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

PEMS 2022

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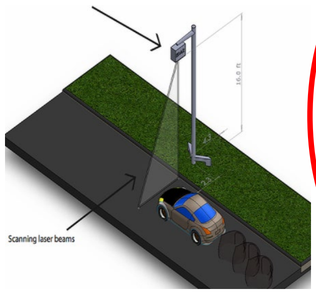
Background

- 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 NOx 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 NOx 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

Low cost/accuracy | Moderate cost/accuracy | High cost/accuracy



OSAR



Remote Sensing

uPEMS

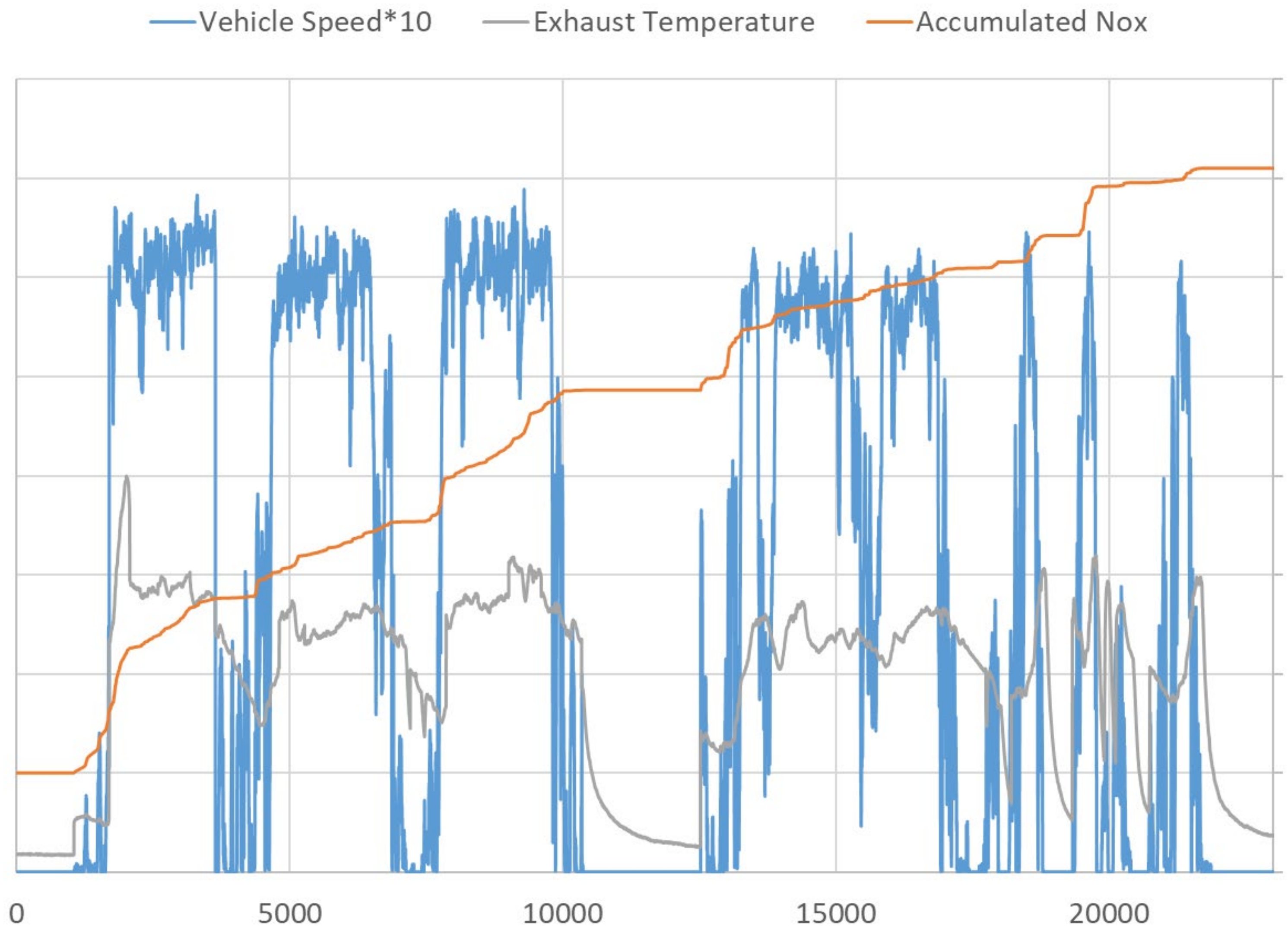
1065 Compliant PEMS

Chassis Testing

NEW METHODS OF EVALUATION

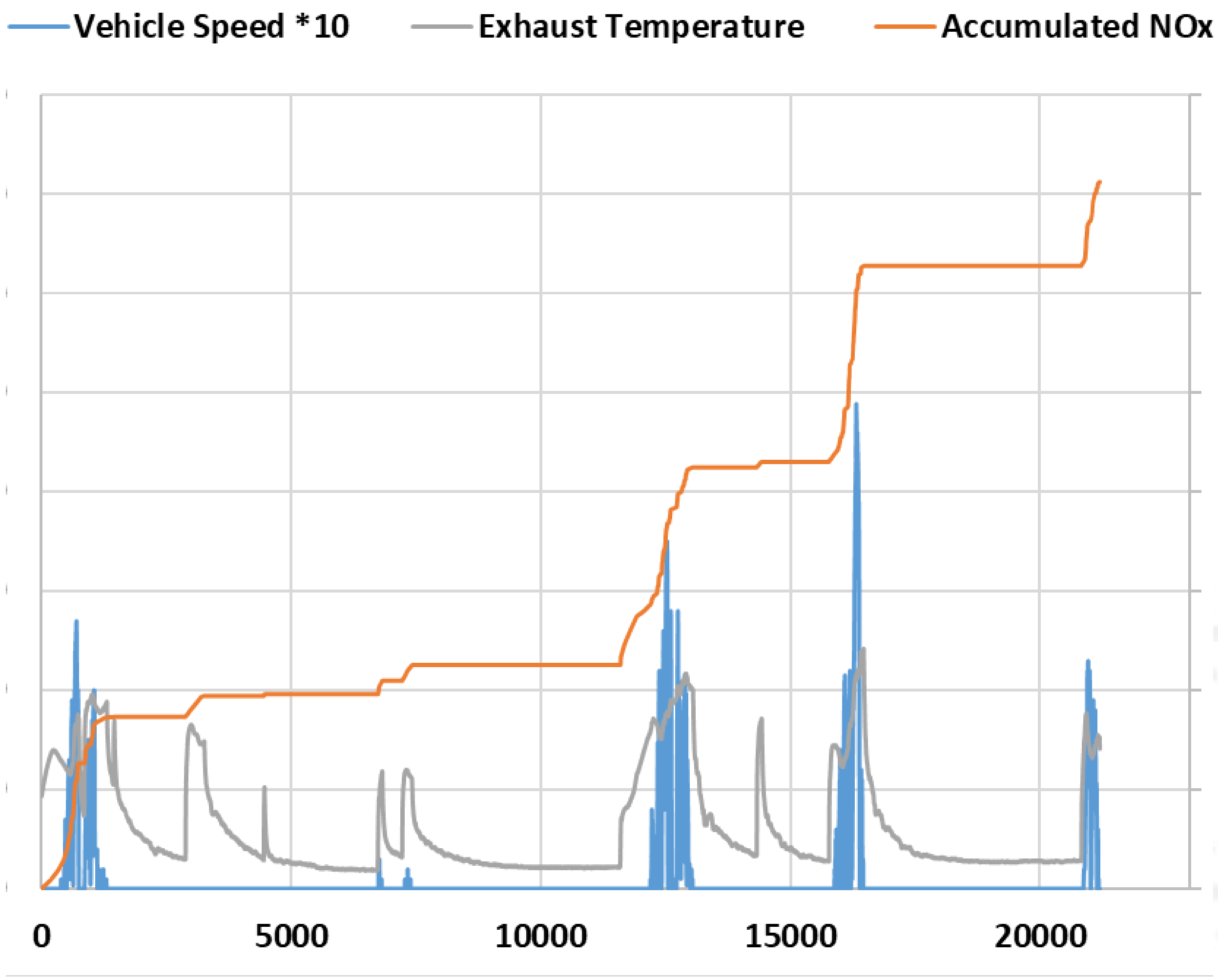
- Understand Inventory
- Take Advantage of Connected and Automated (Electric and Shared)
- Evaluate Conformity, Magnitude, and Suggest Change
- Consider new Drivetrains: Battery Electric, Hybrid Electric, and Fuel Cell

