

Particulate Sensing: Recent Work, Early Observations And Future Directions?

Karl Ropkins^(1,*) , Andrew Burnette⁽²⁾,
Lawrence Mattison⁽³⁾ and Dave Miller⁽³⁾

8th International PEMS Conference & Workshop

PEMS: Moving into the Future of Emissions
Monitoring

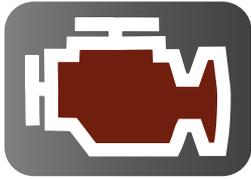
UCR, Riverside, California,
Thursday 22nd to Friday 23rd March 2018

⁽¹⁾ University of Leeds, UK

⁽²⁾ infoWedge, El Dorado Hills, CA

⁽³⁾ 3DATX Corporation, Buffalo, NY

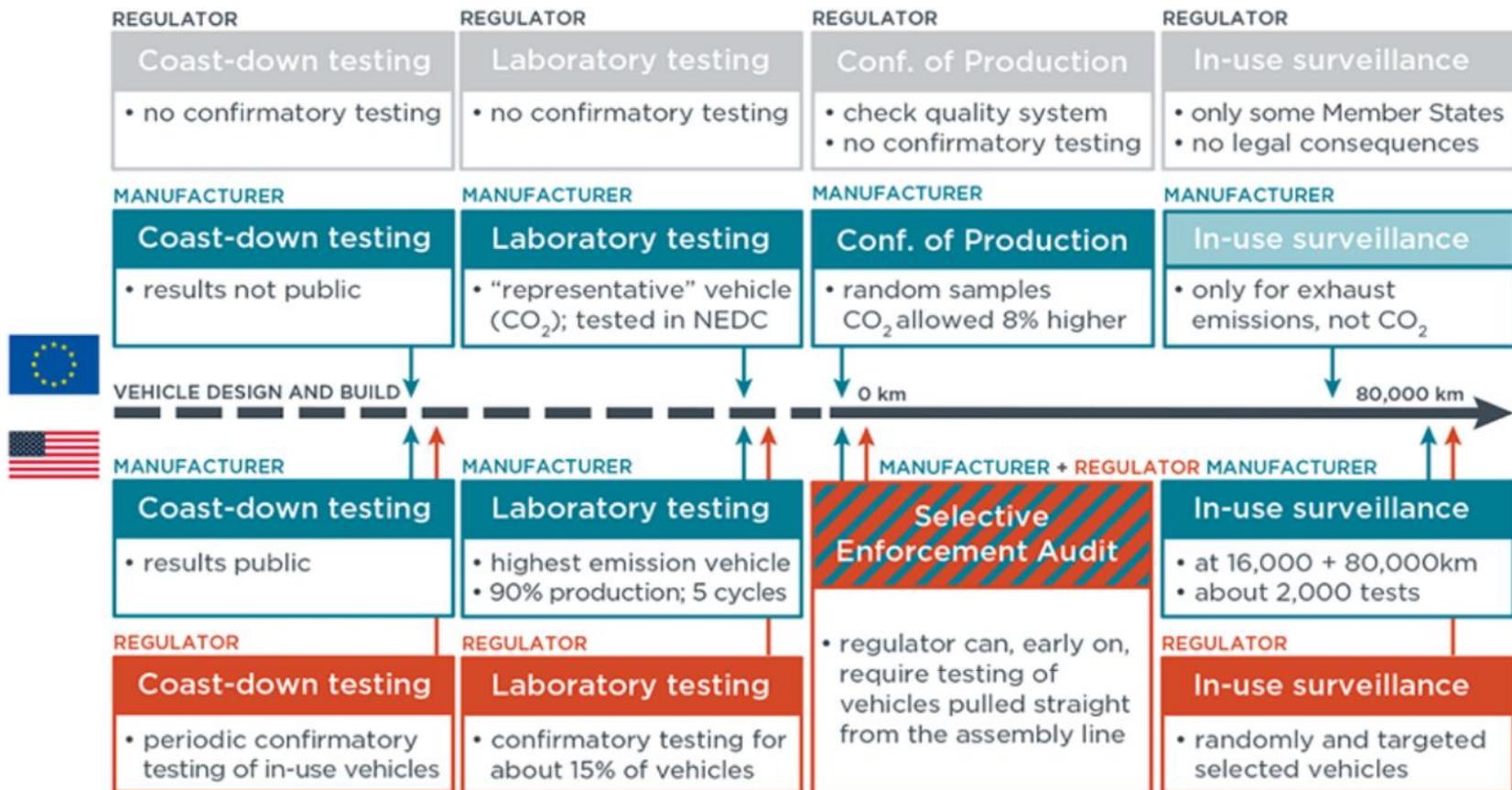
(*) k.ropkins@its.leeds.ac.uk

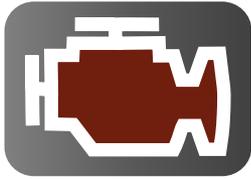


Research Question

Emissions Testing

ICCT white paper (2015) comparing US and European Emissions testing and Enforcement

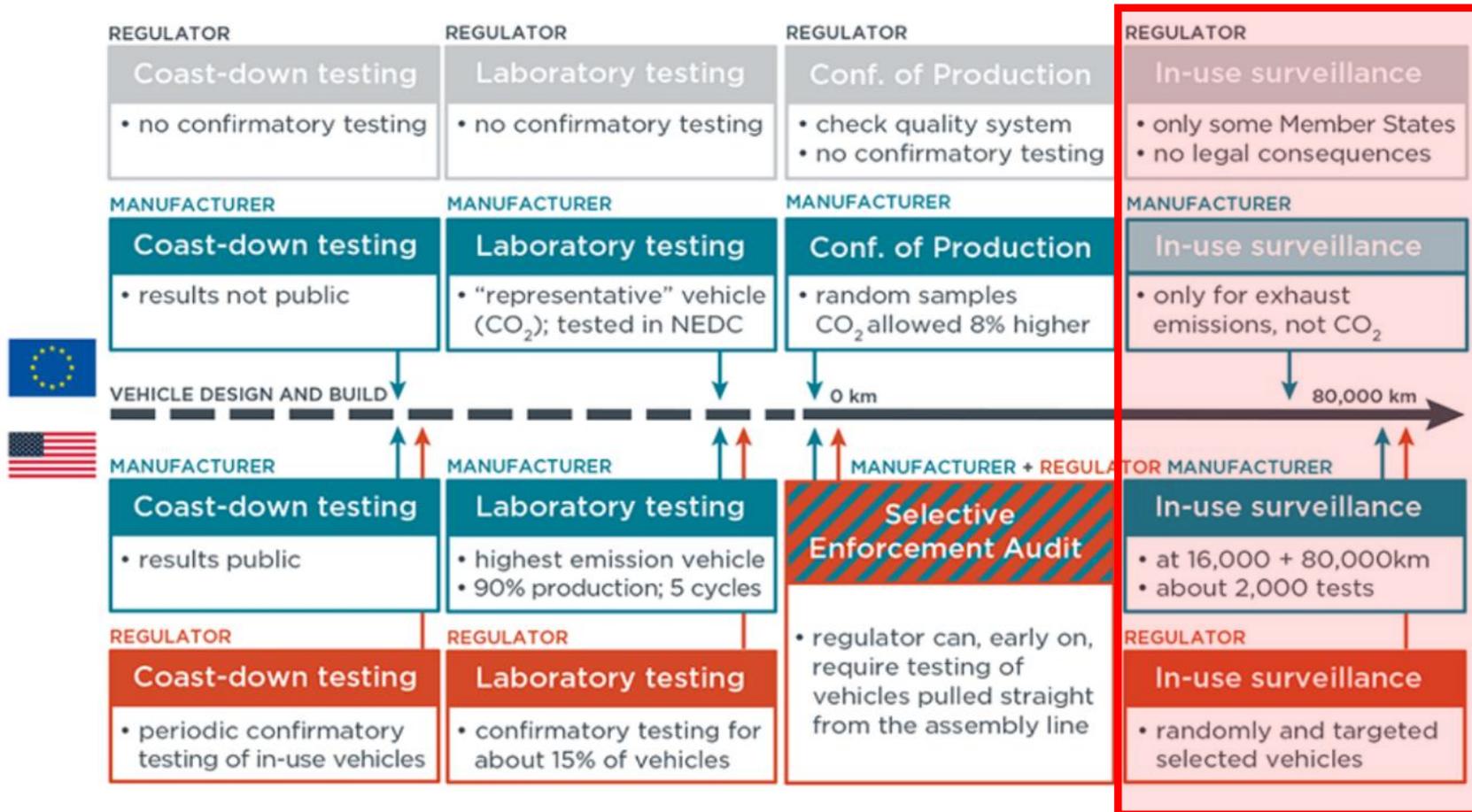


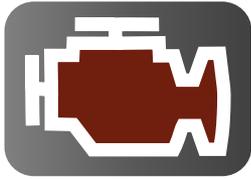


Research Question

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ICCT white paper (2015) comparing US and European Emissions testing and Enforcement





Research Question

Corrective Actions

Table ES1. Evaluation of best practices for compliance and enforcement programs in major vehicle markets.

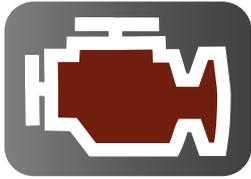
Region/country		Best Practices						
		Establish clear legal authority	Avoid conflicts of interest	Obtain the necessary resources	Conduct reliable testing and checks at all stages of production and use	Use corrective actions	Prioritize data and information transparency	Create a roadmap for program development
Asia	China	●++	●+	●+	●++	●+	●	●+
	India	●+	●+	●+	●+	●	●	●+
	Japan	●++	●++	●+	●++	●++	●	●+
	South Korea	●++	●++	●++	●++	●++	●+	●+
Europe	EU	●	●+	●+	●	●+	●	●+
	France	●+	●	●+	●+	●+	●	●+
	Germany	●+	●	●+	●+	●+	●	●+
	UK	●+	●	●+	●+	●+	●+	●+
North America	California	●++	●++	●++	●++	●++	●+	●+
	Canada	●+	●++	●+	●++	●	●	●+
	Mexico	●+	●+	●	●	●	●	●
	U.S.	●++	●++	●++	●++	●++	●+	●+
South America	Brazil	●++	●+	●+	●	●+	●	●
	Chile	●+	●+	●+	●+	●	●+	●+

● The country does not sufficiently meet any criteria for this practice.

●+ The country meets some criteria for this practice.

●++ The country meets all criteria for this practice.

(ICCT, 2017)



Research Question

Corrective Actions

Table ES1. Evaluation of best practices for compliance and enforcement programs in major vehicle markets.

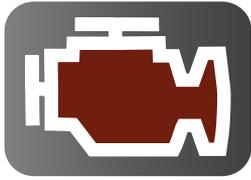
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	South Korea	●++	●++	●++	●++	●++	●+	●+
Europe	EU	●	●+	●+	●	●+	●	●+
	France	●+	●	●+	●+	●+	●	●+
	Germany	●+	●	●+	●+	●+	●	●+
	UK	●+	●	●+	●+	●+	●+	●+
North America	California	●++	●++	●++	●++	●++	●+	●+
	Canada	●+	●++	●+	●++	●	●	●+
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	U.S.	●++	●++	●++	●++	●++	●+	●+
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	Chile	●+	●+	●+	●+	●	●+	●+

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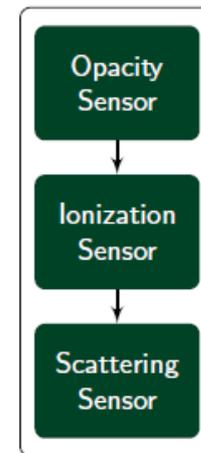
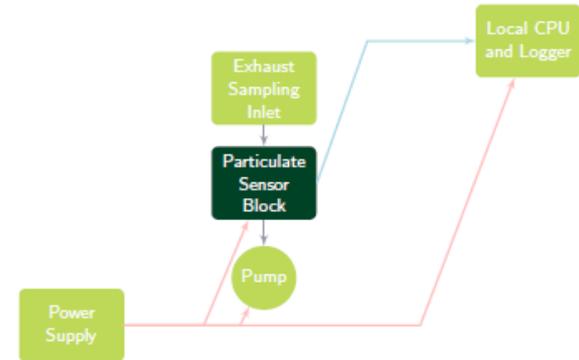
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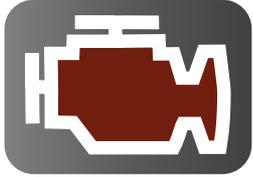
(ICCT, 2017)



Engineering Low-cost Solutions

ParSYNC[®] Particle Module





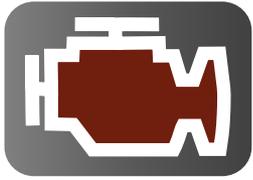
Response Mapping

The current multiplex function (parSYNC*) attempts to:

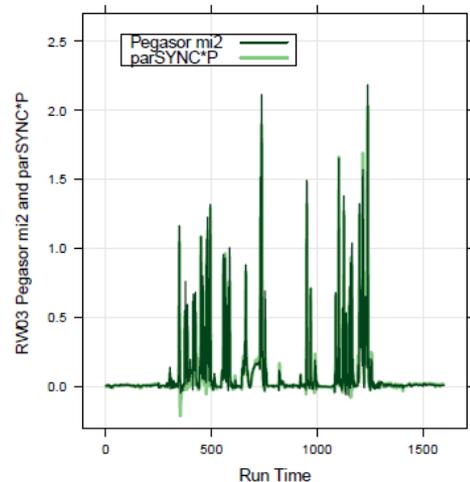
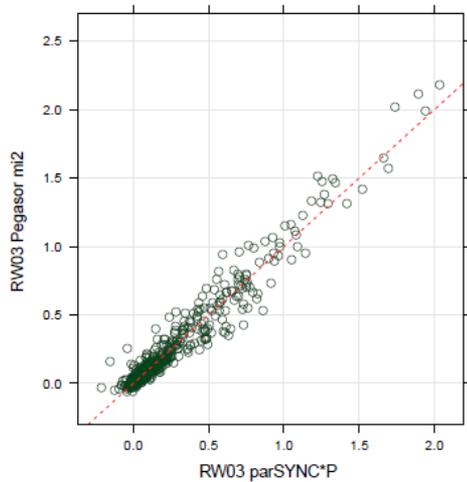
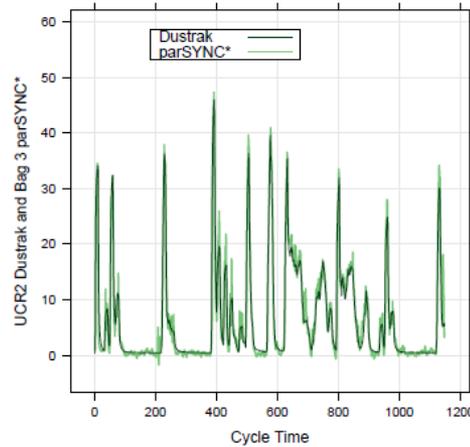
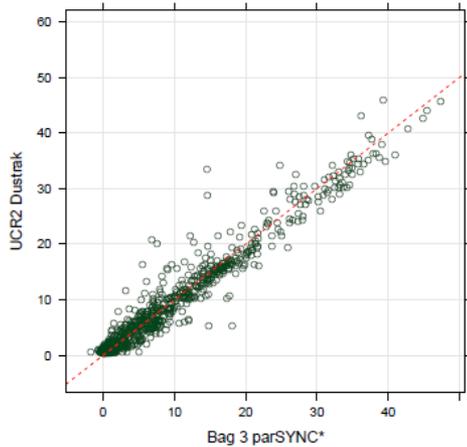
- Map the cross/non-cross correlation behavior of individual sensors onto a reference method robustly
- Correct for the different time resolutions of the sensors and reference method

Three Sensor Fit

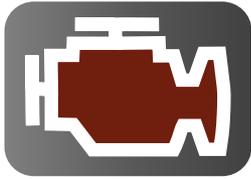
$$\text{parSYNC}^* = [\text{REFERENCE}] = f(\text{parSYNC}1_{t=-1,0,1}) + f(\text{parSYNC}2_{t=-1,0,1}) + f(\text{parSYNC}3_{t=-1,0,1})$$



