

# On-Board Sensing, Analysis, and Reporting (OSAR) Update

North Central Texas Council of Governments  
(NCTCOG)

April 21, 2022

Presented By:

Dr. Kent Johnson and Mike Allen

[kjohnson@cert.ucr.edu](mailto:kjohnson@cert.ucr.edu)

Co-Authors Thomas D. Durbin, Georgios Karavalakis, and Dr. Wayne Miller  
[www.cert.ucr.edu](http://www.cert.ucr.edu)  
(951) 781-5786

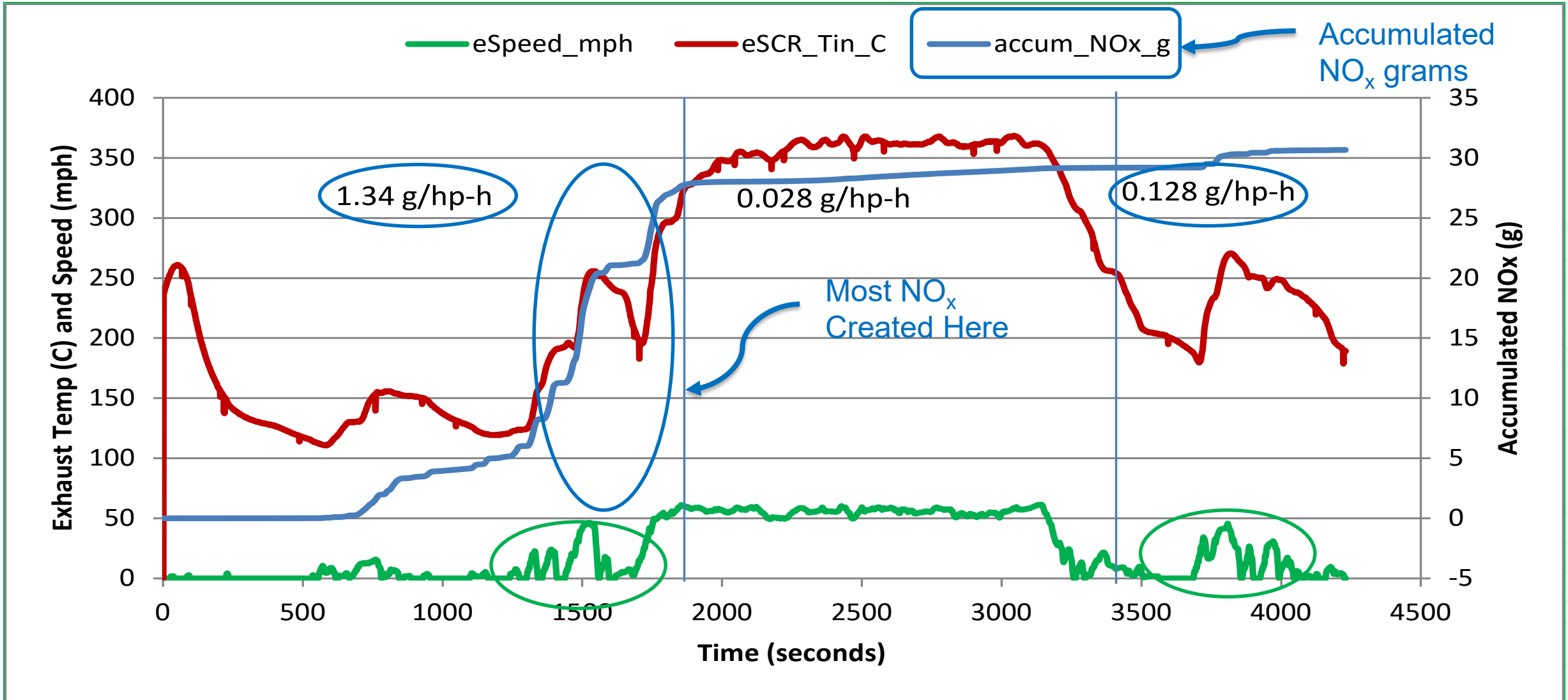
University of California, Riverside  
Center for Environmental Research and Technology  
(CE-CERT)

[www.cert.ucr.edu](http://www.cert.ucr.edu)