Local Goods Movement Vehicles Have Moderate Duty Cycles



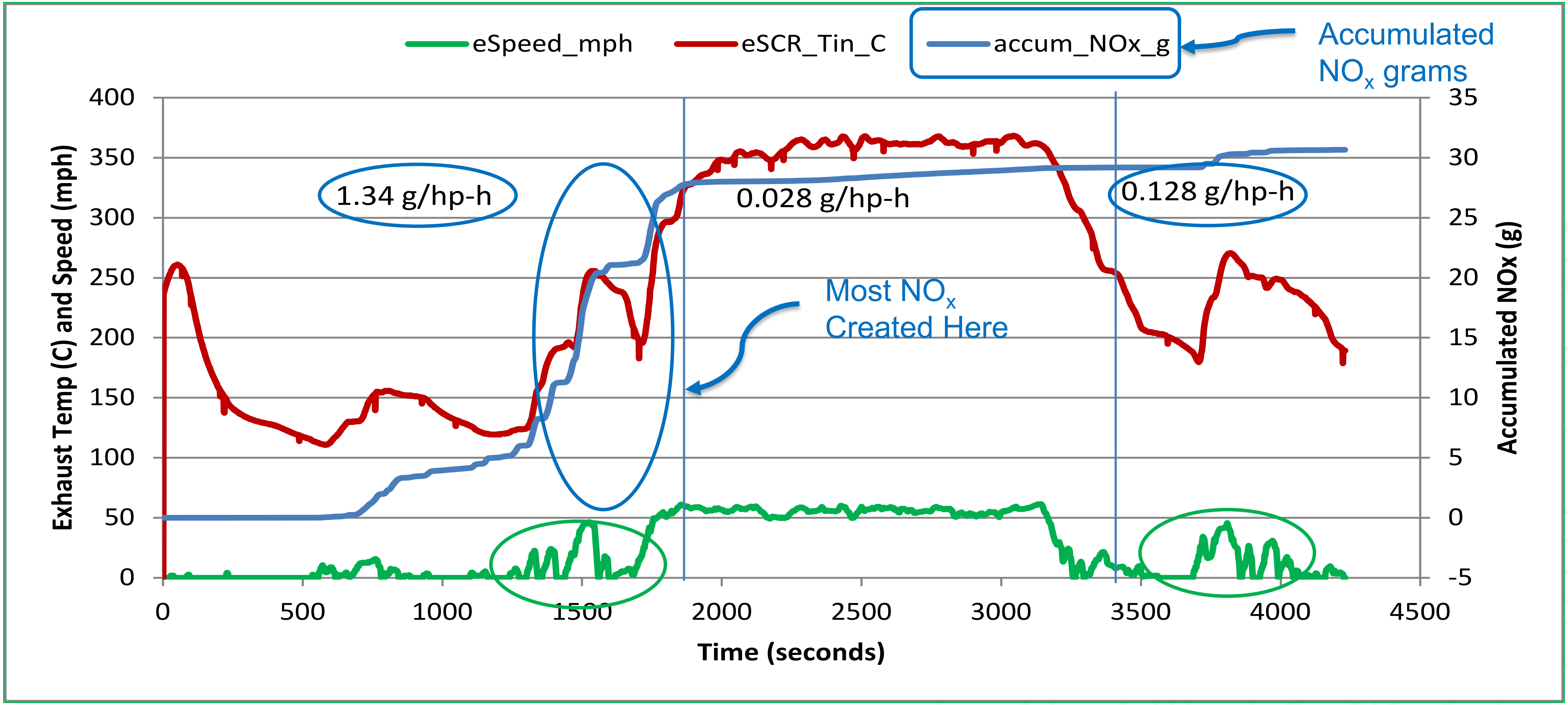
- Representative of HDIUT, may be slightly low since NTEs count are low.
- Binning methods may look reasonable.
- How significant is this data to the inventory?

Local Delivery Vehicles Have Very Low Duty Cycles



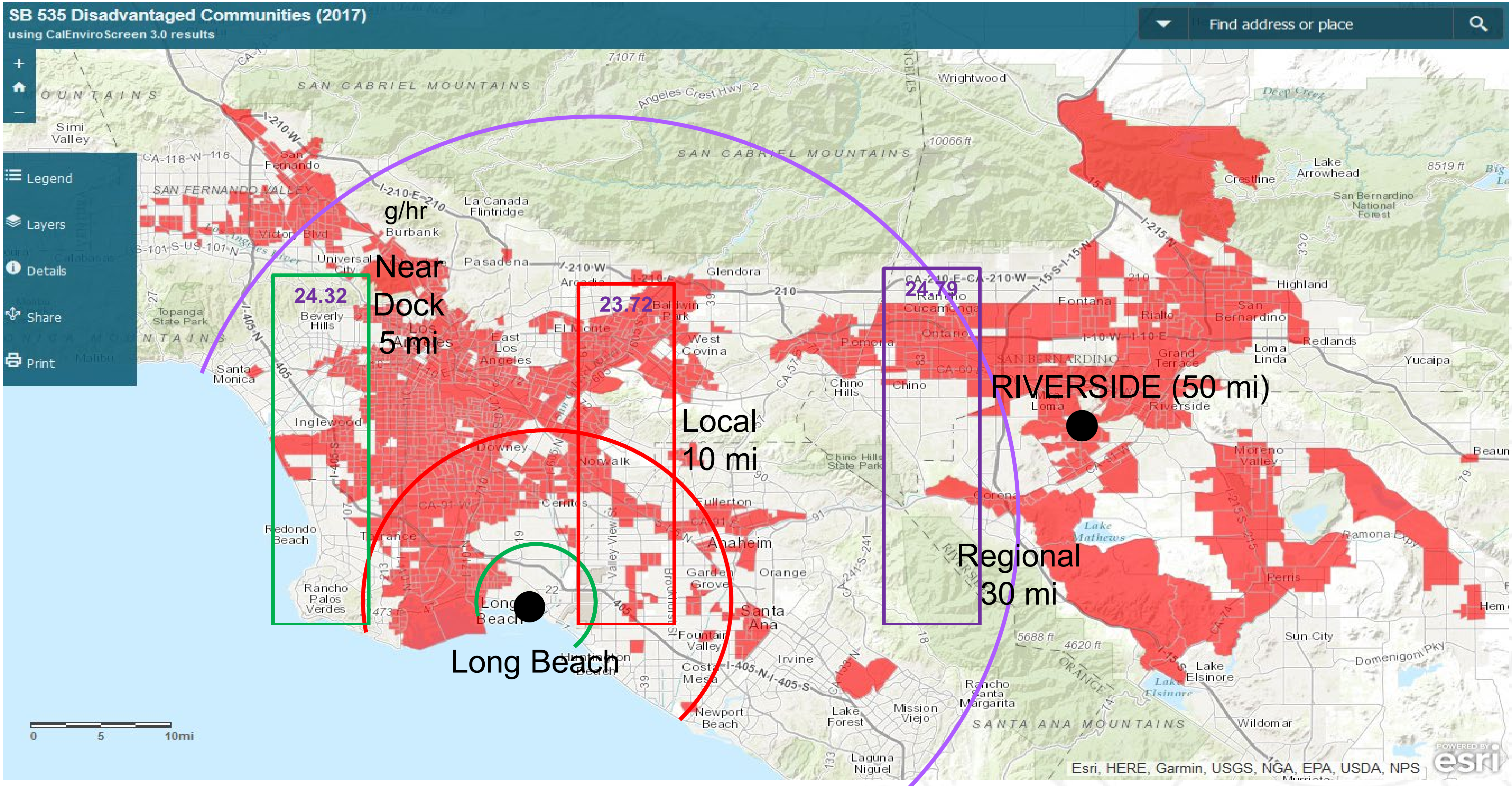
- Not found in the HDIUT program (No NTEs)
- What binning will represent this real data?
- How significant is this data to the inventory?

