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# SOME OBSERVATIONS BASED ON COMPLEMENTARY INTERNATIONAL EVALUATIONS OF EDAR VEHICLE EMISSIONS REMOTE SENSING TECHNOLOGY

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David C. Green<sup>4</sup>; Jim Kemper<sup>5</sup>; Sandeep Kishan<sup>2</sup>;  
Gary W. Fuller<sup>4</sup>; Hu Li<sup>6</sup>; Jim Sidebottom<sup>5,7</sup>; J. Stewart Hager<sup>7</sup>.

7<sup>th</sup> UCR PEMS WORKSHOP AND CONFERENCE  
Riverside, California, March 30-31, 2017

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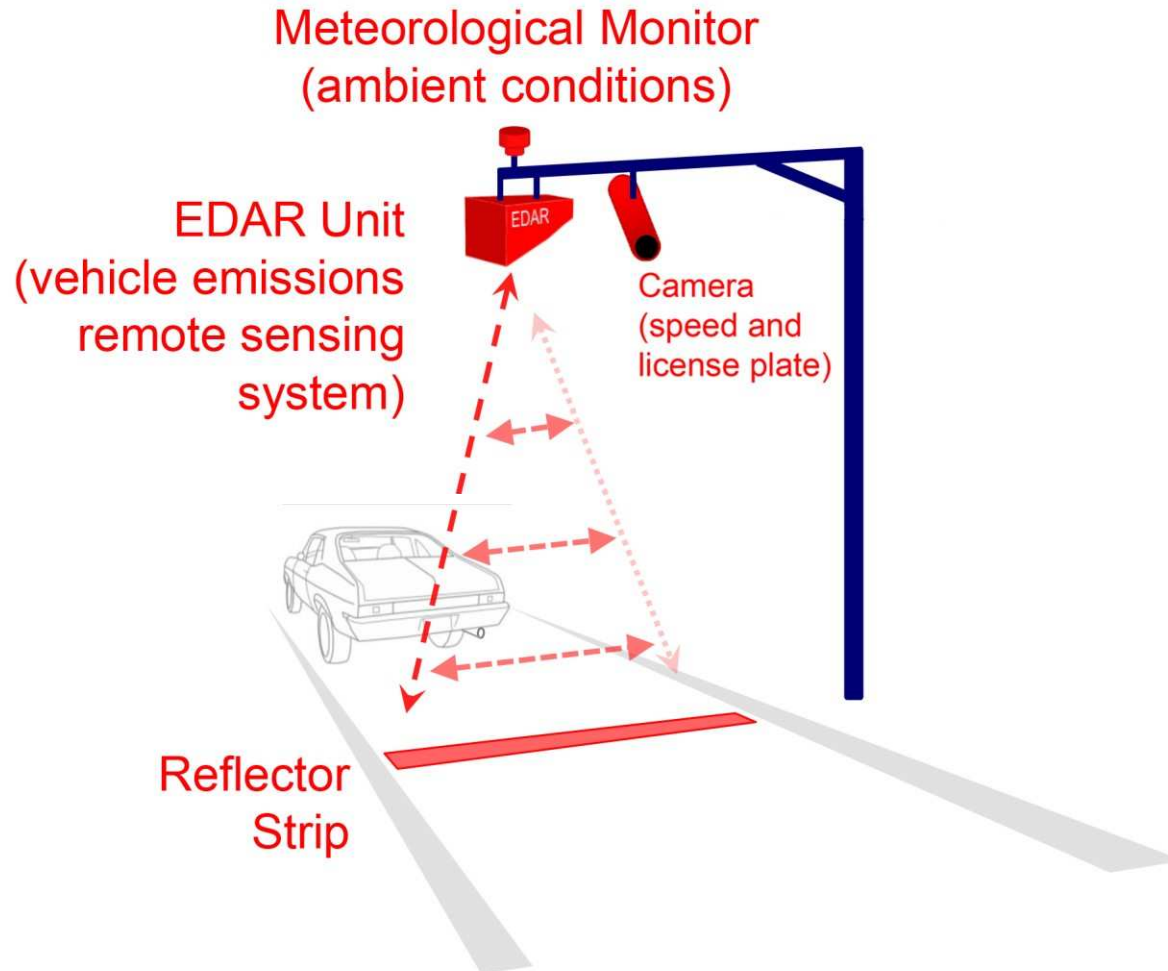
<sup>5</sup> Aurora High Altitude Research Laboratory, Colorado Department of Public Health and Environment (CDPHE), USA

<sup>6</sup> School of Chemical and Process Engineering, University of Leeds, UK

<sup>7</sup> Hager Environmental & Atmospheric Technology (HEAT) LLC, Knoxville, USA

# The Technology: EDAR

(Emission Detection And Reporting)



- Down-facing DiAL VERSS
- Scans down onto road to remotely measure passing vehicle emissions
- Measures CO<sub>2</sub>, CO, NO, NO<sub>2</sub>, SO<sub>2</sub>, HC\* (e.g. discrete CH<sub>4</sub>, C<sub>3</sub>H<sub>8</sub>, etc.), PM...
- One footprint for both heavy and light duty vehicles