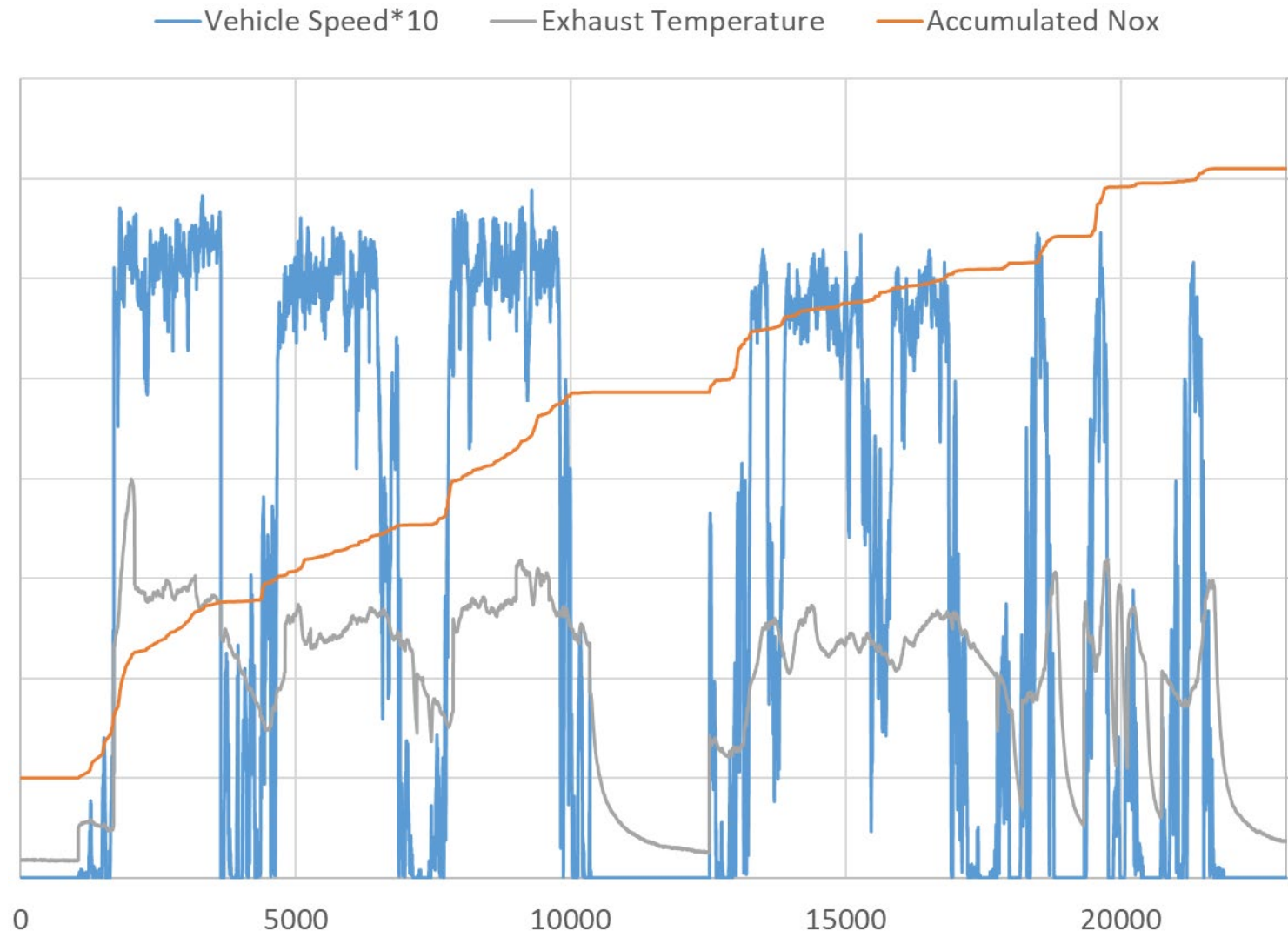
# Data Binning : Background



# These Higher Emissions Result from Real Operation

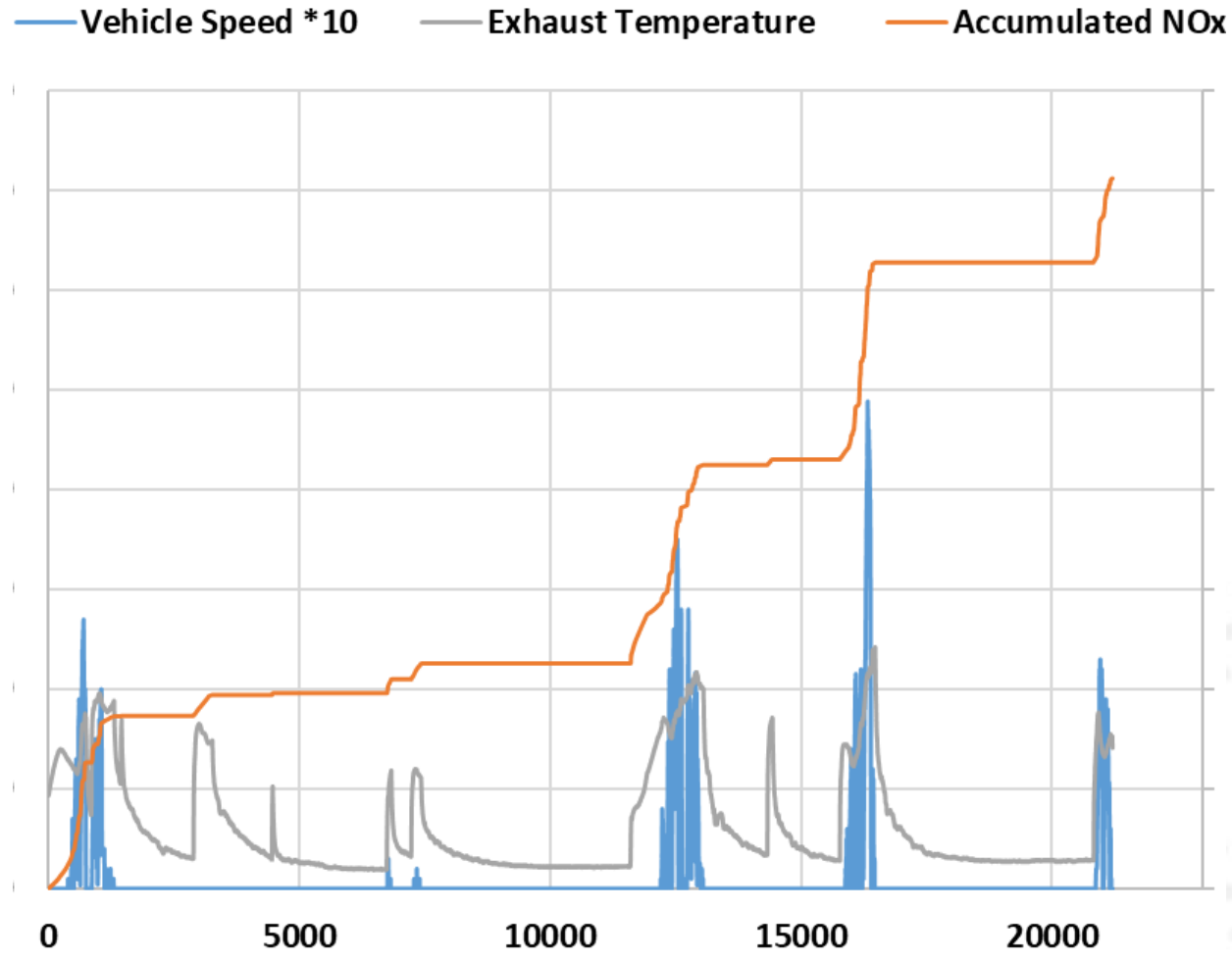


# Local Goods Movement Vehicles Have Moderate Duty Cycles



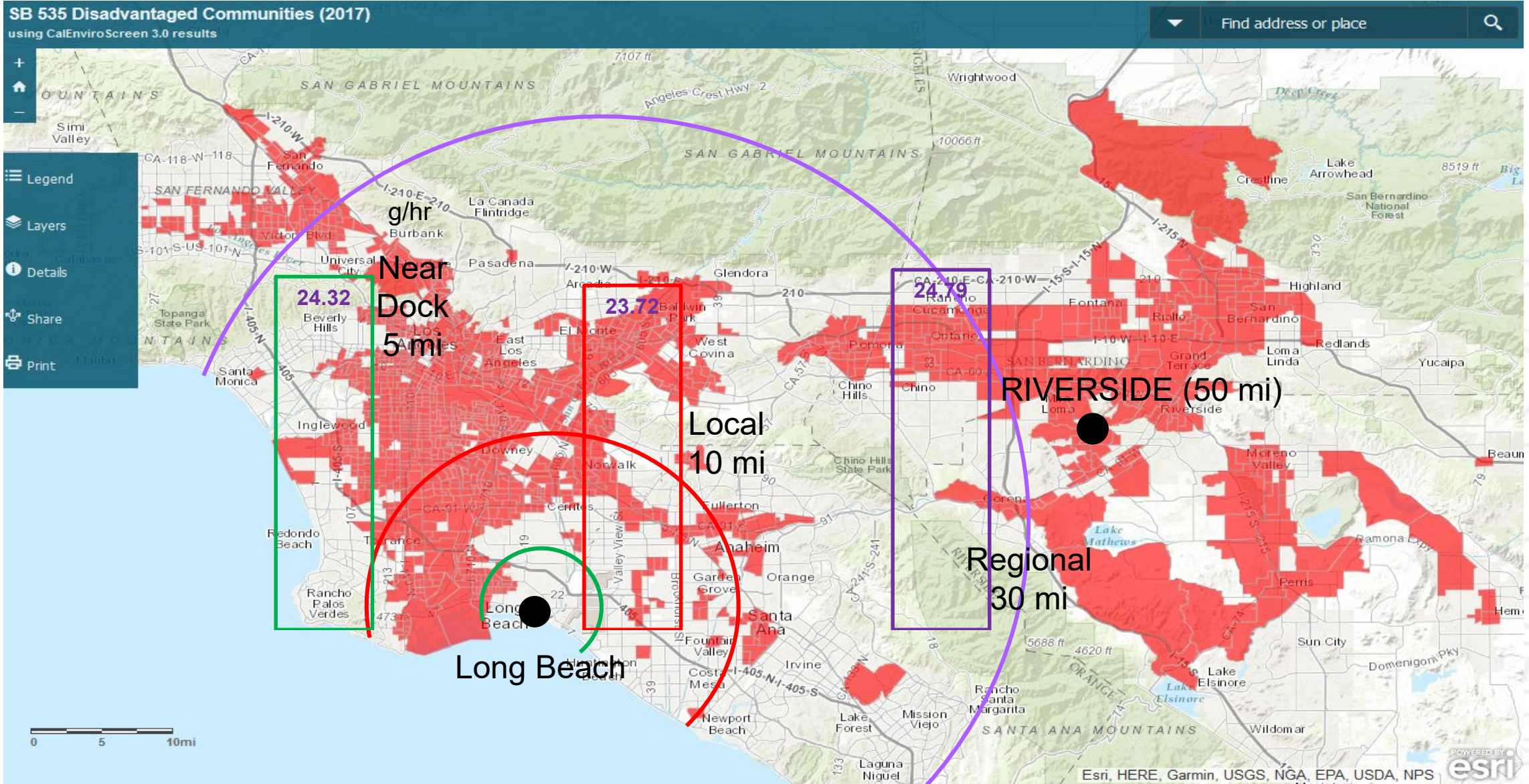
- ▶ Representative of HDIUT, maybe slightly low since NTEs count are low.
- ▶ Binning may look reasonable.
- ▶ How significant is this data to the inventory?

# 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?

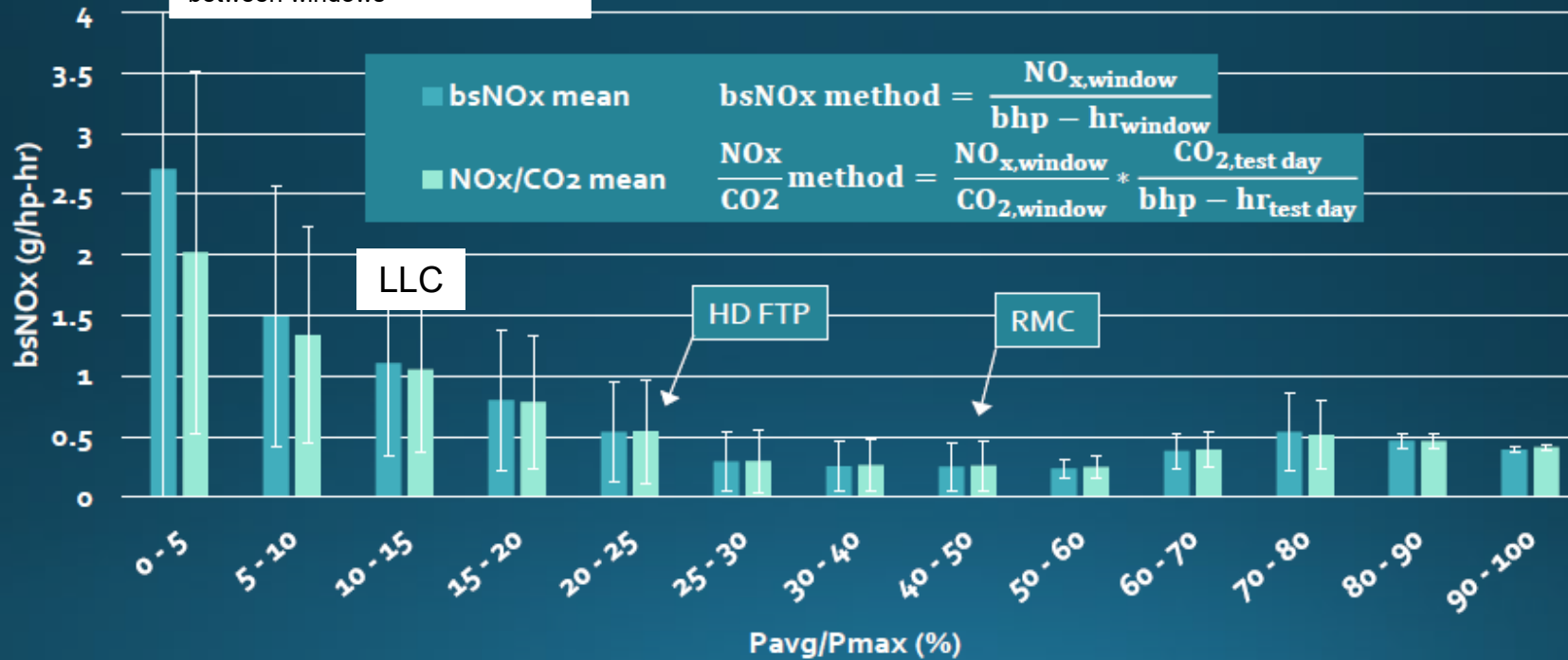
# Real Emissions Impact Real Communities: Location Is Important