Validating Mapping

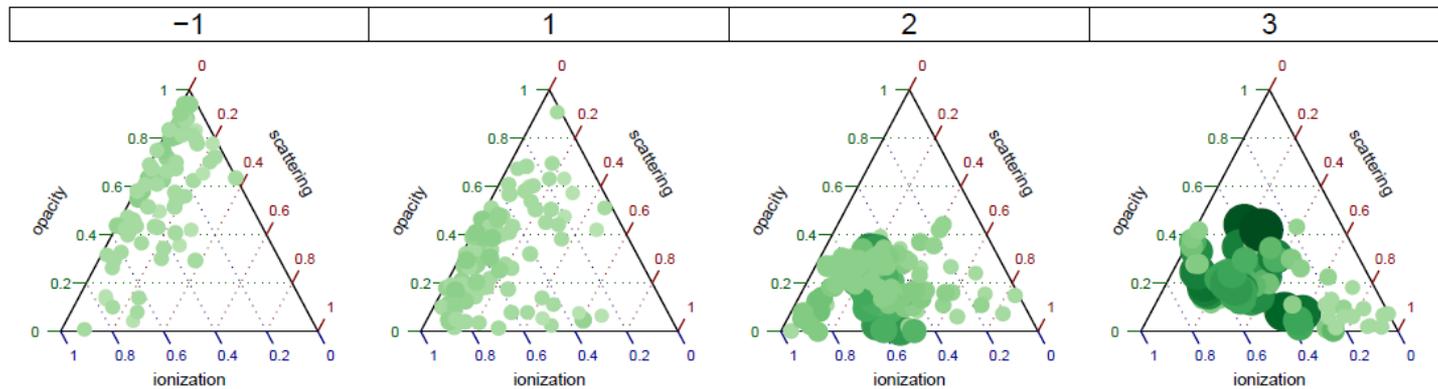
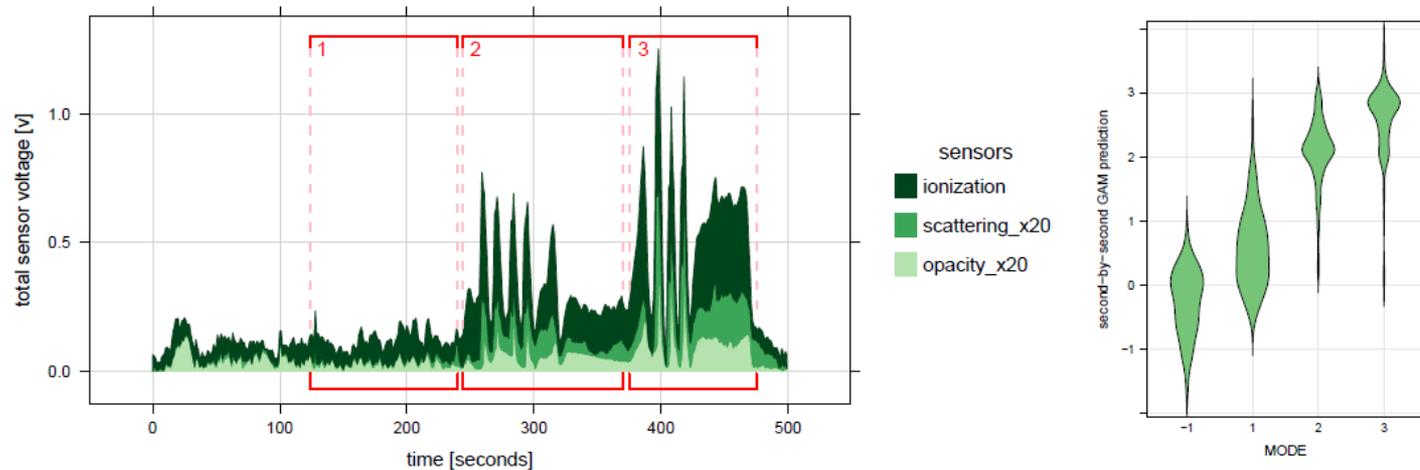


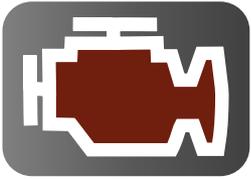
- DUSTRAK and Pegasor sensor maps, parSYNC* and parSYNC*P
- Blind testing on replicate runs
- Both three sensor maps
- Both $R > 0.95$



Developing Diagnostics

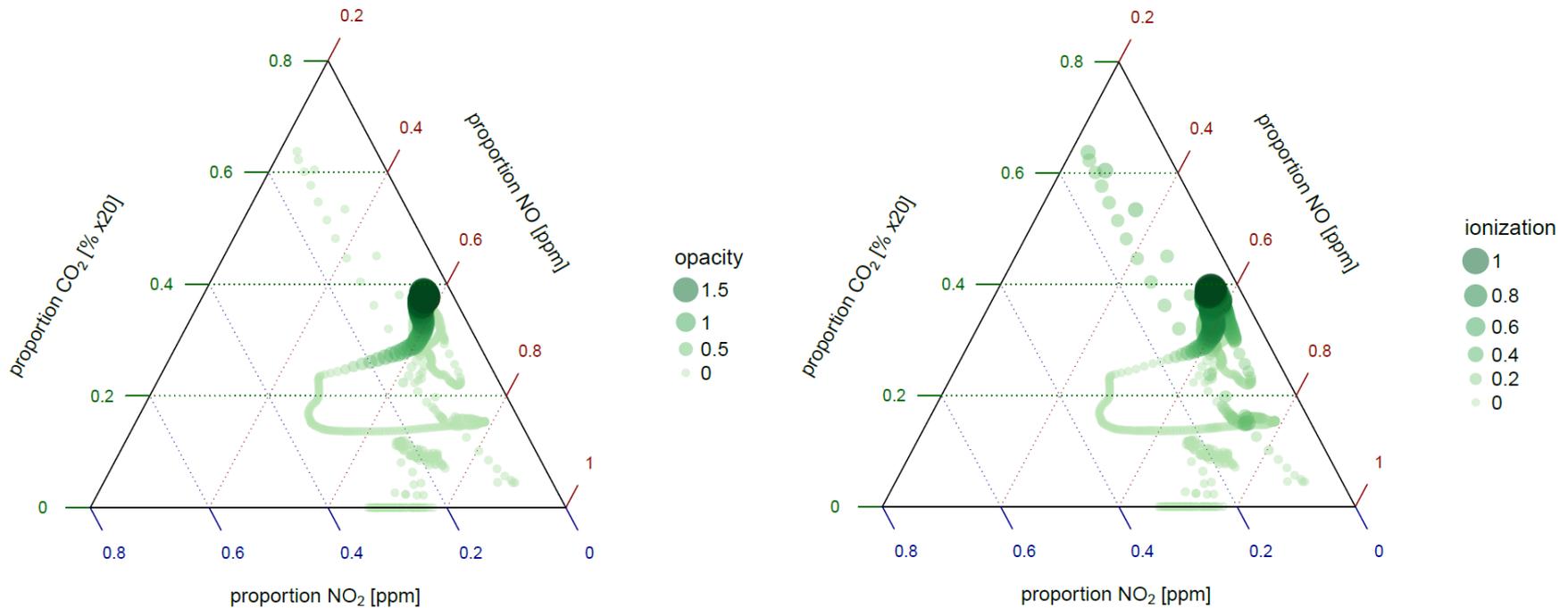
DPF mode: (-1 engine off;) 1 working; 2 failing; 3 failed



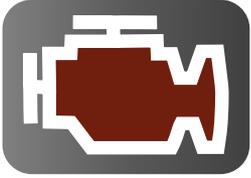


Scoping Instrument Performance

An Older Dirtier Vehicle

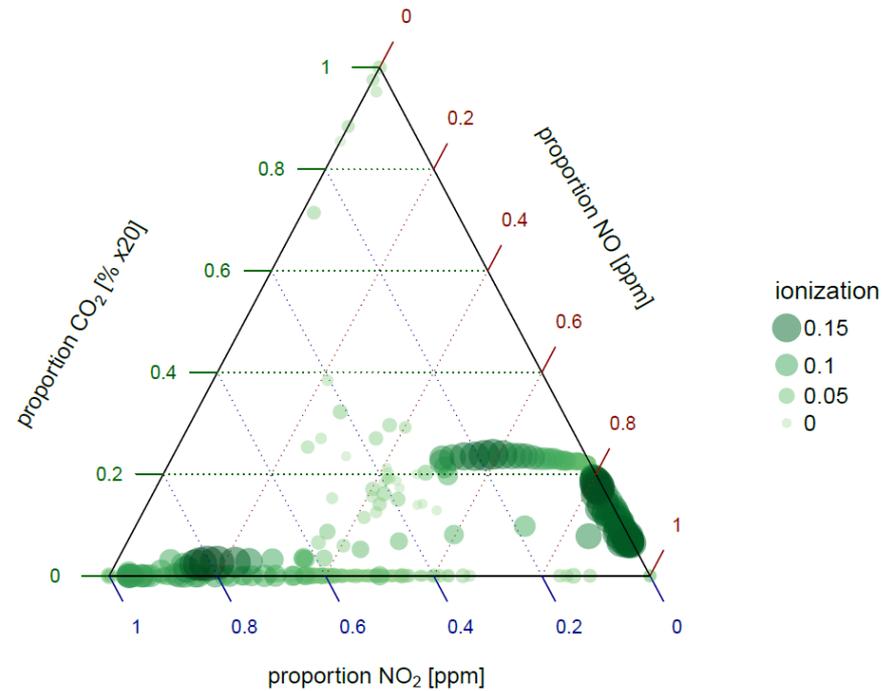
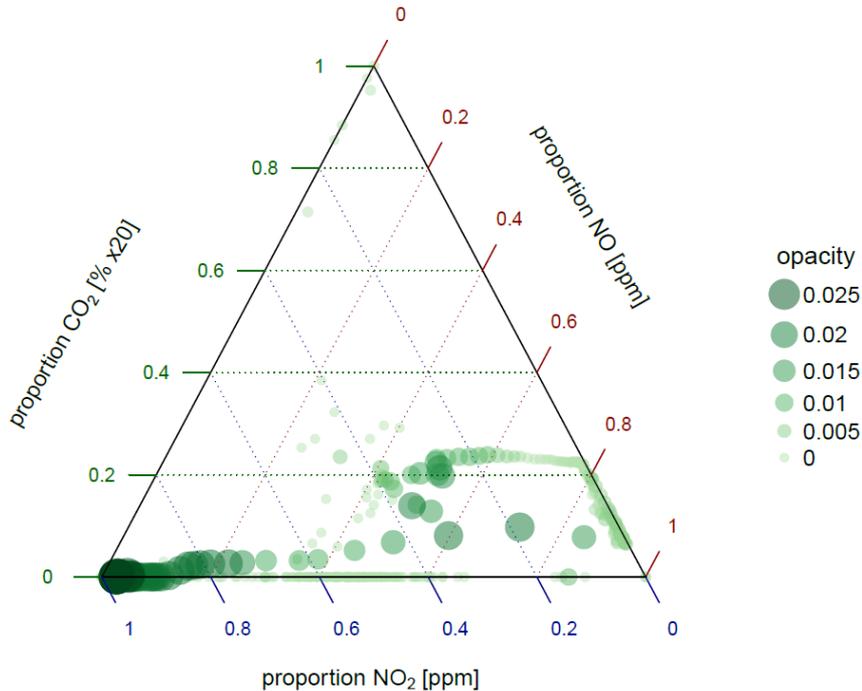


Here, measures of fine and coarse PM, e.g. opacity and ionization, behave similarly but NOT identically, so we have a strong candidate for response mapping

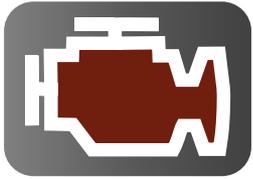


Scoping Instrument Performance

A Newer 'Cleaner' Vehicle

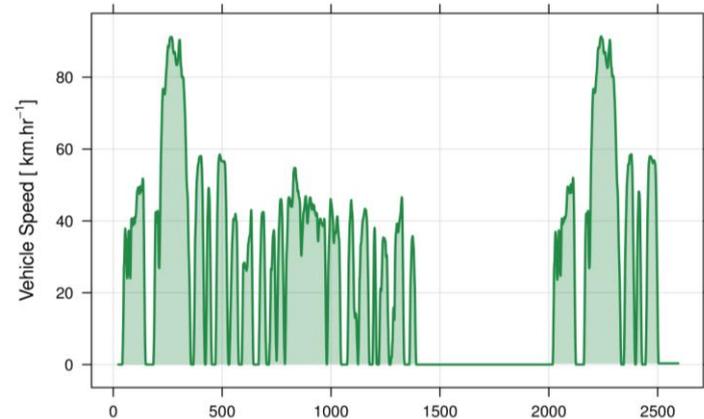


Here, levels are lower but also fine PM dominates and different size ranges behave differently (also opacity meters can be cross-sensitive to NO₂) So response mapping is more challenging

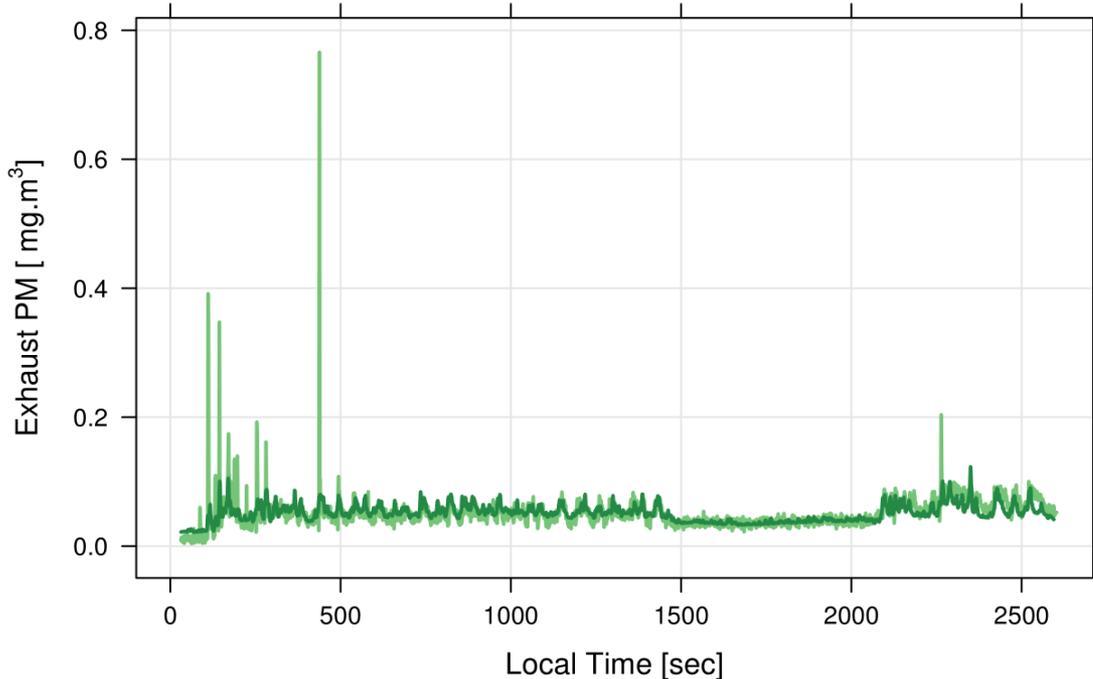


Another 'Clean' Vehicle

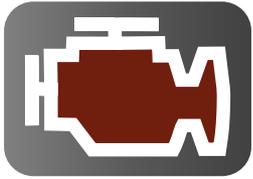
Dynamometer FTP drive cycle
Reference Microsoot



