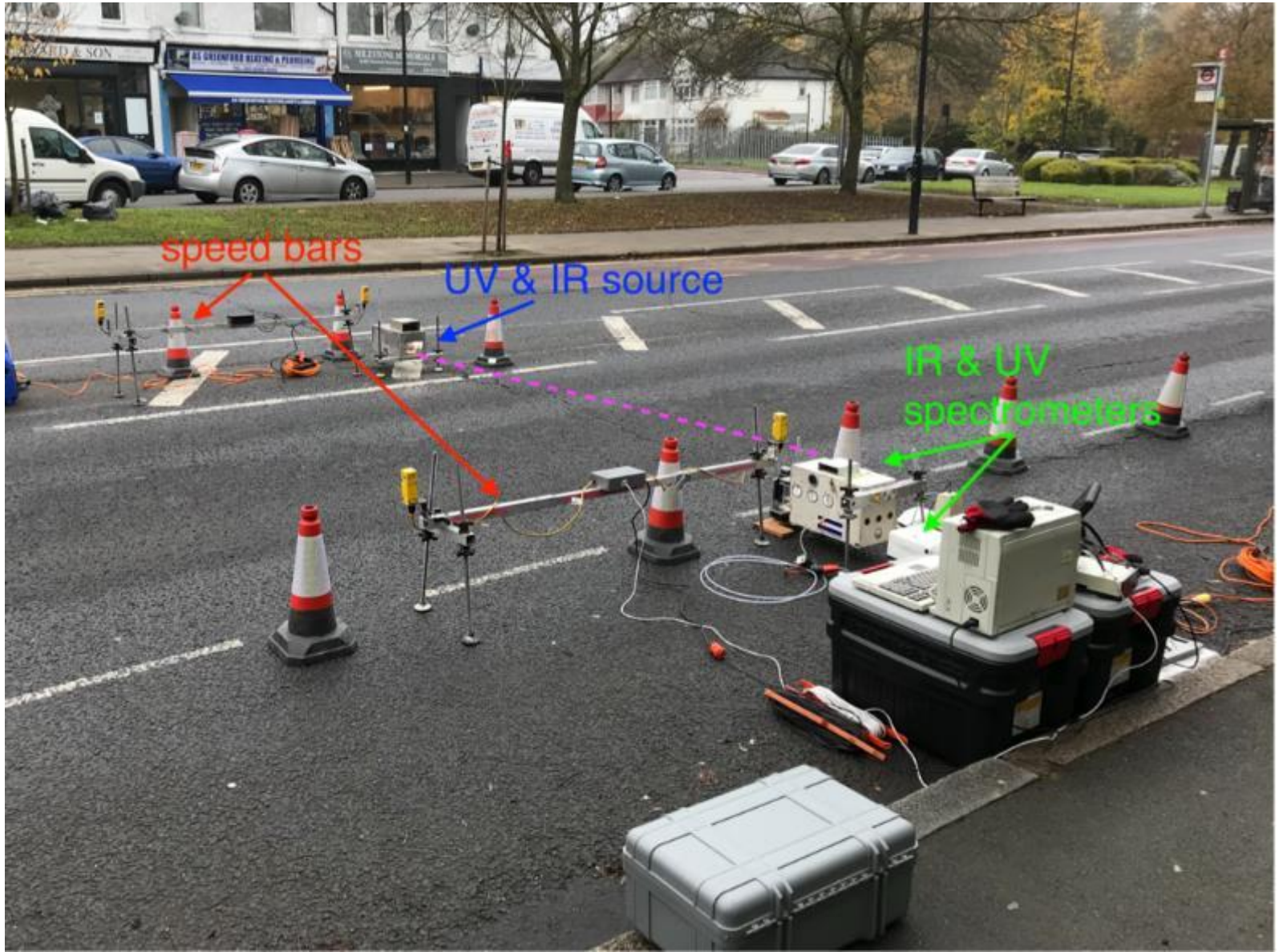
Remote sensing measurements

Non-invasive spectroscopy

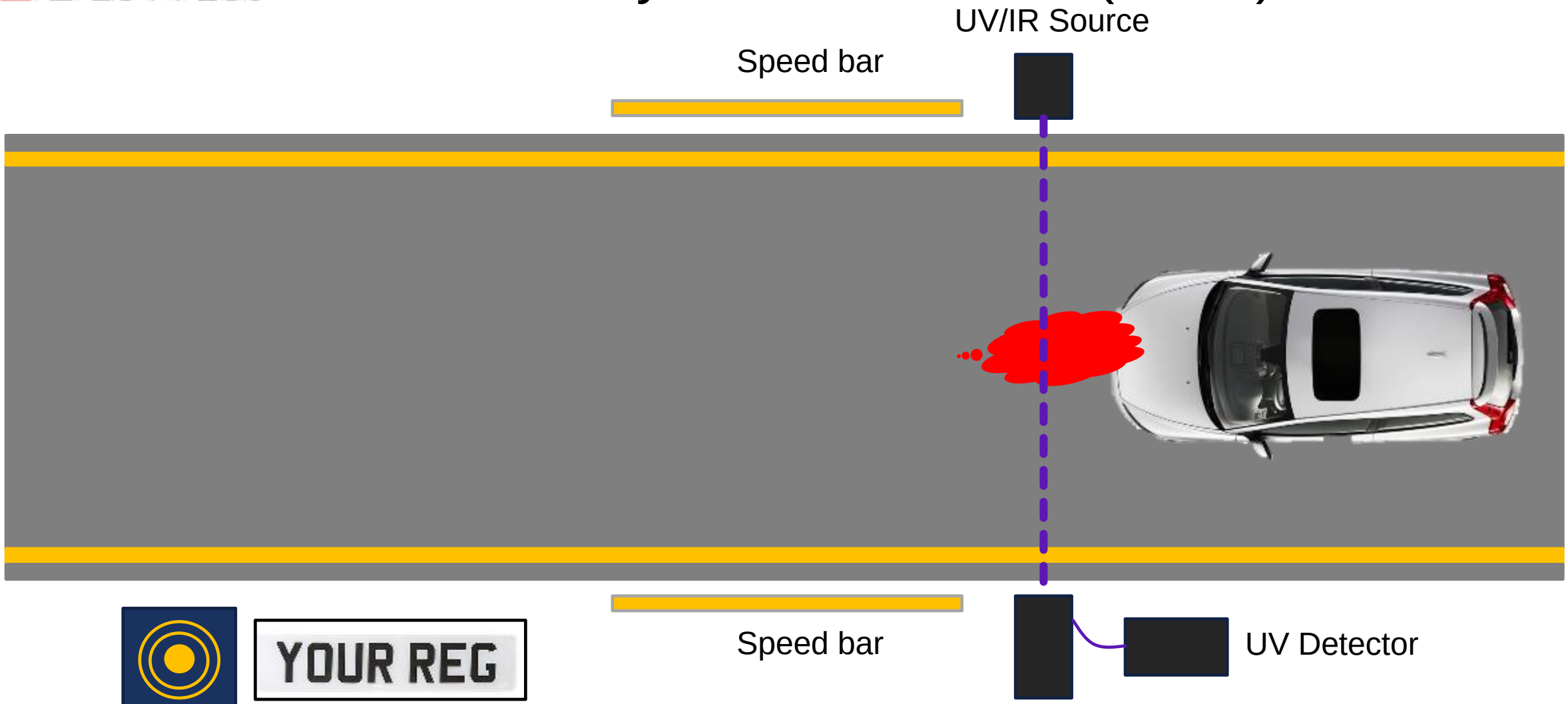
Capture entire fleet emission characteristics