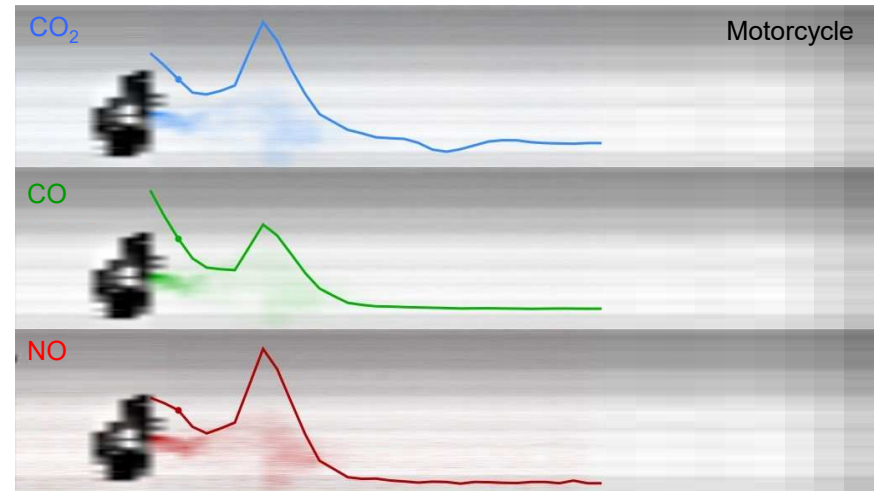
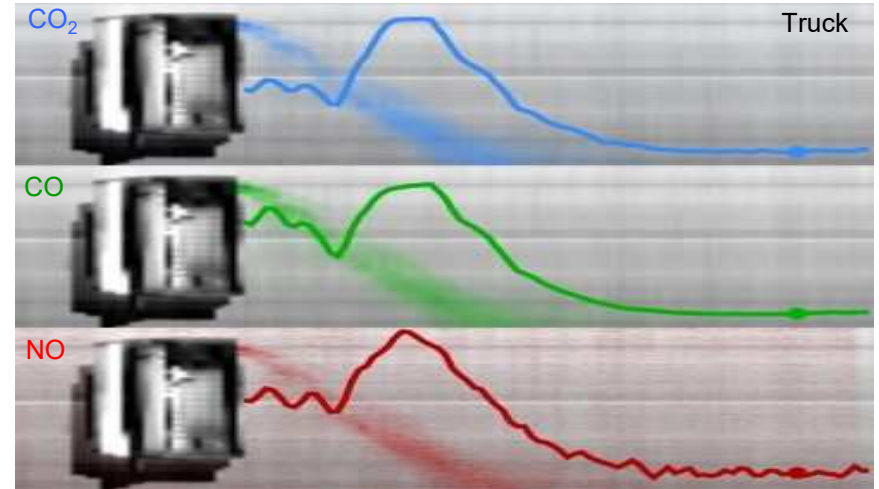
# Example EDAR deployment: Marylebone Road, London, UK



EDAR units  
(one Gases; one PM)



Reflector  
Strip



Example EDAR outputs:  
Passing Vehicle Plume Image and  
Emissions Measurements

# Project

## CDPHE/ERG Simulated Exhaust Gas EDAR (Emissions Detection And Reporting) Study

EDAR Developers:  
Project Partners:

HEAT LLC  
Colorado Department of  
Public Health and  
Environment,  
Eastern Research Group

Project contact:

Tim DeFries (FRG)

Project Implemented by:



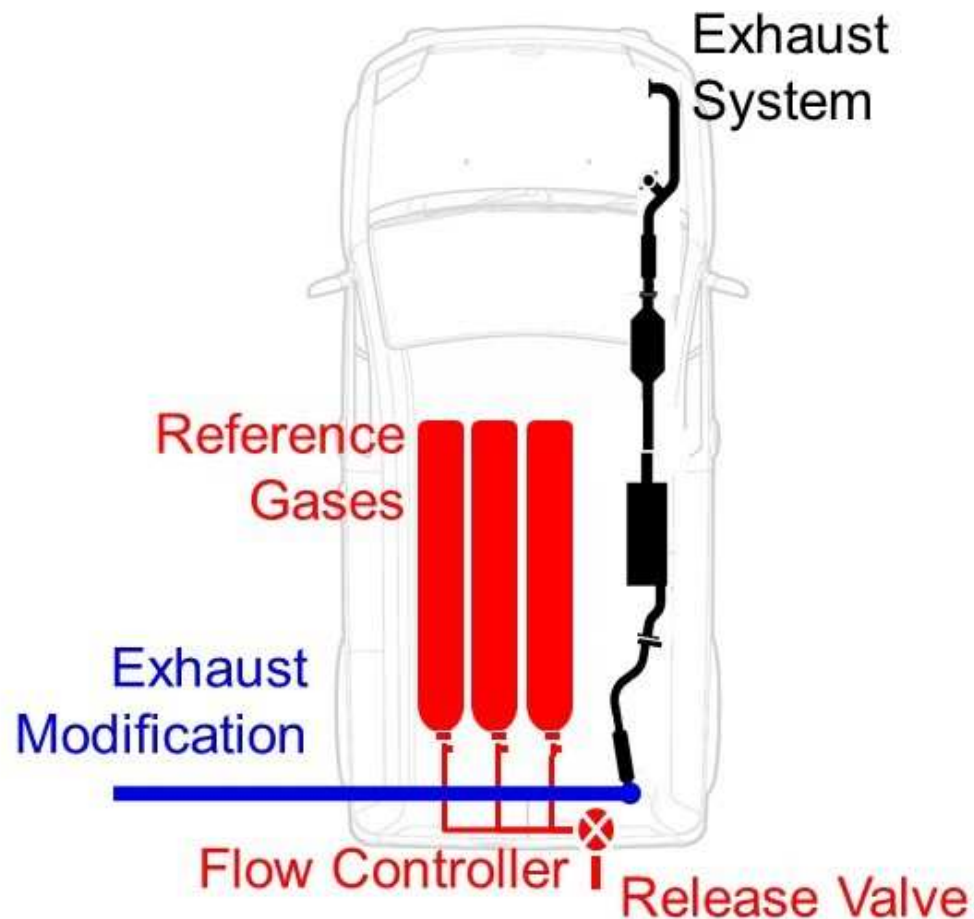
# Gas Audit Evaluation



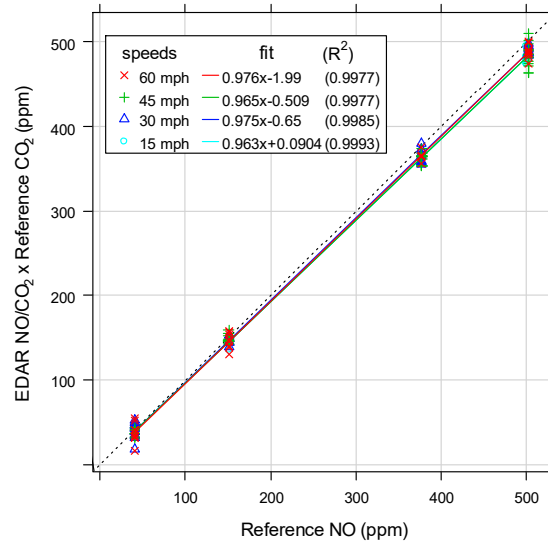
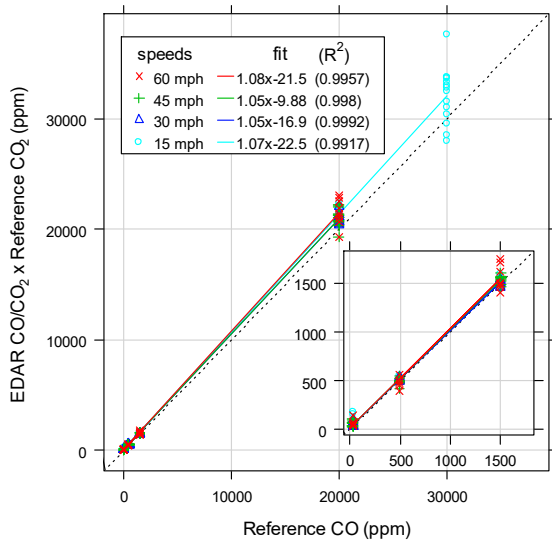
EDAR (Boom Arm) Deployment



Simulated Exhaust Gas Release

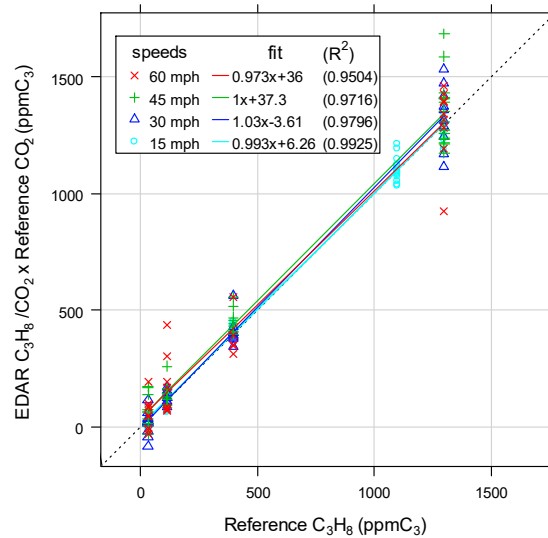
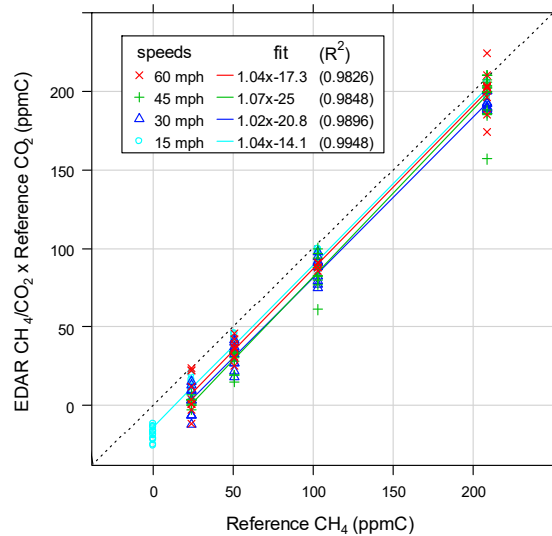


- Drive-through reference gas release sampling
- Highly accurate/stable reference
  - Good measure of instrumental accuracy



## Gas Audit Results

- Good agreement with references (R<sup>2</sup> >0.99 for CO and NO; R<sup>2</sup> >0.95 for HCs)
- Selectivity e.g. discrete hydrocarbons



# Project

## Birmingham and London EDAR (Emissions Detection And Reporting) Demonstration and Evaluation

EDAR Developers:

Project Partners:

HEAT LLC

King's College London

University of Birmingham

University of Leeds

Project Funding:

***DfT LOCAL TRANSPORT AIR QUALITY  
CHALLENGE INNOVATION GRANT  
OCTOBER 2015***

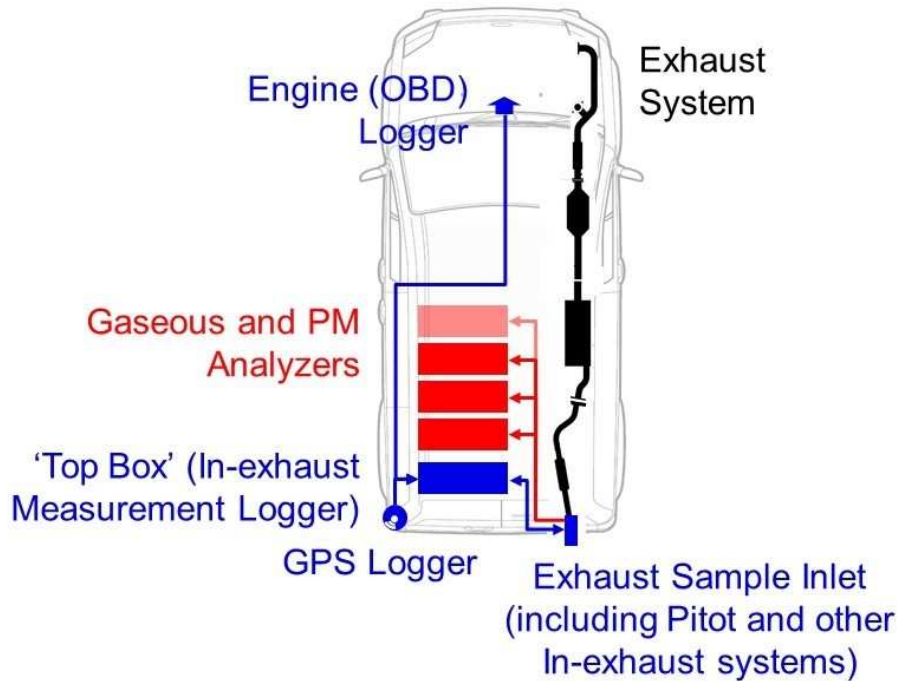


Department  
for Transport

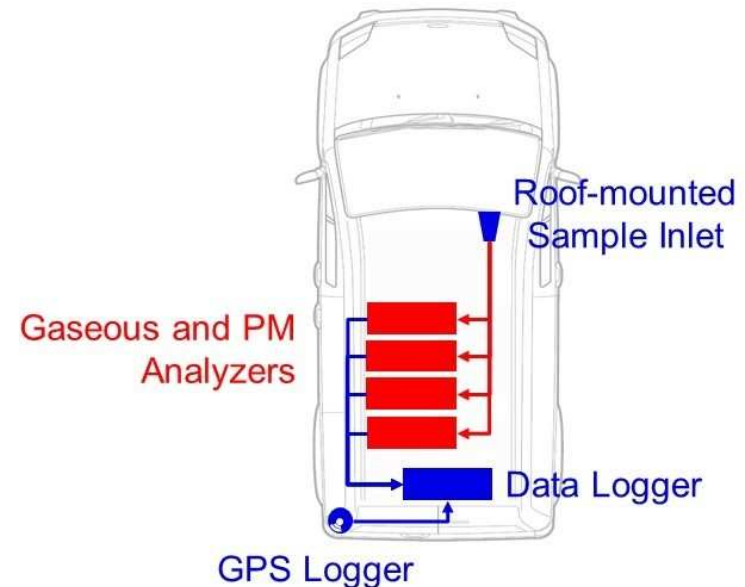


# Real-world Comparison

PEMS Vehicle

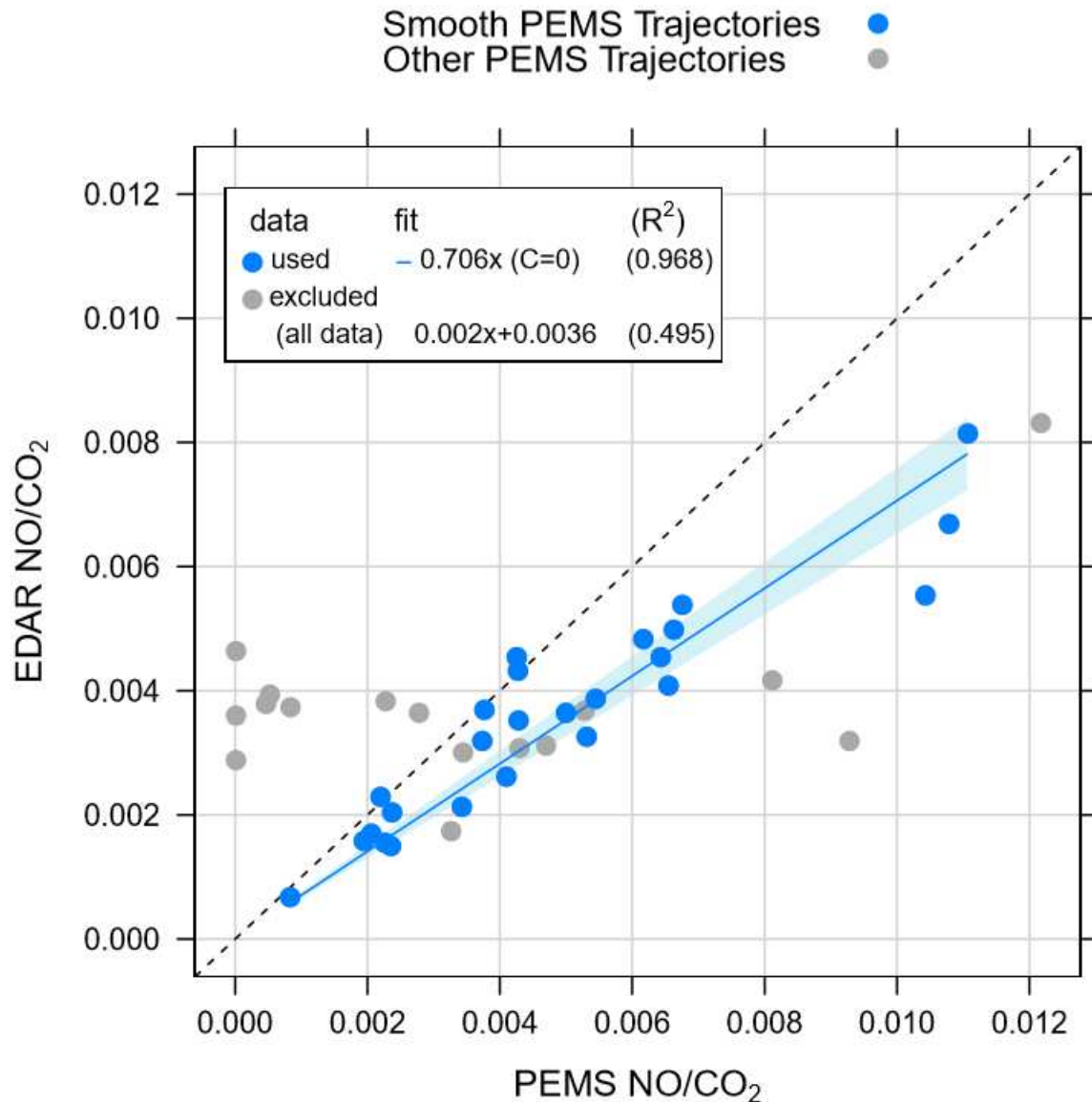


SNIFFER (Car Chaser) Vehicle



- Real-world (challenging) deployment
- Drive-through comparisons
  - PEMS
  - SNIFFER (car chaser)