# MOVES and EMFAC Models View Diesels like this

## In-use Data

Error bars represent 1 stdev between points within a day and between windows

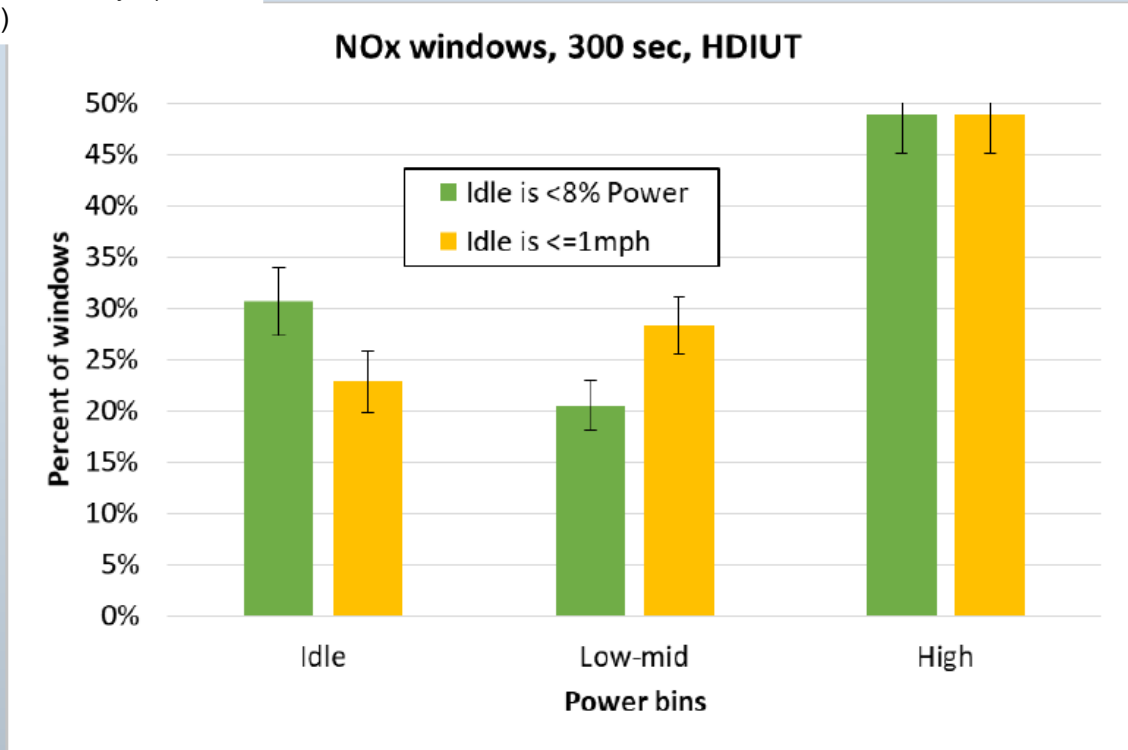
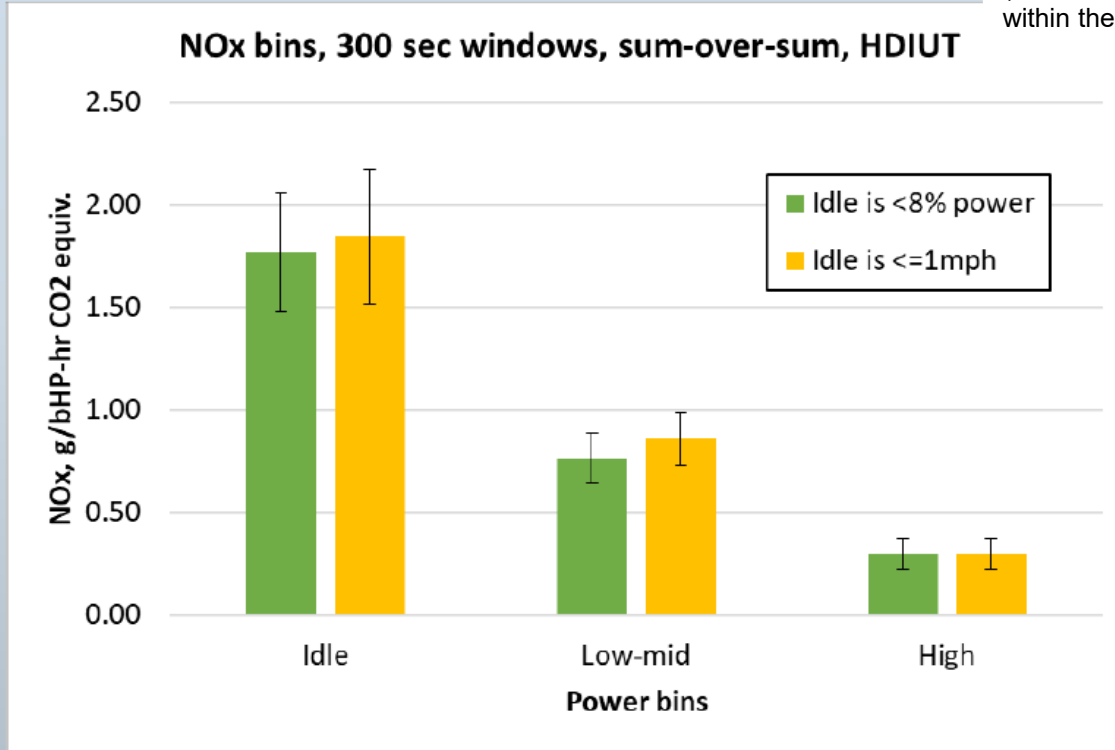


HHD with NOx FEL ≤ 0.20 g/bhp-hr | 85 vehicles, 2.90 million windows

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

# EPAs Draft 3-Bin NOx Binning Specifics (#1)

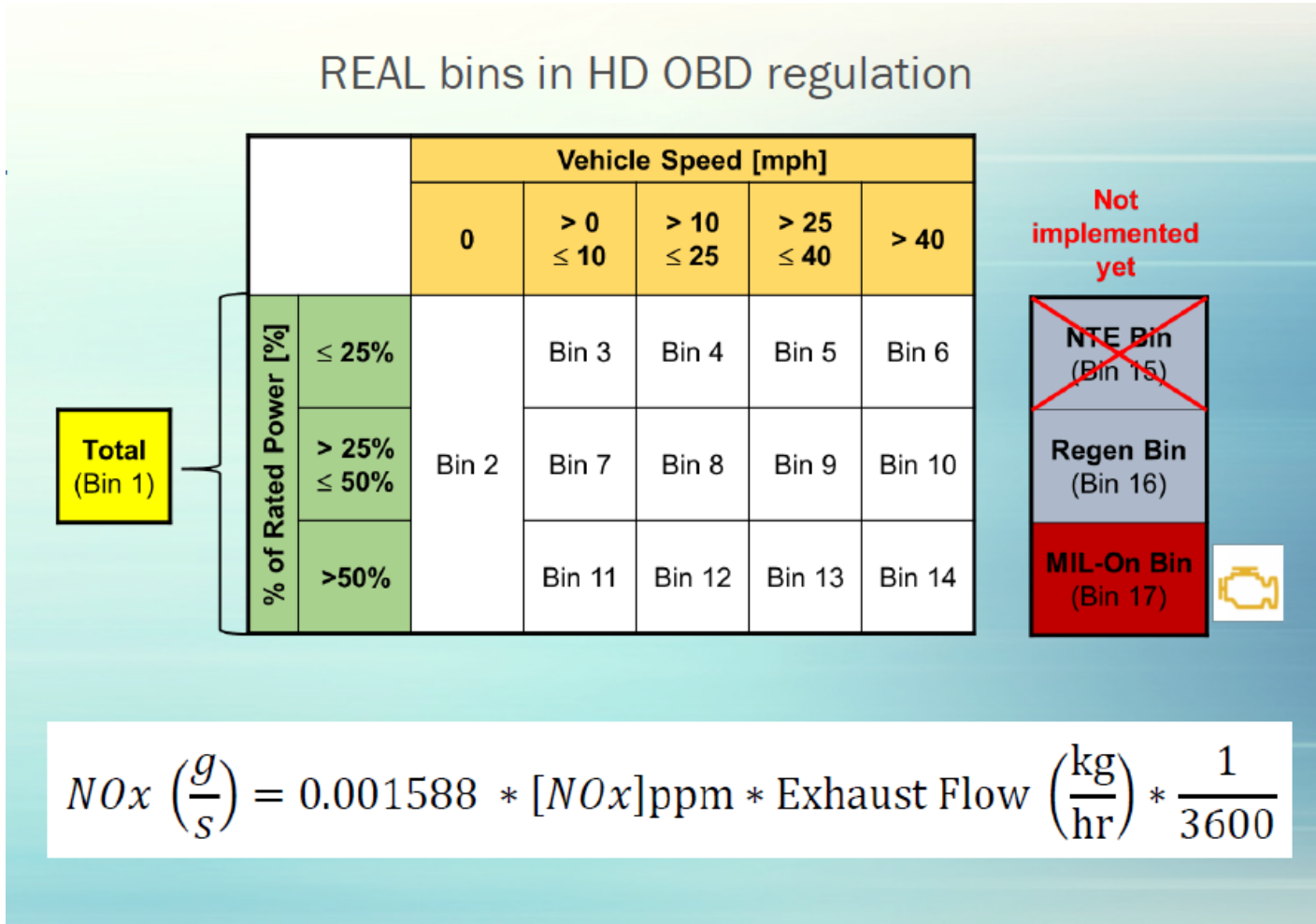
Error bars represent ~3 stdev (95% Conf) between days (not within the test)



- Bars are the 95<sup>th</sup>-ile confidence interval
- Each data point is one vehicle test day



# ARB Binning Method (second by second data)

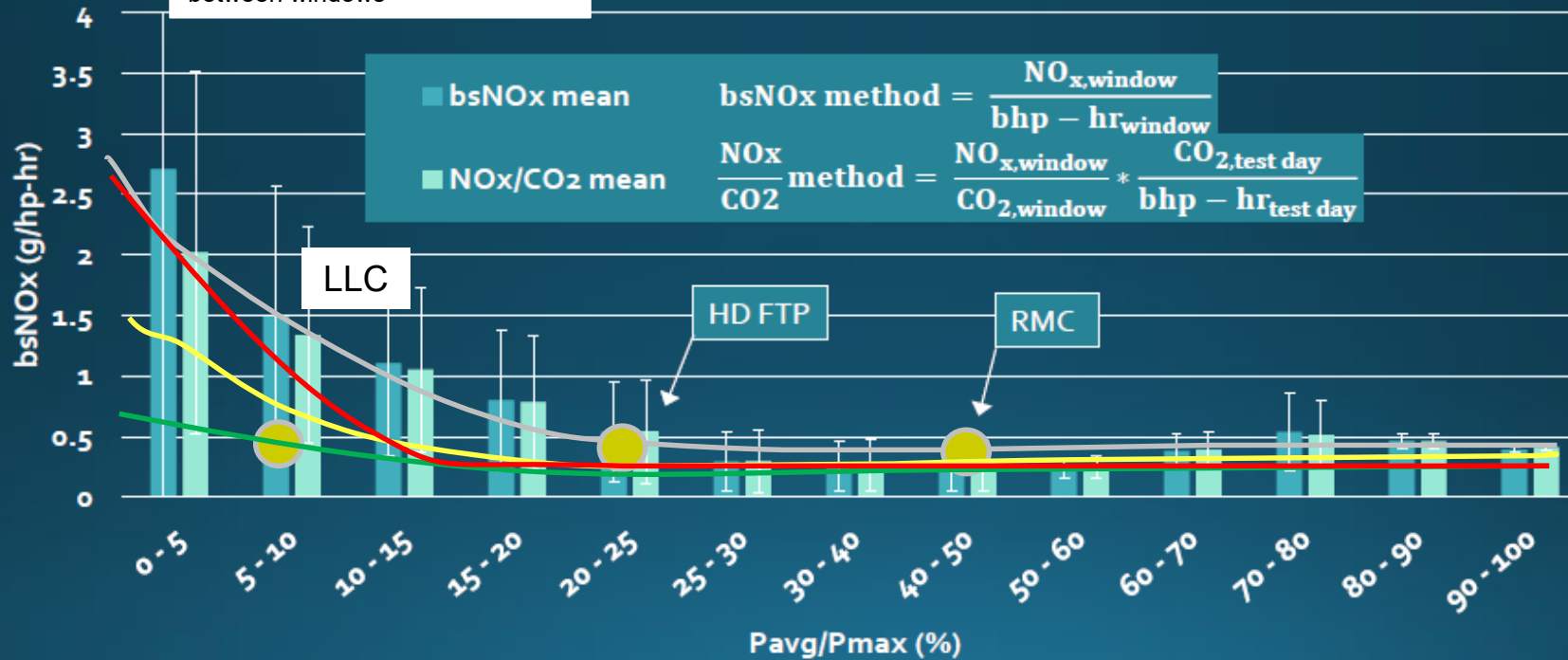


- Implementing this method to look at variability on data sets and compare
  - EPA
  - ARB
  - CE-CERTs

# Binning Prediction Using Some Form of History

## In-use Data

Error bars represent 1 stdev between points within a day and between windows



HHD with NOx 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.