UNIVERSITY OF DENVER

Fuel Efficiency Automobile Test (FEAT)



Fuel Efficiency Automobile Test (FEAT)



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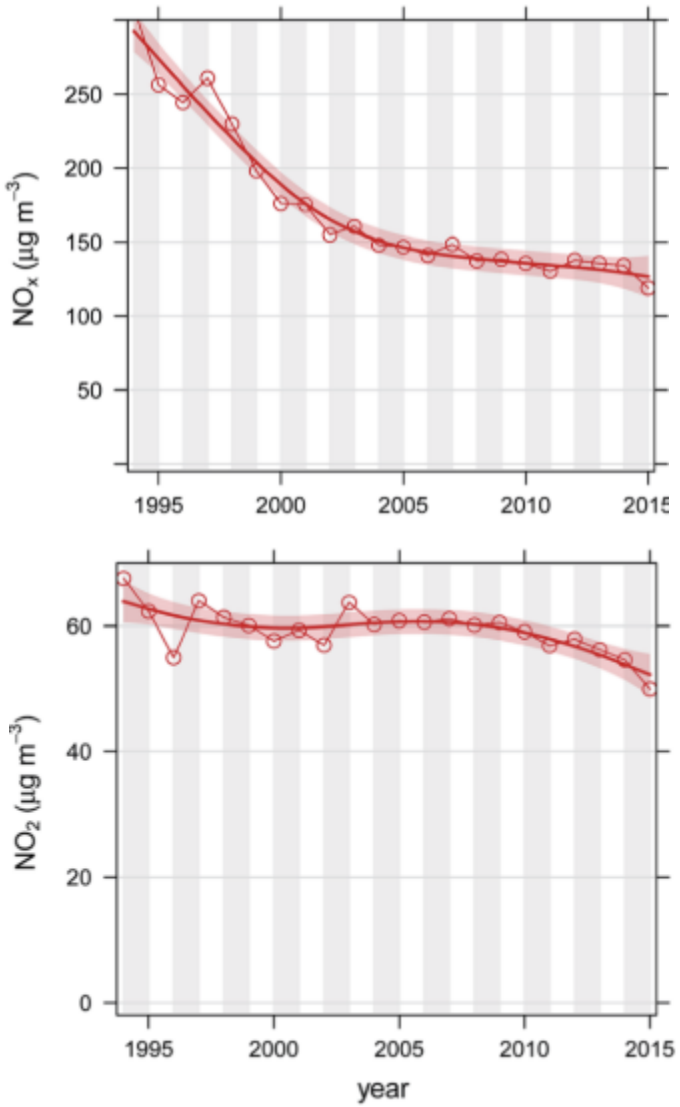
Fuel Efficiency Automobile Test (FEAT)

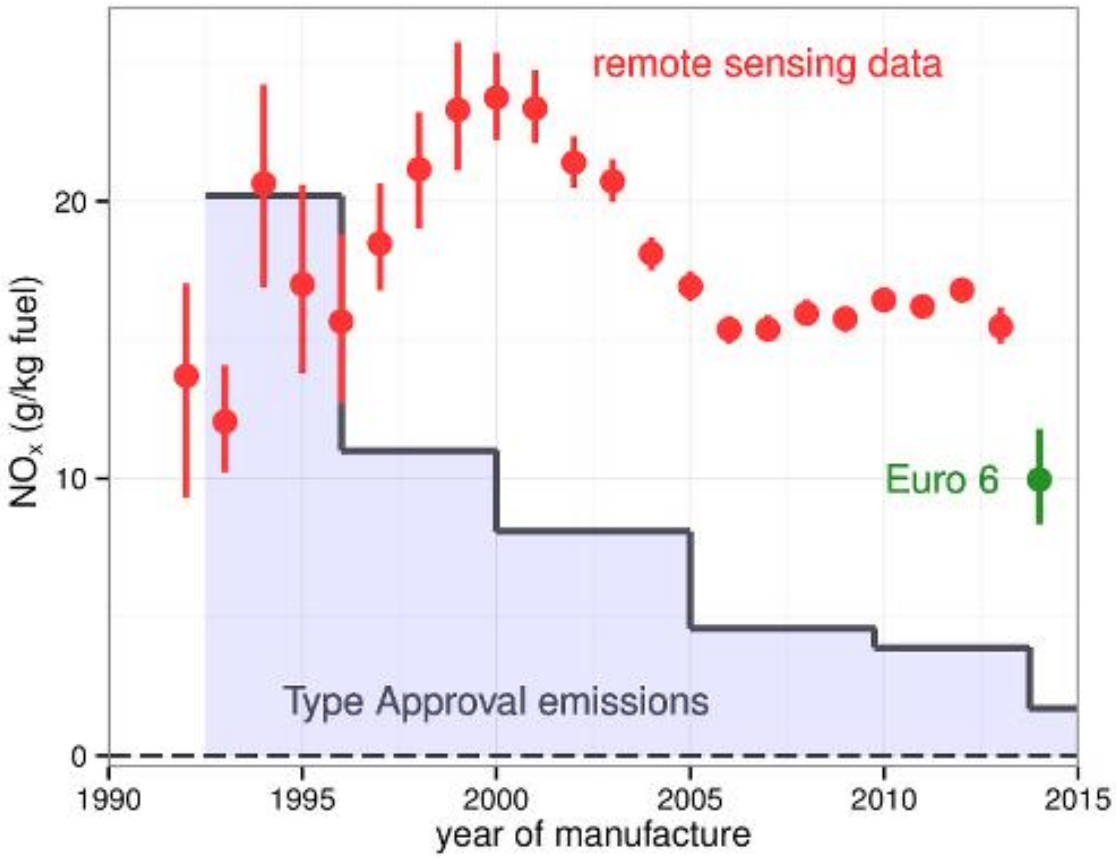
- Remote sensing measurements of vehicle tailpipe emissions
- Nondispersive Infrared (NDIR) measurements of CO_2, CO & HCs
- Dispersive Ultra-Violet (UV) measurements of NO, NO_2, NH_3 & SO_2
- Vehicle speed and acceleration measurements
- Vehicle number plate capture for manufacturer comparison

Previous UK Work



Ambient UK trends for NO_2 & NO_x

Carslaw



Comparison of NO_x Type Approval emission standards to remote-sensing measurements of diesel vehicles