Higher Emissions Result from Real Operation



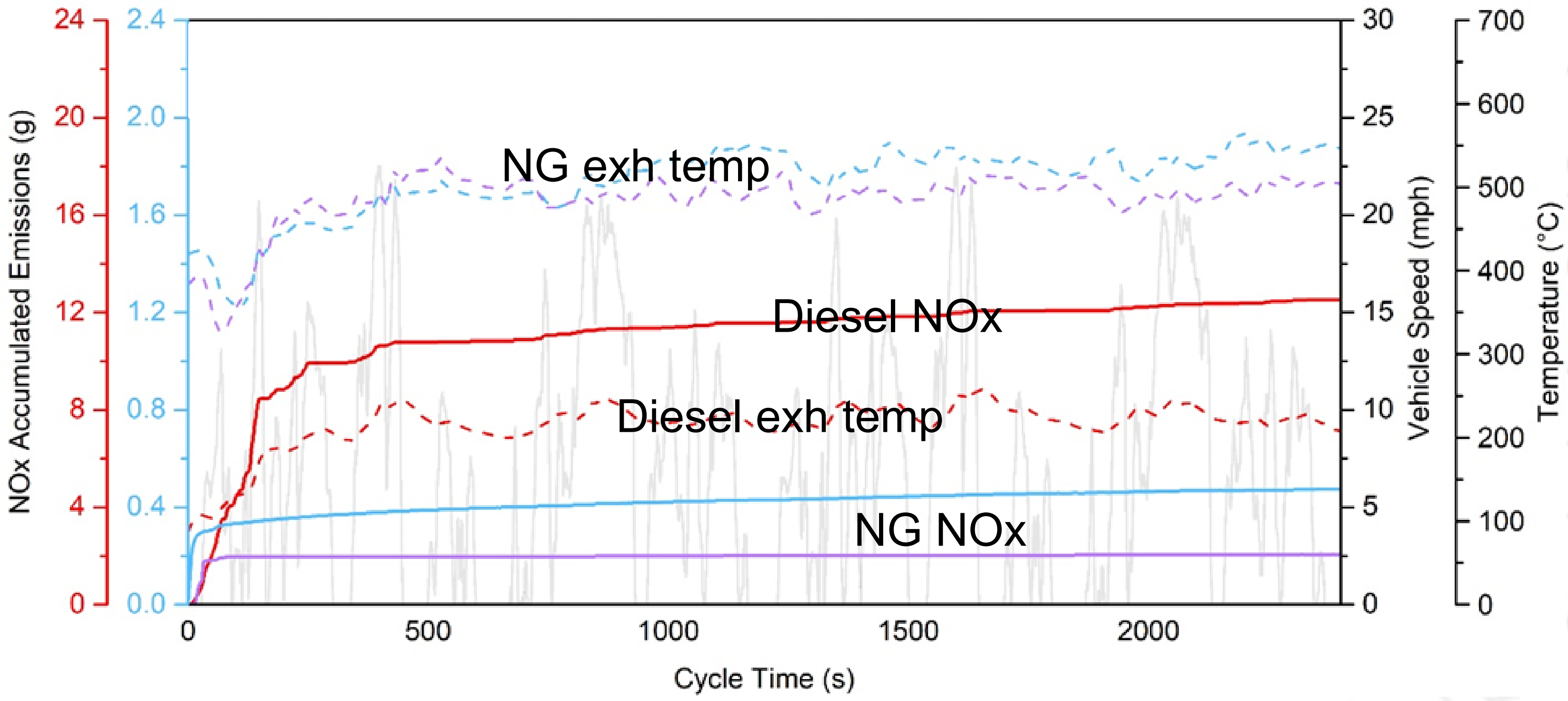
Source: UCR Miller et al (2013), Final report to SC-AQMD and CWI "In-Use Emissions Testing and Demonstration of Retrofit Technology for Control of On-Road Heavy Duty Engines", Sep 2013

Real Emissions Impact Real Communities: Location Is Important



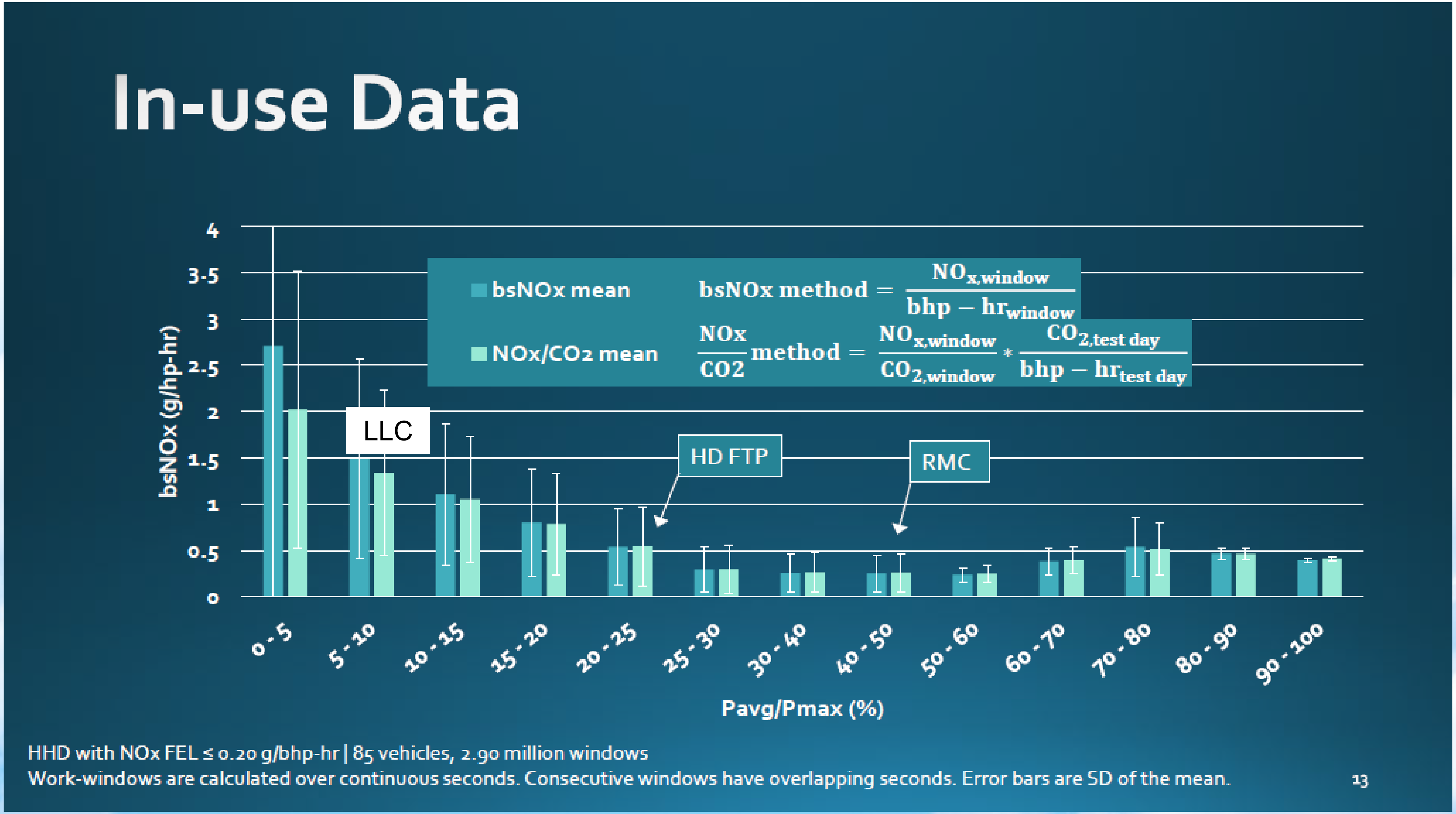
Chassis Cycles Can Really Impact the EF Reported