## Data Binning : UCR Approaches

- ▶ Used existing on-road data
  - Binned by temperature and power (OSAR #2)
- ▶ Designed Engine Dyno Thermal Model Experiment Nox spikes occur with transition from idle to 100% load. (OSAR #3)
  - Binned by temperature (OSAR #3)
  - Binned by power and rate of change of power (OSAR #4)
- ▶ OSAR, Other, and 2030 Engine NOx data
  - Binned by physical activity or return to service conditions (OSAR #5)
  - Comparisons with EPA and ARB binning methods

# SC-AQMD Phase 1: Hardware completed

## EmTrac-6 Core Telemetry System



NOx/O<sub>2</sub> Module

PM Module

Data Logger  
(CAN, GPS, LTE)

GPS & LTE  
Antennas

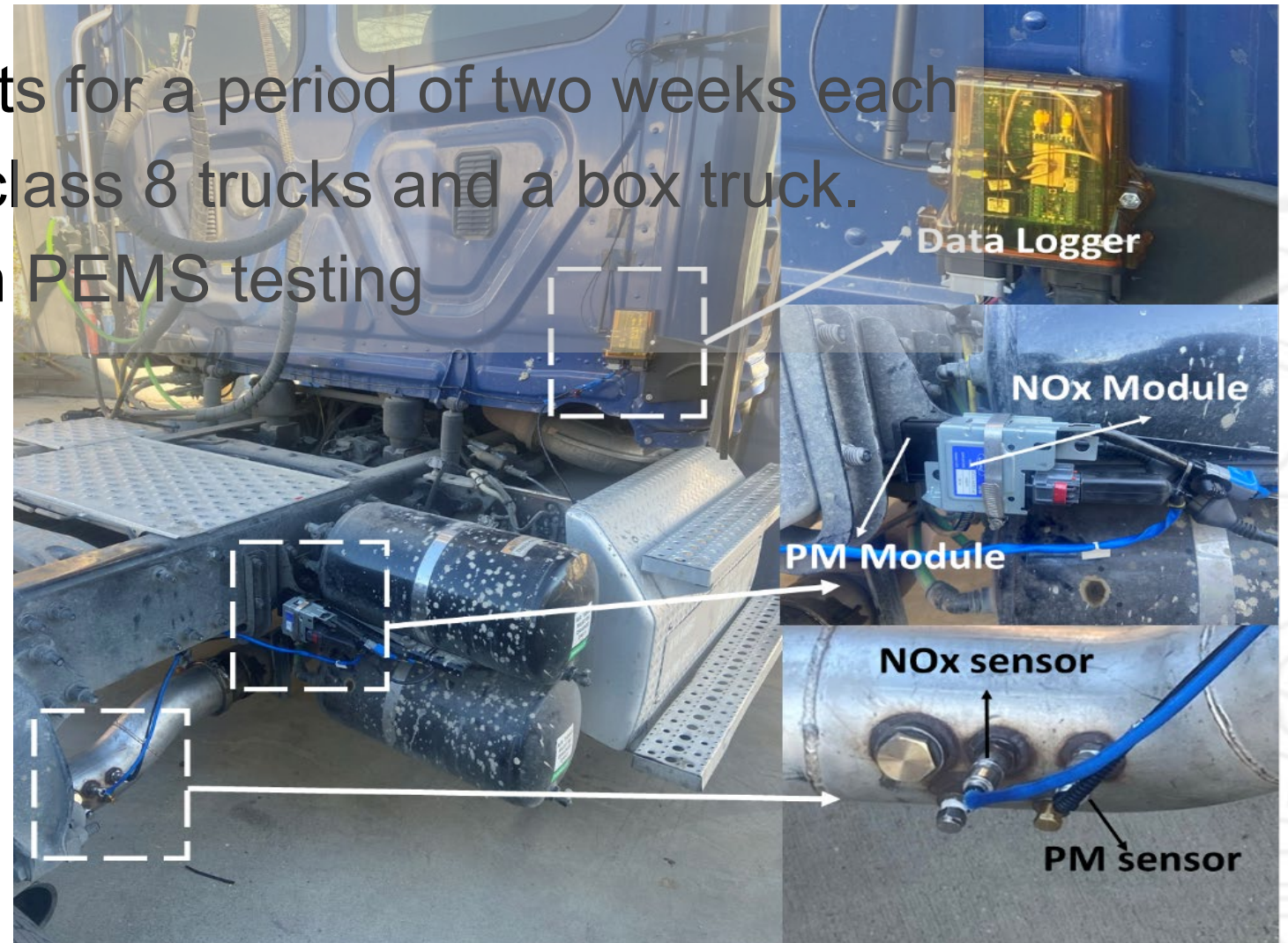
In partnership with



For more information on EmTrac: [pt@emisense.com](mailto:pt@emisense.com)

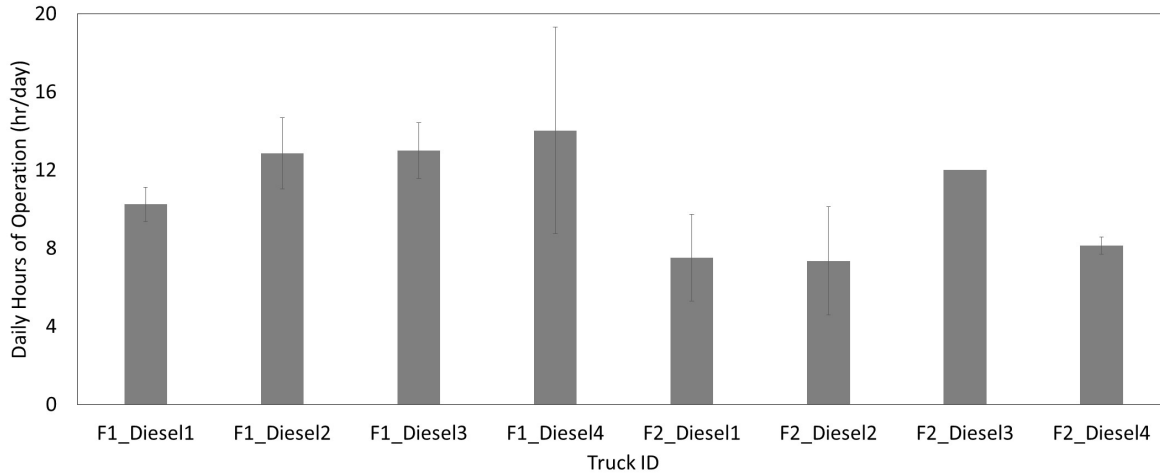
# Initial Field 20 Day Deployment of OSAR Systems

- › 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



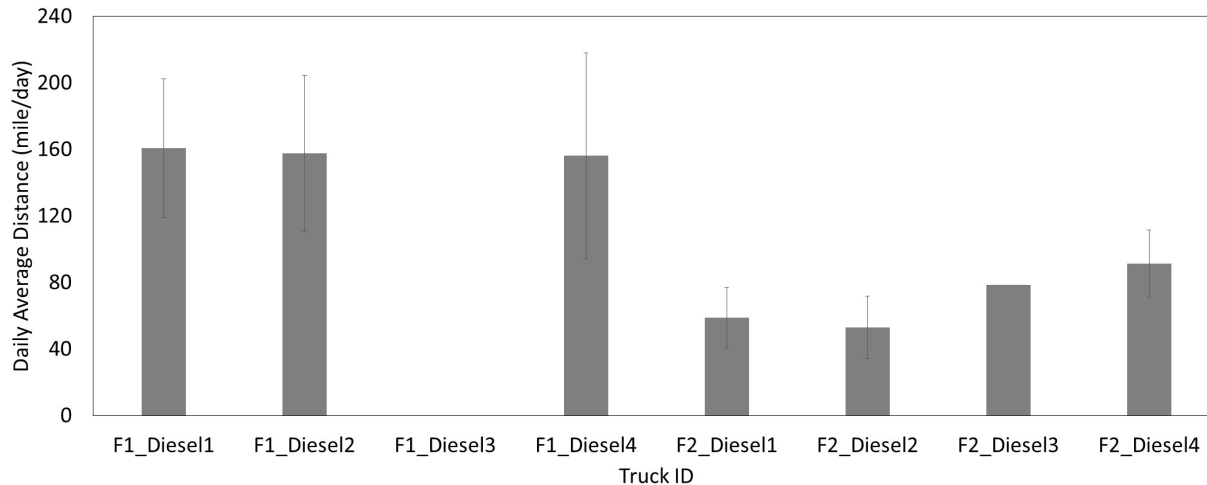
# Activity Patterns from the 20 Days

Daily Hours of Operation

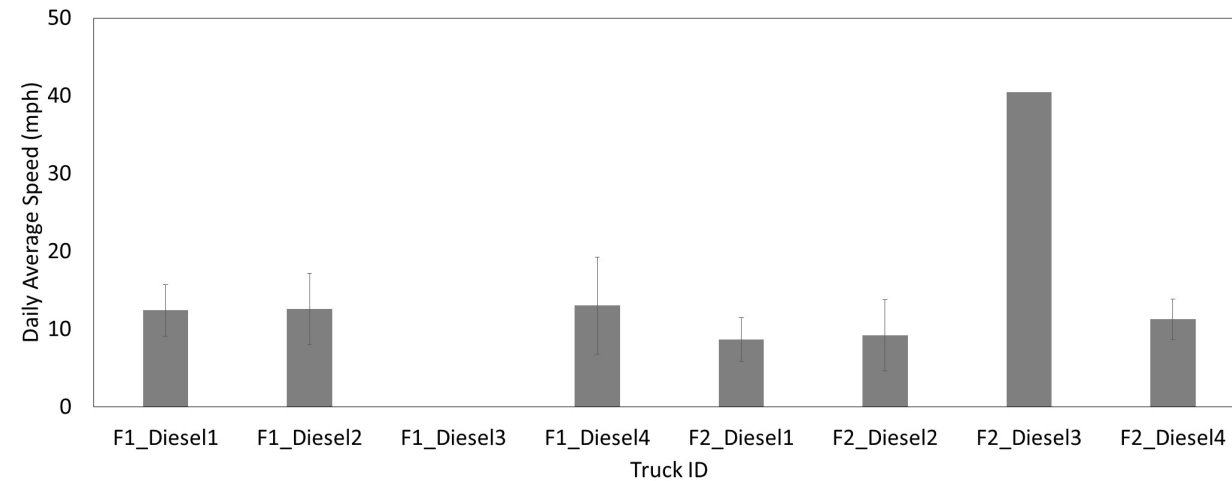


- ▶ Average Hours of Operation per Day
  - ▶ 7.4 (F2\_Diesel2) ~ 14.0 (F1\_Deisel4) hr/day
- ▶ Average Distance per Day
  - ▶ 52.8 (F2\_Diesel2) ~ 160.8 (F1\_Diesel1) mile/day
- ▶ Daily Average Speed
  - ▶ 8.7 (F2\_Diesel1) ~ 40.5 (F2\_Diesel3) mph