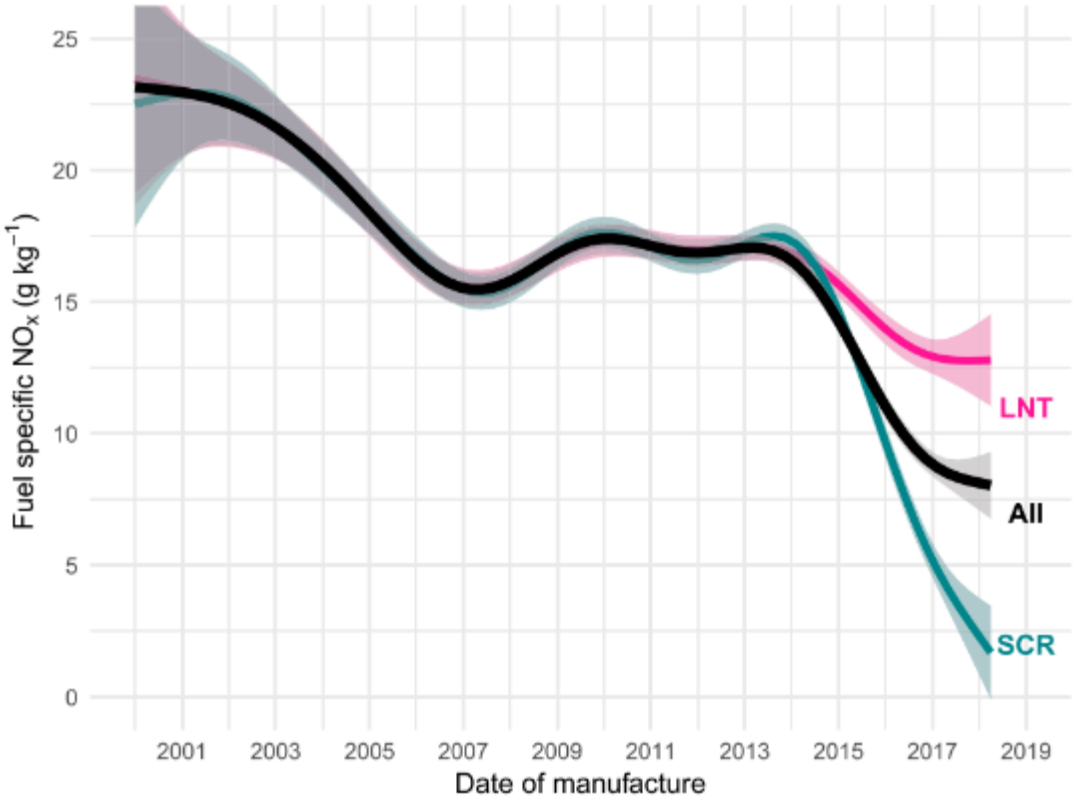
Current UK Work

- Remote-sensing measurements (FEAT instrument, University of Denver)
- London (Putney High Street & Ealing) and York
- October 2017 - March 2018
- ~50,000 vehicles measured (CO, HCs, NH_3, NO and NO_2 emissions)

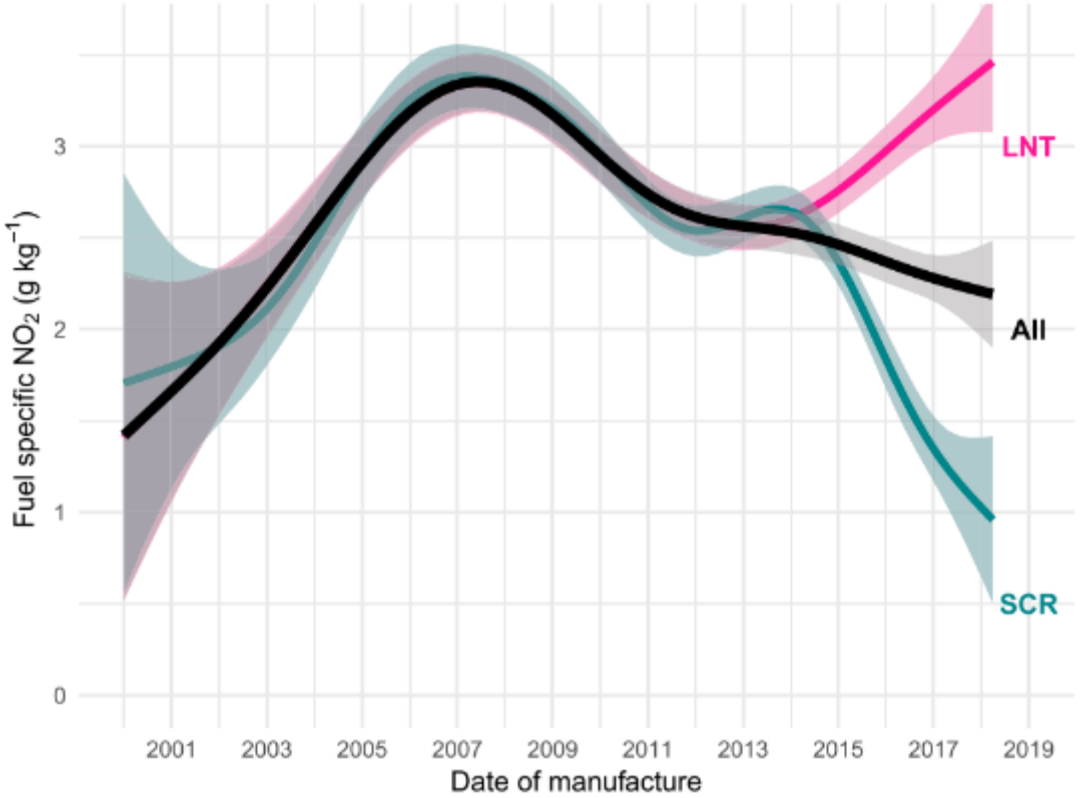
York Ring-Road

Putney High Street
London

UK Diesel Vehicles



Emissions of NO_x (g kg-1 fuel) as a function of vehicle manufacture date for diesel passenger cars.



Emissions of NO_2 (g kg-1 fuel) as a function of vehicle manufacture date for diesel passenger cars.

Carslaw, et al., The diminishing importance of nitrogen dioxide emissions from road vehicle exhaust. Atmospheric Environment: X, 1, p.100002.

