

On-Board Sensing, Analysis, and Reporting (OSAR) Development and Application

PEMS 2022

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Presented By:

Dr. Kent Johnson kjohnson@cert.ucr.edu

Co-Authors Thomas D. Durbin, Georgios Karavalakis, Dr. Chengguo Li, and Dr. Mina Seo
www.cert.ucr.edu
(951) 781-5786

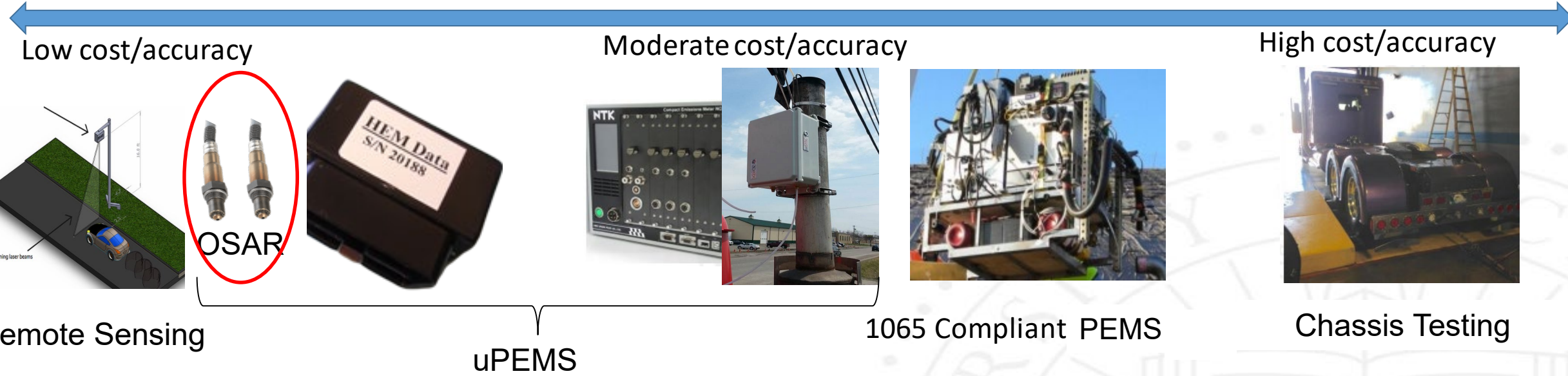
University of California, Riverside
Center for Environmental Research and Technology
(CE-CERT)

www.cert.ucr.edu

Background

- Reducing emissions from Heavy-Duty Diesel On-Road Vehicles and Off-Road Equipment.
- Sensor-based emissions monitoring systems have the potential to significantly improve our understanding of emissions from heavy-duty vehicles and equipment.
- CARB is implementing “Real Emissions Assessment and Logging (REAL)” requirements
 - Requires collection and storage of NO_x emission and fuel consumption data
- Given that sensors will play in CARB’s future regulatory programs, it is important that these sensors have high accuracy, stability, and durability.
 - Especially true as NO_x certification limits drop to levels of 0.05 to 0.02 g/bhp-hr

From The Laboratory to the Real World: A Vision of Data, Measurements, and Modeling with uPEMs – OSAR

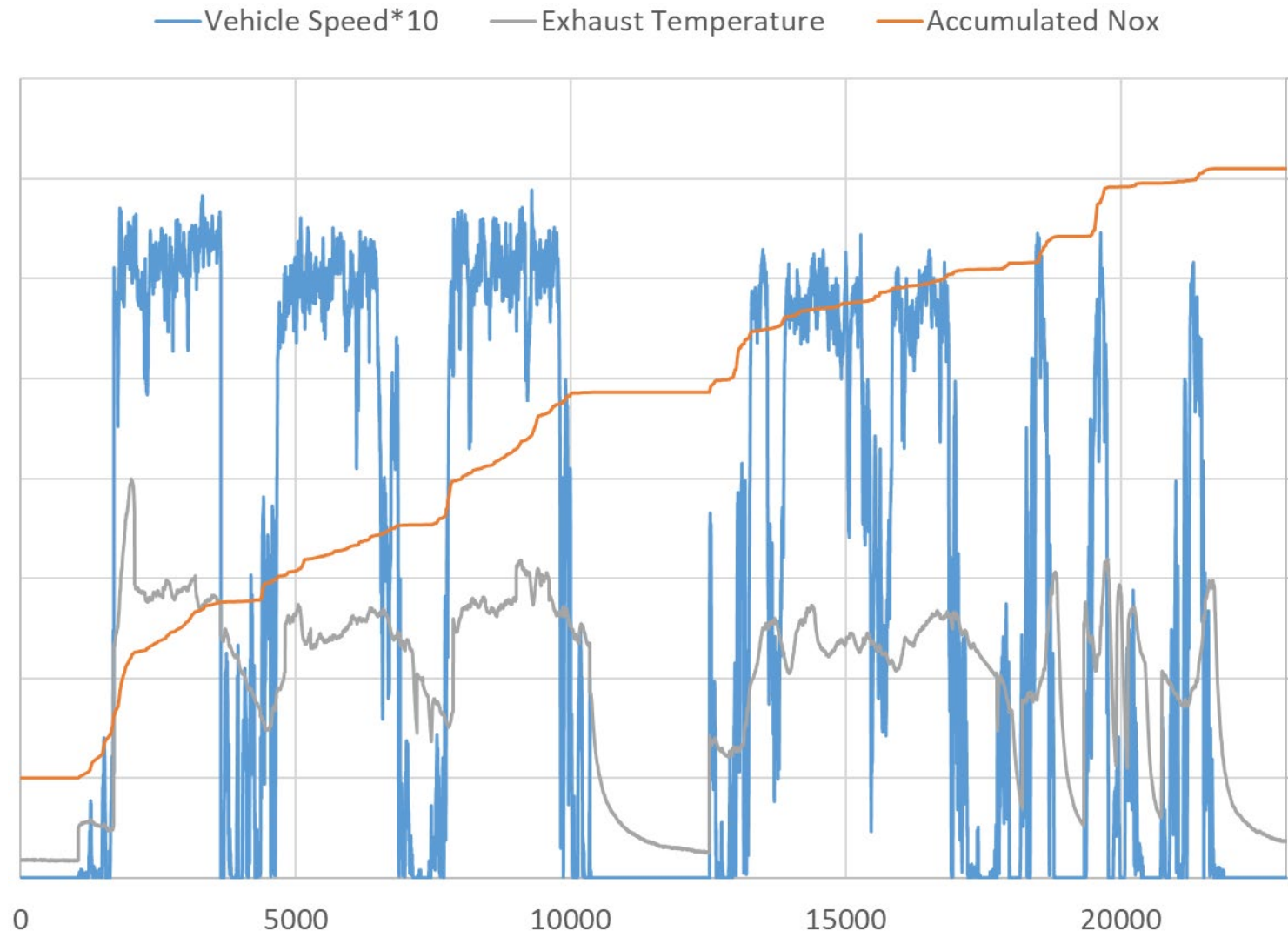


NEW METHODS OF EVALUATION

- Understand Inventory
- Take Advantage of Connected and Automated (Electric and Shared)