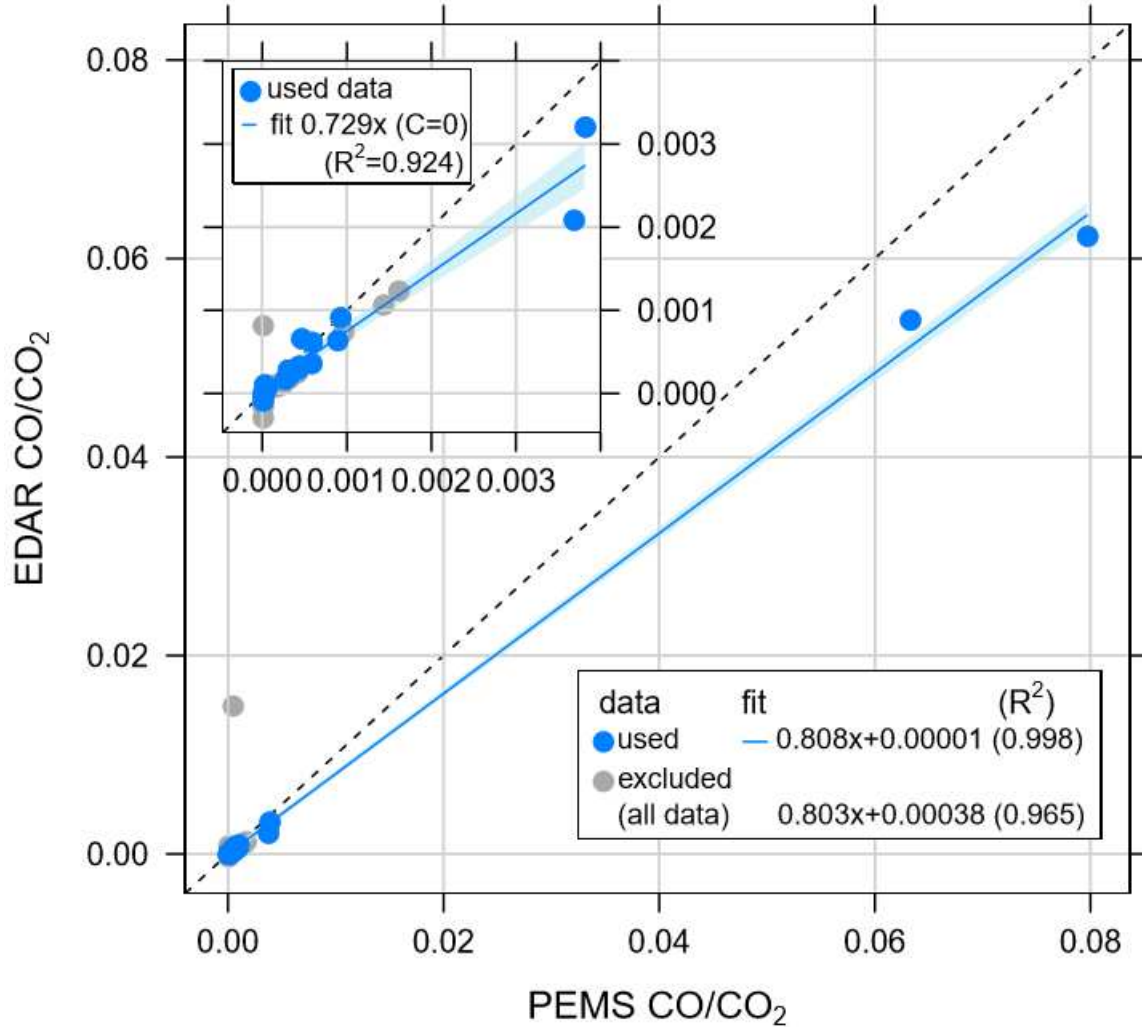




## PEMS Comparisons

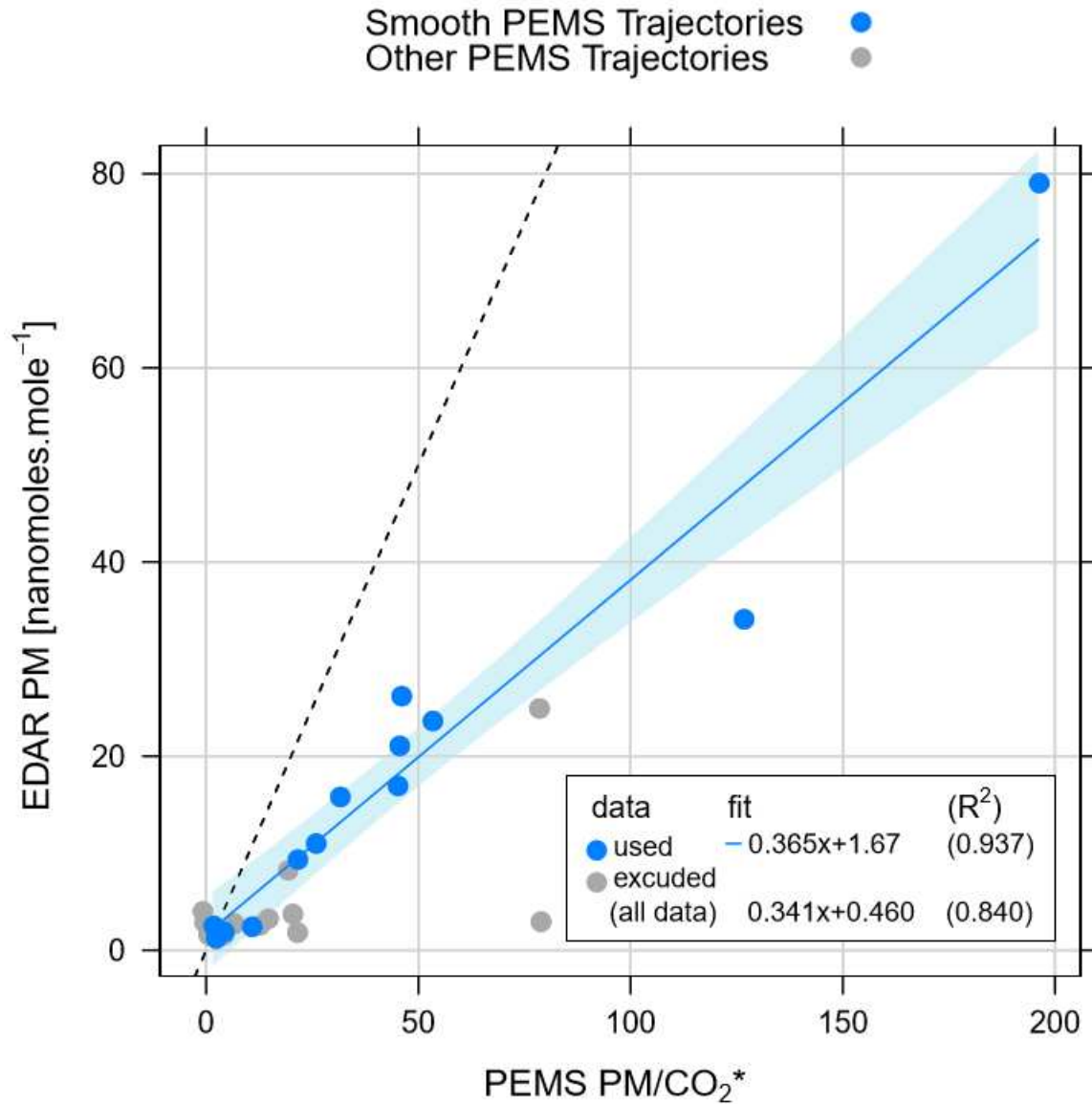
- Good agreement (within experimental limits)
- R<sup>2</sup> > 0.95 for NO/CO<sub>2</sub>;  
R<sup>2</sup> > 0.90 for CO/CO<sub>2</sub> and PM/CO<sub>2</sub>;
- R<sup>2</sup> > 0.80 for NO<sub>2</sub>/CO<sub>2</sub> (but arguably least certain measurement)