New Delhi Measurements

Project background

- Indian vehicle emission factors poorly understood
- No previous independent real-world vehicle emission data

Project aims:

- Generate new emission factors from remote-sensing
- Refine vehicle source in SAFAR Emissions Inventory

New Delhi Measurements

- Measurements at entrance to Indira Gandhi Delhi Technical University for Women(IGDTUW)
- >200 vehicles (Cars, lorries, motorbikes, …)
- Compare findings to European remote-sensing data
- Merge data with larger remote-sensing studying by International Centre for Automotive Technology (ICAT)

New Delhi Measurements

Tool Booth - Gurugram

IGDTUW - New Delhi

New Delhi Measurements

Private Car

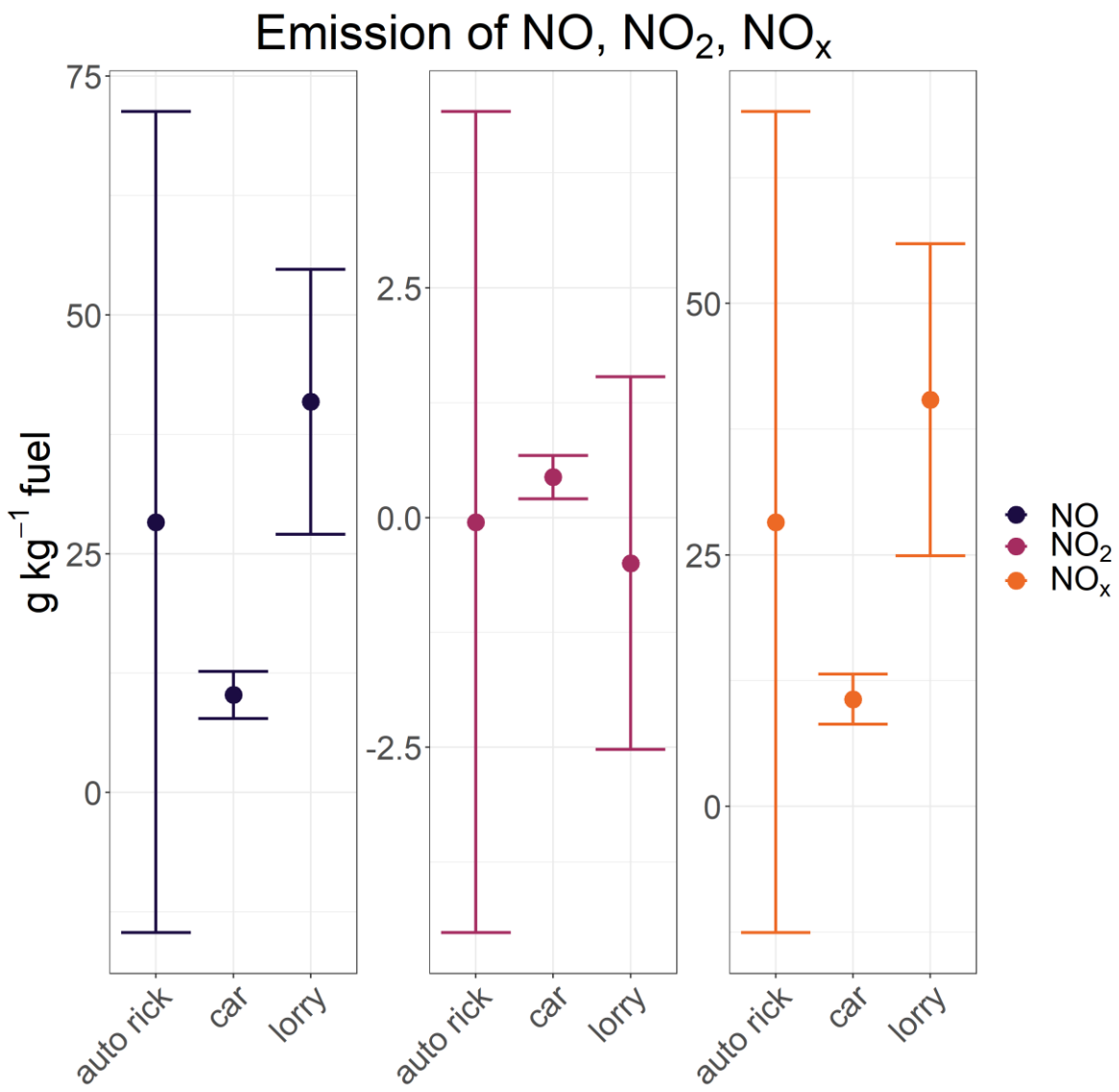
Motorbike

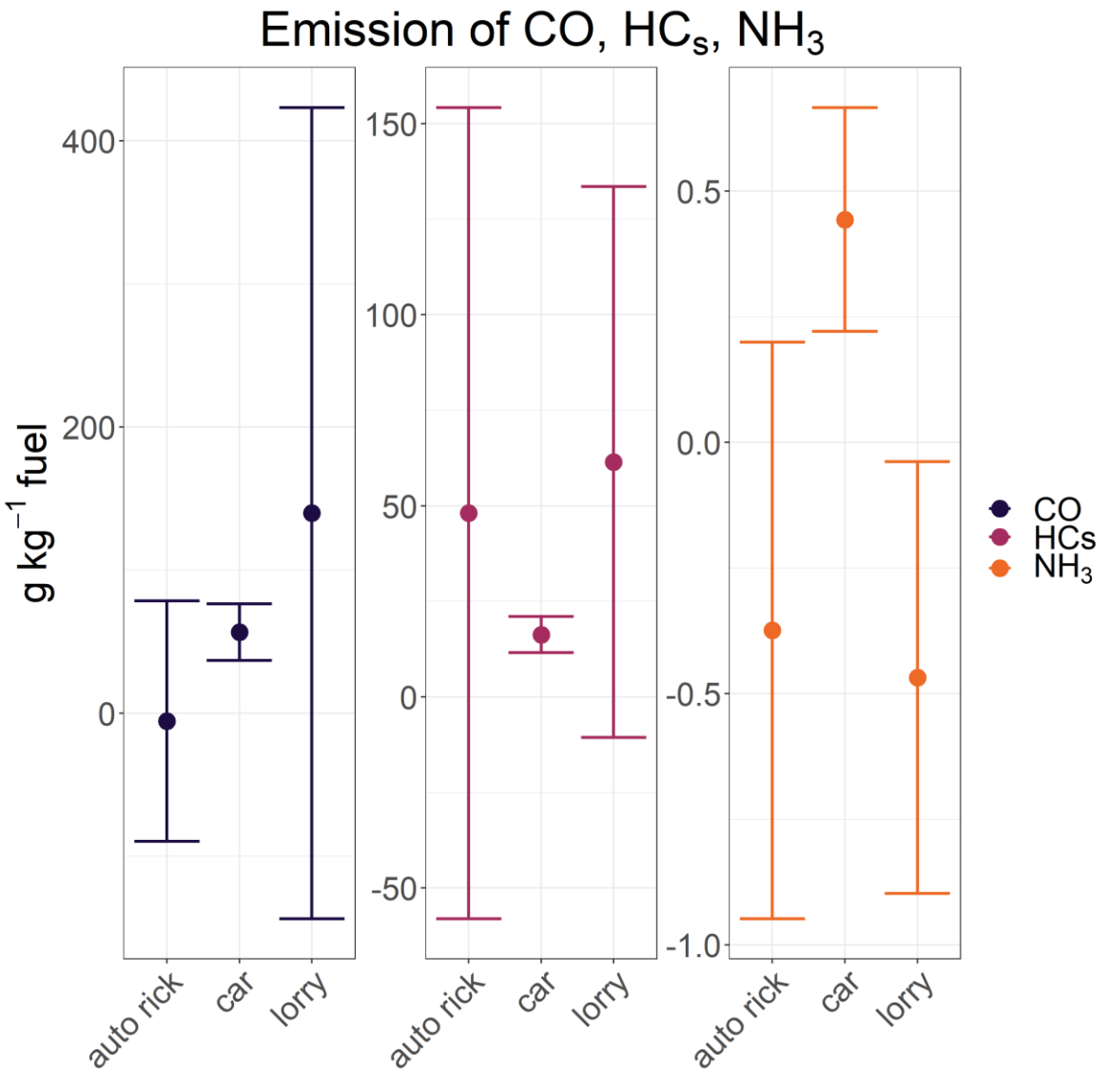
Auto Rickshaw

Lorry (Medium Goods Vehicle)