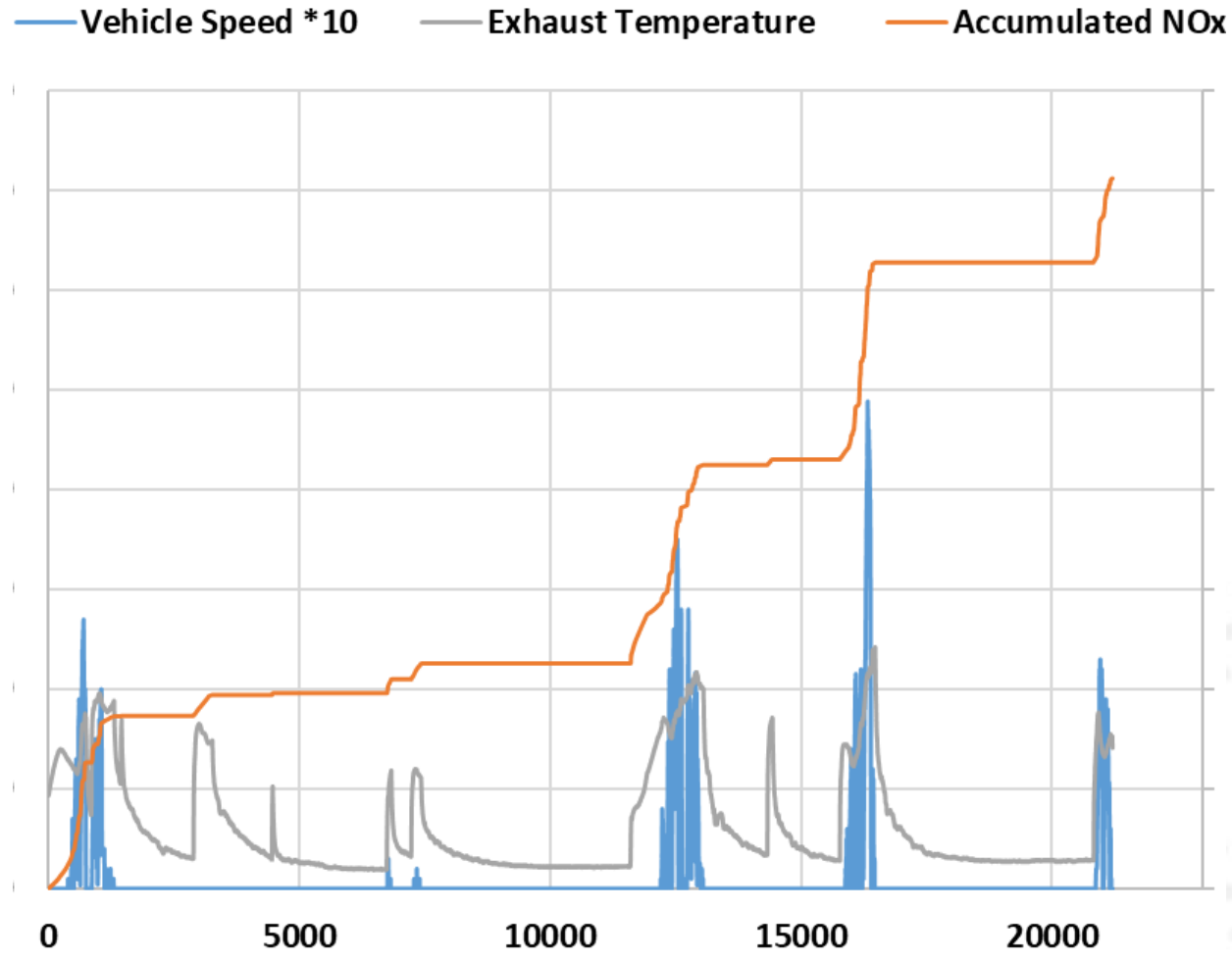
- Evaluate Conformity, Magnitude, and Suggest Change
- Consider new Drivetrains: Battery Electric, Hybrid Electric, and Fuel Cell

Local Goods Movement Vehicles Have Moderate Duty Cycles



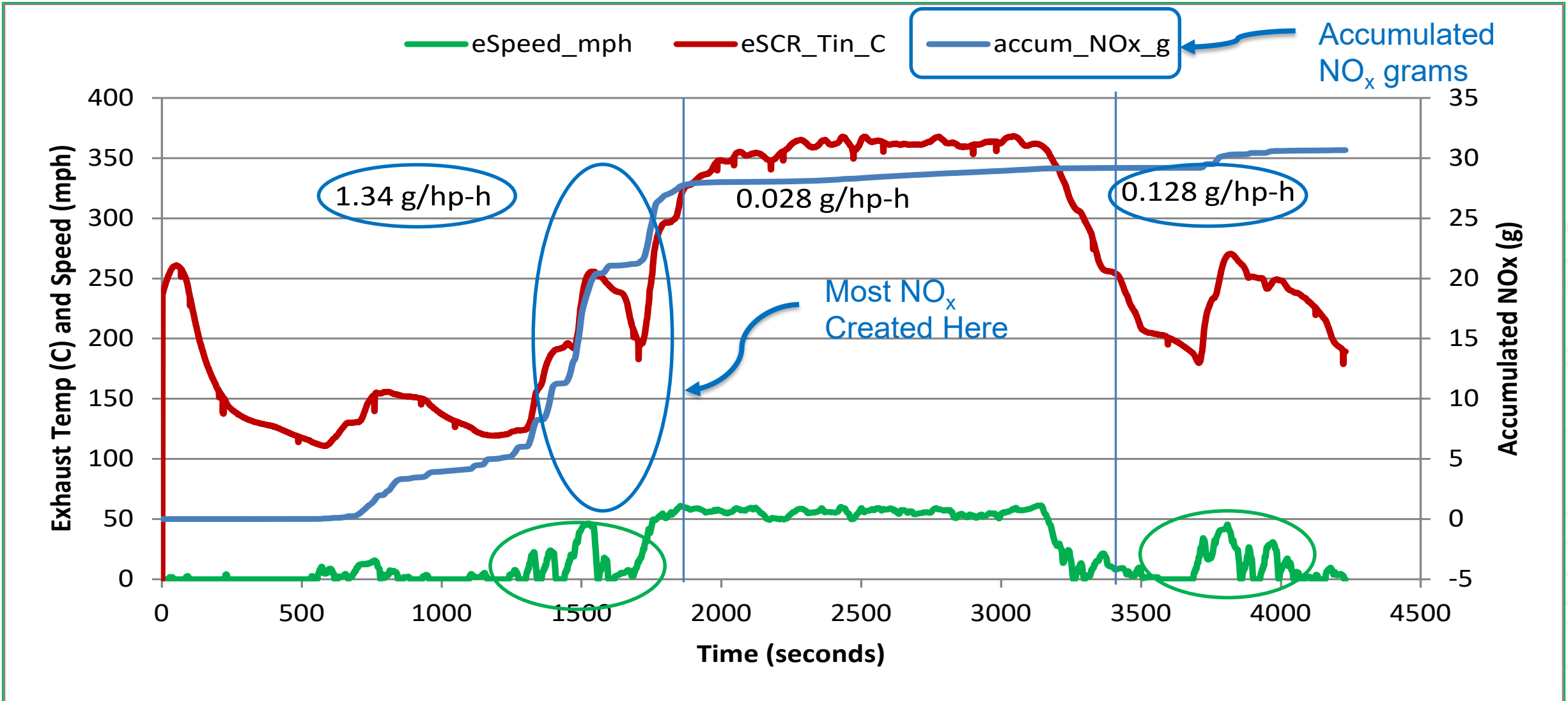
- ▶ Representative of HDIUT, may be slightly low since NTEs count are low.
- ▶ Binning methods may look reasonable.
- ▶ How significant is this data to the inventory?