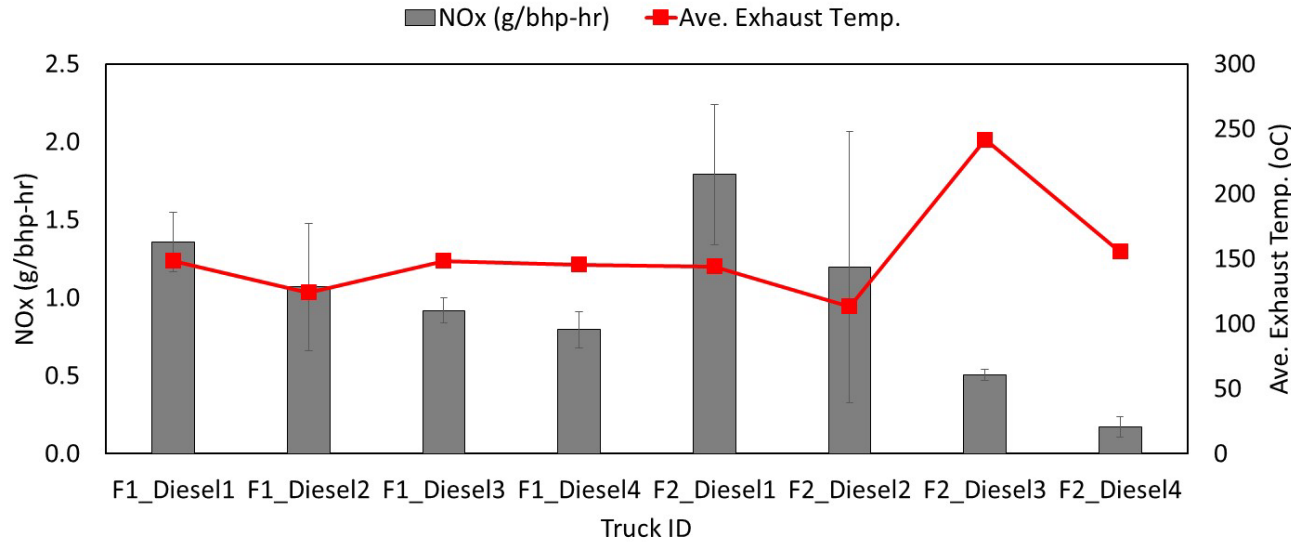
Daily Average Distance



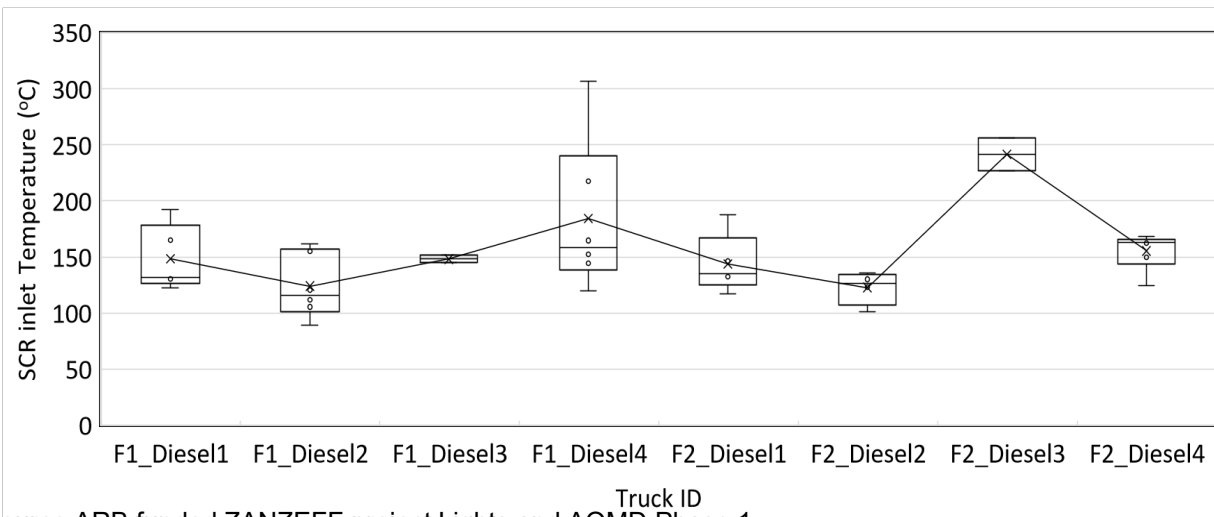
Daily Average Speed



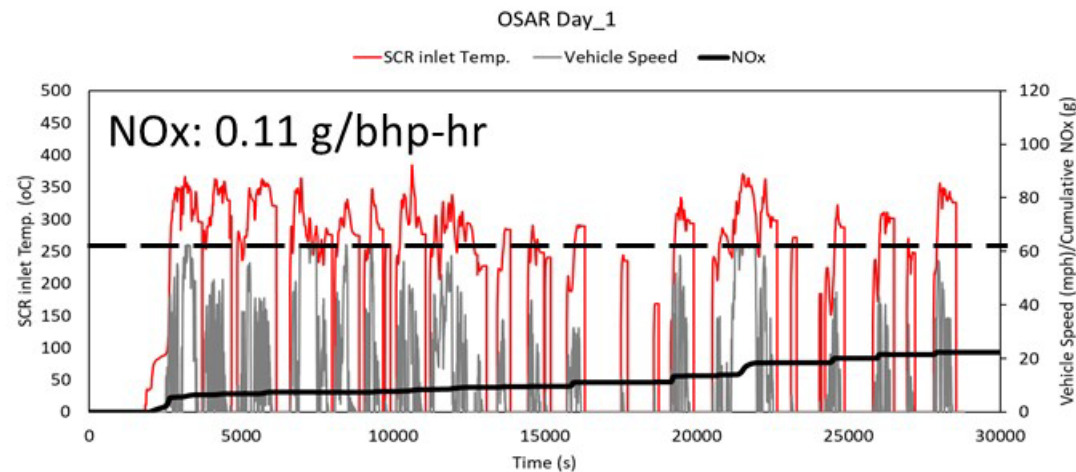
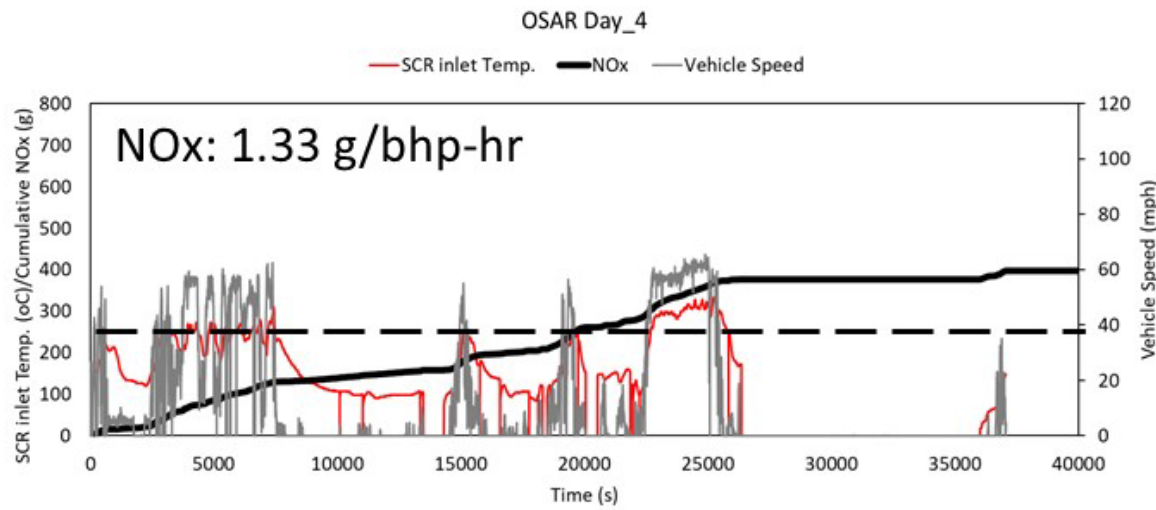
# Integrated NOx Emissions



- 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



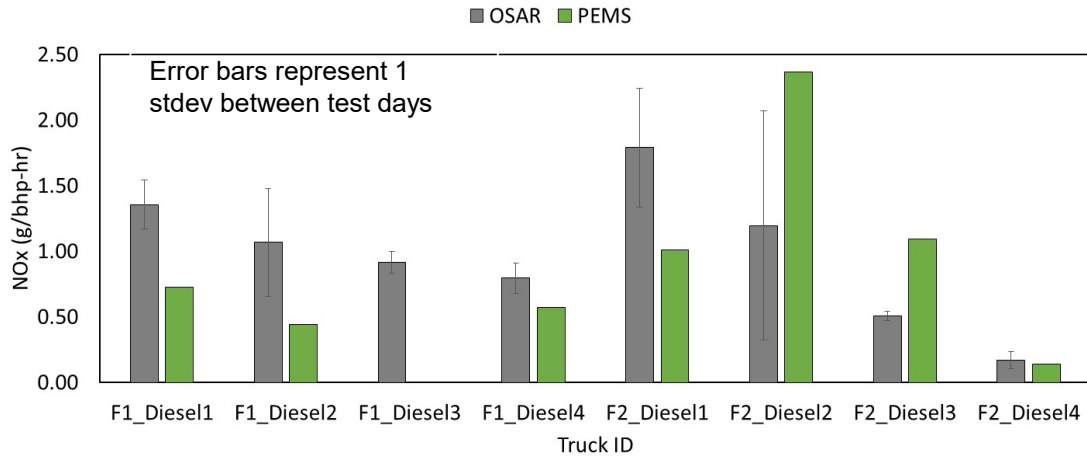
# NOx Emissions Change by a Factor of 10 Between Cycles