Microsoot ParSYNC*

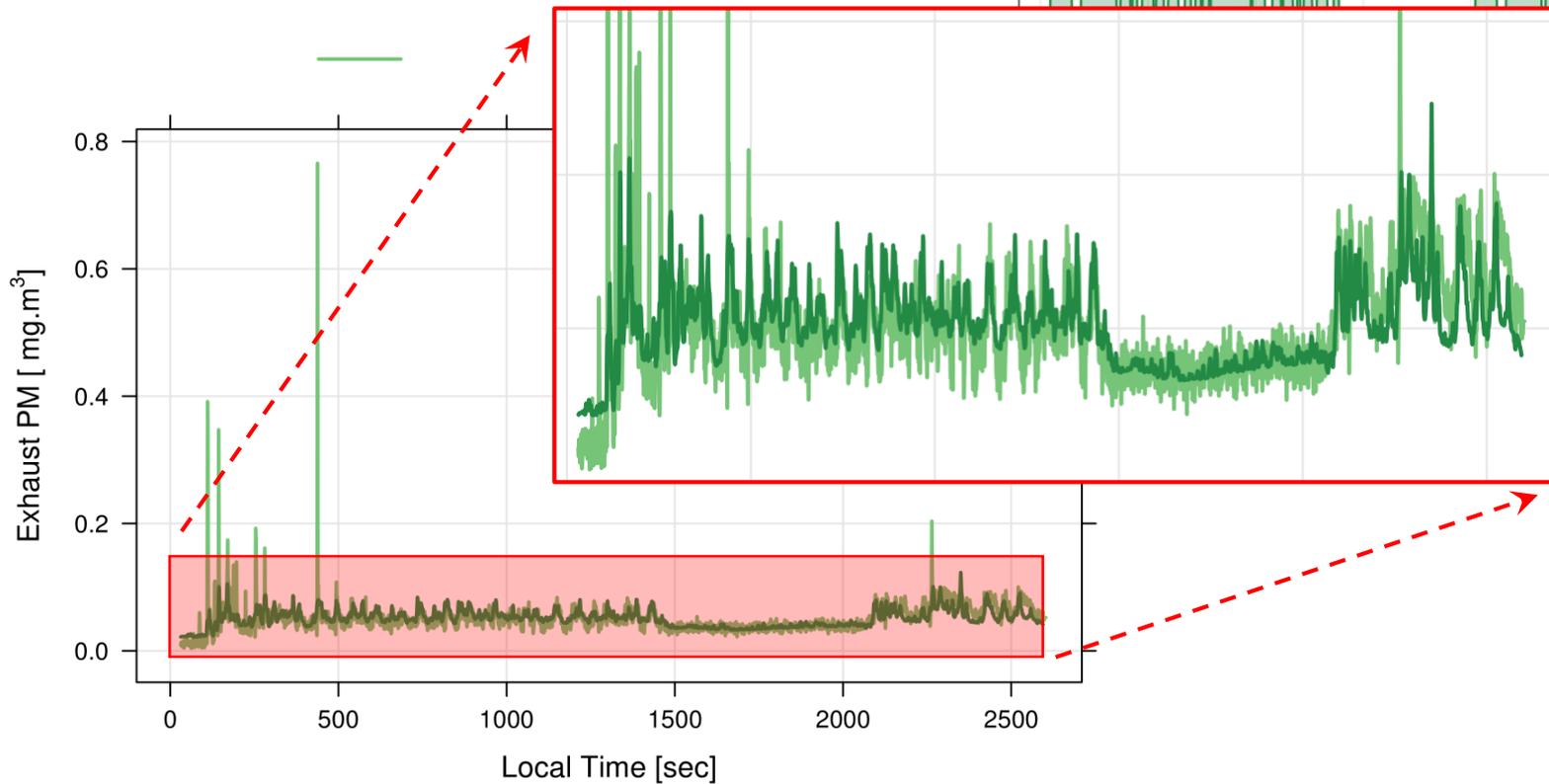
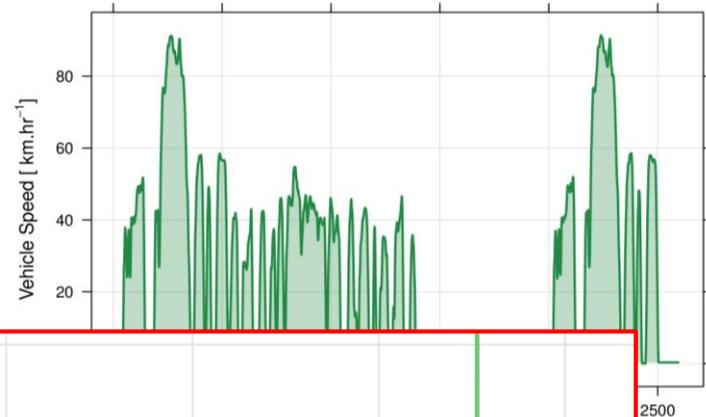


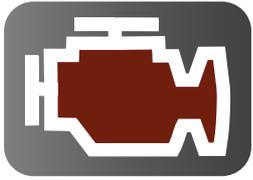
See something very similar but (surprisingly) main features are not observed



Another 'Clean' Vehicle

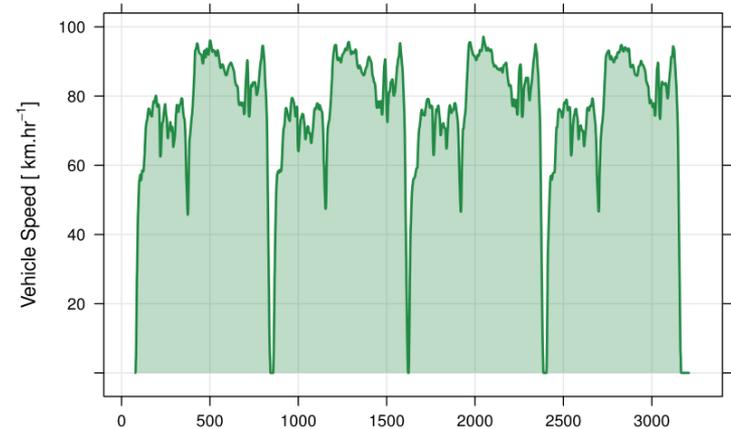
Dynamometer FTP drive cycle
Reference Microsoot



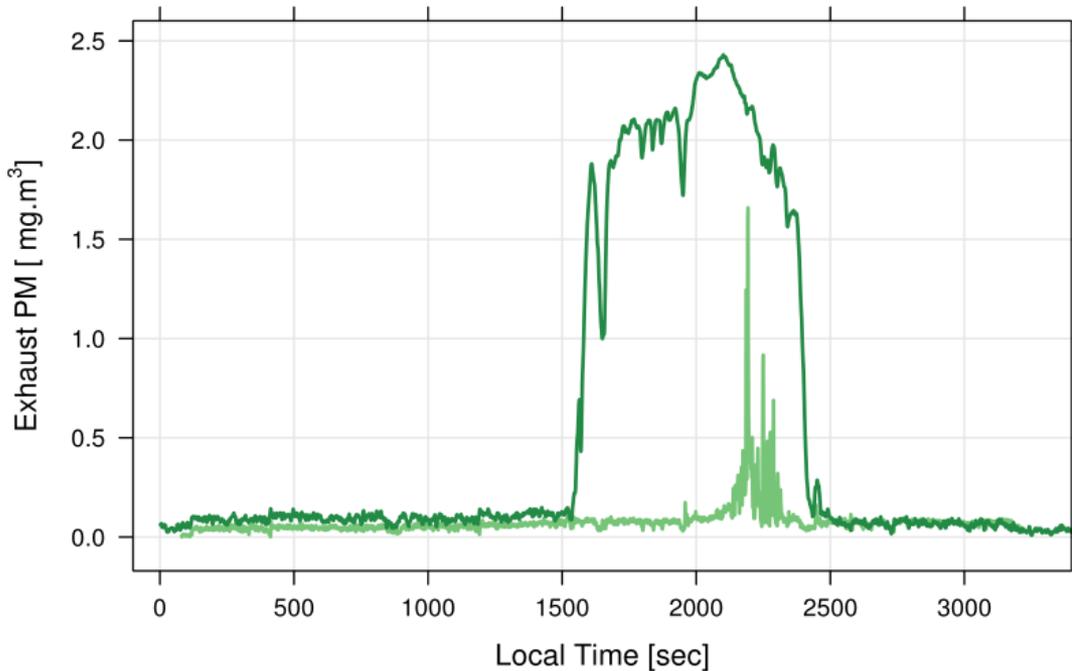


Same Vehicle 'Regen' Event

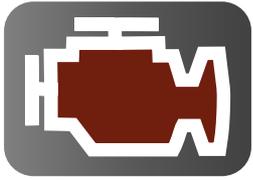
Dynamometer HWFET drive cycle
Reference Microsoot



Microsoot ParSYNC*

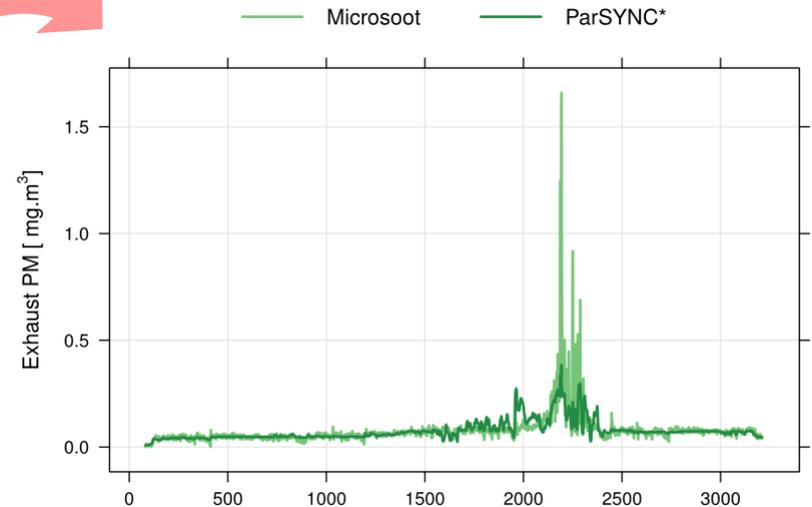
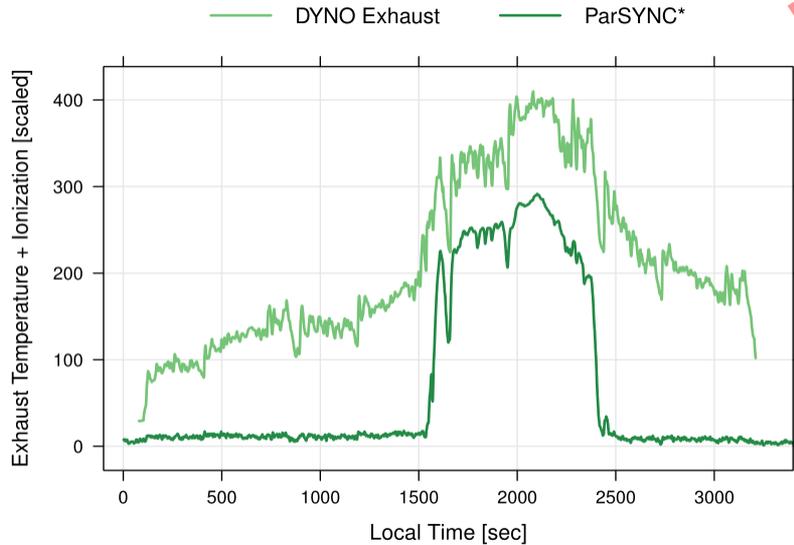


Here ParSYNC output dominated by ionization signal and it start earlier and is much larger than reference

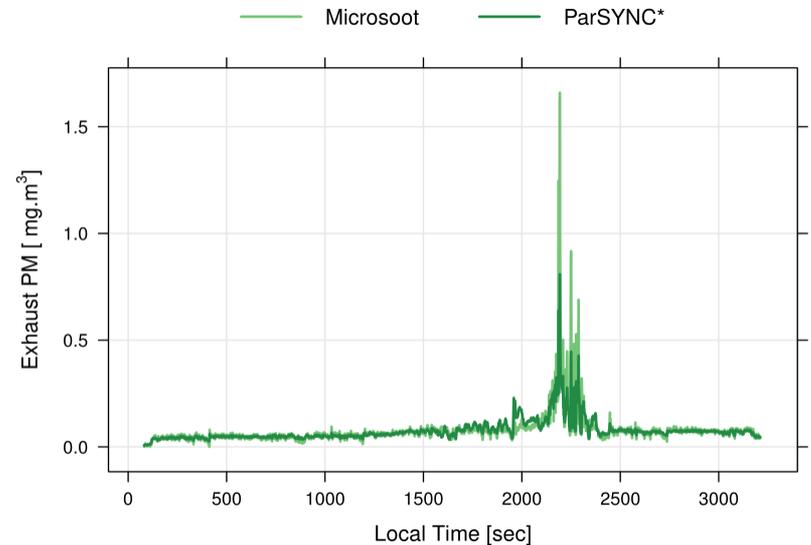


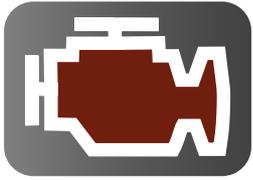
Scoping Instrument Performance

Same Vehicle 'Regen' Event



Fitting this to exhaust temperature (and pressure) we get a NEGATIVE component that maps onto reference



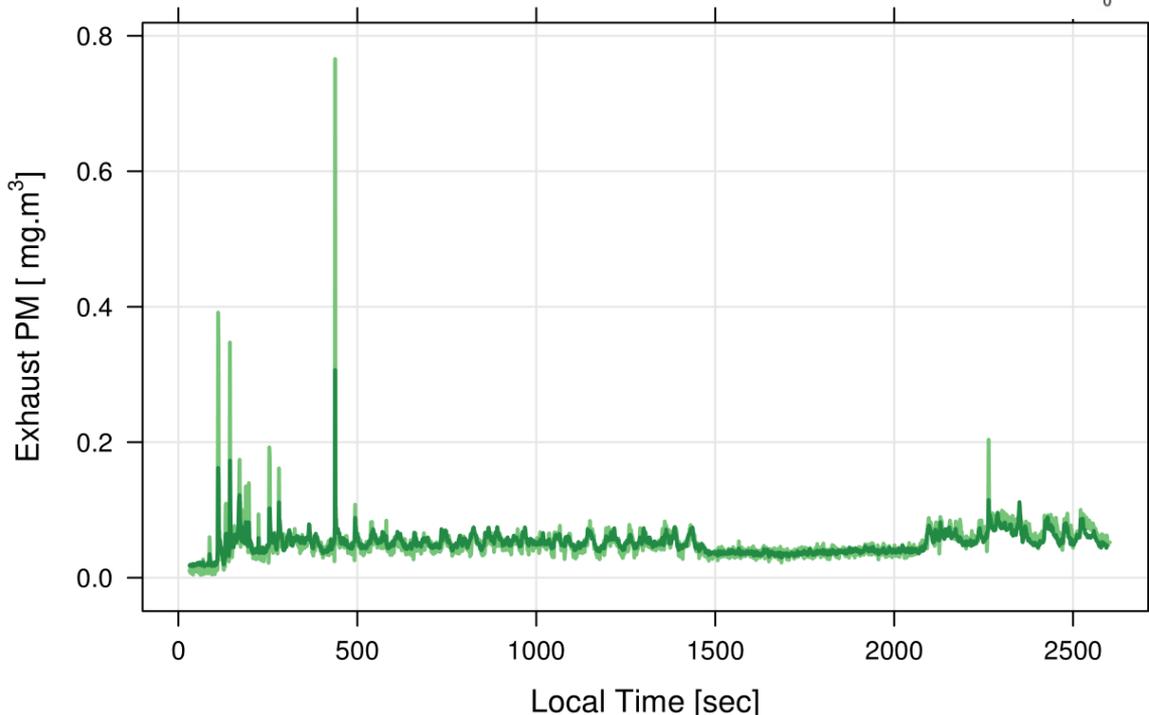
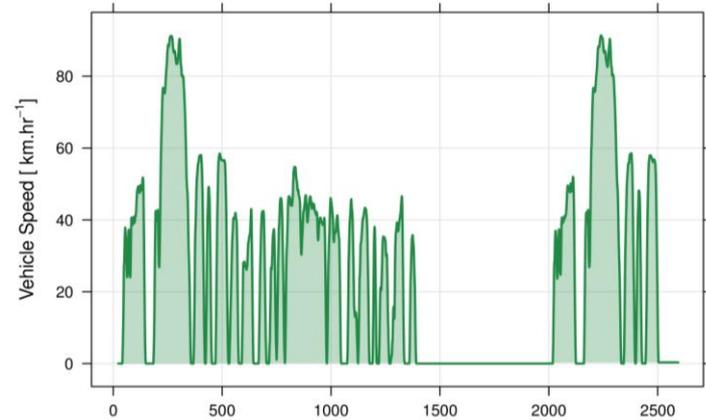


Scoping Instrument Performance

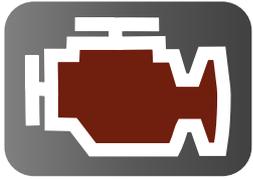
Applying to non-Regen FTP

Dynamometer FTP drive cycle
Reference Microsoot
Correcting for Exhaust Conditions

Microsoot ParSYNC*



Again we are seeing some BUT not all the same features, so tracking some but not all reference behavior



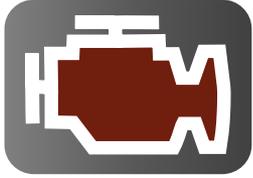
Questions

I would like to end this presentation with a question of my own before asking if you have any questions yourselves...