- More than 90% of the NOx 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)



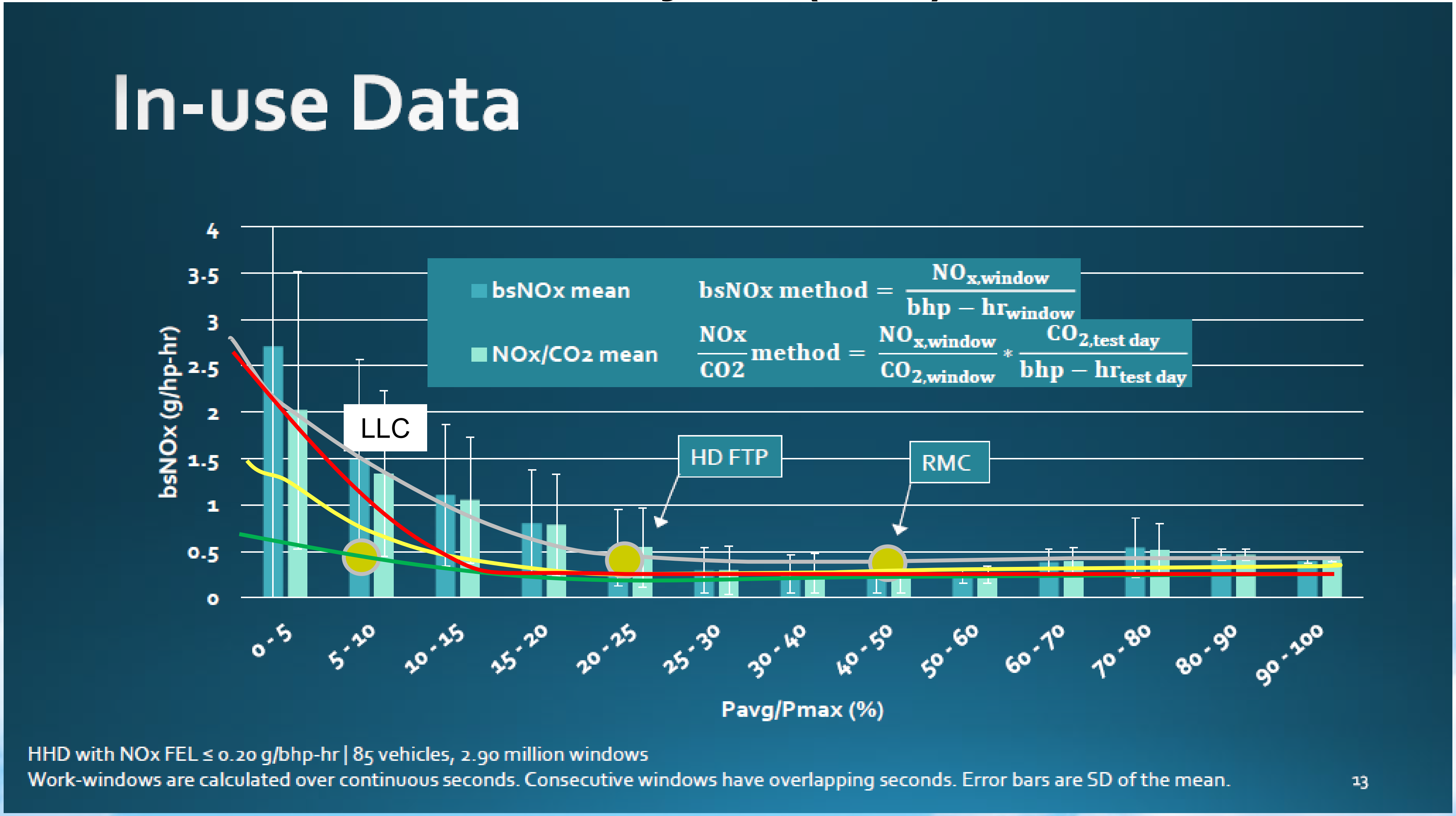
- If the test cycle were 4 hrs long (typical for a fleet), the emissions for the NG vehicle would **decreased** by a **factor of 6** where for the diesel it would only reduce by a factor of 2
- So what is important accuracy or continuous in-use measurements.

MOVES and EMFAC Models View SCR Diesels Like This



Source: James Sanchez EPA's Cleaner Trucks Initiative ERC 2019 Symposium

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



Source: Modified by UCR from James Sanchez EPA's Cleaner Trucks Initiative ERC 2019 Symposium

Objective

- To develop and implement a sensor-based emissions monitoring system.
  - On-board Sensing and Report (OSAR) system.
- To monitor NOx 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