Local Delivery Vehicles Have Very Low Duty Cycles

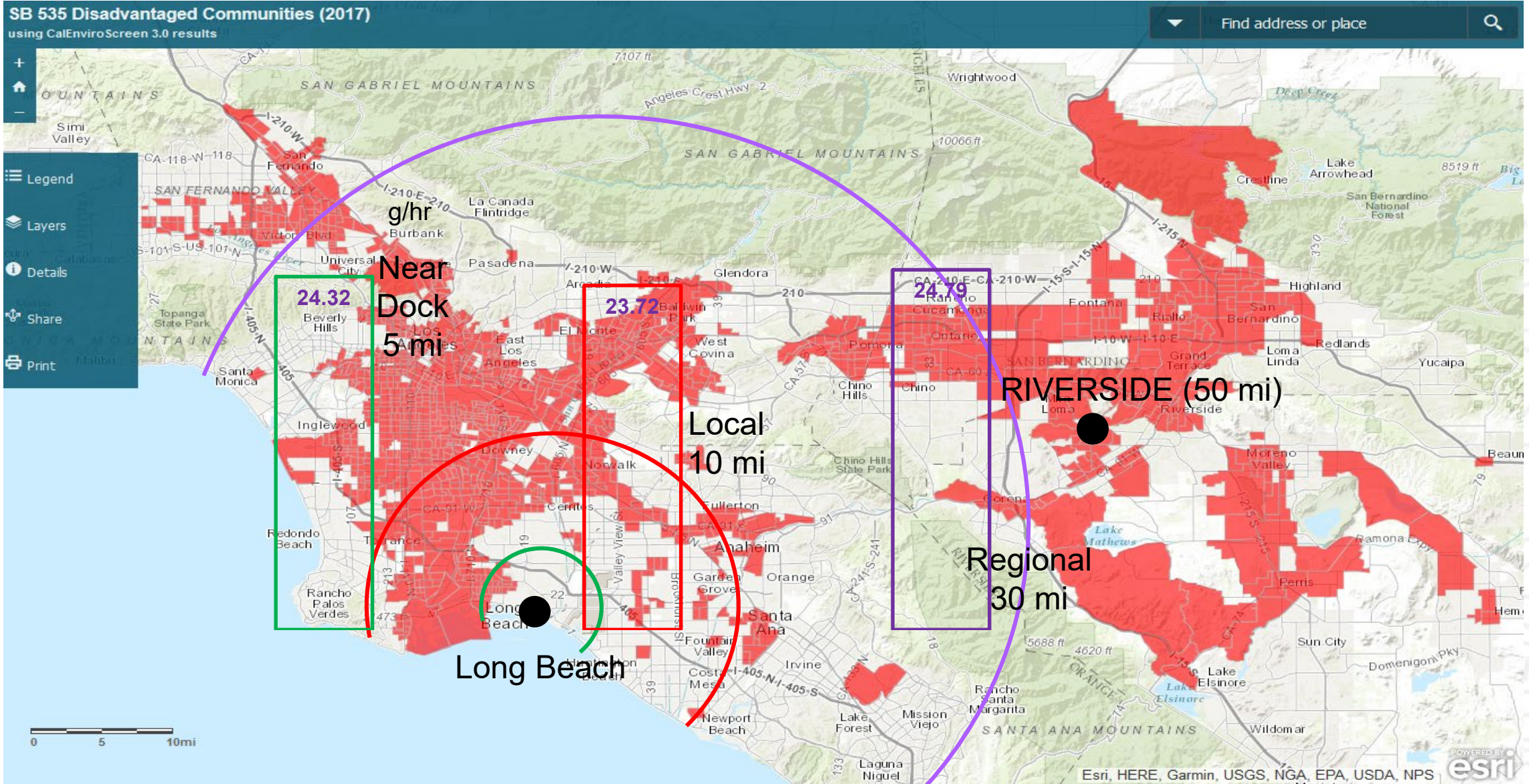


- ▶ Not found in the HDIUT program (No NTEs)
- ▶ What binning will represent this real data?
- ▶ How significant is this data to the inventory?

Higher Emissions Result from Real Operation

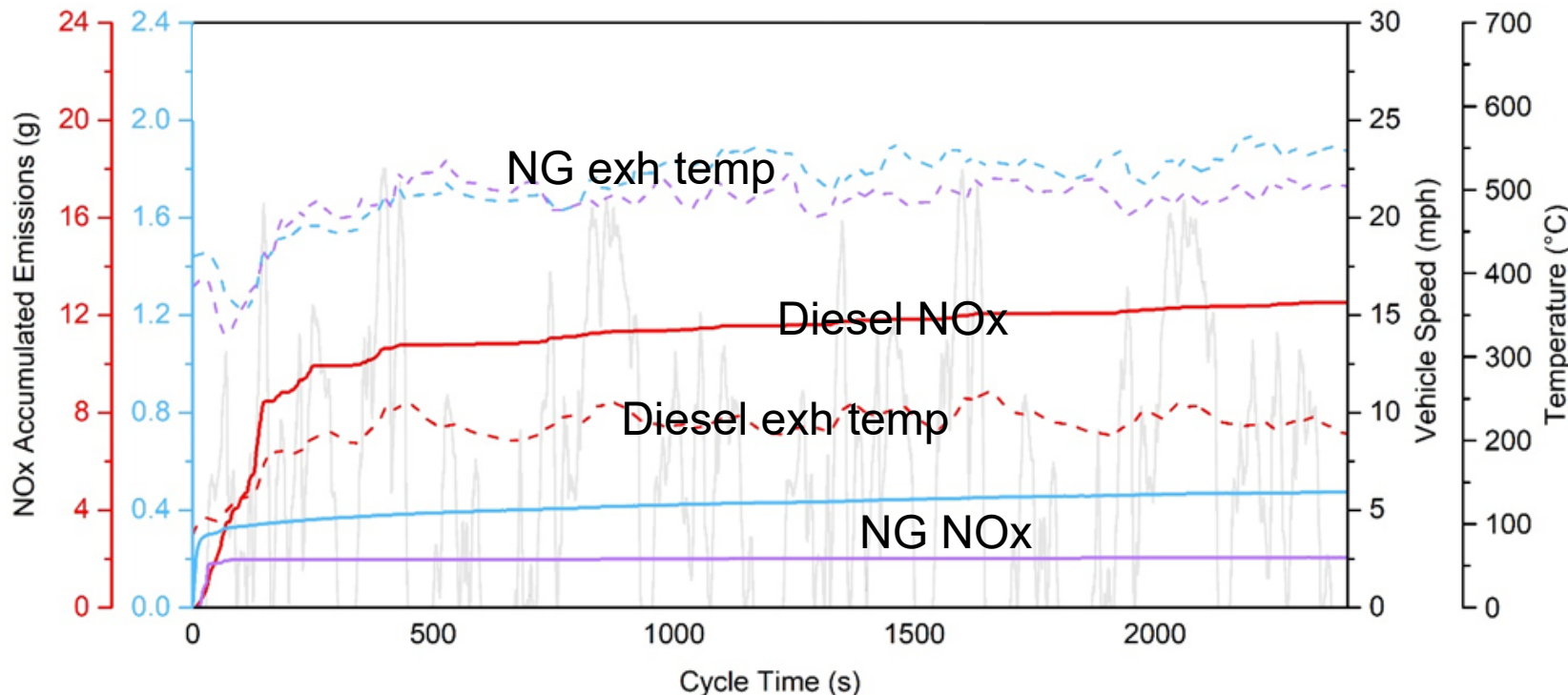


Real Emissions Impact Real Communities: Location Is Important



Chassis Cycles Can Really Impact the EF Reported

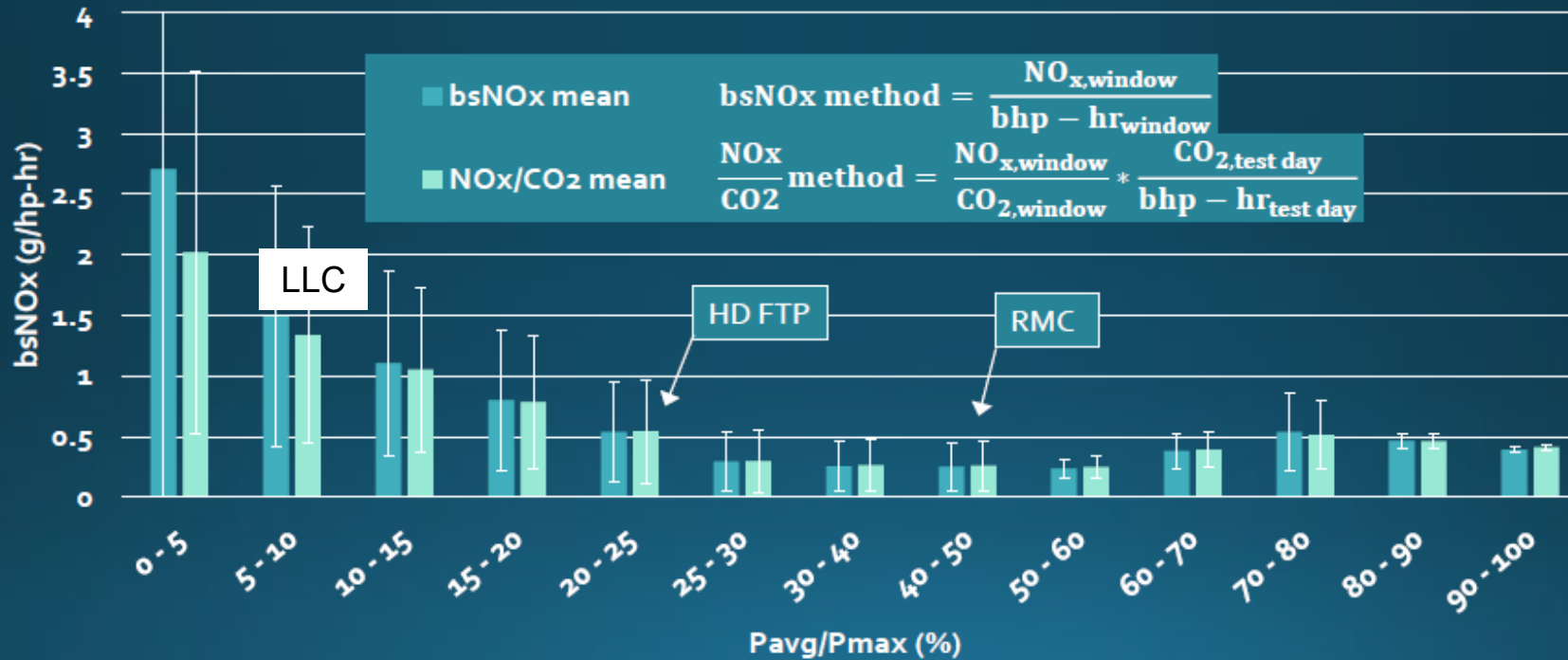
- More than 90% of the NO_x emissions for a 0.02 NG vehicle were in the first 50 seconds
- The Diesel took about 5 min to accumulate to 90% of the total mass and continued to accumulate over the test cycle and would be even higher if there were long periods of idle (as found with many real in-use test programs)