What we have is a very early and very tentative observation based on one vehicle and one reference method but...

We think we are looking at the '*wake of the ship*' rather than the '*ship*' and we may need both the ship and the sea (the particle and the exhaust environment) to produce the '*wake*.'

Is this a viable monitoring strategy or should we be designing it out of the next generations of the unit, or is it even extra information?



Acknowledgements

Thank You

We gratefully acknowledge the contributes of many others who provided vehicles, equipment, labor and parallel data

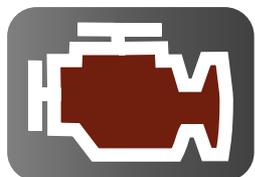
Without your input this work would not have been possible

Karl Ropkins - k.ropkins@its.leeds.ac.uk

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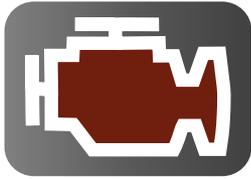


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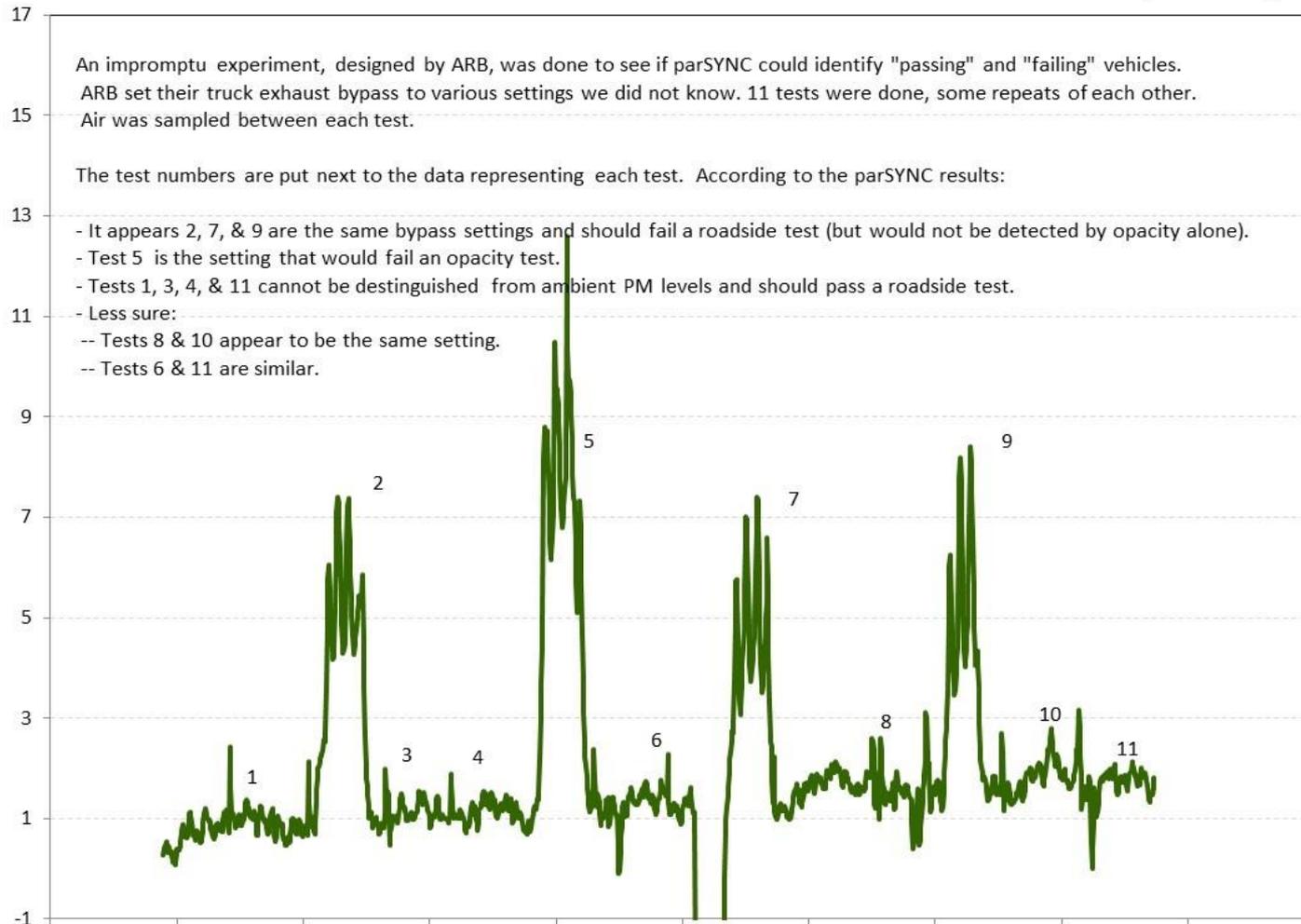
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Supporting Information

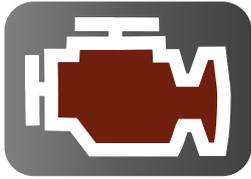


Developing Diagnostics

Jan 22, 2016 at ARB, El Monte.

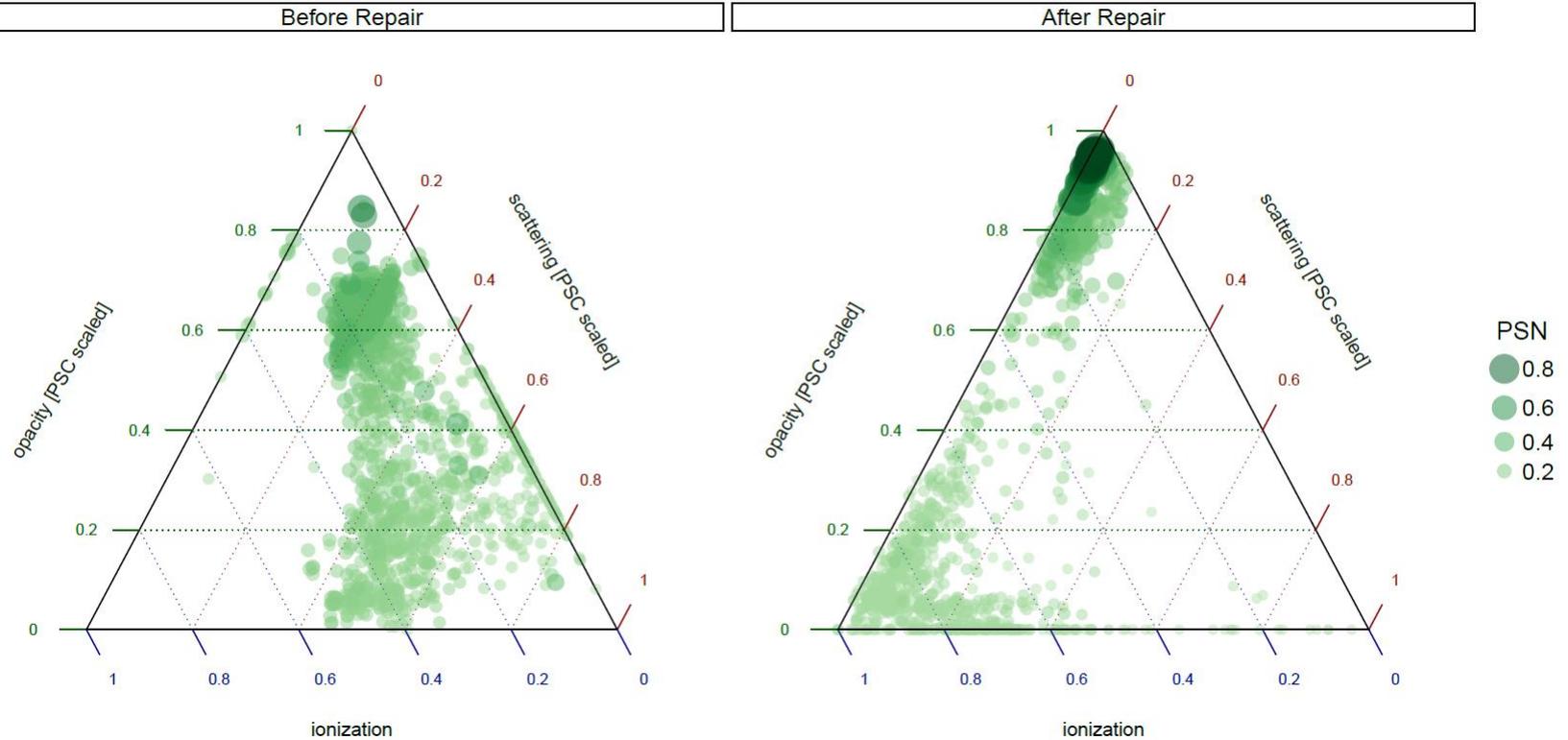


11:16:48 AM 11:19:41 AM 11:22:34 AM 11:25:26 AM 11:28:19 AM 11:31:12 AM 11:34:05 AM 11:36:58 AM 11:39:50 AM 11:42:43 AM 11:45:36 AM

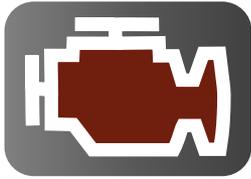


Vehicle A Before and After Repair

Diagnostics



The larger amounts of PM associate with opacity, indicating relatively coarse emissions after repair

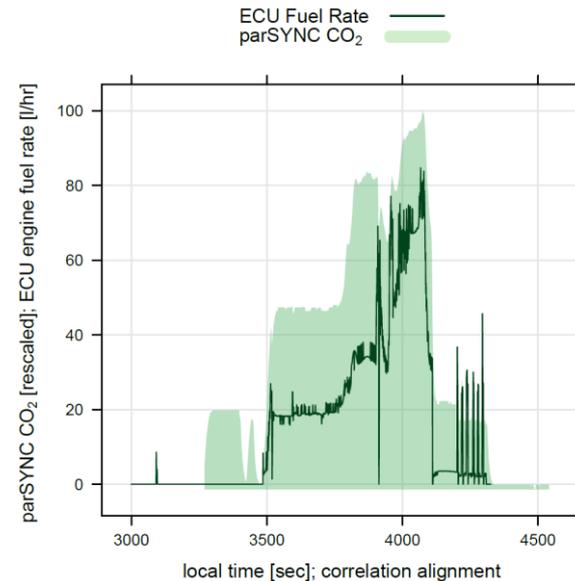
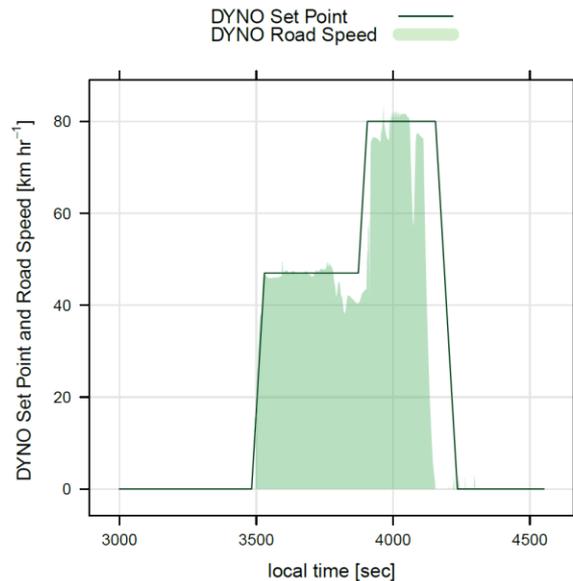


Example Before and After Repair

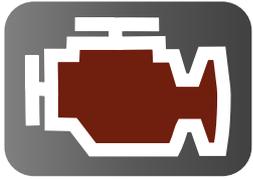
Data Collection

Test procedure (before and after repair):

- Dynamometer test (modified AC50/80 Short Test)
- SNAP test



(Data collected: Dynamometer records; ECU logger;
candidate analysers/sensor systems)



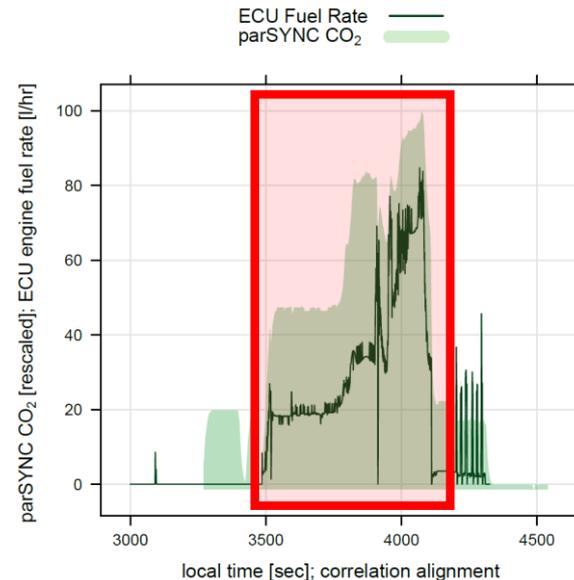
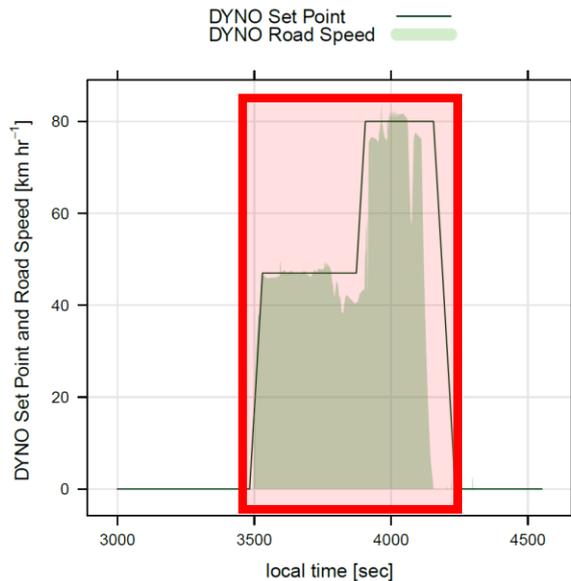
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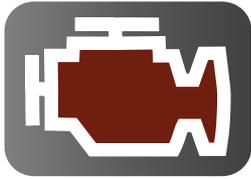
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Note: Not all vehicles always able to complete DYNO cycle



(Data collected: Dynamometer records; ECU logger; candidate analysers/sensor systems)