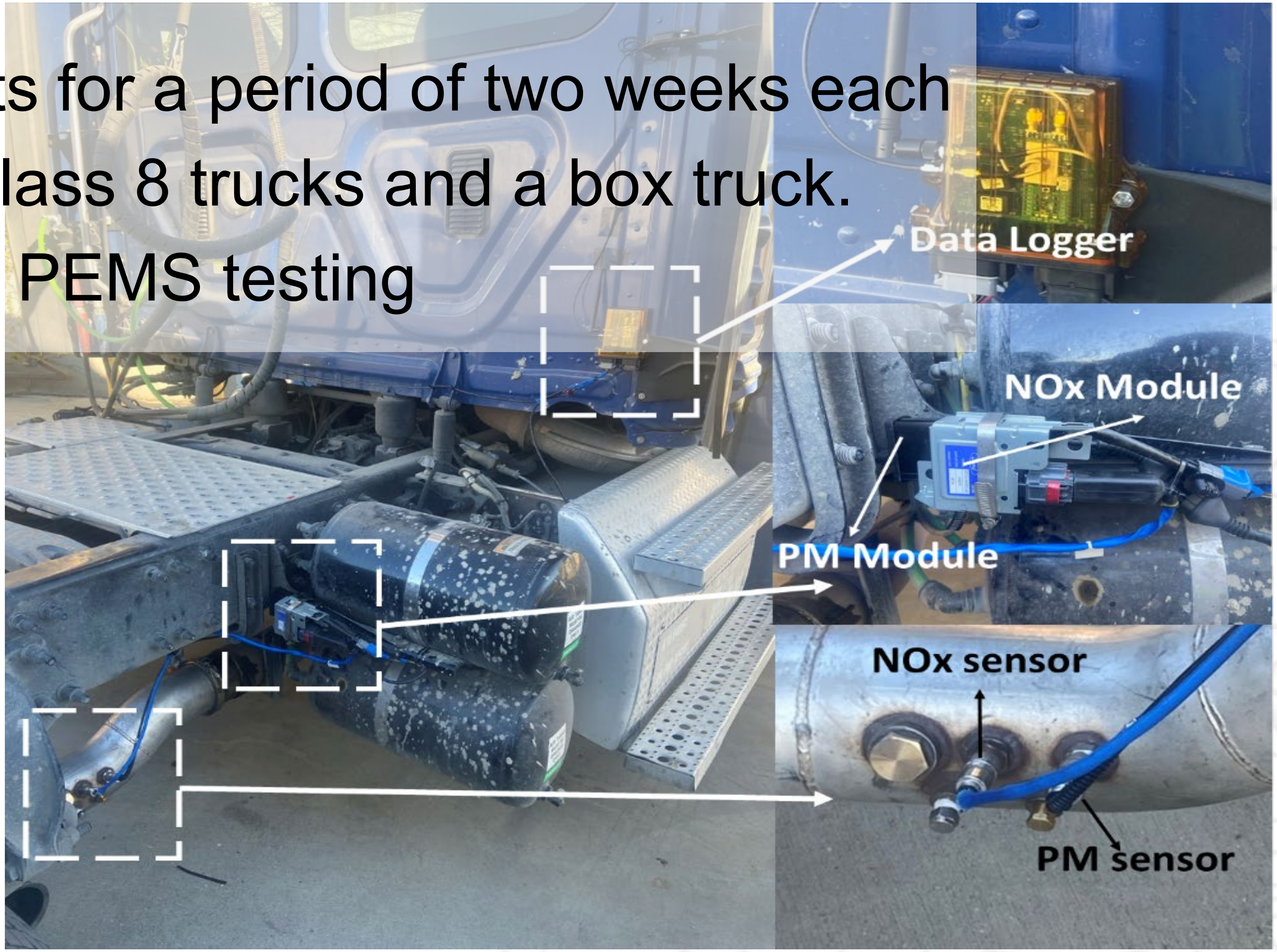
OSAR System Development

NOx Sensor

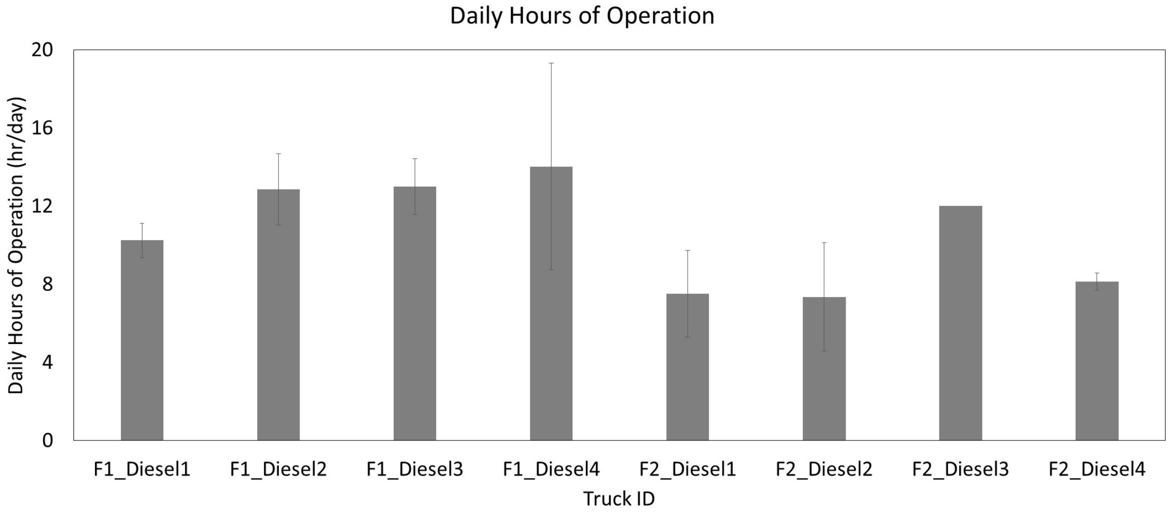
PM Sensor

Initial Field Deployment of OSAR Systems

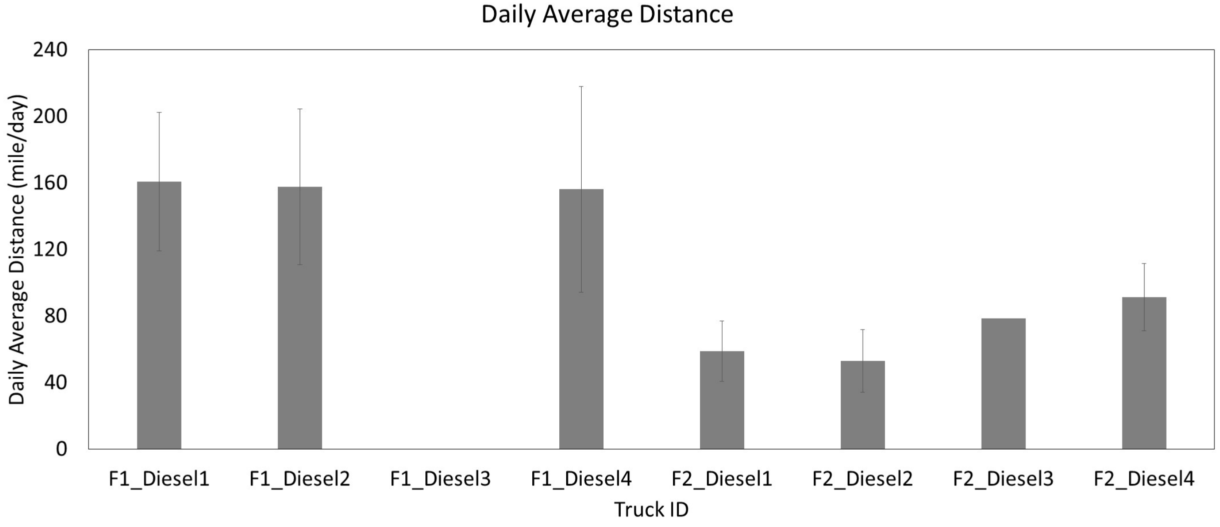
- 8 vehicles from two fleets for a period of two weeks each
- Test vehicles included class 8 trucks and a box truck.
- Cross comparisons with PEMS testing