- If the test cycle were 4 hrs long (typical for a fleet), the emissions for the NG vehicle would **decreased** by a **factor of 6** where for the diesel it would only reduce by a factor of 2
- So what is important accuracy or continuous in-use measurements.

MOVES and EMFAC Models View SCR Diesels Like This

In-use Data

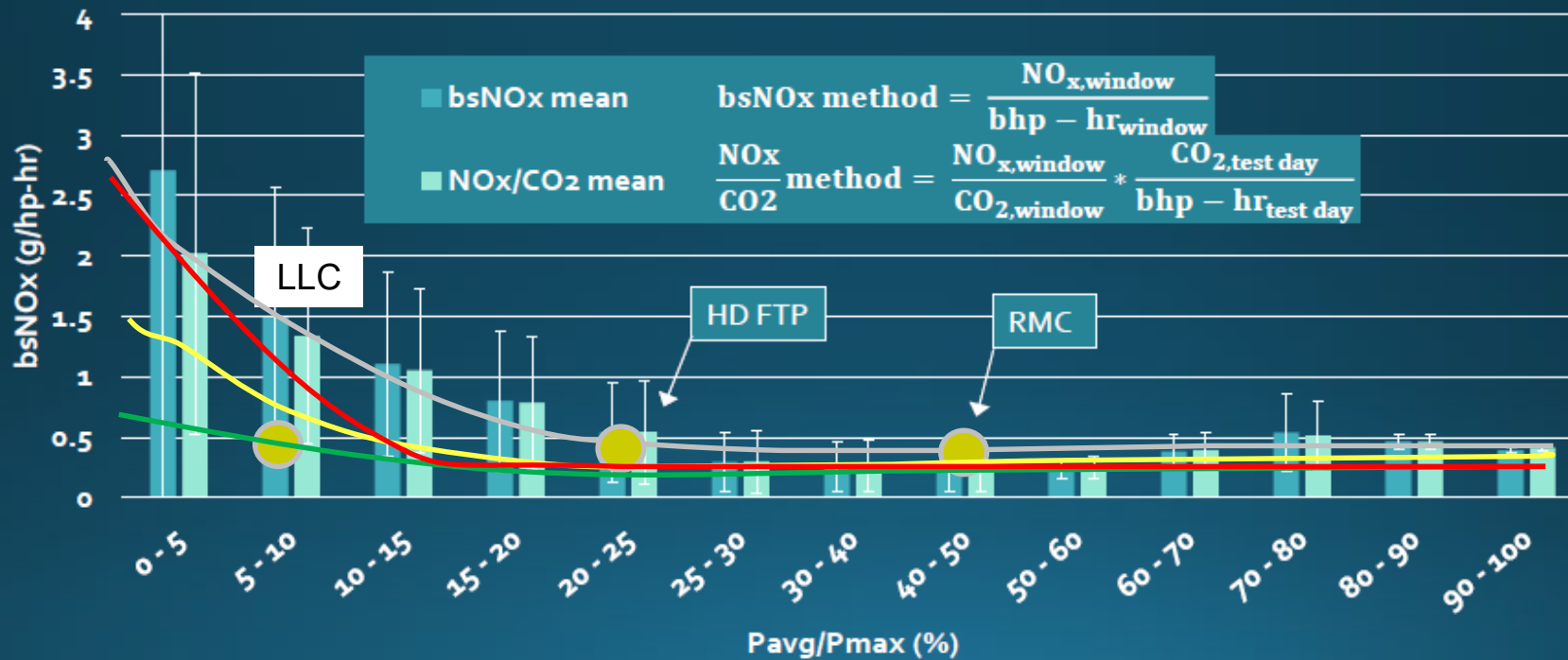


HHD with NO_x FEL ≤ 0.20 g/bhp-hr | 85 vehicles, 2.90 million windows

Work-windows are calculated over continuous seconds. Consecutive windows have overlapping seconds. Error bars are SD of the mean.

What Will the New Low Load Cycle (LLC) do to In-Use Binning

In-use Data



HHD with NO_x FEL ≤ 0.20 g/bhp-hr | 85 vehicles, 2.90 million windows

Work-windows are calculated over continuous seconds. Consecutive windows have overlapping seconds. Error bars are SD of the mean.

Objective

- To develop and implement a sensor-based emissions monitoring system.
 - On-board Sensing and Report (OSAR) system.
- To monitor NO_x and PM emissions from a small fleet of Heavy-Duty Diesel Vehicles (HDDVs) using sensors.
- To evaluate the potential effectiveness of sensor-based monitoring.
- Data analysis of real-world data sets to obtain emissions profiles on a real-time and spatial basis