Mean and 95% confidence

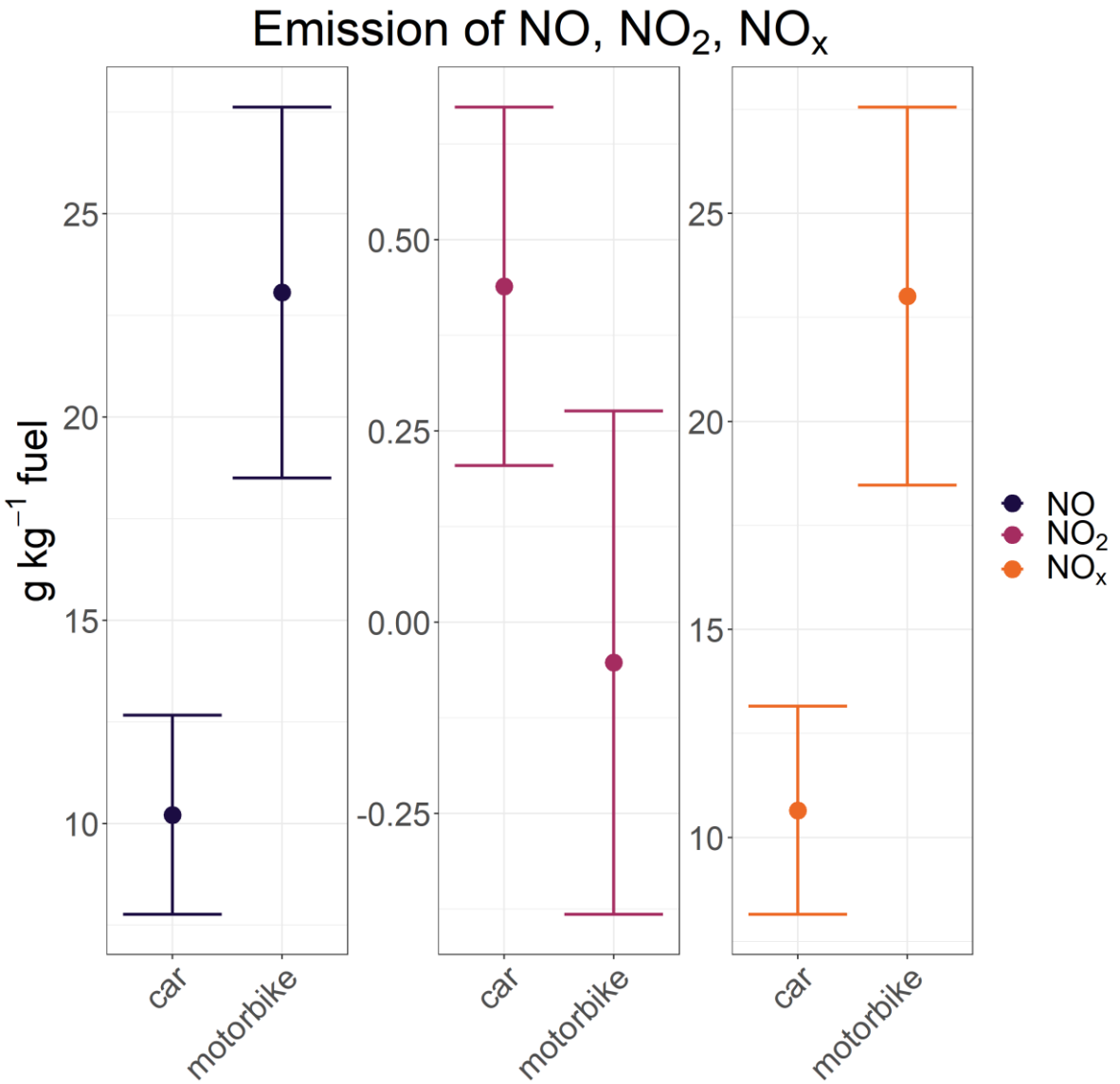
New Delhi Vehicles

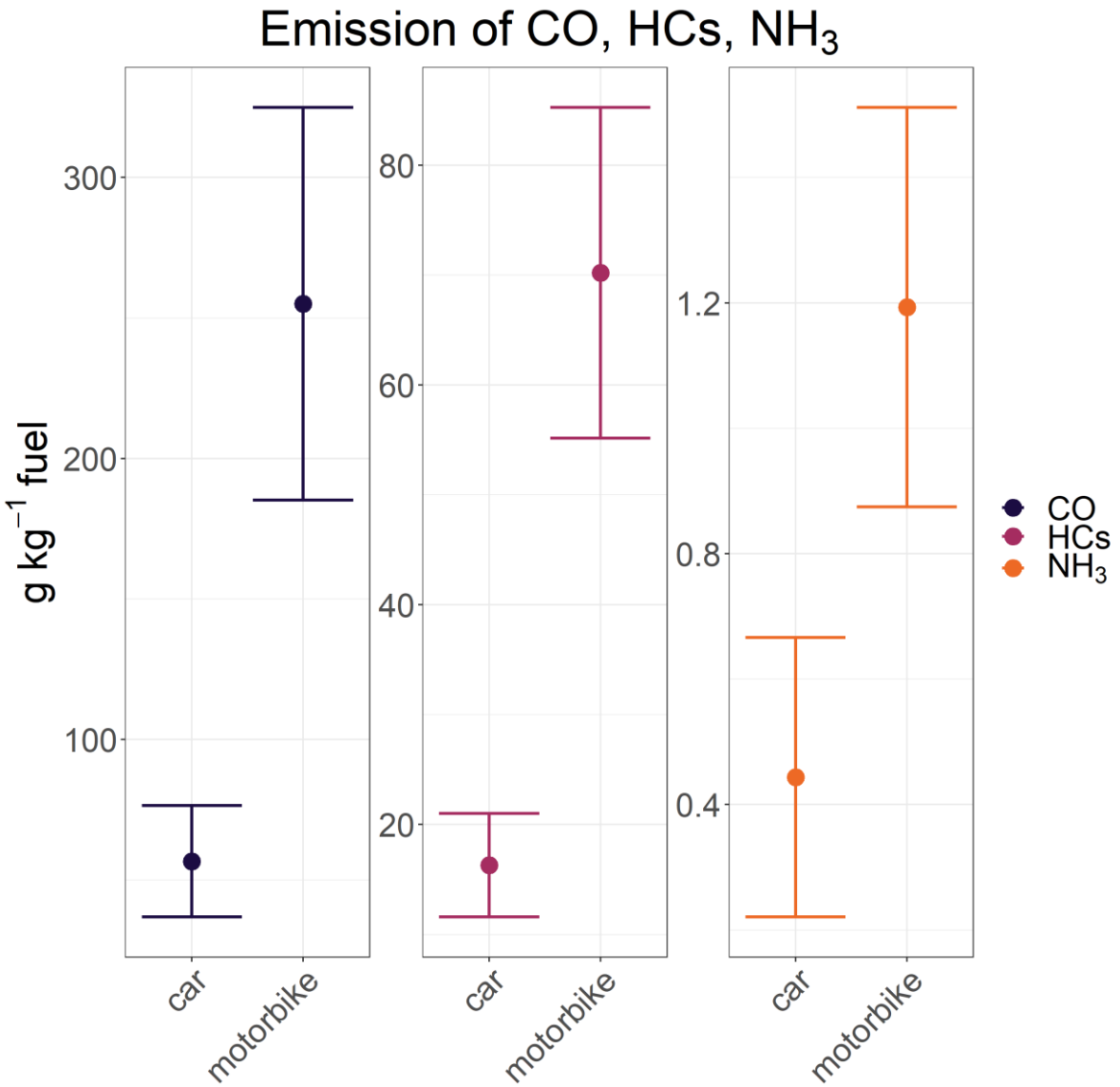




Mean and 95% confidence

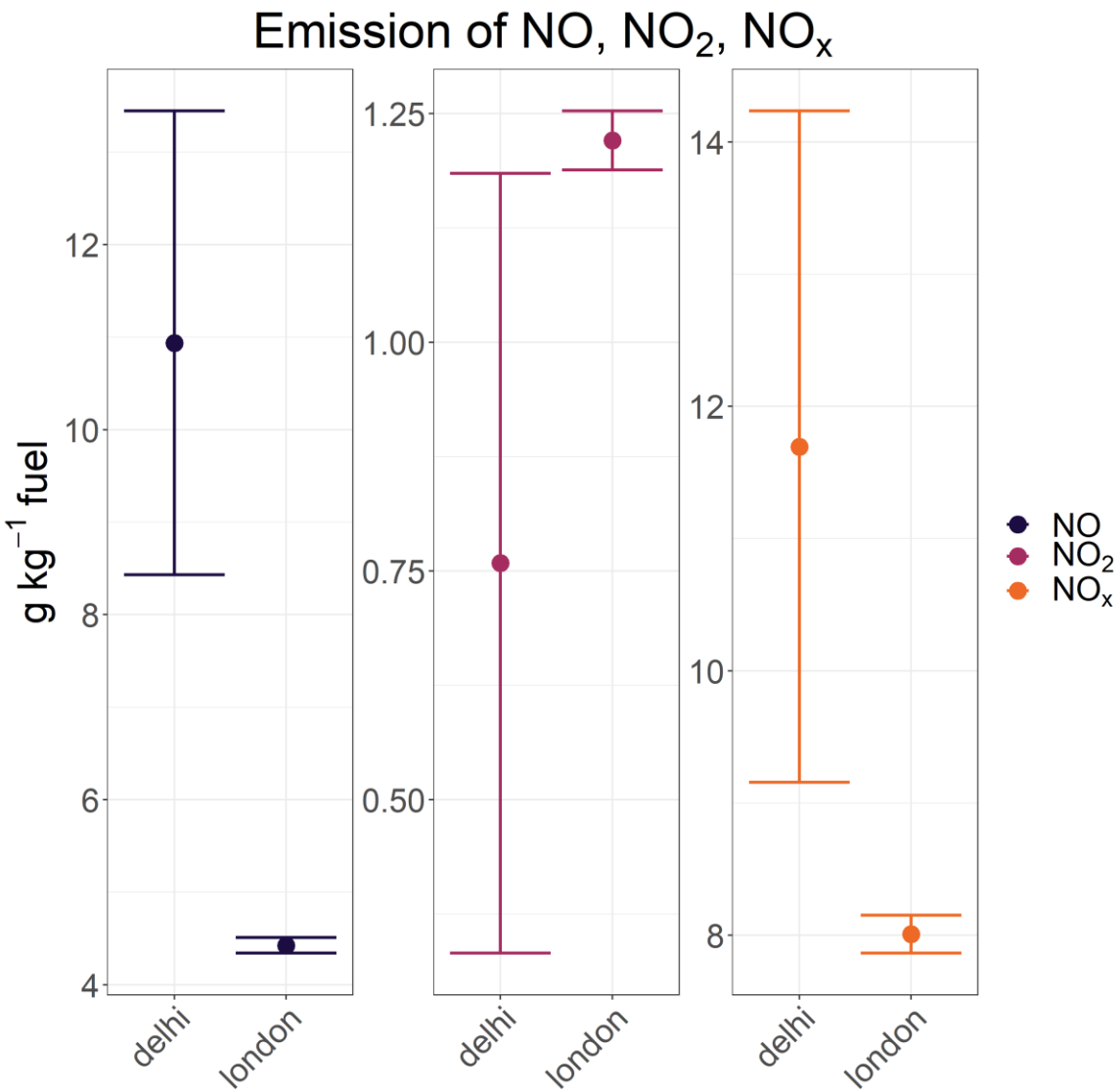
Motorbikes

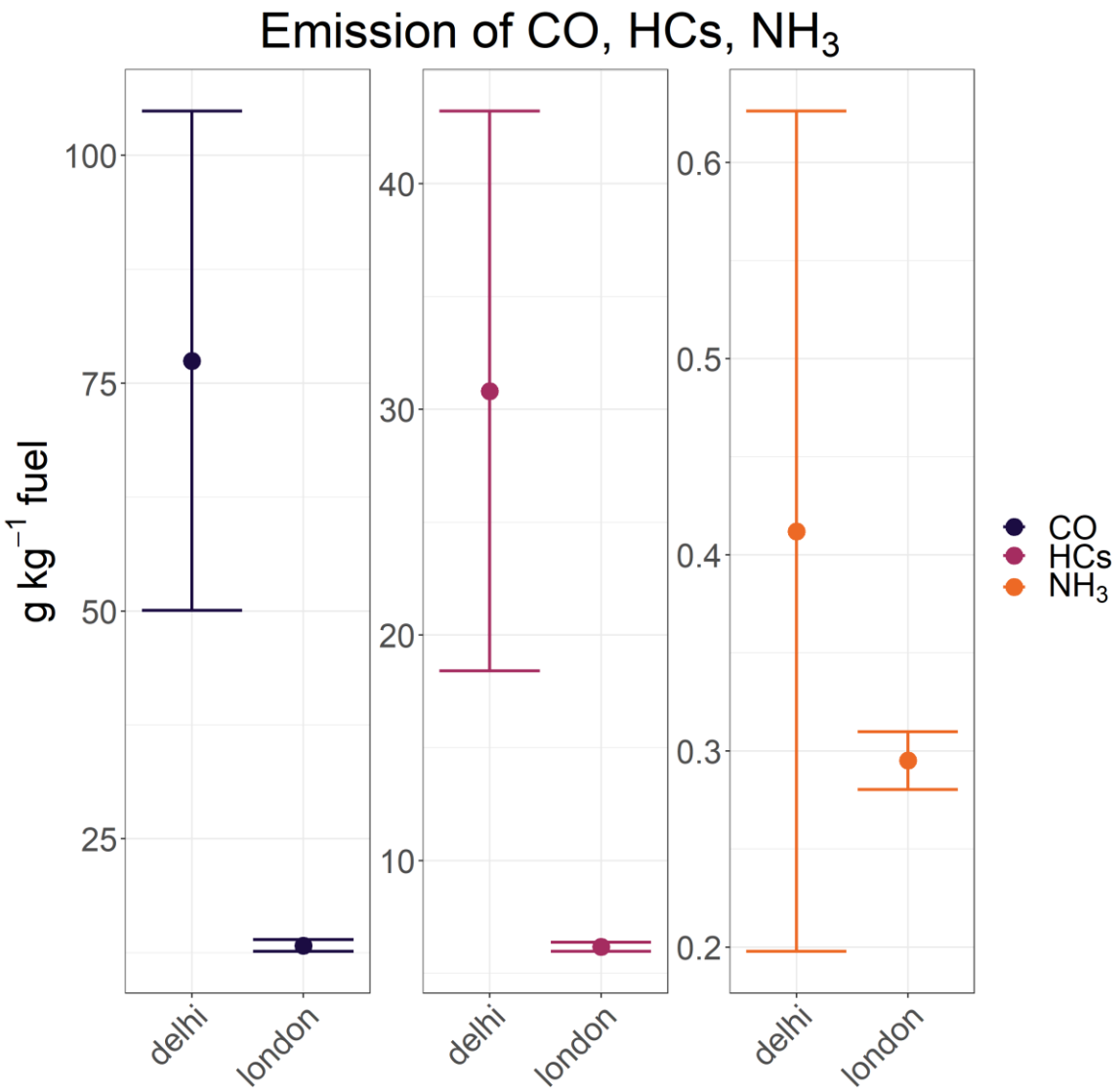




Mean and 95% confidence

Private Vehicles