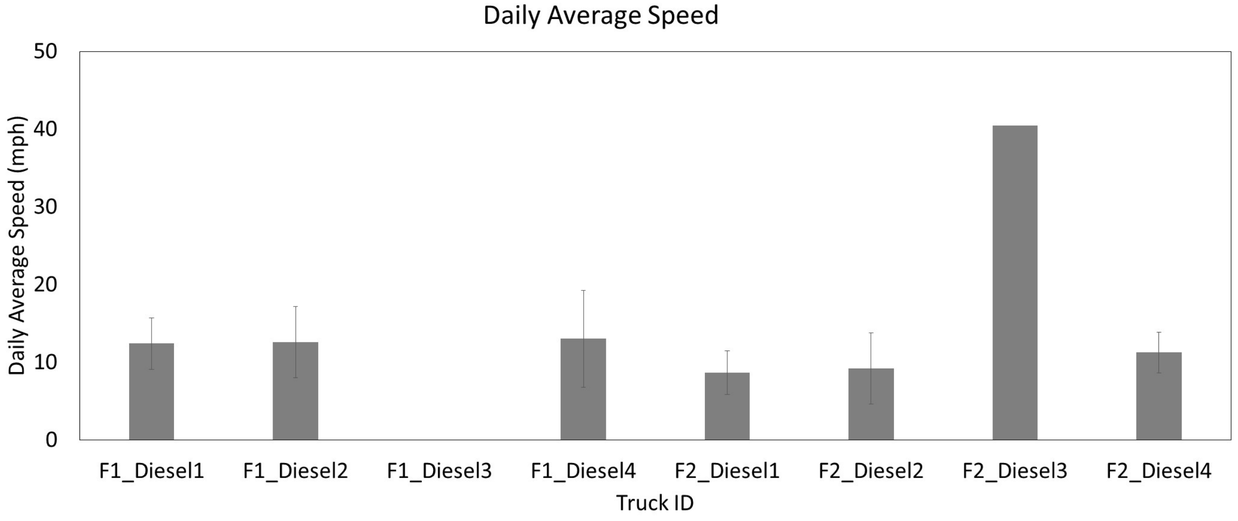


Activity Patterns

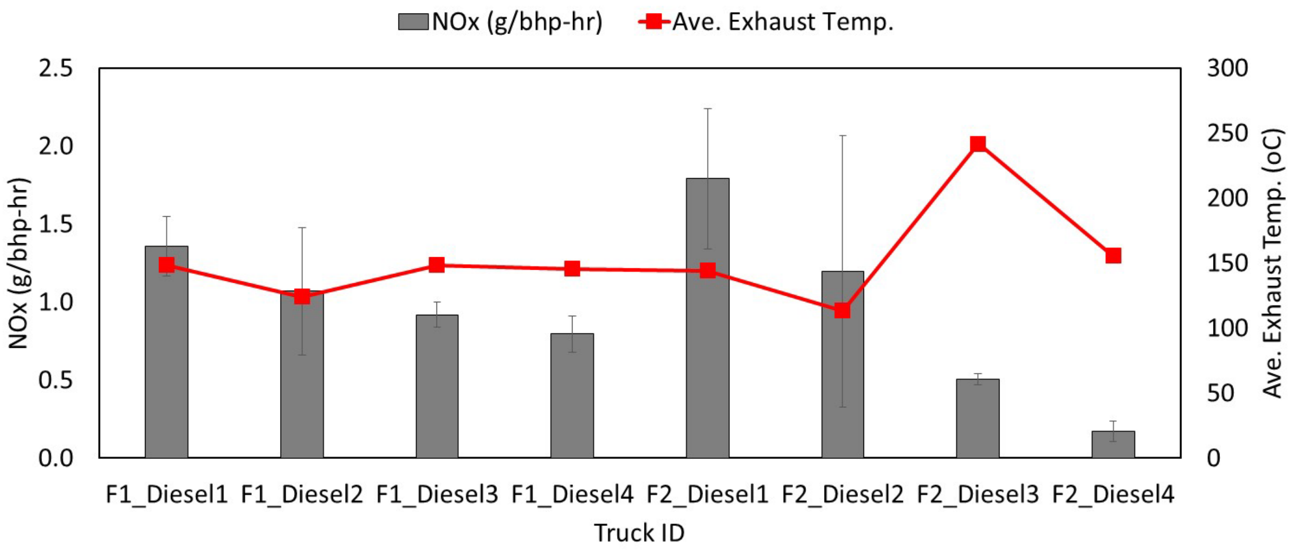


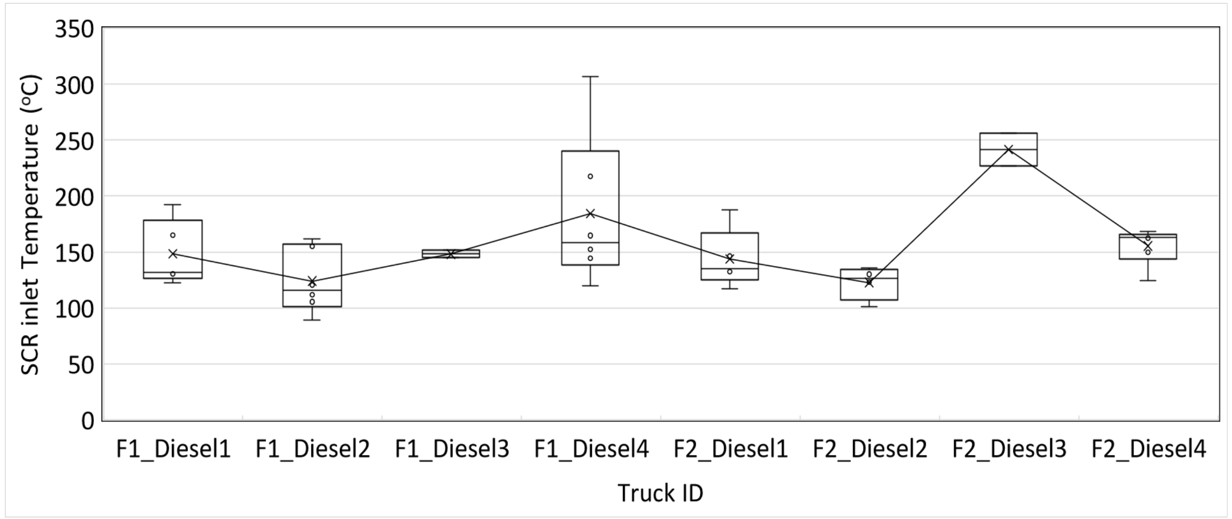
- Average Hours of Operation per Day
  - 7.4 (F2_Diesel2) ~ 14.0 (F1_Deisel4) hr/day
- Average Distance per Day
  - 52.8 (F2_Diesel2) ~ 160.8 (F1_Diesel1) mile/day
- Daily Average Speed
  - 8.7 (F2_Diesel1) ~ 40.5 (F2_Diesel3) mph





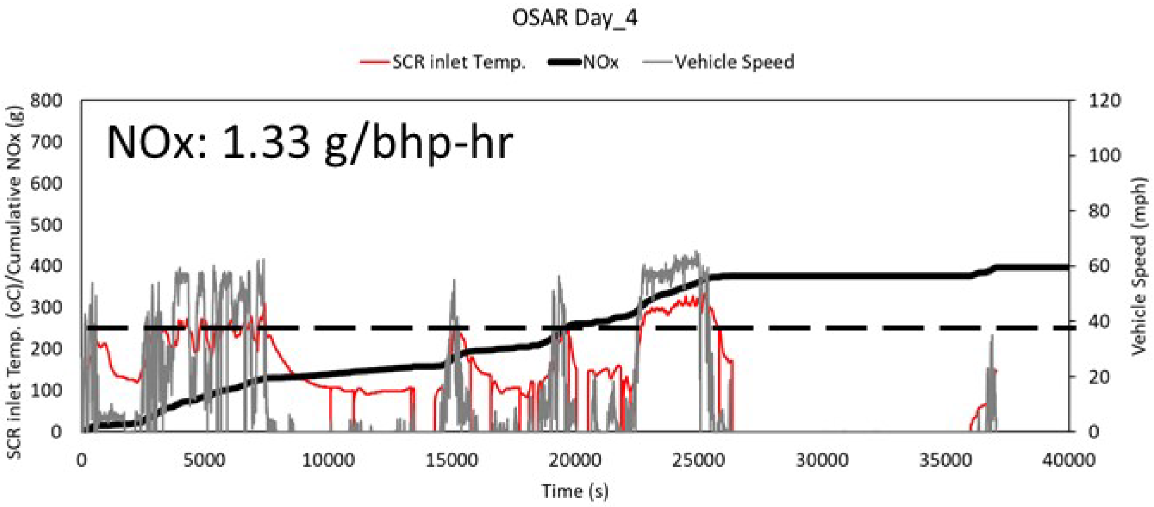
Integrated NOx Emissions

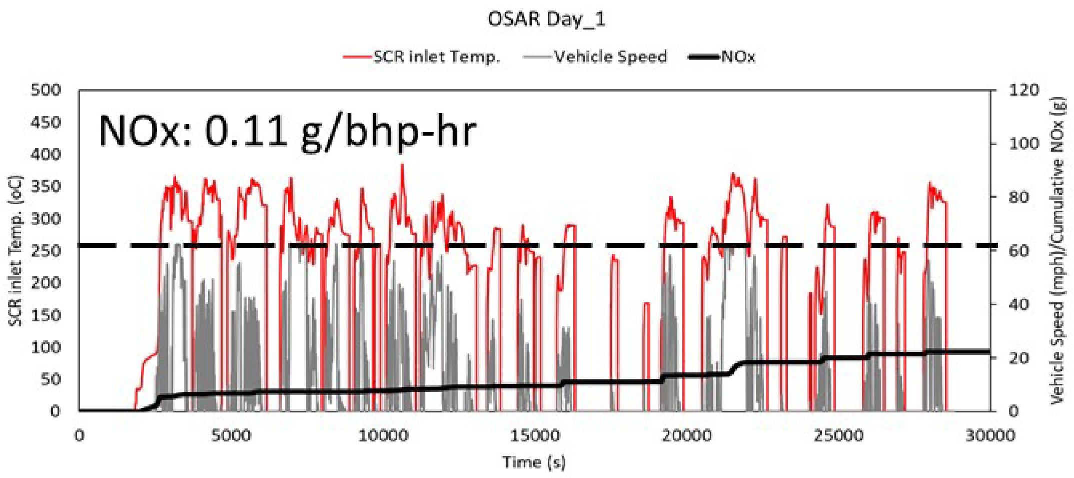




- Brake-specific, distance-specific NOx emissions
  - With corresponding average exhaust temperatures for the vehicles
- On a g/bhp-hr basis
  - 0.17 (F2_Diesel4) ~ 1.79 (F2_Diesel1)
- Exhaust temperatures ranged
  - 113 to 245 ^{o}C