OSAR System Development



NOx Sensor

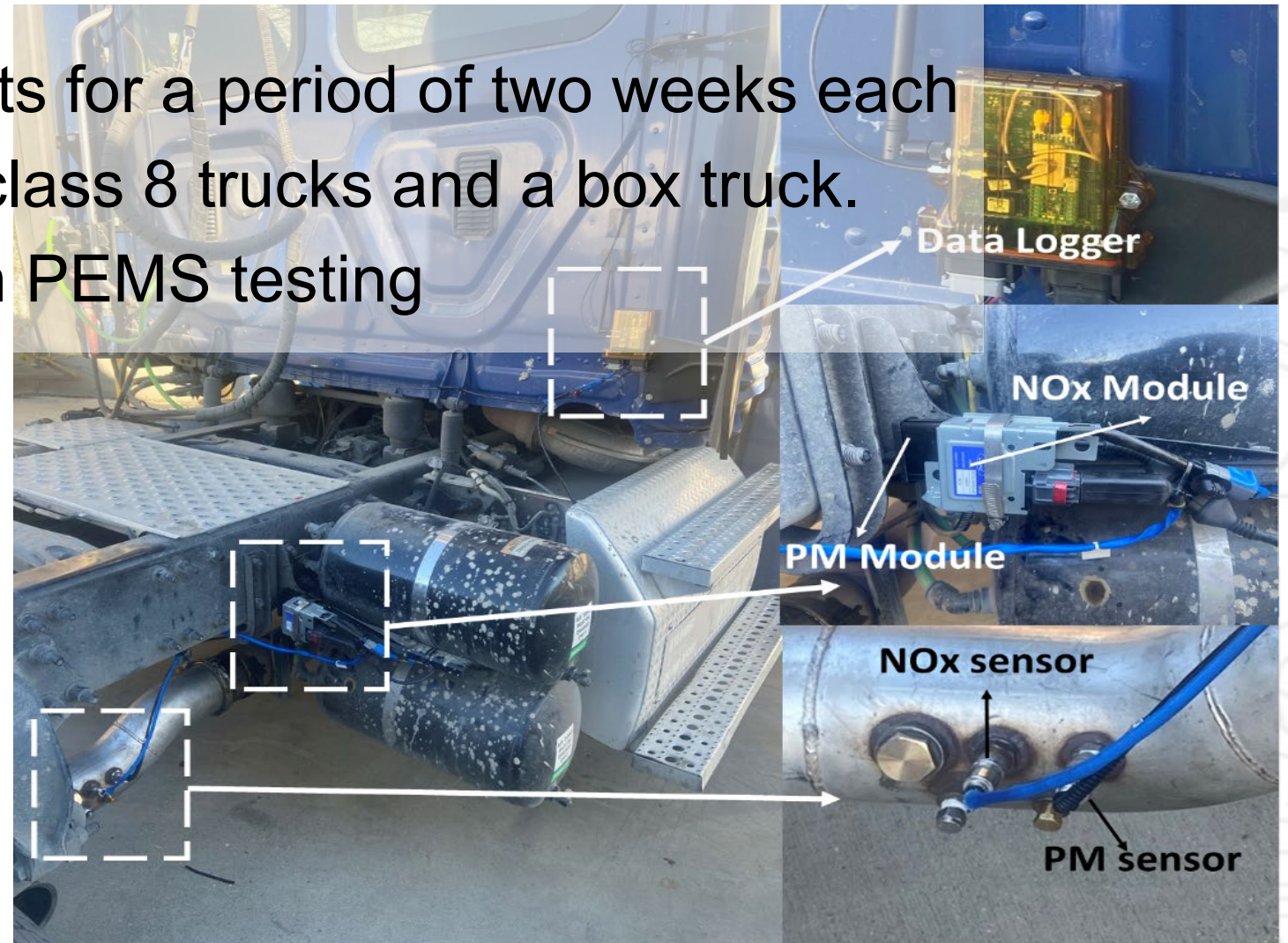


PM Sensor



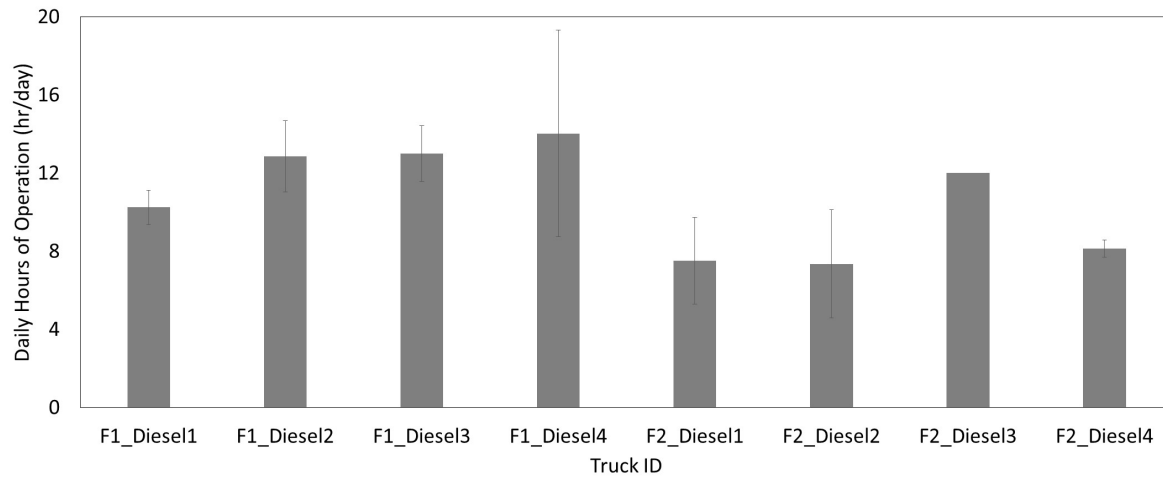
Initial Field Deployment of OSAR Systems

- › 8 vehicles from two fleets for a period of two weeks each
- › Test vehicles included class 8 trucks and a box truck.
- › Cross comparisons with PEMS testing



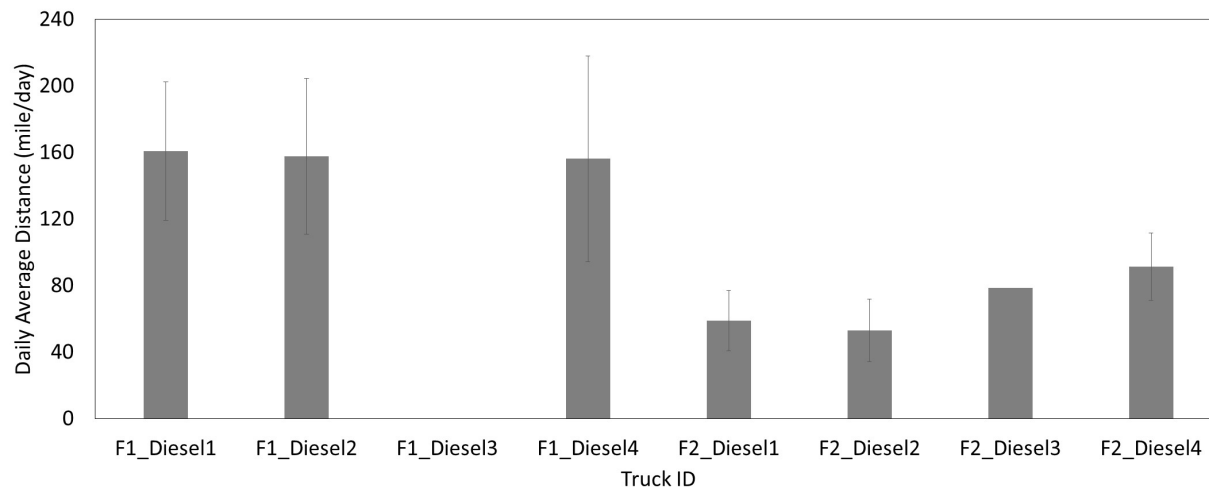
Activity Patterns

Daily Hours of Operation

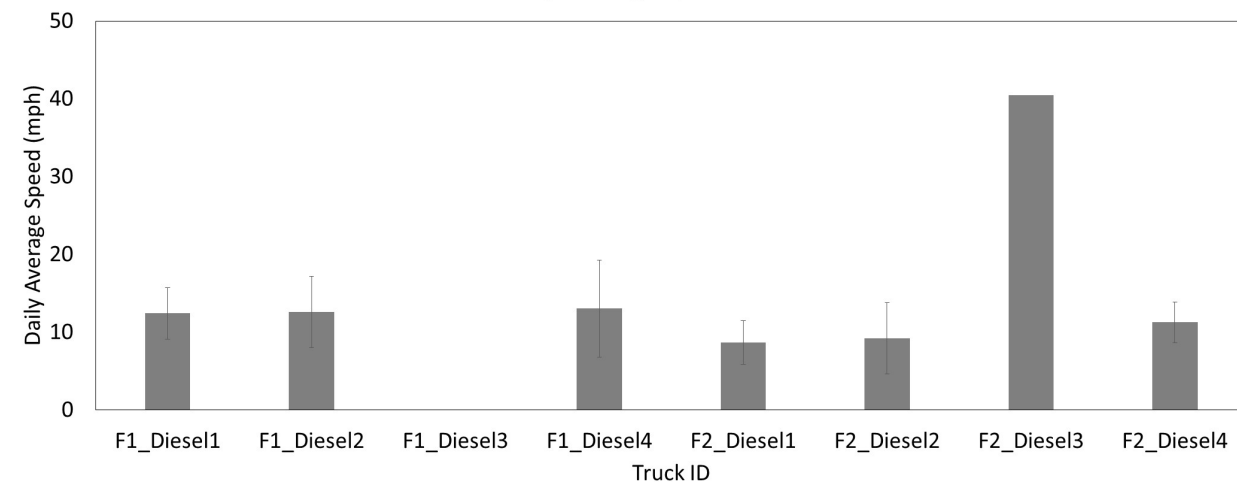


- ▶ Average Hours of Operation per Day
 - ▶ 7.4 (F2_Diesel2) ~ 14.0 (F1_Deisel4) hr/day
- ▶ Average Distance per Day
 - ▶ 52.8 (F2_Diesel2) ~ 160.8 (F1_Diesel1) mile/day
- ▶ Daily Average Speed
 - ▶ 8.7 (F2_Diesel1) ~ 40.5 (F2_Diesel3) mph