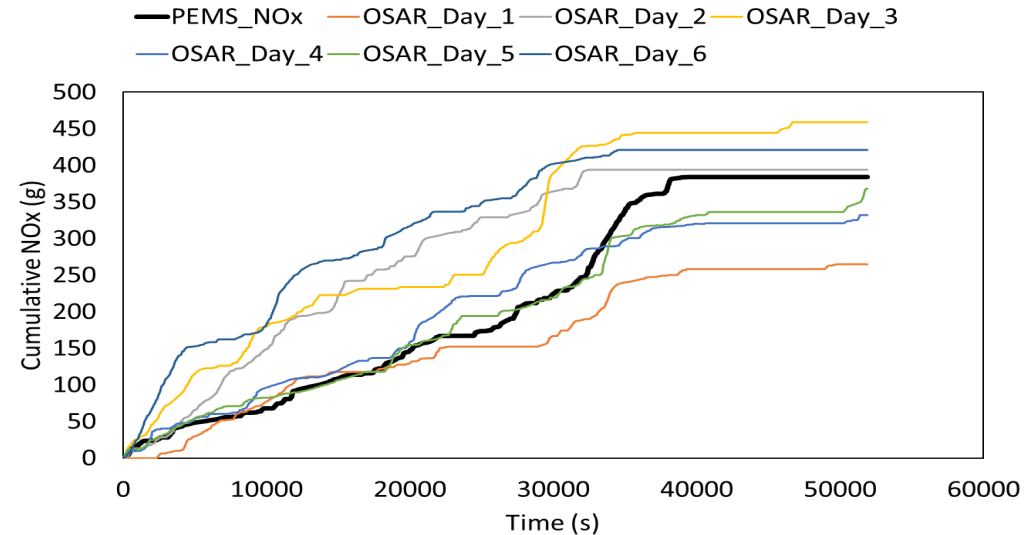
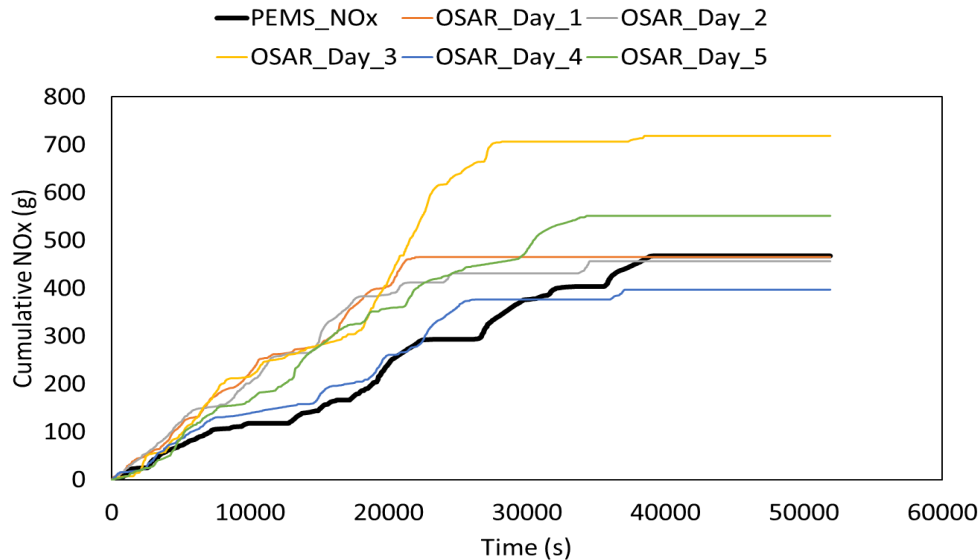
- ▶ Accumulated NOx with Vehicle speed and SCR inlet temperature
  - ▶ Graphs for NOx 0.11 & 1.33 g/bhp-hr
- ▶ Average NOx emissions change for different days.
  - ▶ Route for vehicles was usually different from day to day operation,
  - ▶ This impacts the SCR temperature and the formation of NOx emissions.



# 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

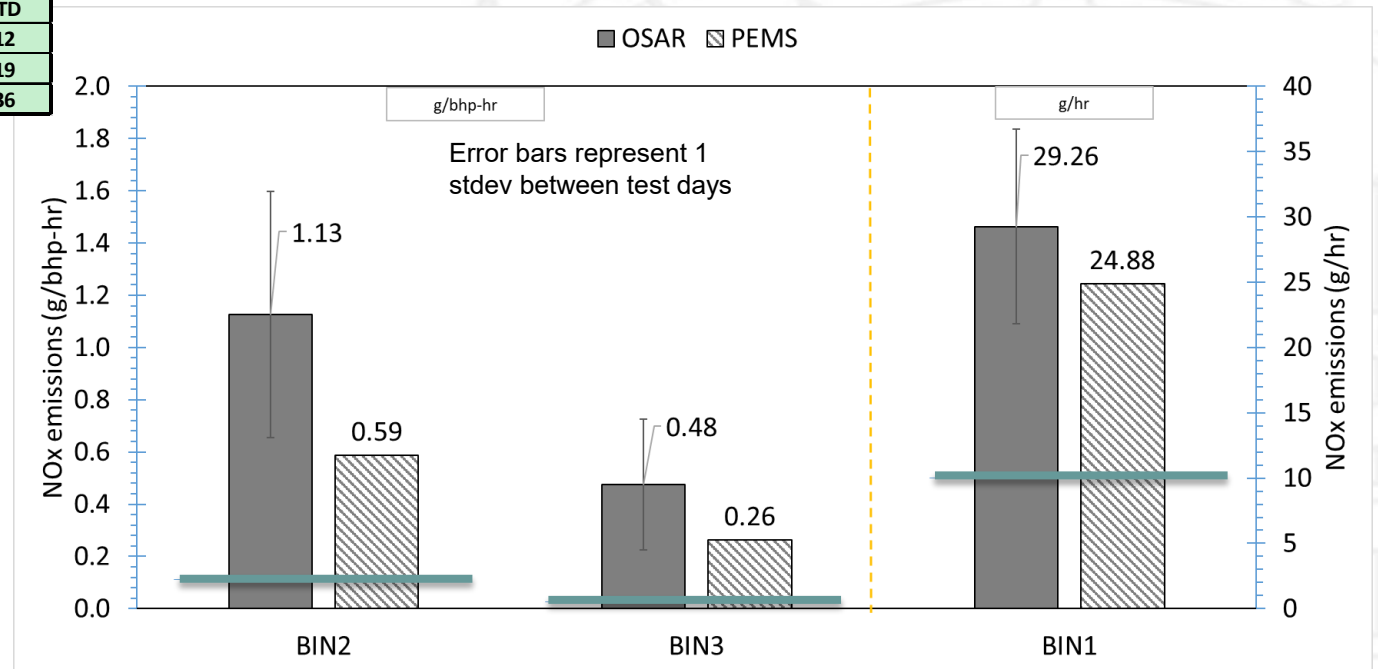
Bin			PEMS	OSAR					OSAR_AVE	
				day1	day2	day3	day4	day5	Ave. NOx	STD
BIN1	Idle	g/hr	24.88	21.00	35.74	22.32	30.06	37.20	29.26	7.45
BIN2	MedLoad	g/bhp-hr	0.59	0.68	1.77	0.78	0.94	1.47	1.13	0.47
BIN3	HighLoad	g/bhp-hr	0.26	0.46	0.91	0.31	0.33	0.36	0.48	0.25

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

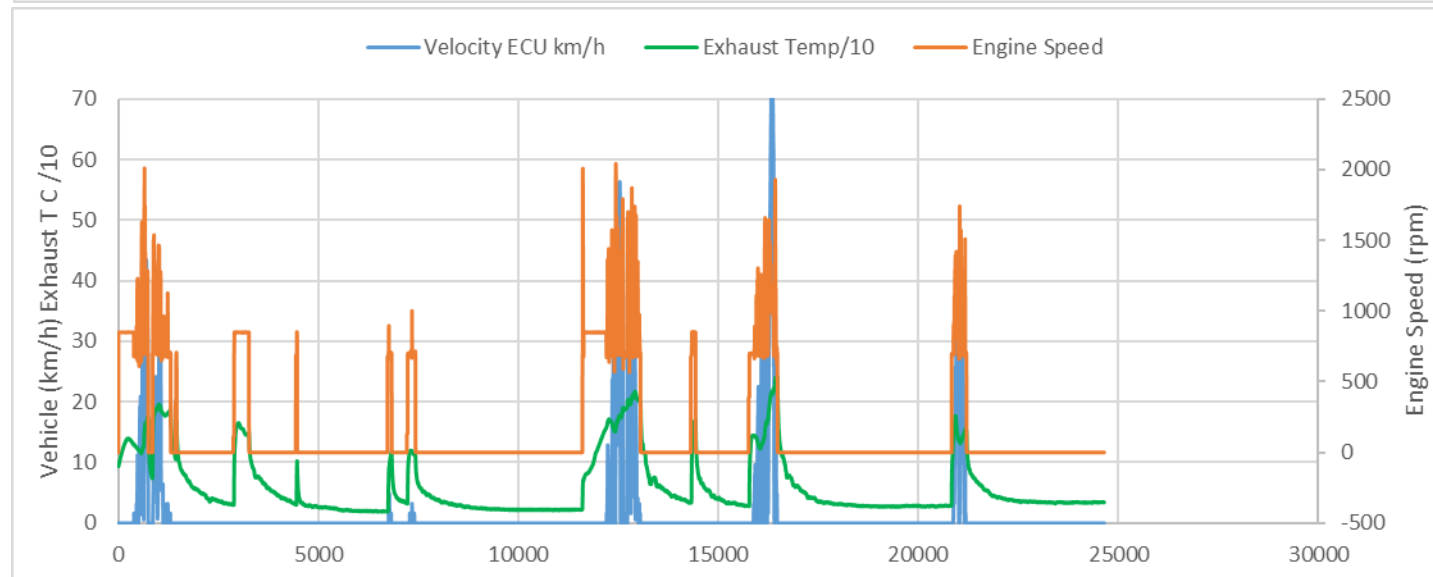
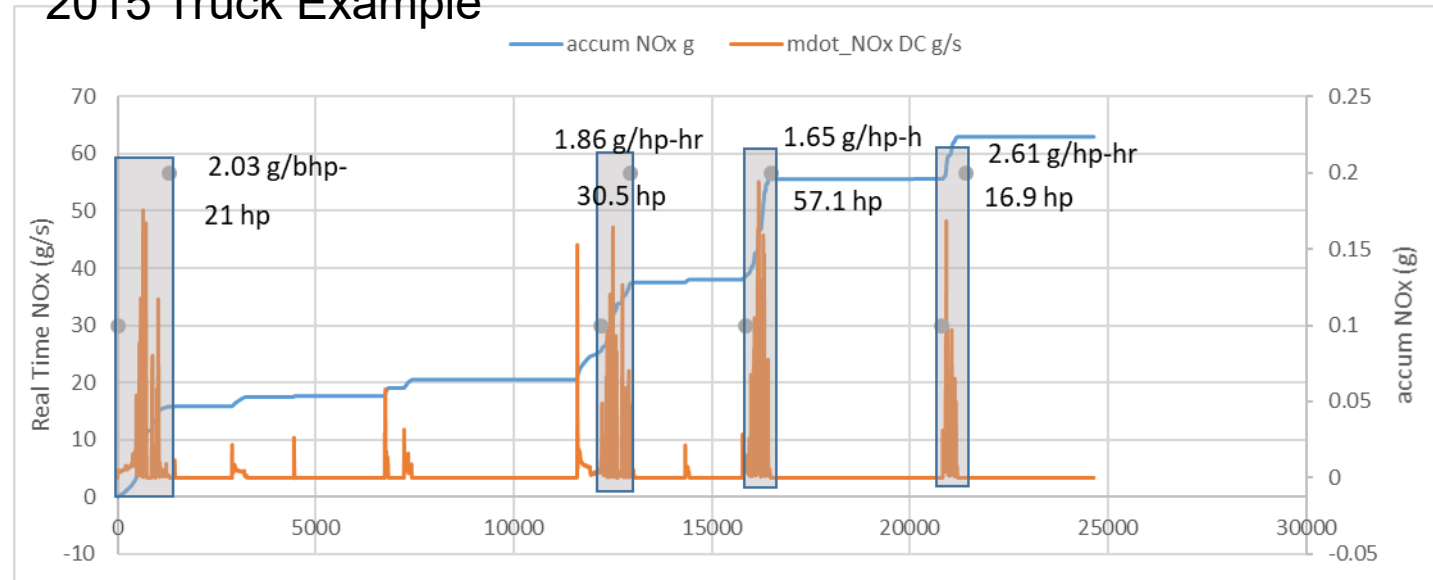
- In-Use 3 BIN analysis starts in MY 2024 with full phase in by 2030
- The 3 BIN includes Idle/low load, medium load, an high load