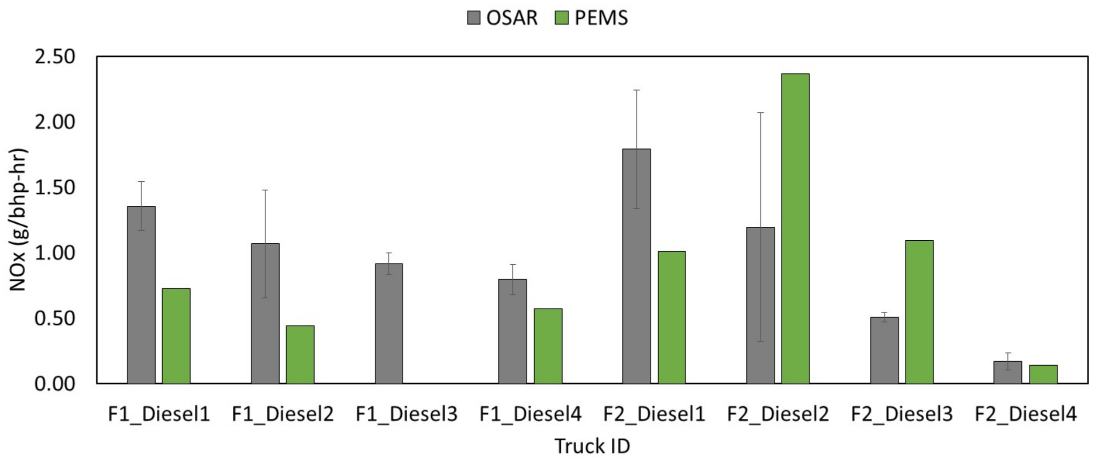
NOx Emissions Change by a Factor of 10 Between Cycles



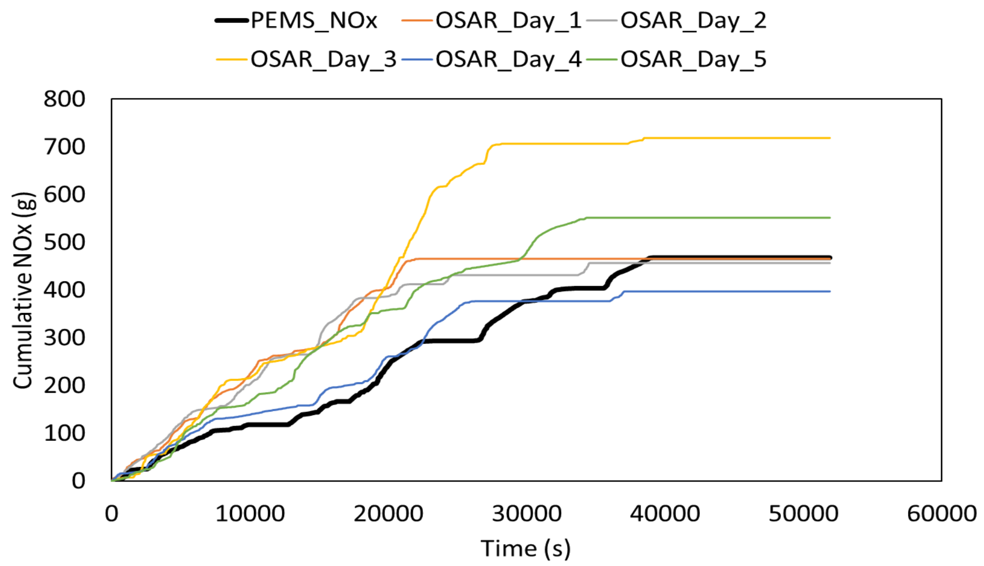


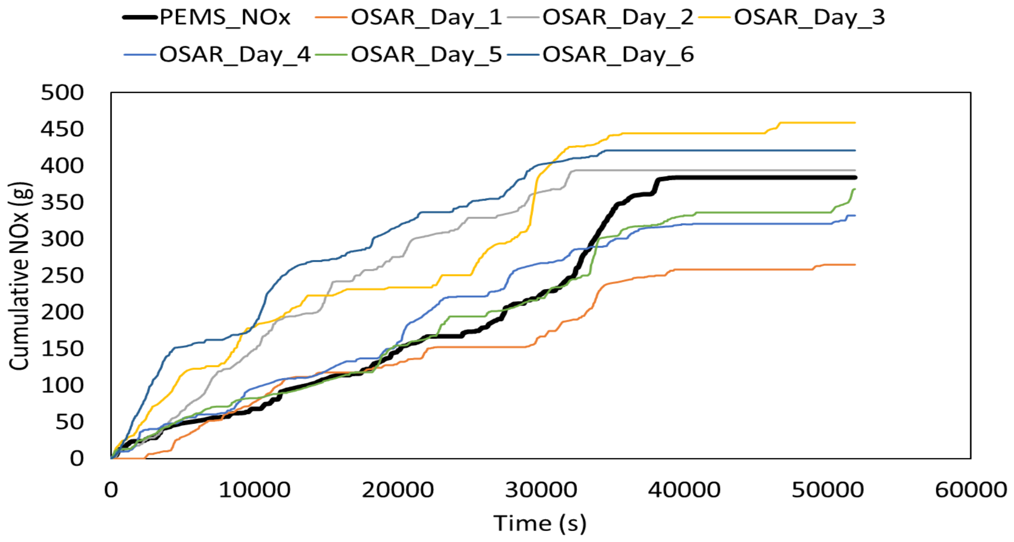
- Accumulated NOx with Vehicle speed and SCR inlet temperature
  - Graphs for NOx 0.11 & 1.33 g/bhp-hr
- Average NOx emissions change for different days.
  - Route for vehicles was usually different from day to day operation,
  - This impacts the SCR temperature and the formation of NOx emissions.