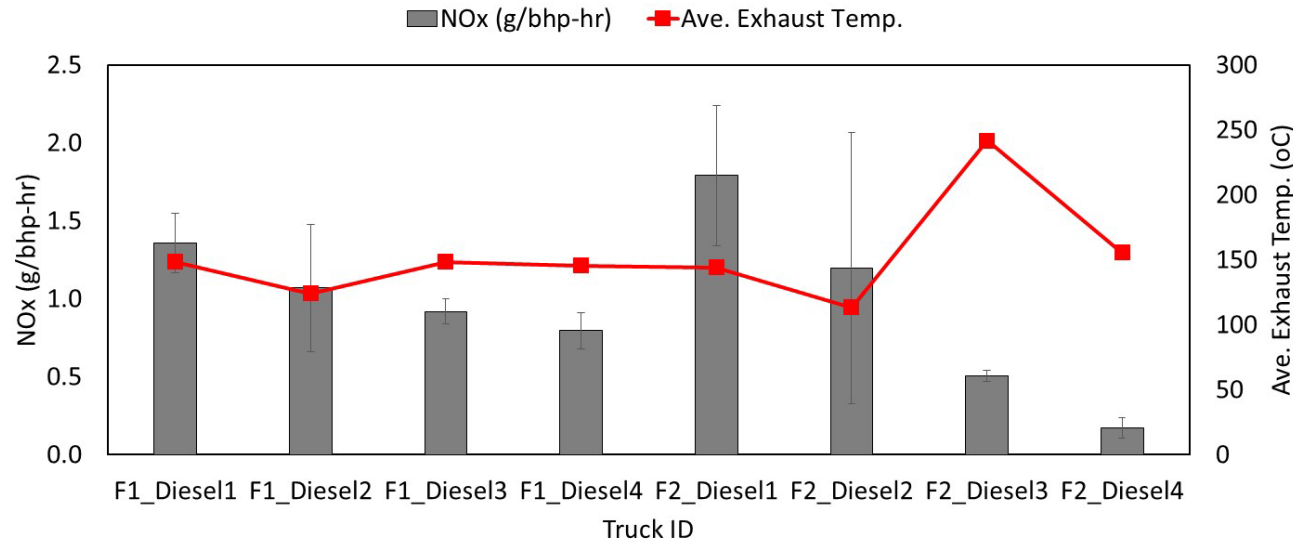
Daily Average Distance



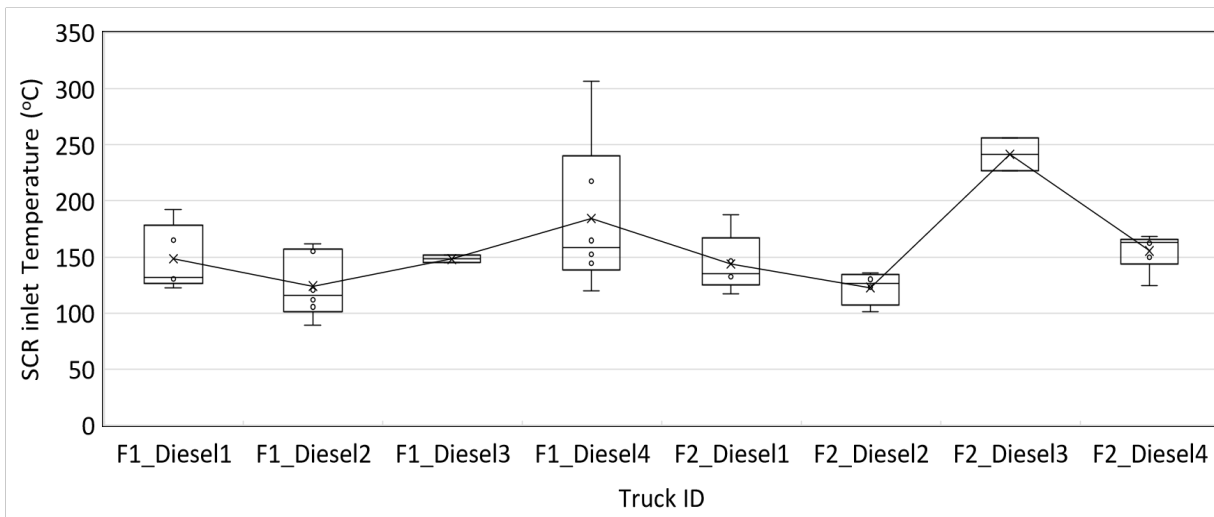
Daily Average Speed



Integrated NOx Emissions

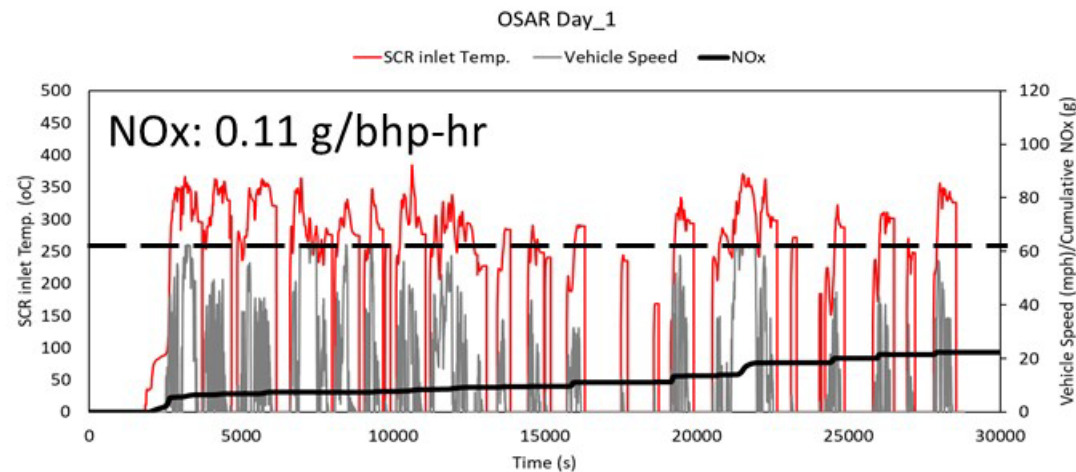
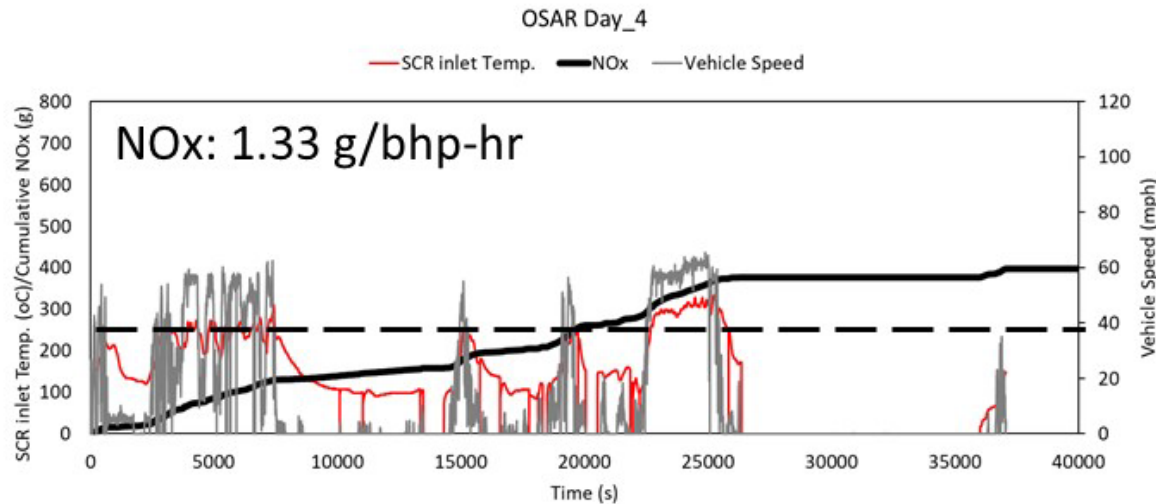


- Brake-specific, distance-specific NOx emissions
 - With corresponding average exhaust temperatures for the vehicles