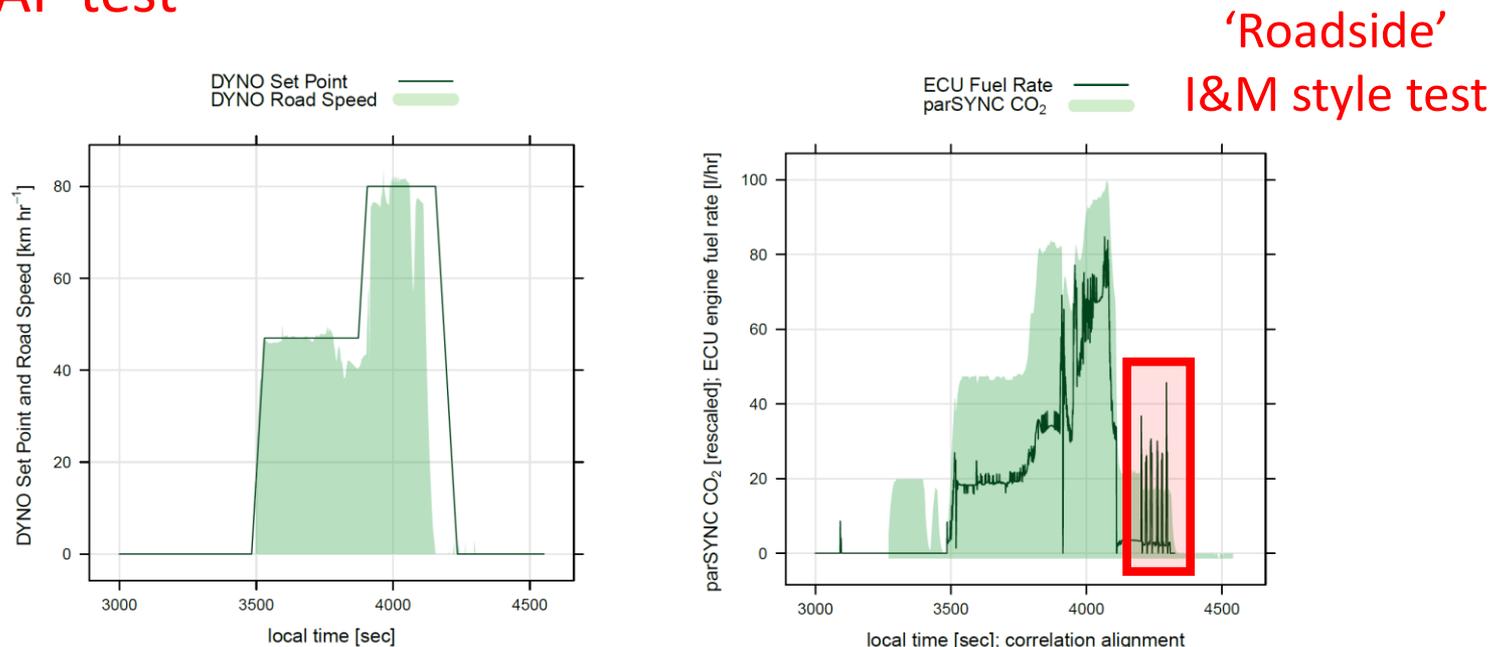


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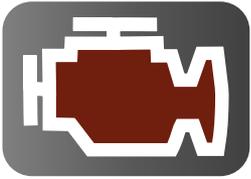
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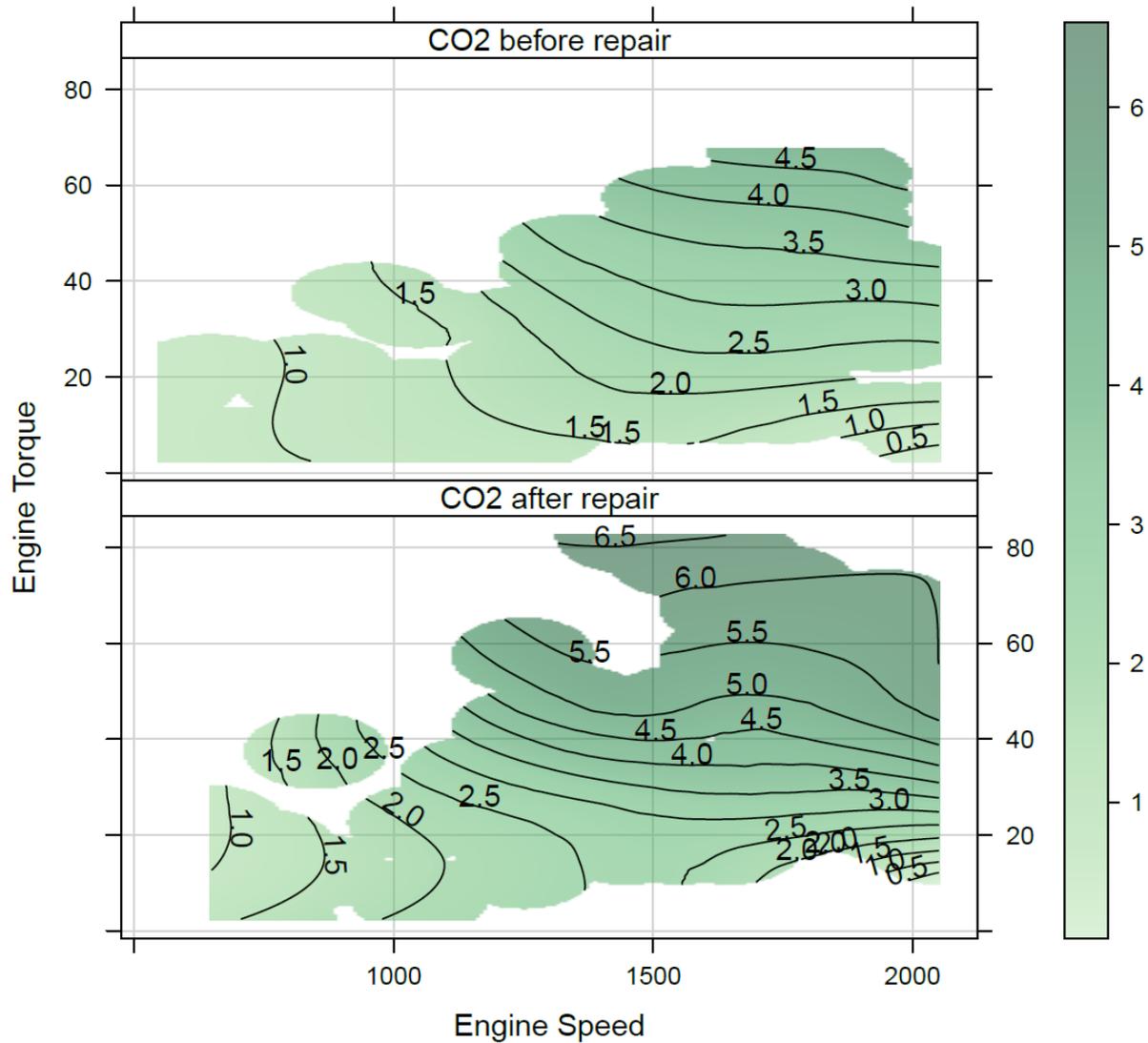


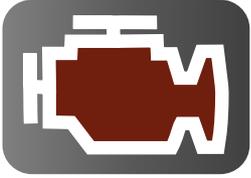
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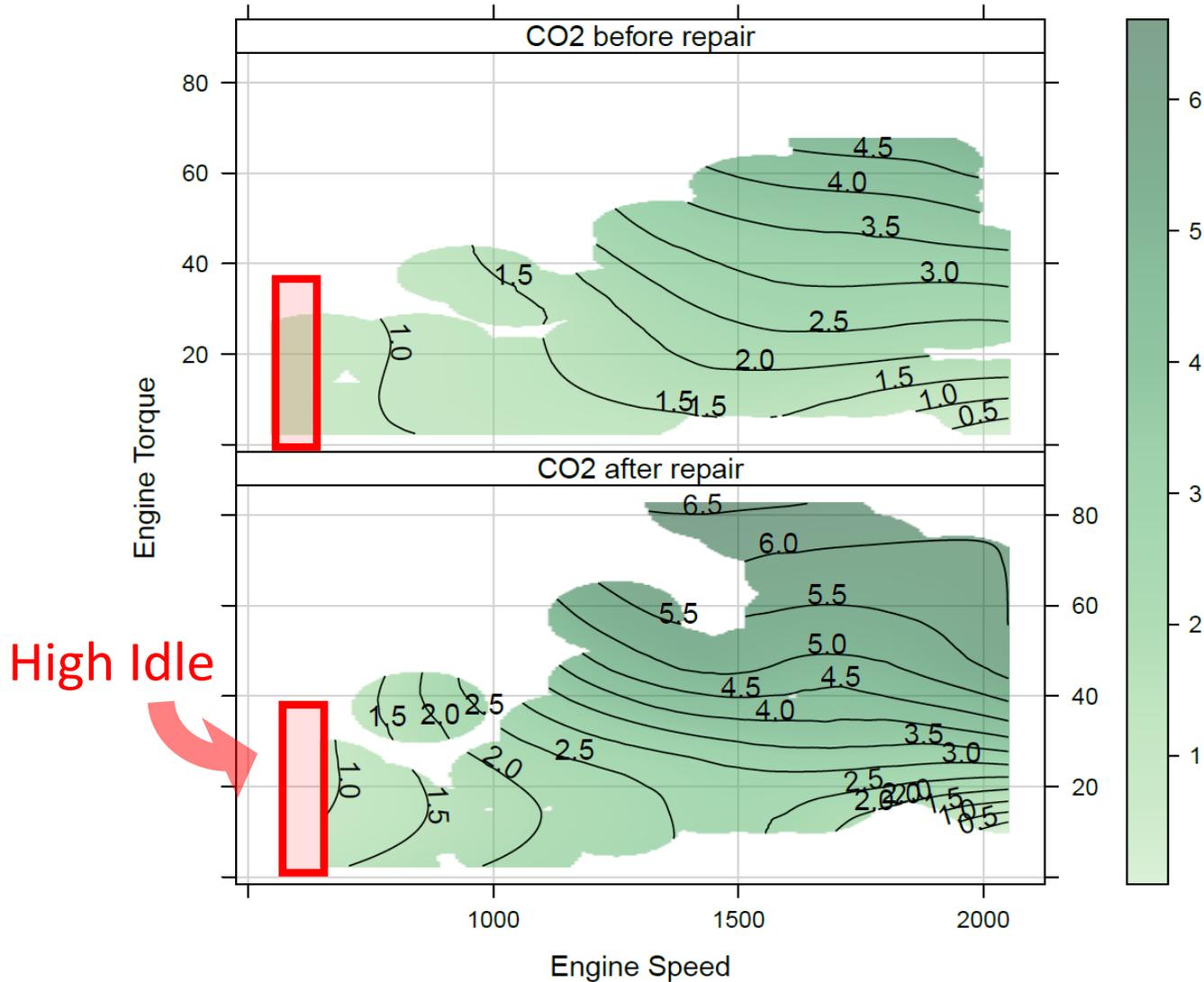
CO2 Engine Map

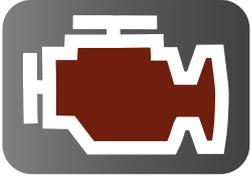




Vehicle A Before and After Repair

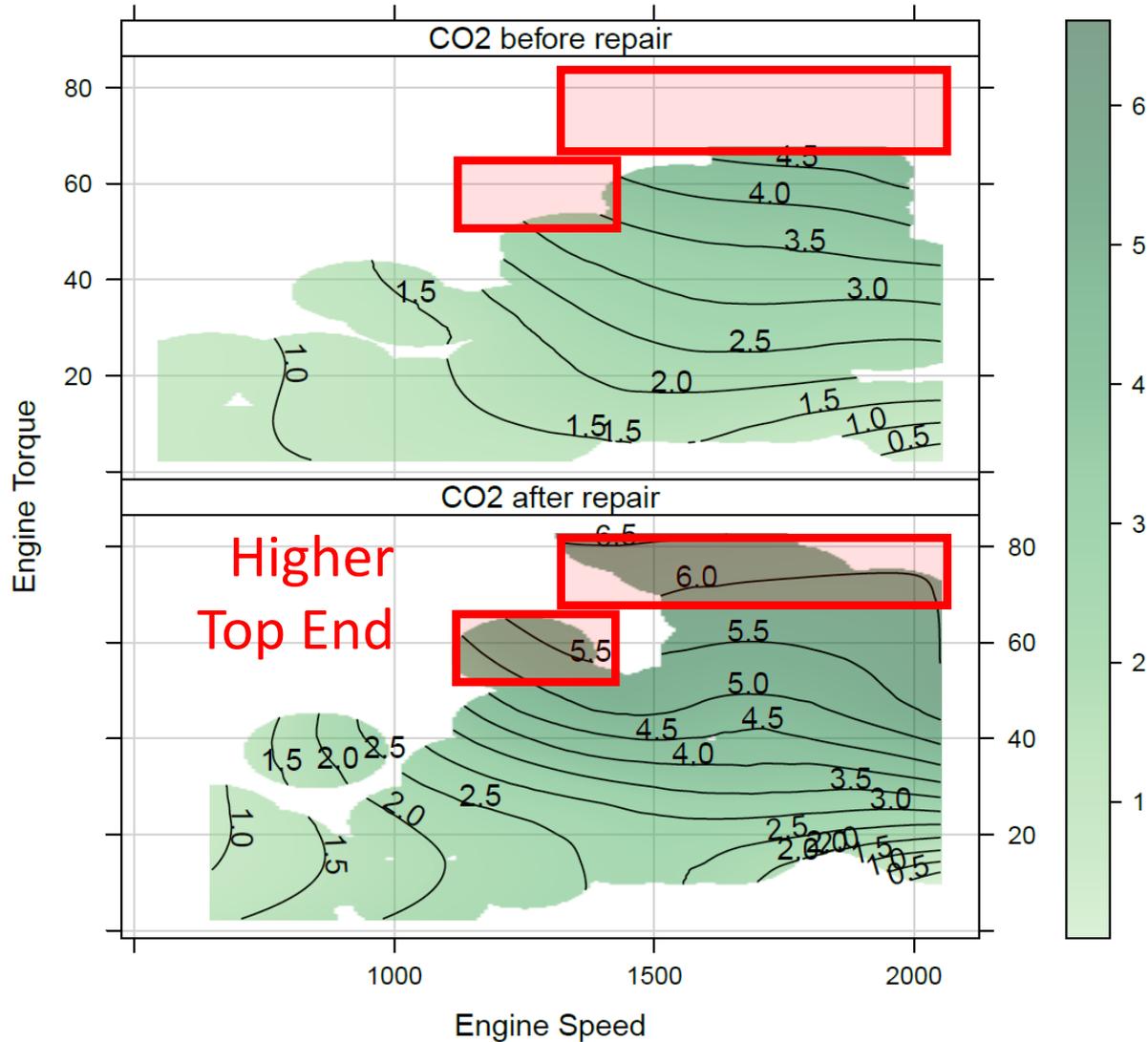
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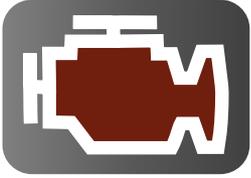