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



# Binning on Physical Activity: Return To Service, Modified

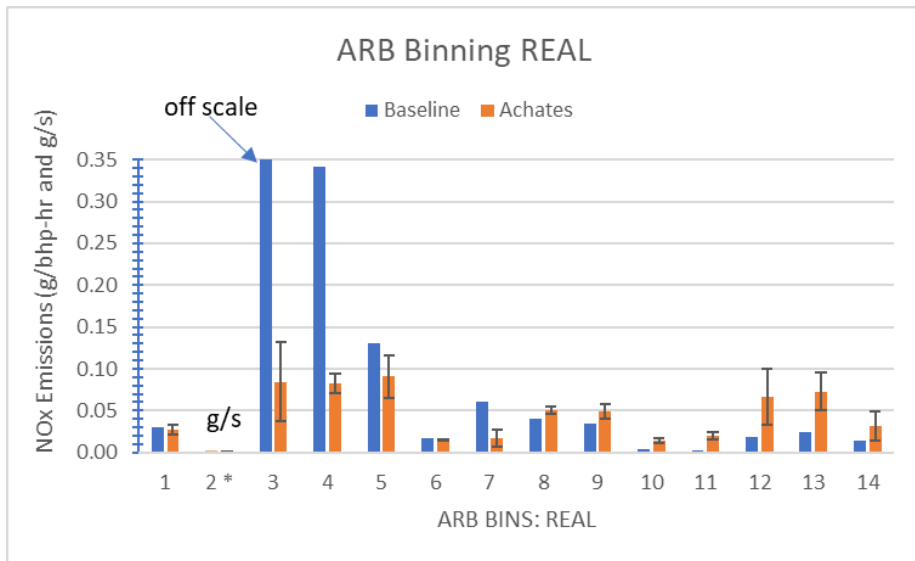
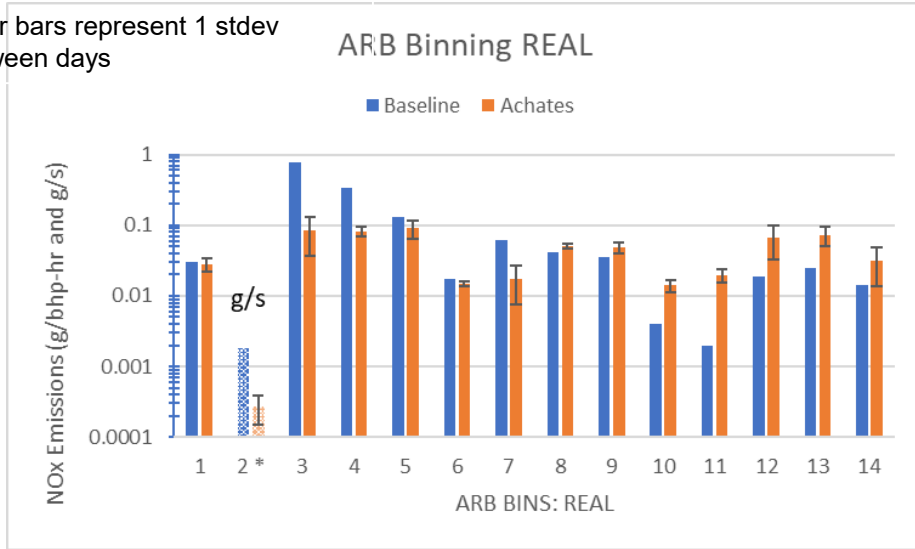
## 2015 Truck Example



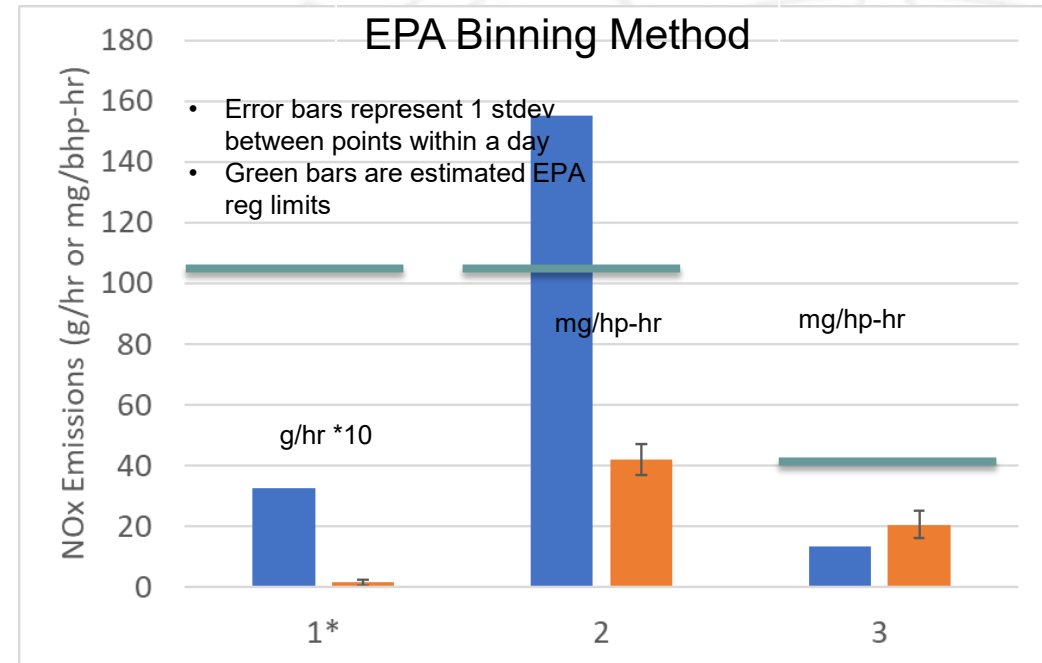
- Bin 1 cold start (work 5 hp-hr)
- Bin 2 idle
  - (no vehicle speed and > 5 min)
- Bin 3, 4, 5 and 6 return to service
  - Bin 3 Load 0-5%
  - Bin 4 Load 5-10%
  - Bin 5 Load 10-20%
  - Bin 6 Load >20%
- Bin 7 and 8 higher loads
  - Bin 7 hp 10-30%
  - Bin 8 hp method >30%
- Approach promising. More analysis needed to implement method

# ARB and EPA BIN Analysis: Low NOx Truck

Error bars represent 1 stdev between days

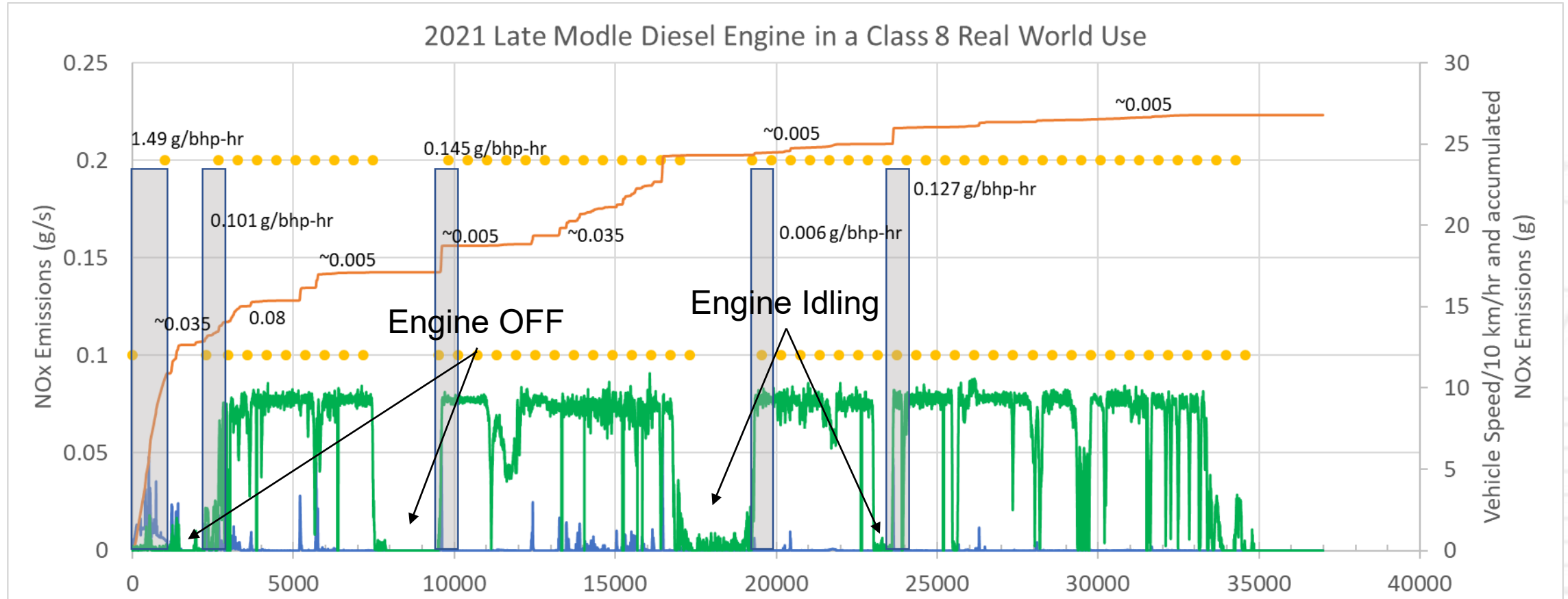


- ARB binning
  - NOx ranged from 0.002 to 0.8 g/bhp-hr
  - NOx range needed to be plotted on a log scale
- EPA binning shows less variability between bins