Private Vehicles

Species	Mean emission/ g kg^{-1} fuel	London emission/ g kg^{-1} fuel	Ratio/ Delhi to London
NO	10.94	4.43	2.47
NO_2	0.76	1.22	0.62
NO_x	11.67	8.00	1.46
CO	77.45	13.28	5.83
HCs	30.81	6.18	4.97
NH_3	0.41	0.29	1.41

Vehicle Driven Emissions

BT Tower - London

IGDTUW – Kashmere Gate New Delhi

Emission Measurements

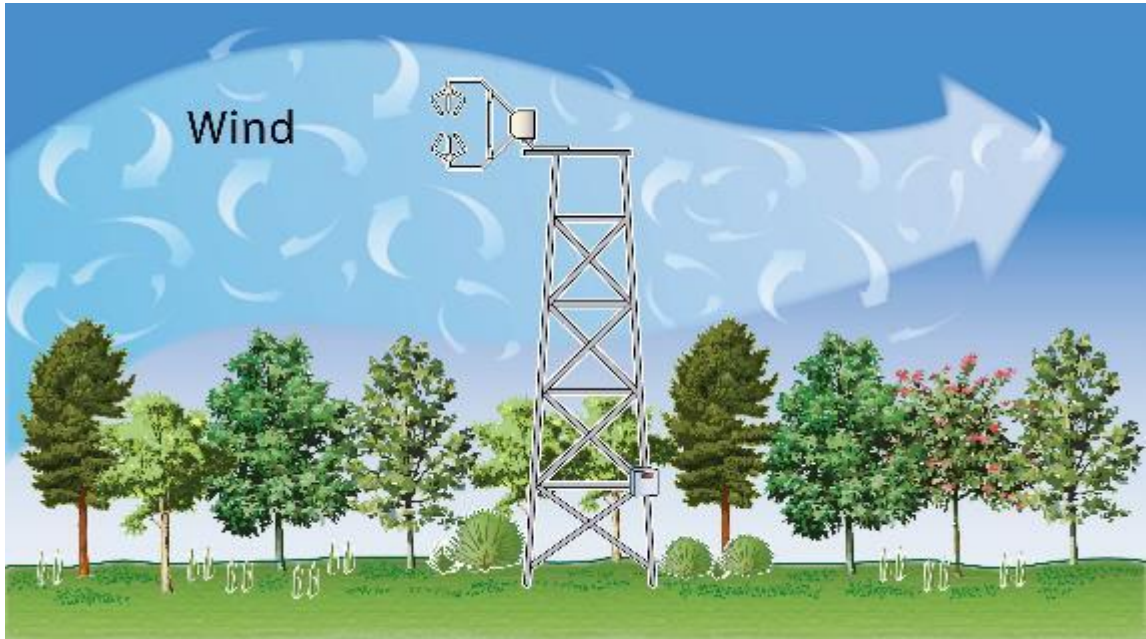
- Measure emission rates via eddy-covariance
- Calculate covariance between instantaneous deviation from the mean between vertical wind speed and concentration
- Sample from an elevate point, fast measurements (>1 s)