Vehicle A Before and After Repair

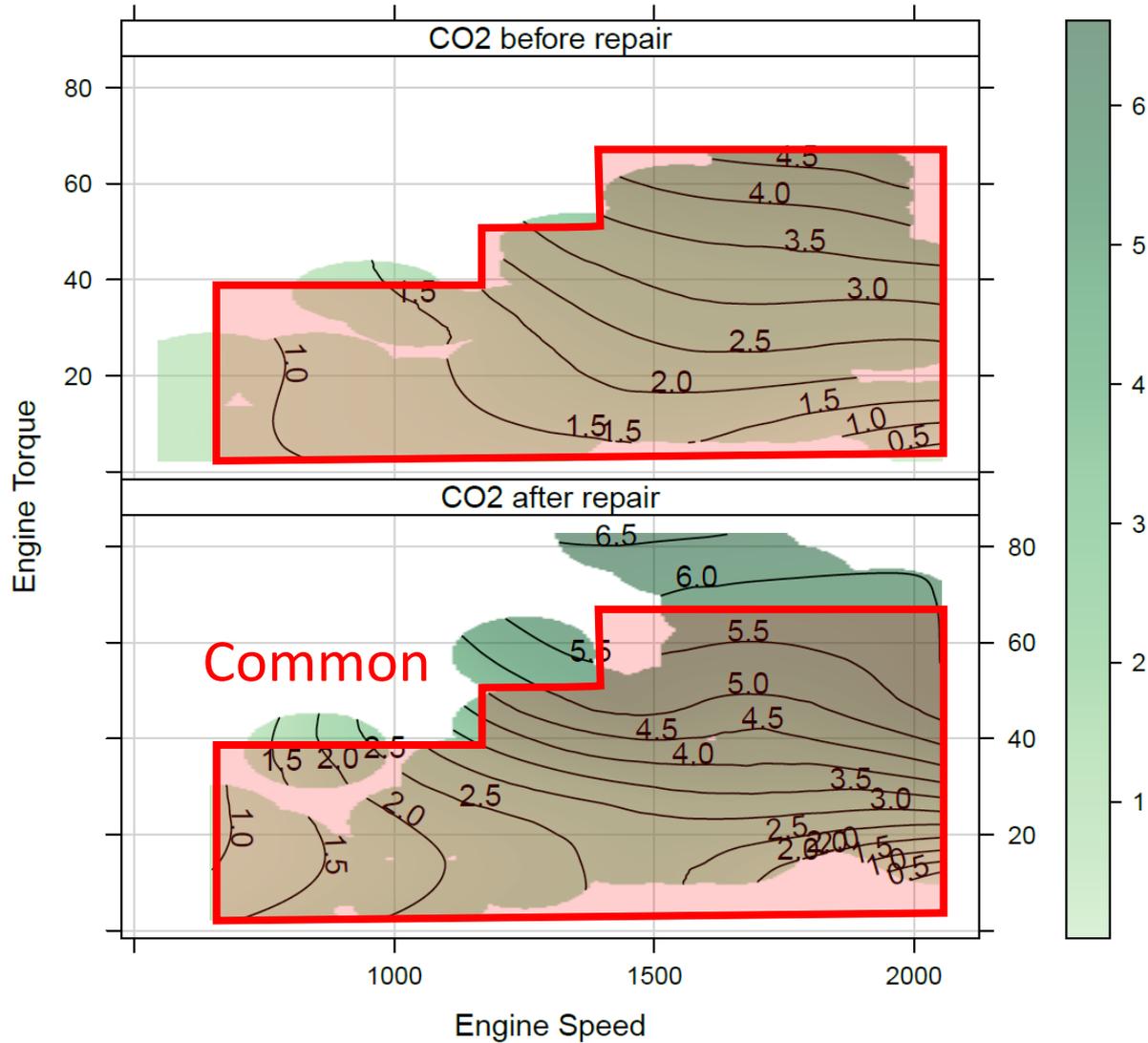
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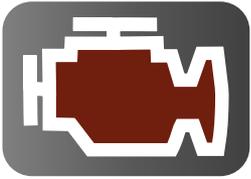




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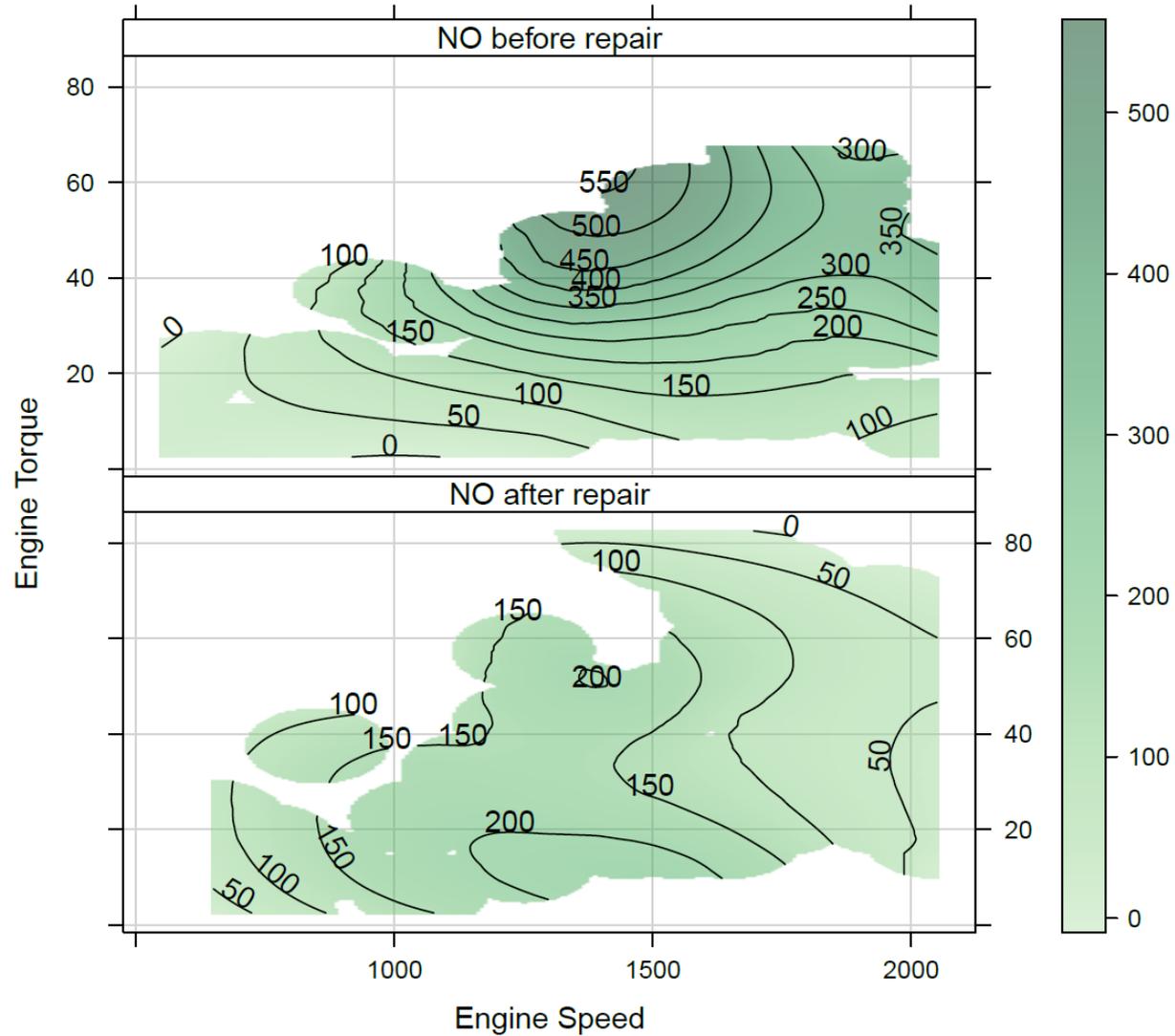
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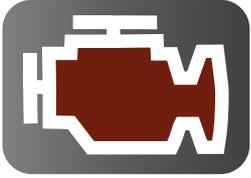




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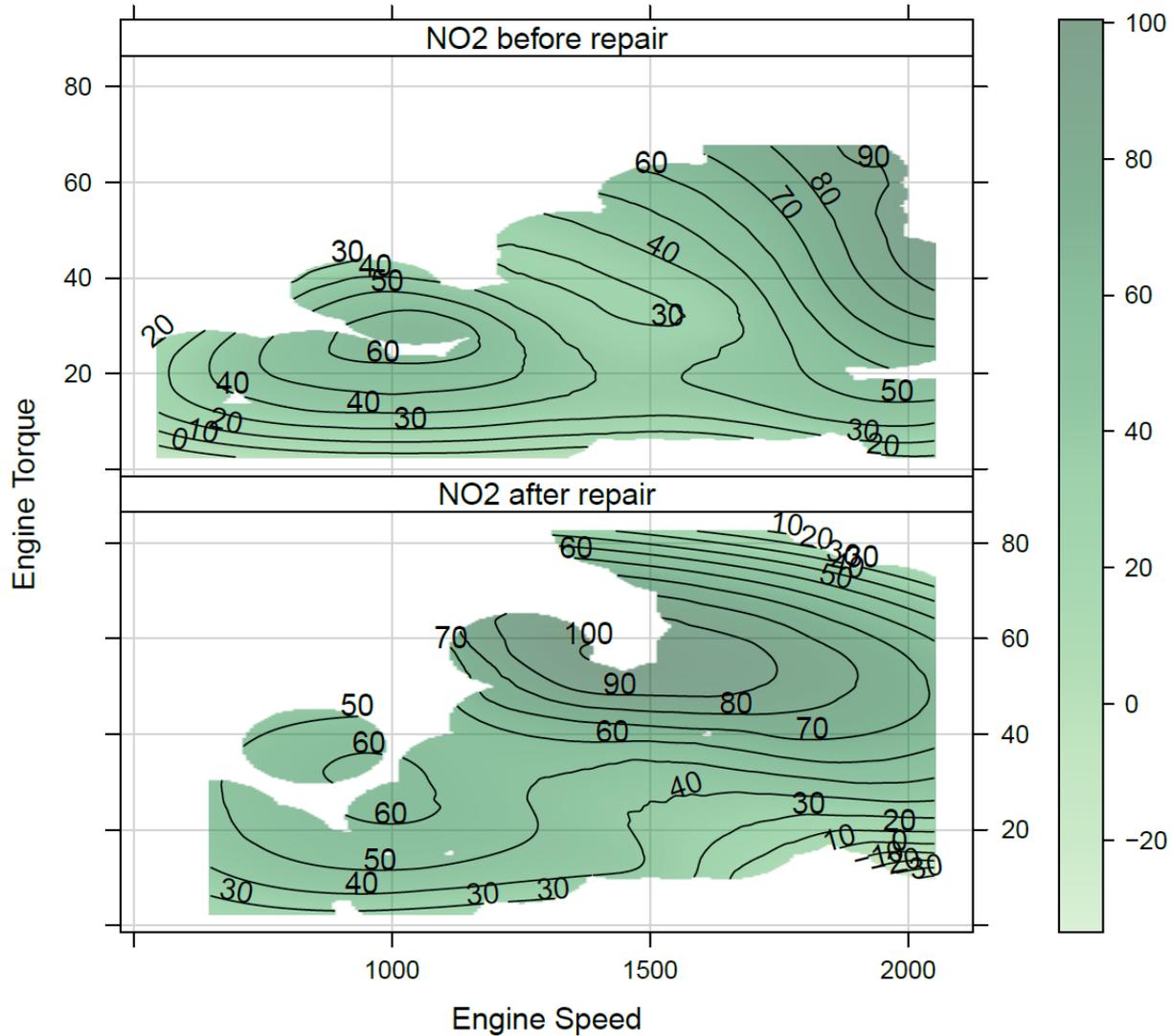
NO Engine Map

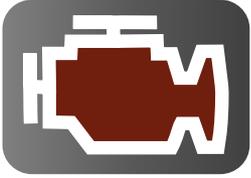




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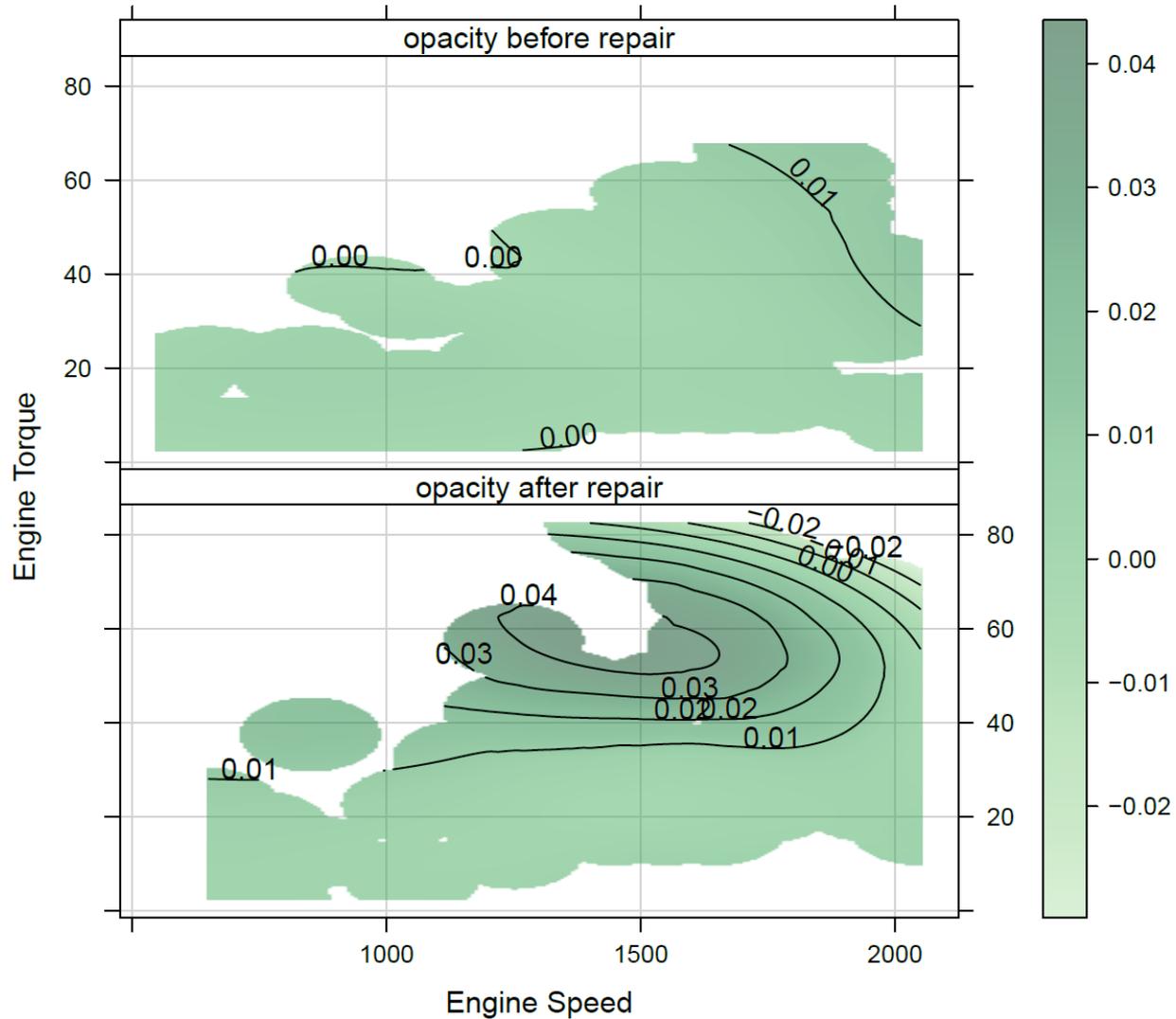
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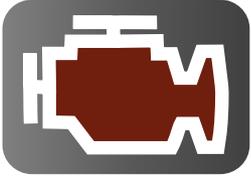




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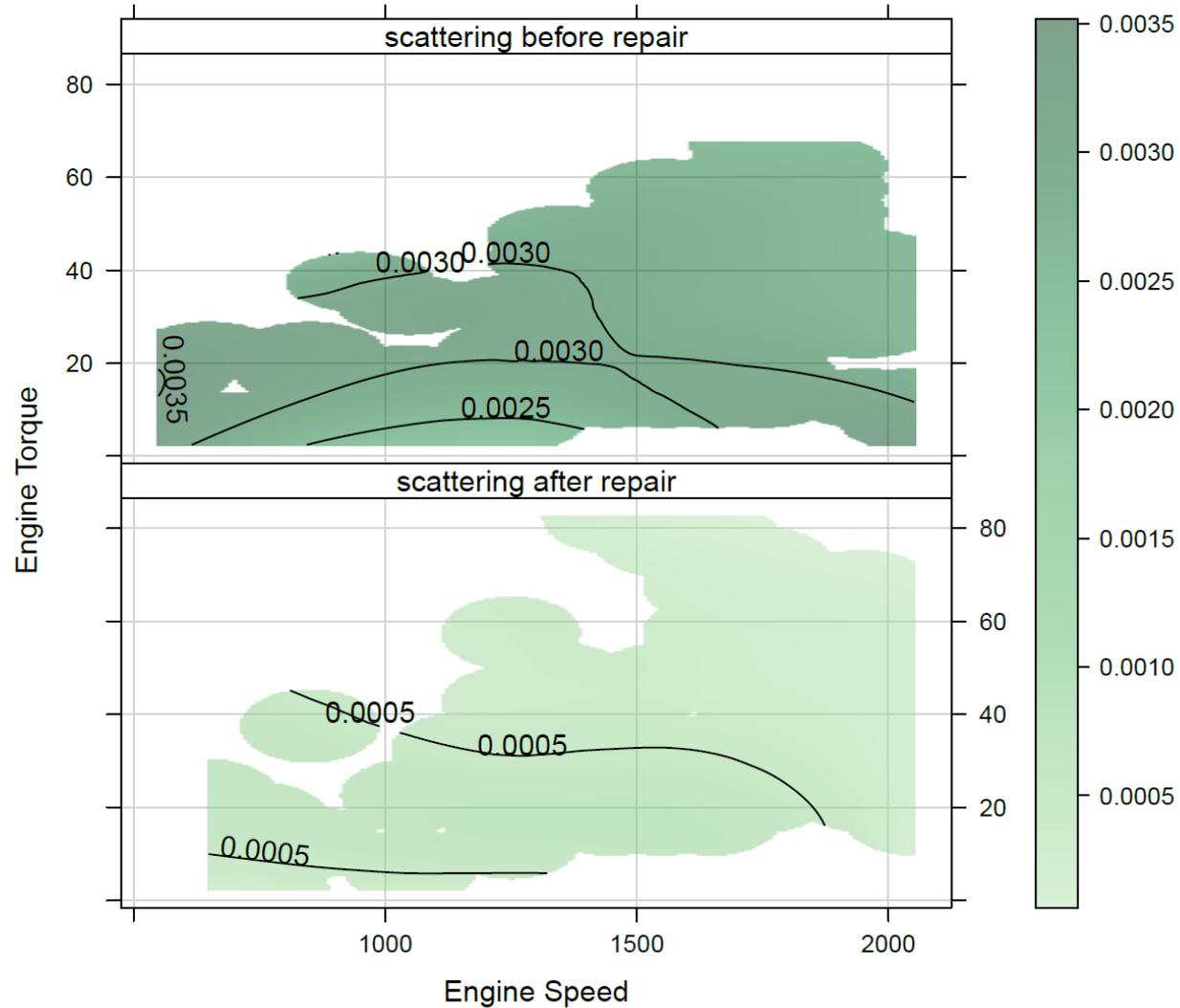
Opacity Engine Map