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

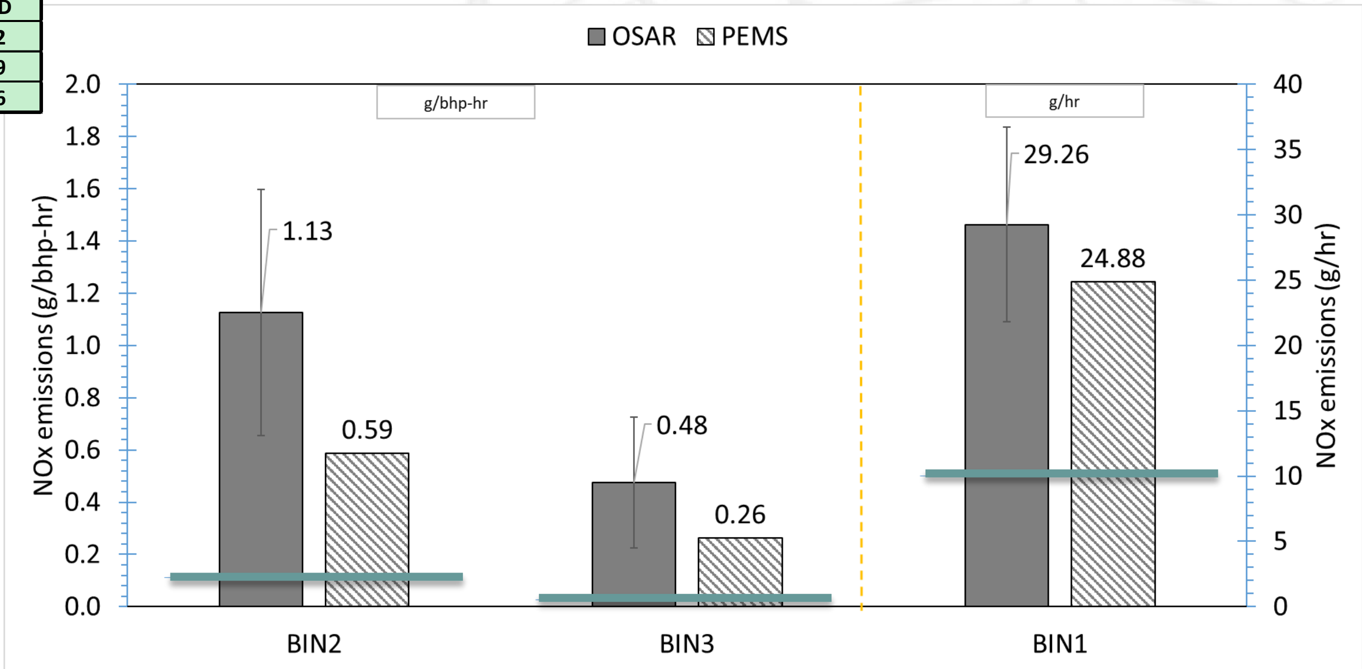
Bin			PEMS	OSAR					OSAR_AVE	
				day1	day2	day3	day4	day5	Ave. NOx	STD
BIN1	Idle	g/hr	24.88	21.00	35.74	22.32	30.06	37.20	**29.26**	**7.45**
BIN2	MedLoad	g/bhp-hr	0.59	0.68	1.77	0.78	0.94	1.47	**1.13**	**0.47**
BIN3	HighLoad	g/bhp-rh	0.26	0.46	0.91	0.31	0.33	0.36	**0.48**	**0.25**

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**

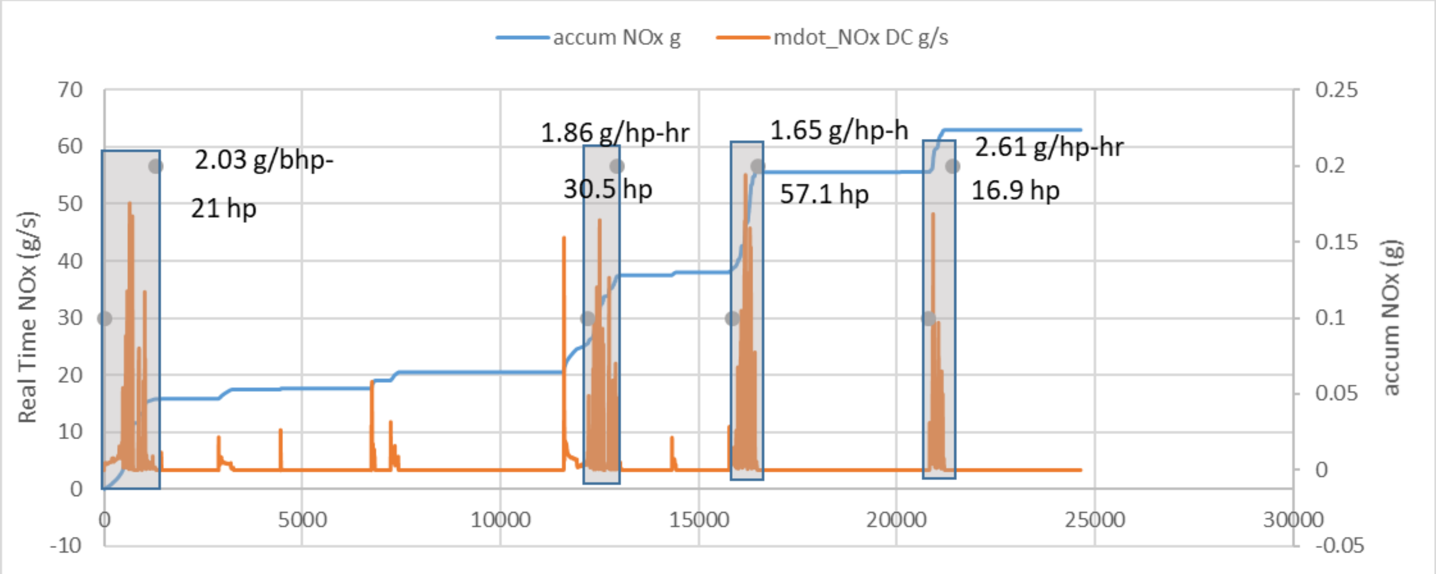
Bin			PEMS	OSAR					OSAR_AVE	
				day1	day2	day3	day4	day5	Ave. NOx	STD
BIN1	Idle	Deg C	155	132	152	156	130	133	**141**	**12**
BIN2	MedLoad	Deg C	224	221	202	240	192	201	**211**	**19**
BIN3	HighLoad	Deg C	307	336	387	354	297	309	**336**	**36**

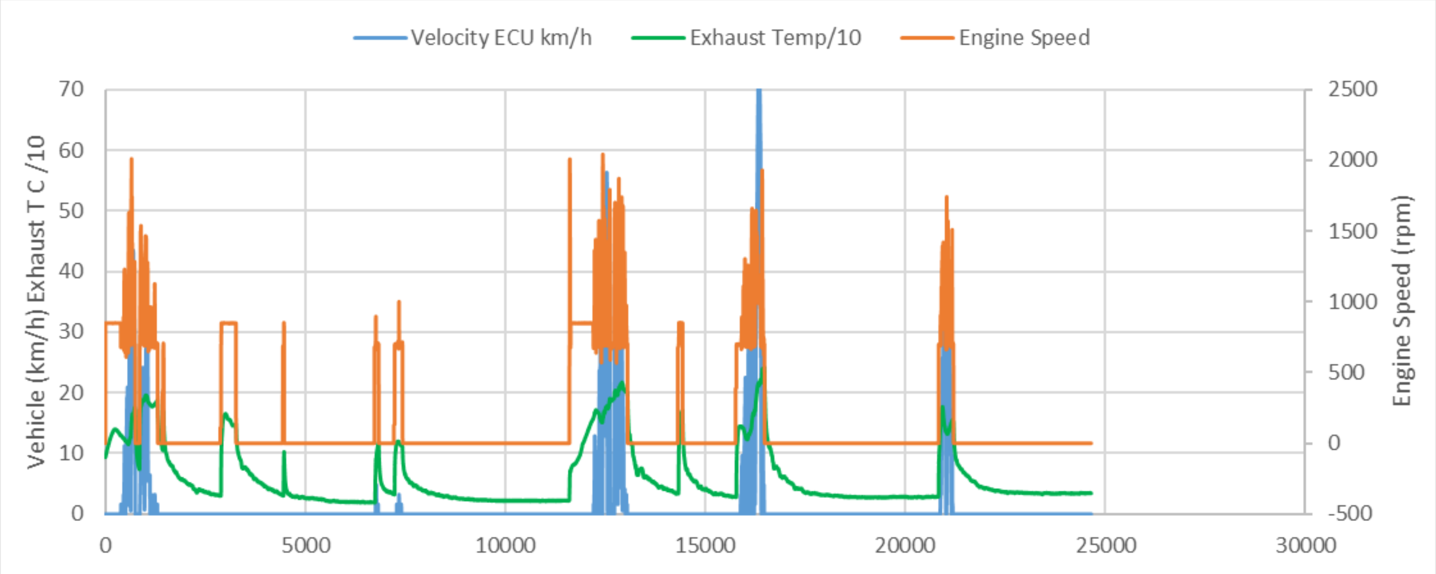
- In-Use 3 BIN analysis starts in MY 2024 with full phase in by 2030
- The 3 BIN includes Idle/low load, medium load, an high load

- 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 CO_2)
- 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 CO_2 method 10-30%
  - Bin 7 CO_2 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 NOx 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