$$F \approx \overline{w'c'}$$

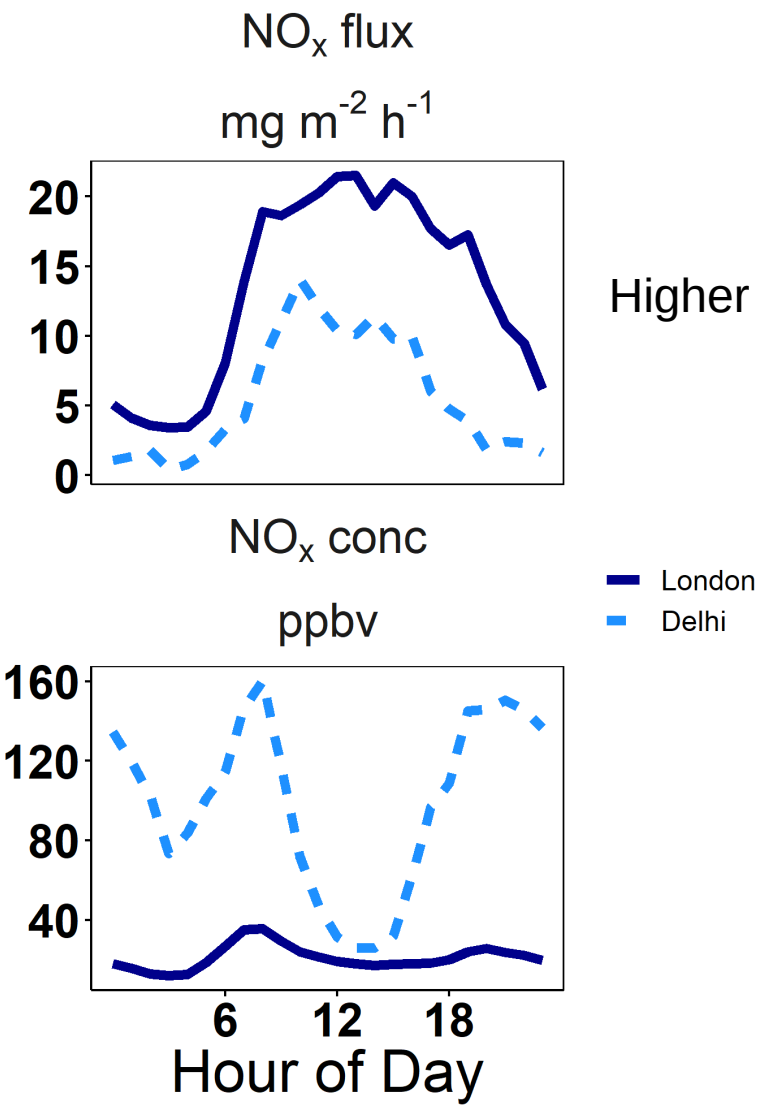
eddy-flux

instantaneous vertical wind

instantaneous concentration

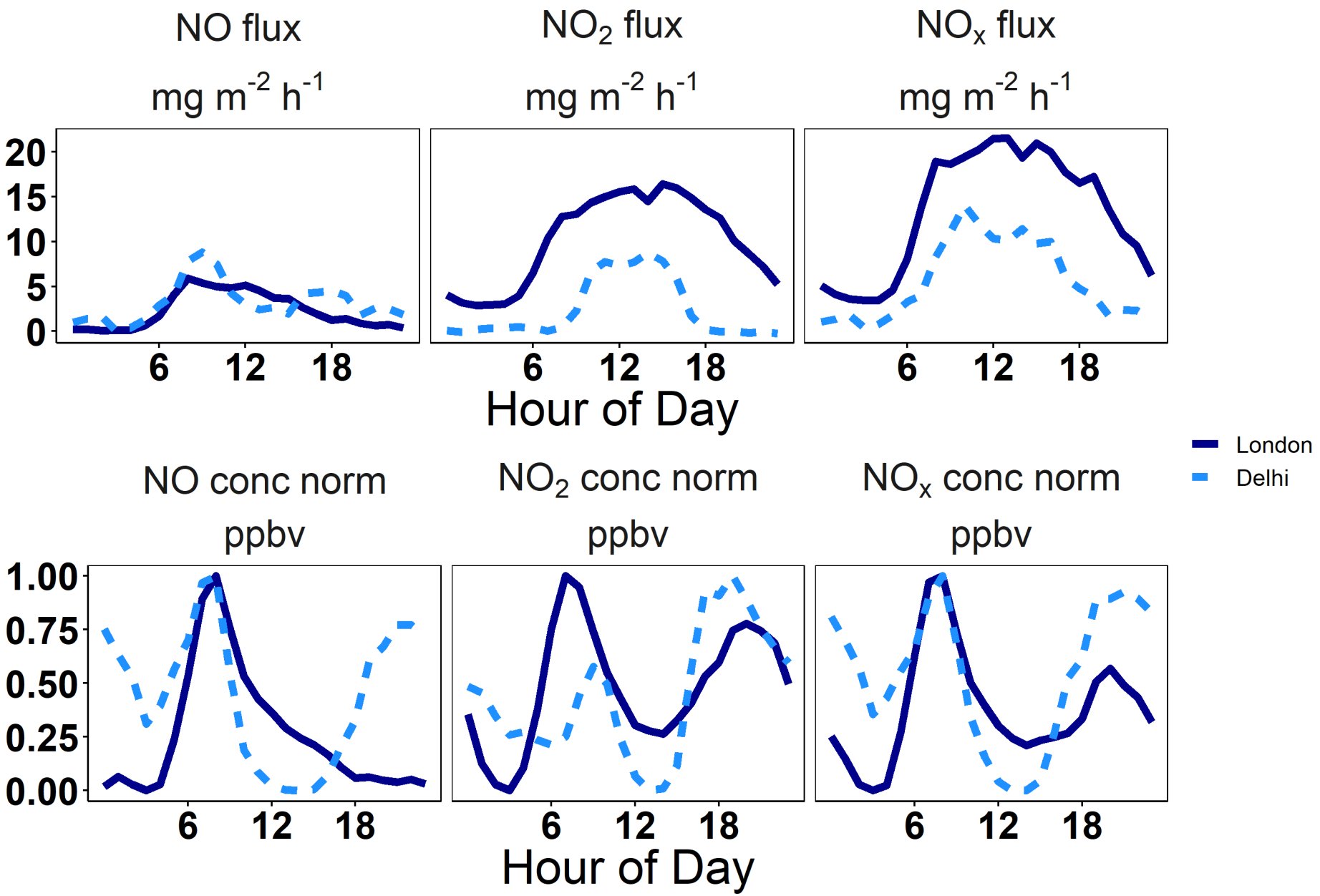


Emission Measurements



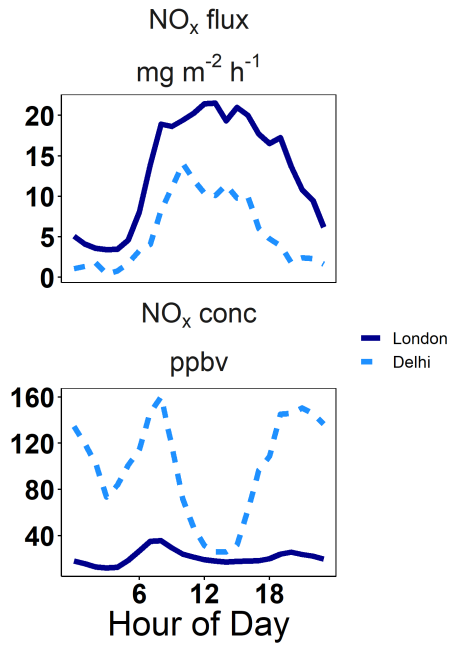
Higher NO_x emissions in London

High NO_x concentrations in Delhi


NO flux
mg m-2 h-1
NO2 flux
mg m-2 h-1
NOx flux
mg m-2 h-1
20
15
10
5
0
6
12
18
Hour of Day
NO conc norm
ppbv
NO2 conc norm
ppbv
NOx conc norm
ppbv
1.00
0.75
0.50
0.25
0.00
6
12
18
Hour of Day
London
Delhi

Emission Measurements

- BT Tower influenced by larger vehicles and other sources
- Less primary NO_2 emitted in New Delhi
- Older exhaust after-treatment technology
- Meteorology and regional transport probably the cause of the very high Nox levels in Delhi



New Delhi

London

CONCLUSIONS

- Novel insight into New Delhi vehicle fleet
- Initial findings show high NO, CO and HCs from vehicles
- Low NO_2 emissions from private vehicles in New Delhi
- Difficult to compare two cities in relation to vehicle driven emissions

FUTURE WORK

- Compare FEAT data to OPUS Inspection measurements (ICAT)
- 195,000 vehicles measured over 6 months (May-October 2018)
- Multiple measurement sites around New Delhi (Toll booths, main roads)
- Vehicle emission data of: CO,HCs, NH_3 and NO in g/(kg fuel)
- Vehicle information from New Delhi database

ACKNOWLEDGEMENTS

- Dr Gary Bishop - University of Denver (USA) for lending FEAT instrument

- Dr Ranu Gadi - Indira Gandhi Delhi Technical University for Women (IGDTUW)