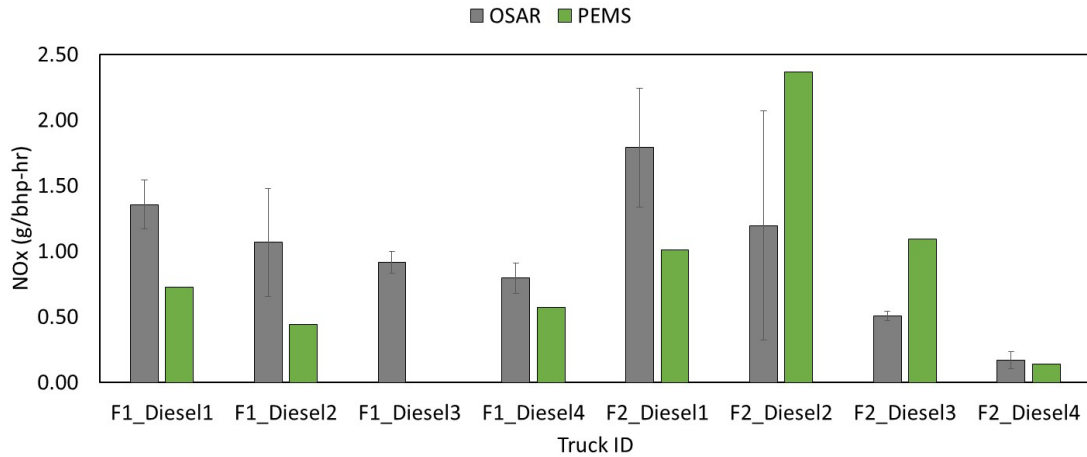
- On a g/bhp-hr basis
 - 0.17 (F2_Diesel4) ~ 1.79 (F2_Diesel1)
- Exhaust temperatures ranged
 - 113 to 245 °C

NOx Emissions Change by a Factor of 10 Between Cycles

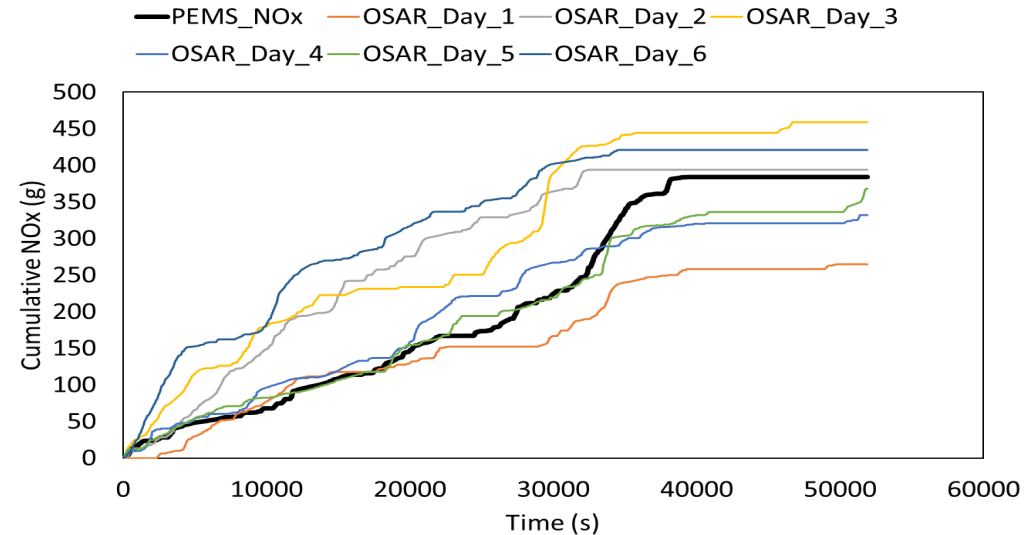
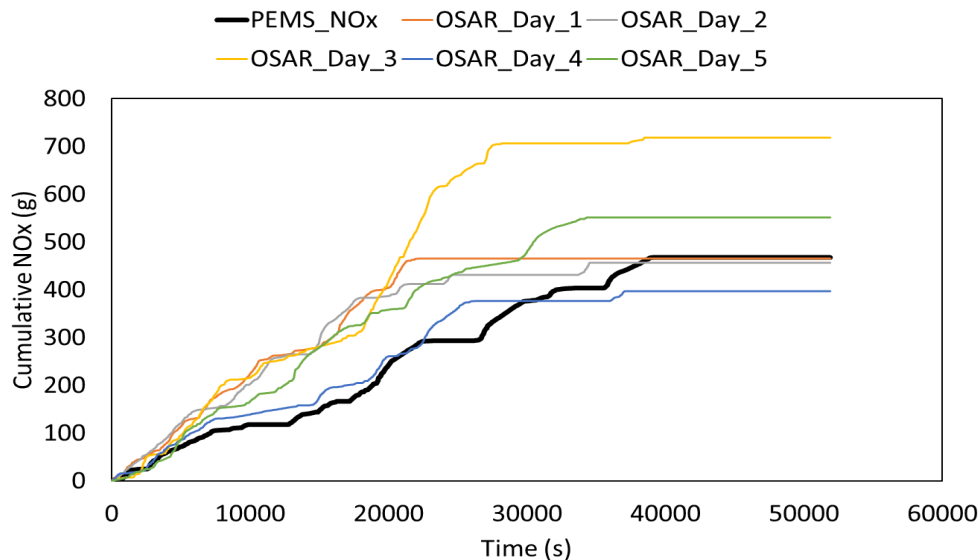


- ▶ Accumulated NOx with Vehicle speed and SCR inlet temperature
 - ▶ Graphs for NOx 0.11 & 1.33 g/bhp-hr
- ▶ Average NOx emissions change for different days.
 - ▶ Route for vehicles was usually different from day to day operation,
 - ▶ This impacts the SCR temperature and the formation of NOx emissions.

NOx Emissions – Comparisons with PEMS Data



- ▶ The emissions change between days on the same vehicle.
- ▶ PEMS data presented the emissions measured by one day.
- ▶ OSAR data showed several days continuous monitoring results.



EPA 3 BIN Analysis: Selected OSAR and PEMS data

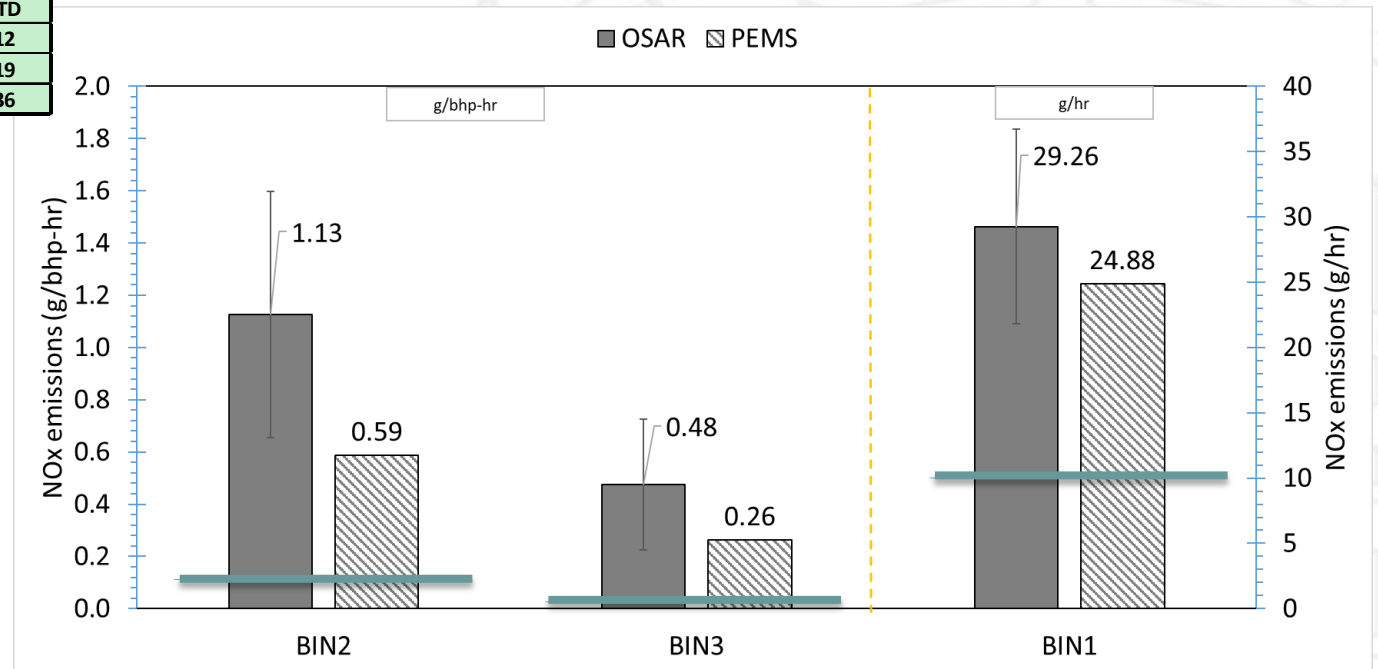
Bin			PEMS	OSAR					OSAR_AVE	
				day1	day2	day3	day4	day5	Ave. NOx	STD
BIN1	Idle	g/hr	24.88	21.00	35.74	22.32	30.06	37.20	29.26	7.45
BIN2	MedLoad	g/bhp-hr	0.59	0.68	1.77	0.78	0.94	1.47	1.13	0.47
BIN3	HighLoad	g/bhp-rh	0.26	0.46	0.91	0.31	0.33	0.36	0.48	0.25