Smooth PEMS Trajectories ●  
 Other PEMS Trajectories ●



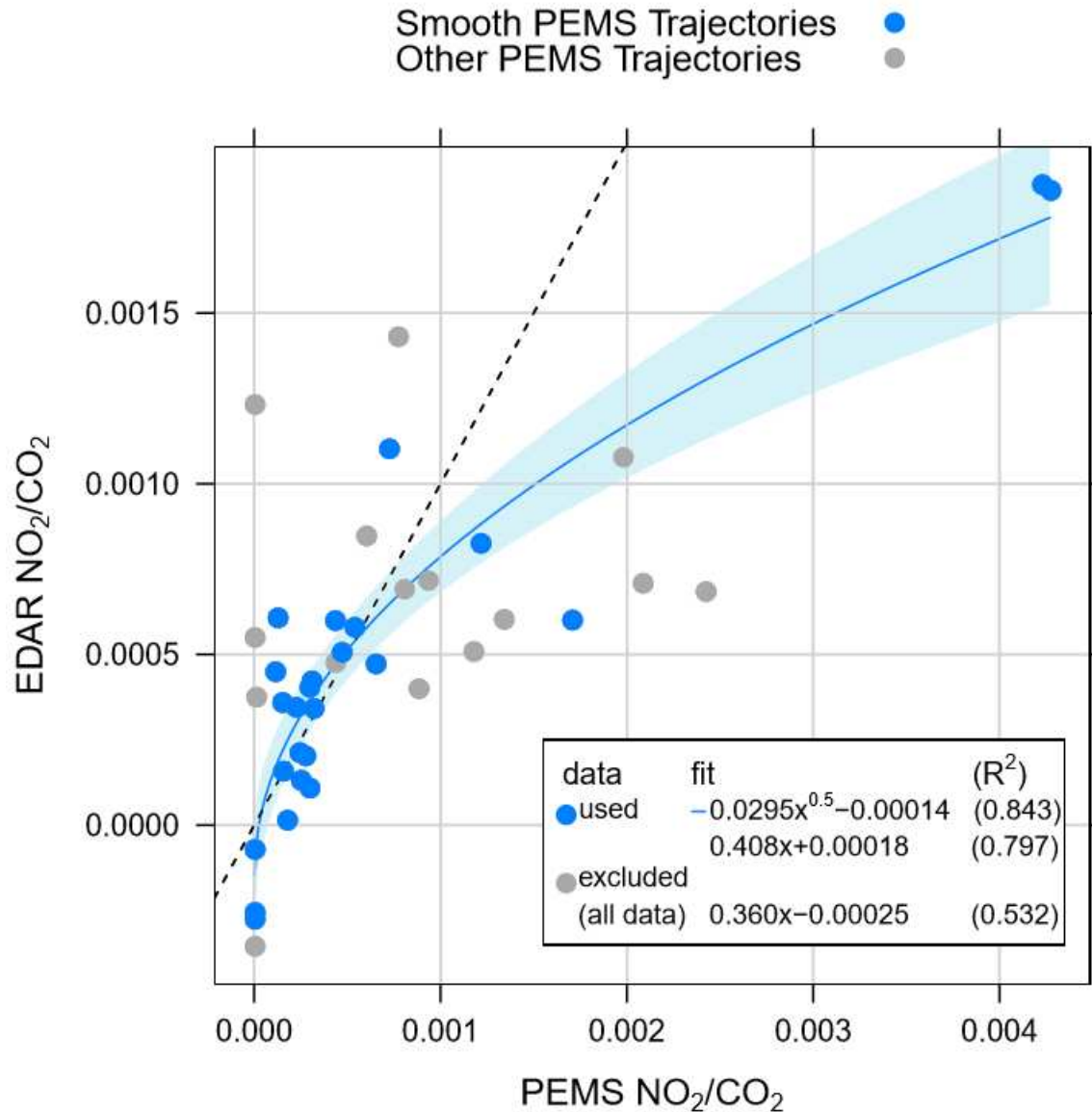
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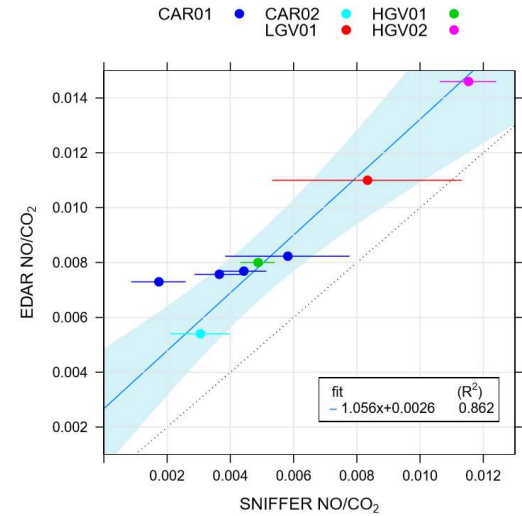