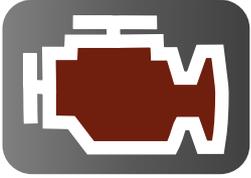




Vehicle A Before and After Repair

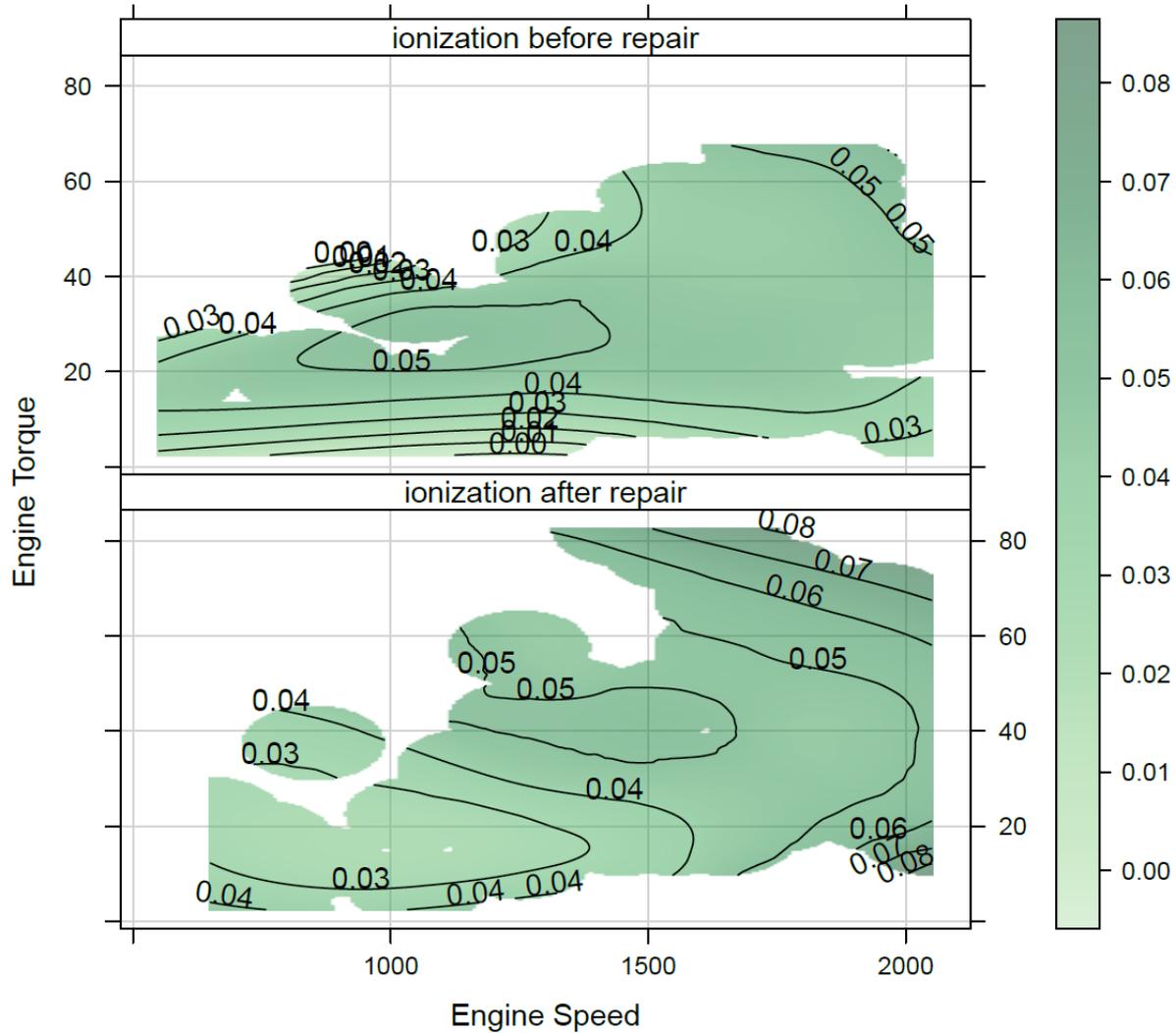
Scattering Engine Map

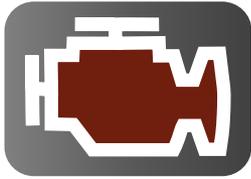




Vehicle A Before and After Repair

Ionization Engine Map





Vehicle A Before and After Repair

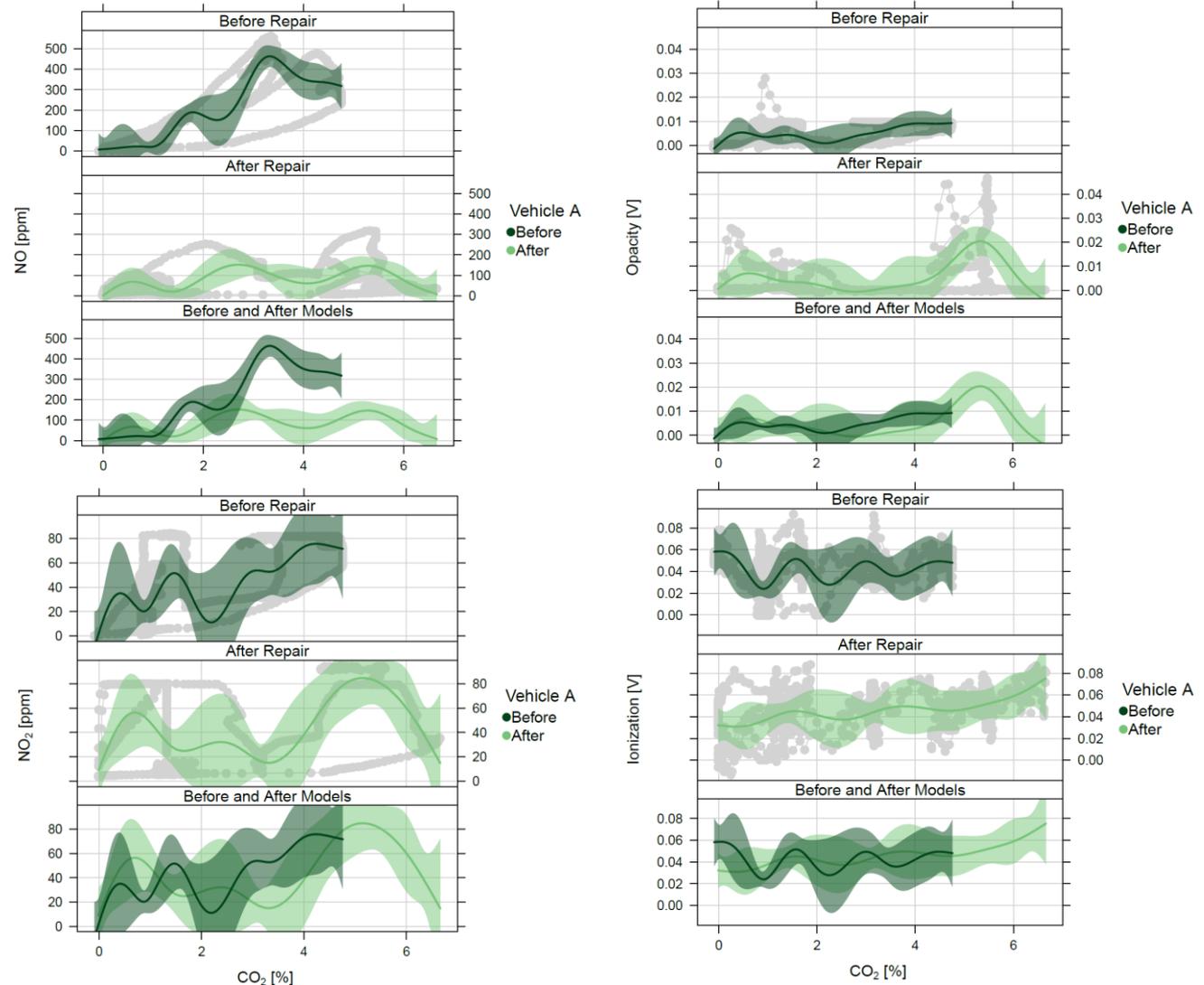
Diagnostics

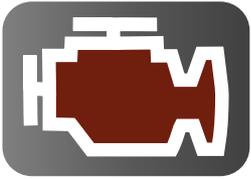
CO₂ Maps

- On-board diagnostic
- All data from one source
- Independent of OBD

*Quick question
(good or bad fix?)*

(Thanks to Norbert Ligterink/TNO)

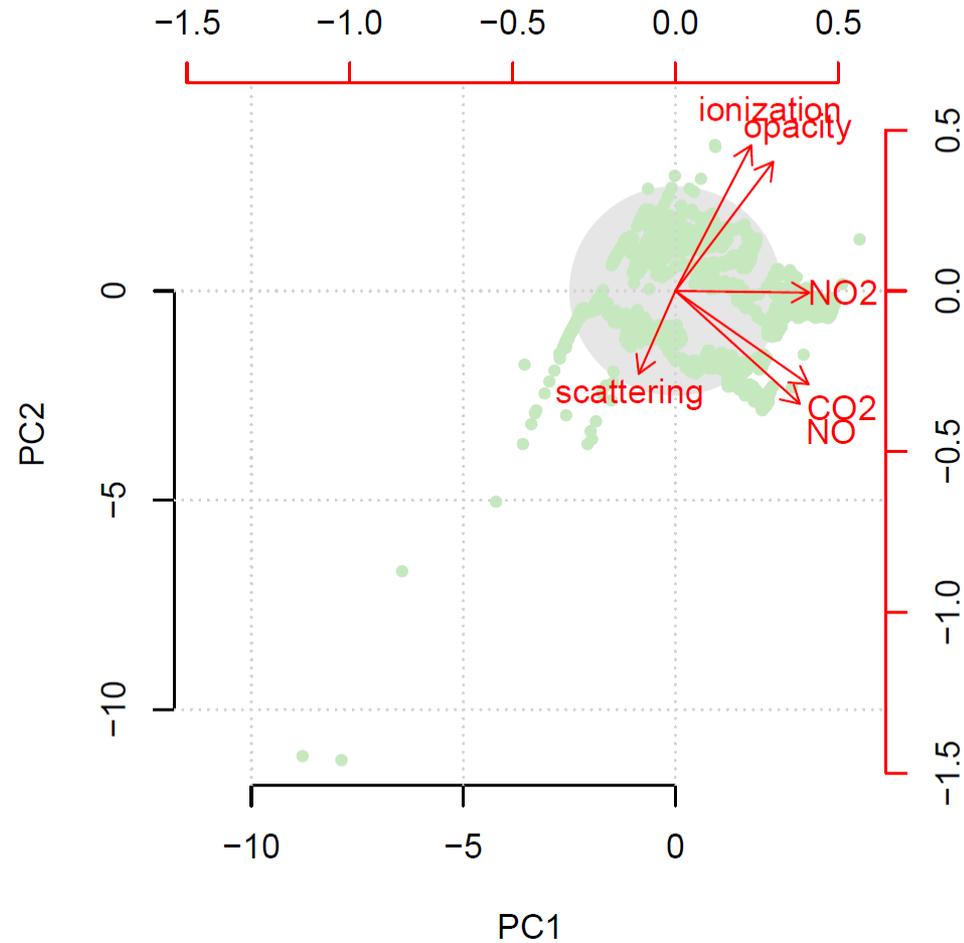
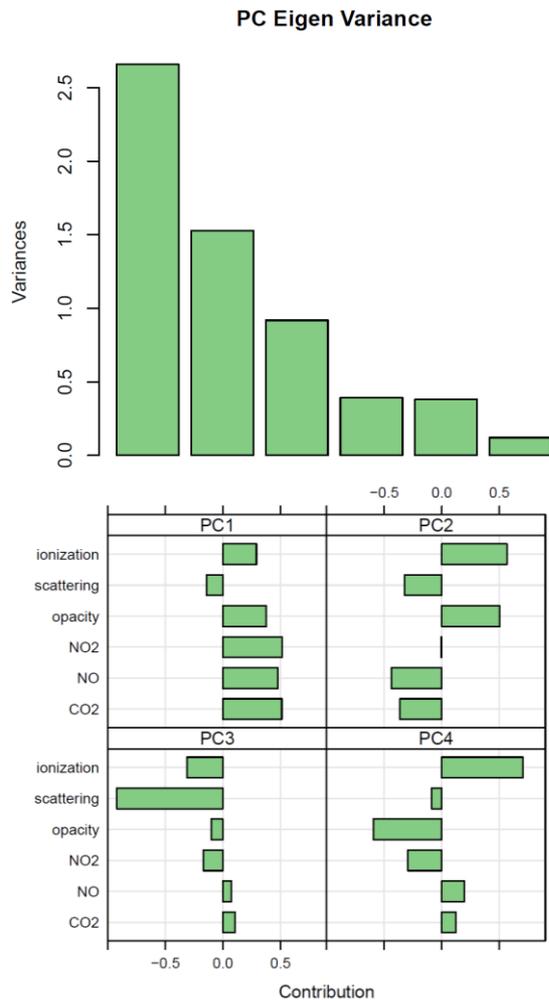


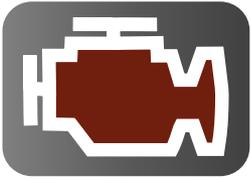


Vehicles Before and After Repair

Diagnostics

PCA of Vehicle A Emissions (before repair)