Bin			PEMS	OSAR					OSAR_AVE	
				day1	day2	day3	day4	day5	Ave. NOx	STD
BIN1	Idle	Hp	12.11	5.21	8.52	7.63	11.03	10.87	8.65	2.42
BIN2	MedLoad	Hp	59.64	58.49	39.81	53.04	45.36	45.55	48.45	7.32
BIN3	HighLoad	Hp	116.96	163.14	166.50	137.38	137.61	135.98	148.12	15.30

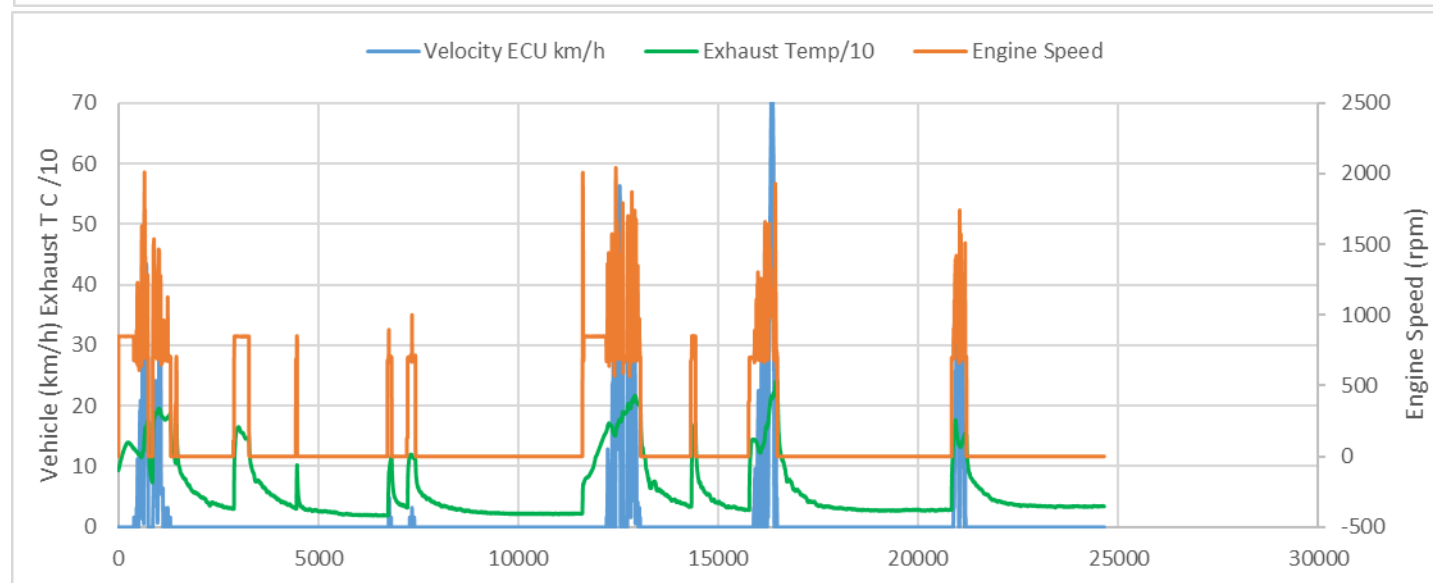
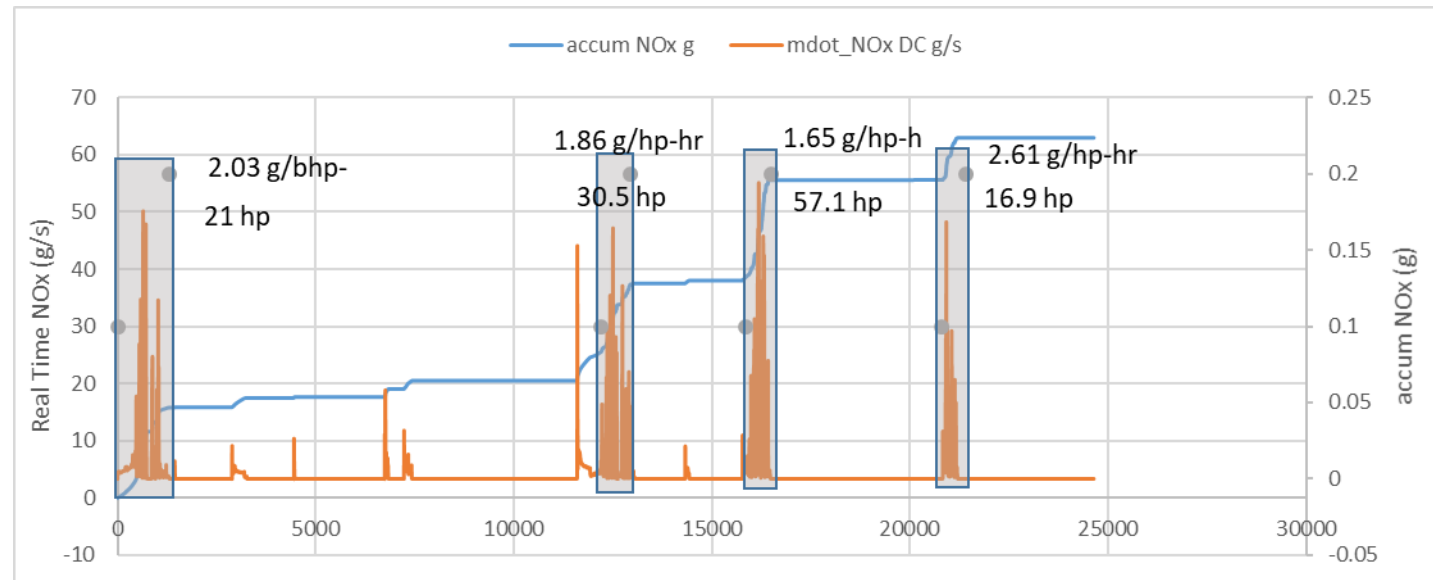
Bin			PEMS	OSAR					OSAR_AVE	
				day1	day2	day3	day4	day5	Ave. NOx	STD
BIN1	Idle	Deg C	155	132	152	156	130	133	141	12
BIN2	MedLoad	Deg C	224	221	202	240	192	201	211	19
BIN3	HighLoad	Deg C	307	336	387	354	297	309	336	36

- In-Use 3 BIN analysis starts in MY 2024 with full phase in by 2030
- The 3 BIN includes Idle/low load, medium load, an high load

- New regulations should show significant reductions for all three BINs
- Figures show variability between days not measurement uncertainty



Binning Based on Physical Activity: Return To Service



- Bin 1 cold start (time and/or CO2)
- Bin 2 idle
 - (no vehicle speed and > 5 min)
- Bin 3, 4, and 5 return to service
 - Bin 3 Load 0-5%
 - Bin 4 Load 5-10%
 - Bin 6 Load 10-20%
 - Bin 7 Load >20%
- Bin 7 and 8 higher loads
 - Bin 6 CO2 method 10-30%
 - Bin 7 CO2 method >30%

Next Steps

- › OSAR systems will be redeployed in the field
 - › An additional 2 months of data collection for one project
 - › An additional 10 months of data collection for another project
- › Additional projects
 - › Sensor development project
 - › Evaluate state-of-art and advanced NO_x sensors, PM, and others
 - › Deploying on 100 HDDVs & 20 Off-road diesel engines for one month
 - › Deploying on 15 HDDVs and 15 ORDEs for a year
 - › Deploying on 40 HDDVs for a year
- › Data analysis
 - › Binning method development
 - › Online web server visual aid system