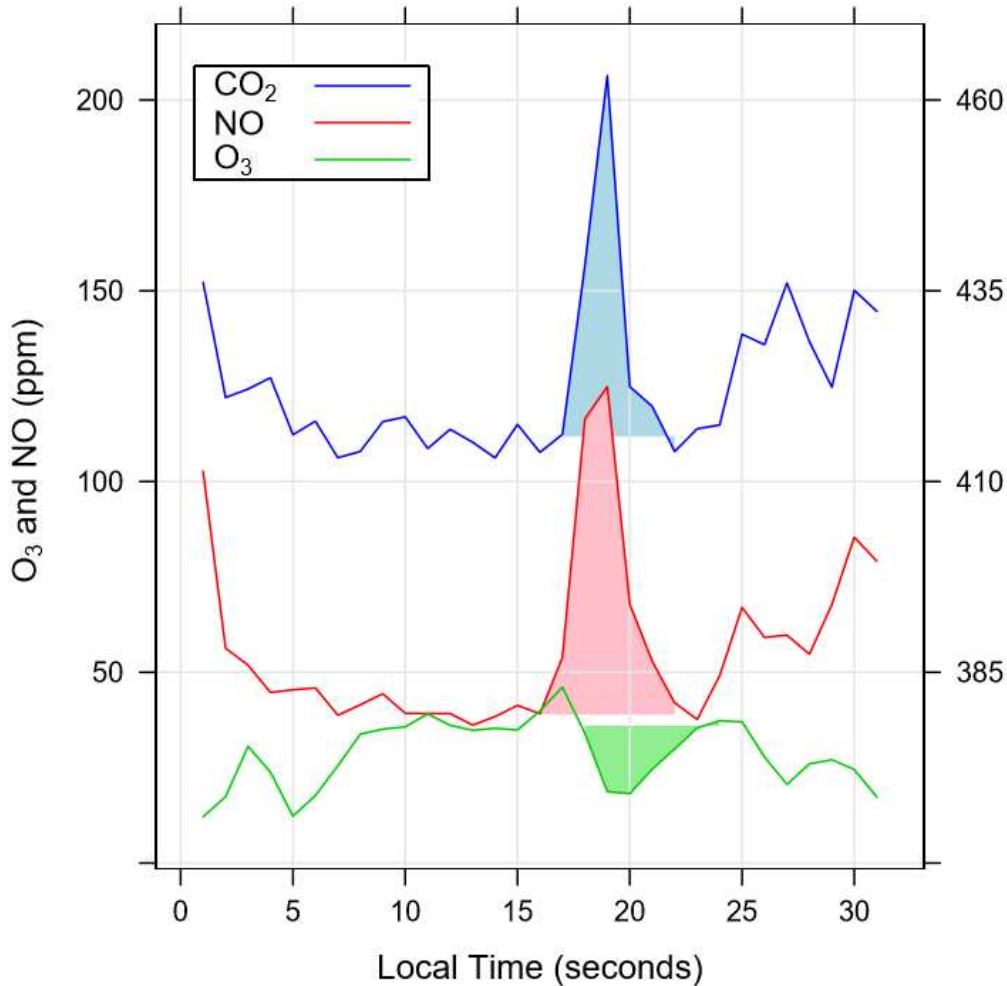
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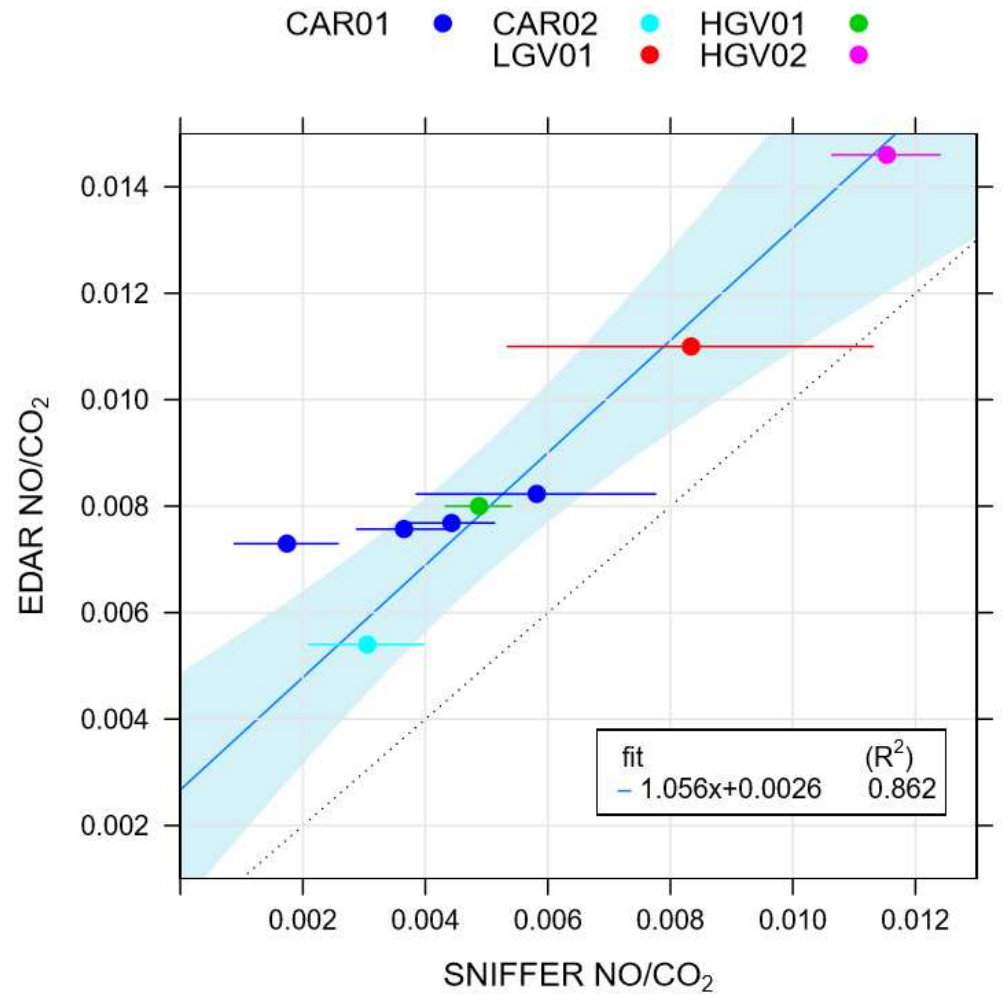
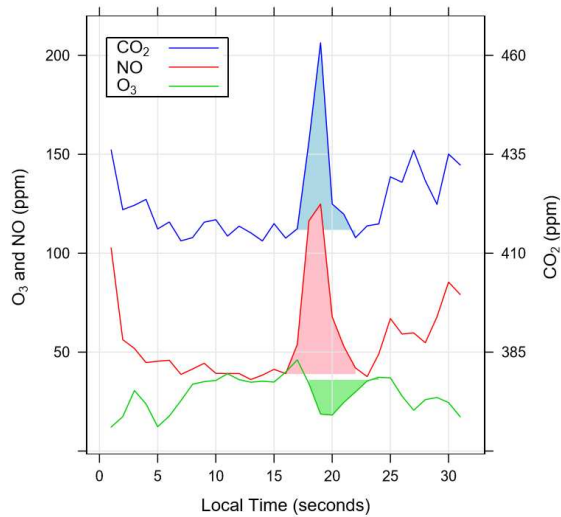
## PEMS Comparisons