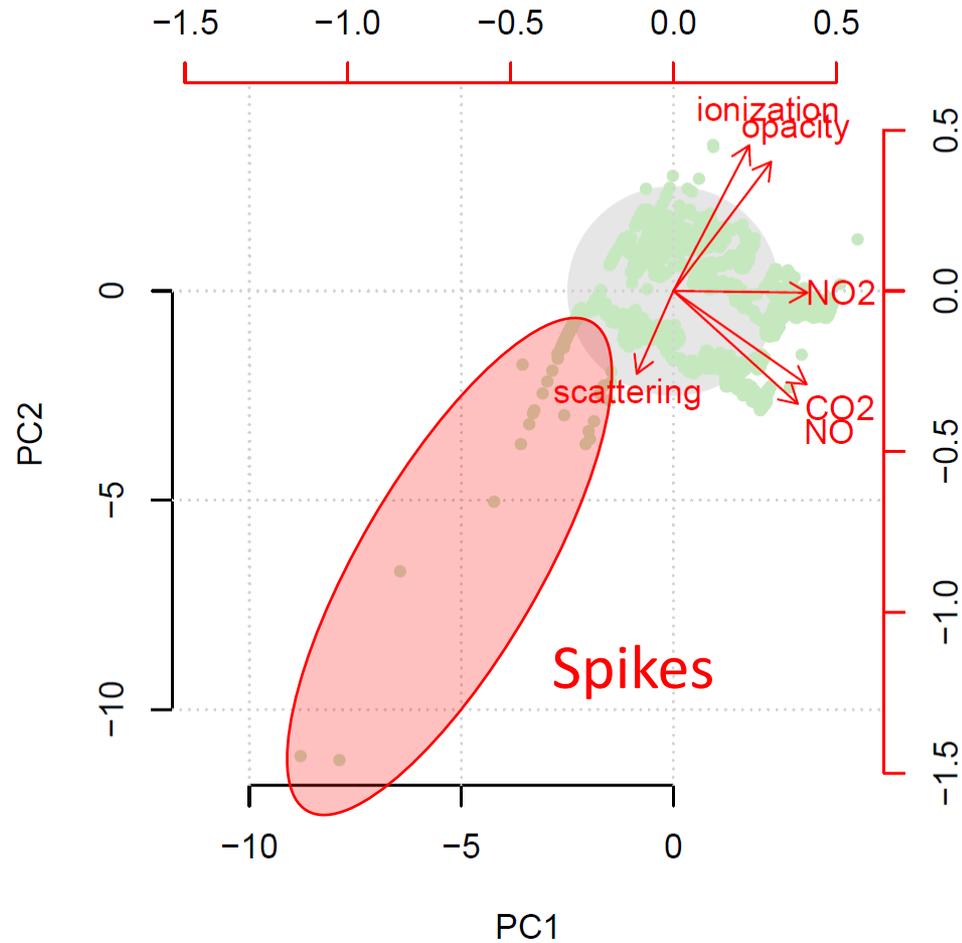
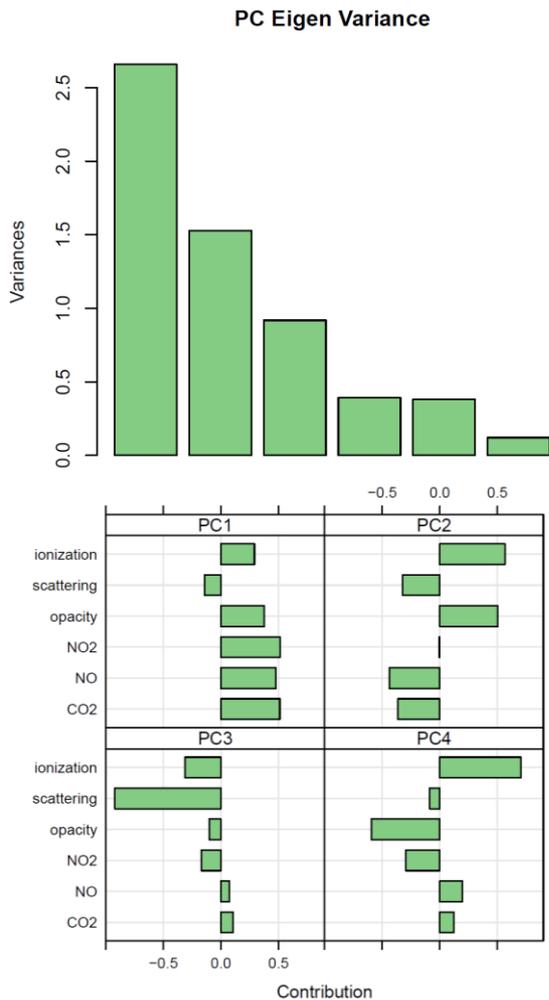


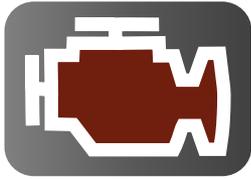


Vehicles Before and After Repair

Diagnostics

PCA of Vehicle A Emissions (before repair)

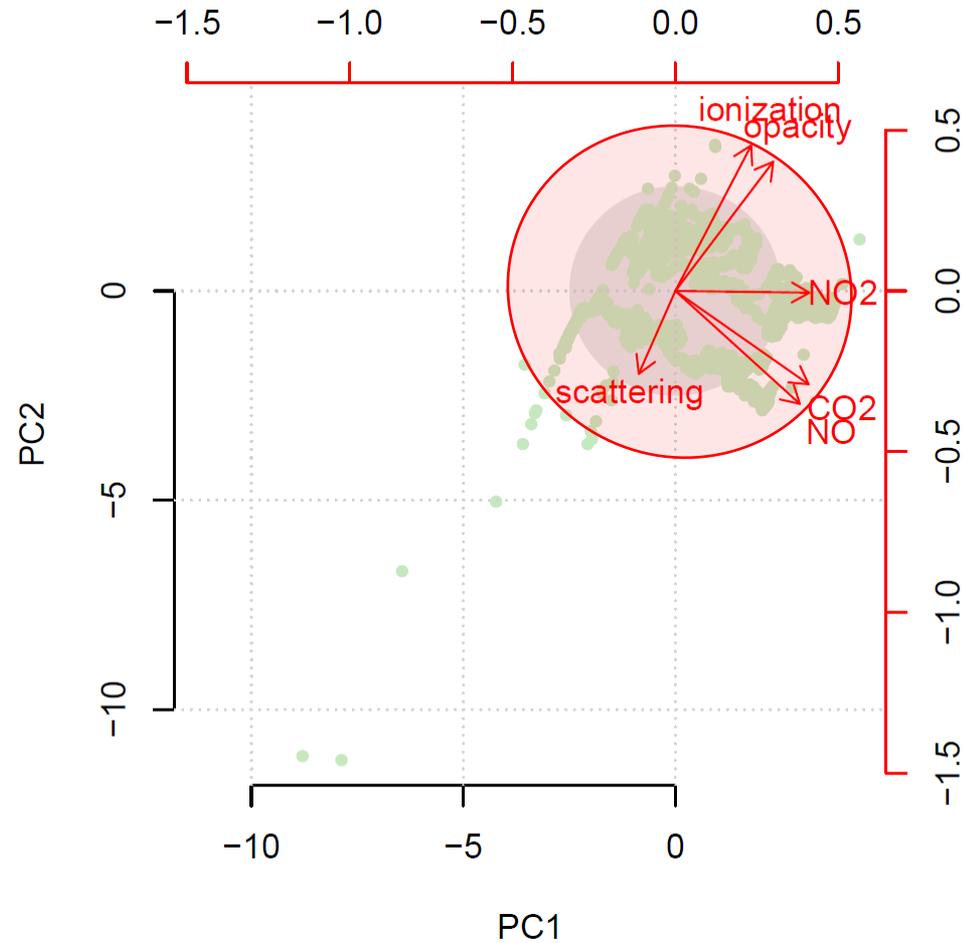
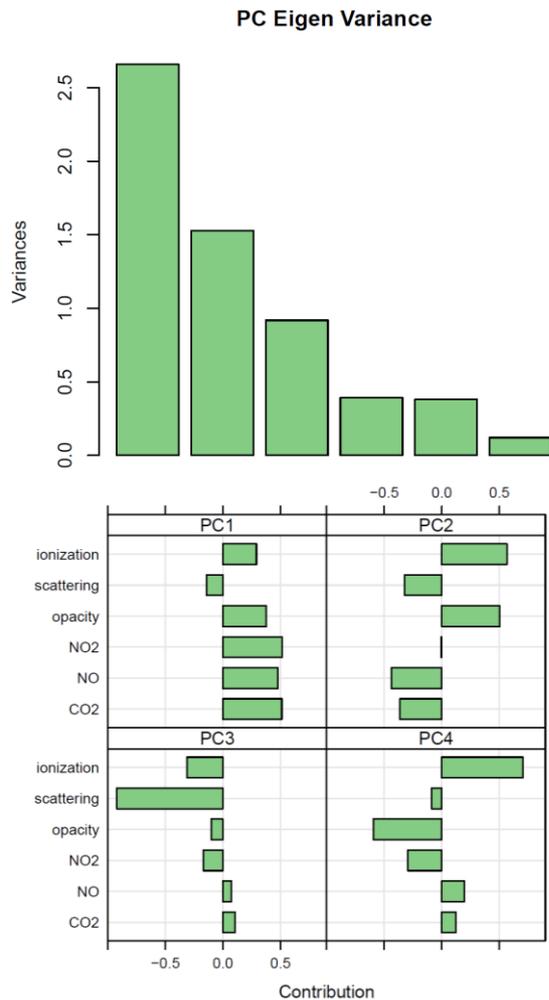


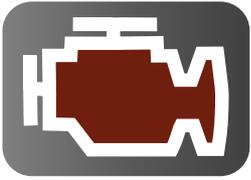


Vehicles Before and After Repair

Diagnostics

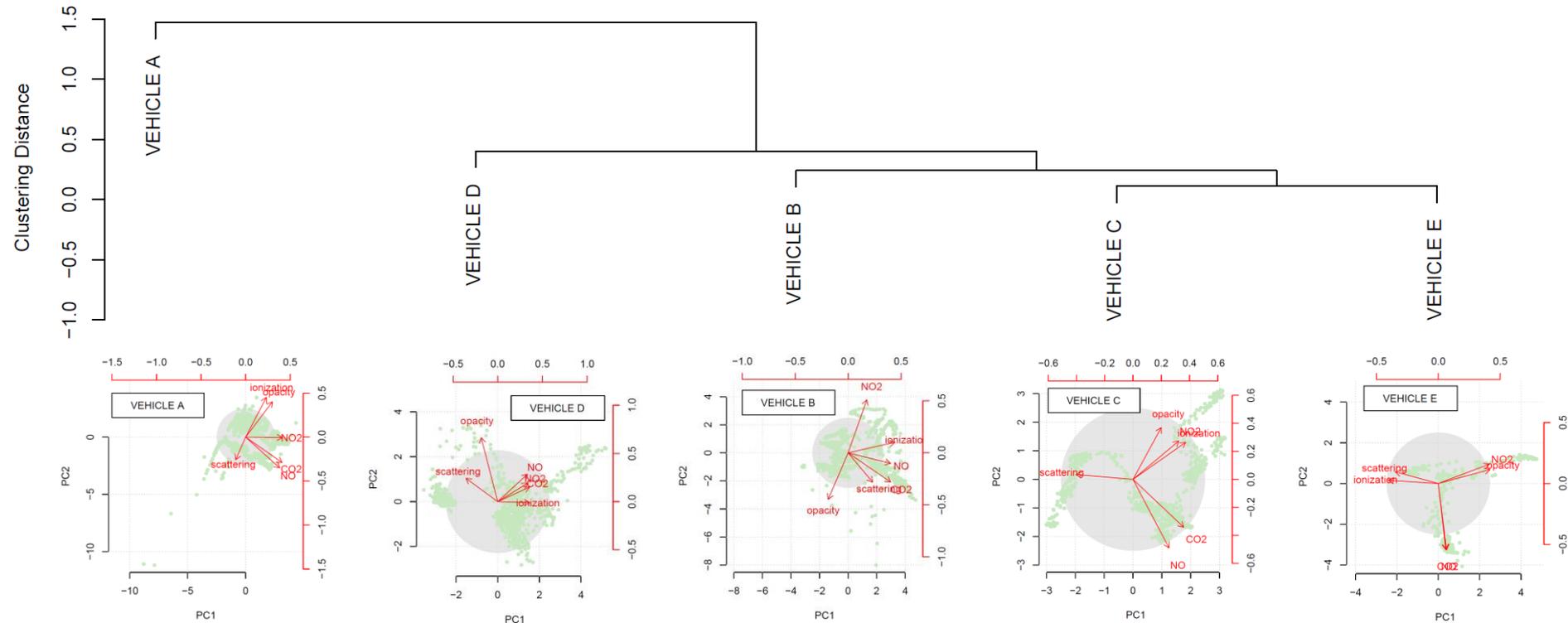
PCA of Vehicle A Emissions (before repair)



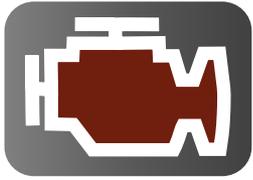


Vehicles Before and After Repair

Diagnostics

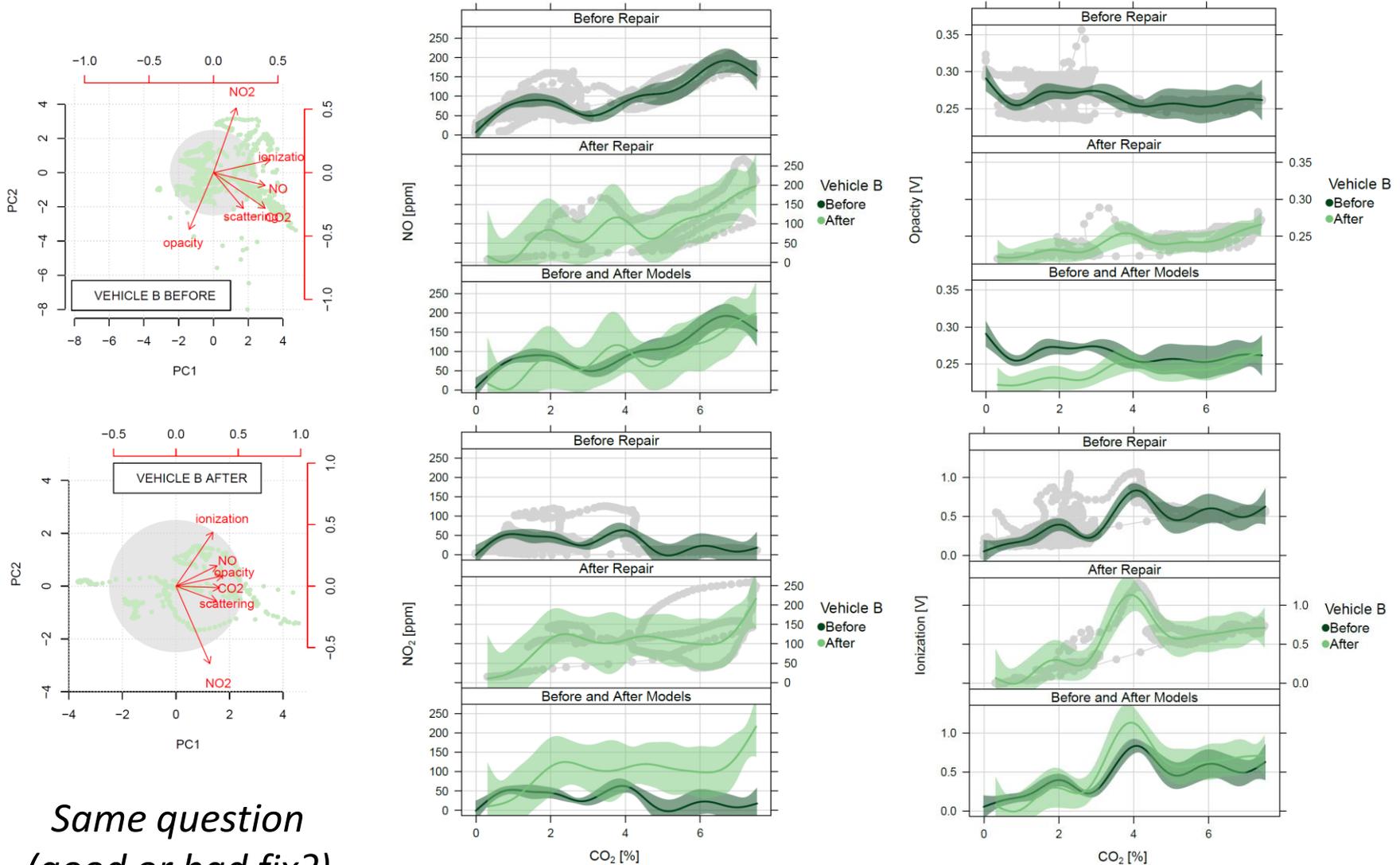


The better behaving vehicles tend to have
PCA profiles are more similar but more importantly less chaotic
... giving an early indication of further diagnostic potential



Vehicle B Before and After Repair

Diagnostics



*Same question
(good or bad fix?)*