- Good agreement (within experimental limits)
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- R<sup>2</sup> > 0.80 for NO<sub>2</sub>/CO<sub>2</sub> (but arguably least certain measurement)



### SNIFFER (car chaser) Comparisons

- Measurement required correction for post-exhaust chemistry (e.g.  $\text{NO}$  depletion by  $\text{O}_3$ )



## SNIFFER (car chaser) Comparisons

- Good agreement (within experimental limits)  
 e.g.  $R^2 > 0.85$  for NO/CO<sub>2</sub>

- Results also indicate similar agreement for different vehicle types

# Conclusions

From the CDPHE/ERG Simulated Exhaust Gas Study:

EDAR has:

- High instrumental accuracy (e.g.,  $R^2 > 0.99$  CO, NO;  $> 0.95$  HCs)
- Low drift and negligible speed dependency

From the UoB/UoL/KCL Real-world Comparison:

(In conventional use) EDAR was:

- In good agreement with other real-world measurement methods  
e.g., NO/CO<sub>2</sub>  $R^2 = 0.96$  and  $0.86$  for PEMS and SNIFFER, respectively
- Results for NO<sub>2</sub> and PM were also highly encouraging

NOTE: *while we cannot say unequivocally that EDAR performs as well in the real-world as it does relative to a simulated exhaust gas, we have no evidence that it does not*

BUT more generally...

This combination provides a comprehensive basis for the independent third-party evaluation of EDAR (or VERSS) performance



Thank you  
...and any questions?

## Acknowledgments

TD: contributions from Carl Fulper and US Environmental Protection Agency, colleagues at Eastern Research Group Inc and Colorado Department of Public Health and Environment

KR and FP: contributions of Jim Mills and the Air Monitors team as part of the Birmingham and London EDAR deployments; input, help and advice of multiple collaborators at UK Department for Transport, Transport Systems Catapult, UK Department for Environment, Food and Rural Affairs, Transport for London, Birmingham City Council, Greenwich Council, City of University of Westminster involved of the logistics of the same work

KR: Kent Johnson (UCR) on experimental design; Katrina Hemingway on slide preparation