# Binning Physical Activity: Return To Service, Modified

Low NOx Engine



- ▶ Hot running emission range from 0.005 to 0.145 g/bhp-hr
- ▶ Cold start at 1.49 and 50% of the emissions in 40 min from a 10 hr day

# Back Up Slides

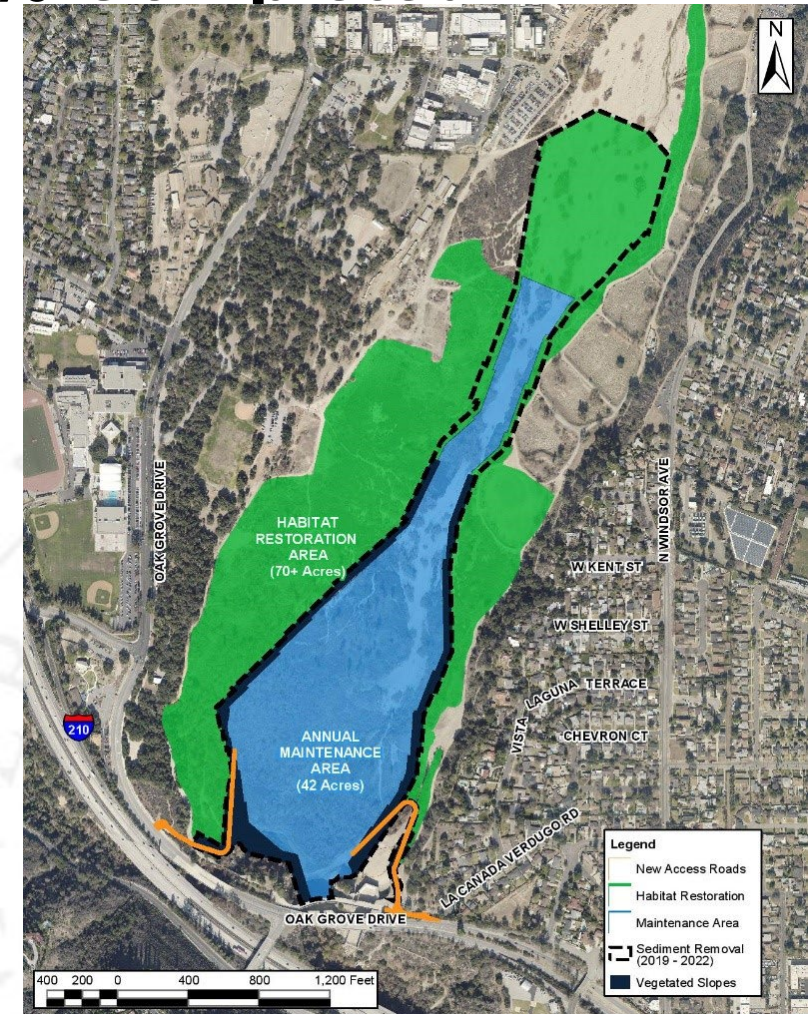


# OSAR Funded Project And Other OBD Projects



# OBD Project: Devil's Gate Project: 100% Completed

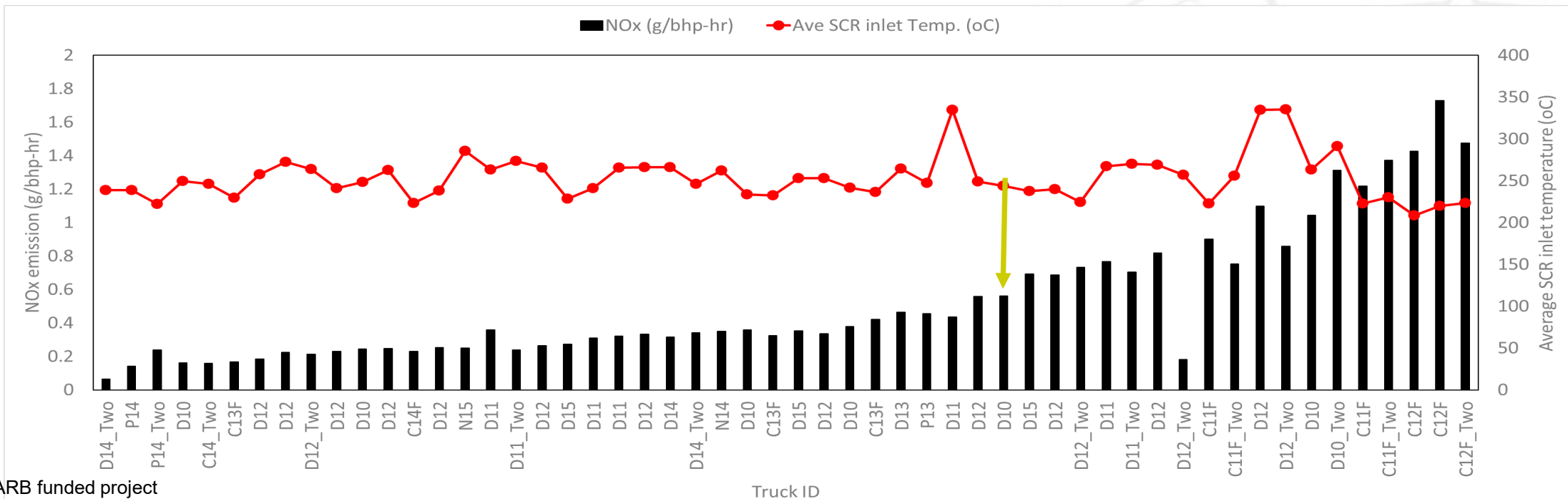
- Remove 1.7 million cubic yards of excess sediment in 4 year (2 more years)
- Hauling 5 days a week from 7am-3pm
- Conduct mobile source emissions testing of sediment removal trucks to evaluate emissions performance measures





# Devil's Gate: NOx Results OBD Sensors

- ❑ ~1/3<sup>rd</sup> of trucks operating at or below NOx standard of 0.2 g/bhp-hr
- ❑ ~2/3<sup>rd</sup> of trucks operating at or below 0.4 to 0.5 g/bhp-hr (~average emissions level)
- ❑ Overall fleet average = 0.45 g/bhp-hr, for non-credit engines = 0.38 g/bhp-hr
- ❑ Three highest emitters are 2011-2012 “credit” engines



# OSAR Specific Funded Project

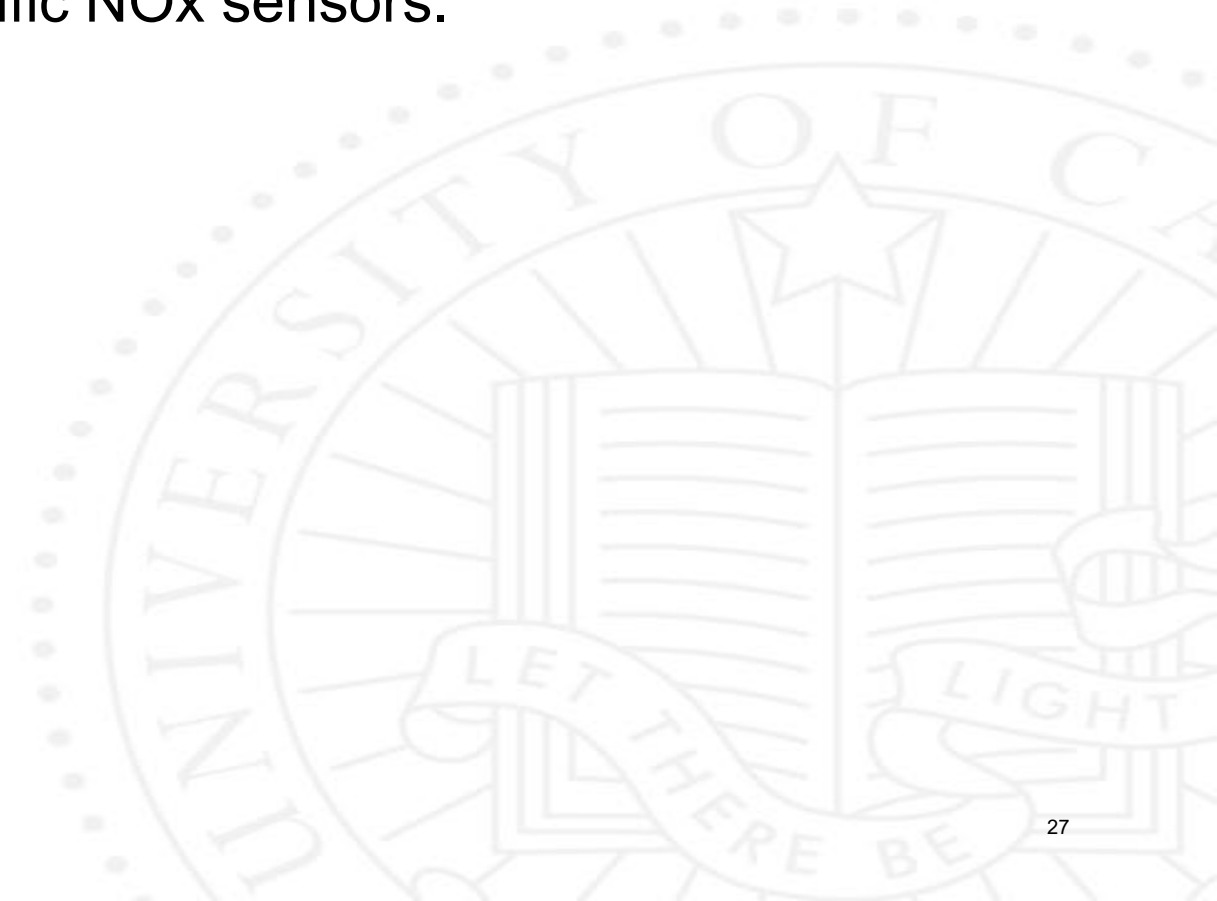
- ▶ **SC-AQMD phase 1 (50% completed)**
  - ▶ Eight trucks (two vocations)
  - ▶ Integrate ECU, GPS, NOx, PM sensors
  - ▶ Operate for 12 months (maybe extend)
  - ▶ Operate at key on (and leave on for short delay)
- ▶ **Lights ZANZEFF (completed)**
  - ▶ Eight trucks
  - ▶ Two weeks
  - ▶ Compare to PEMS data from one day
  - ▶ Compare to PAMS data from 90 plus days
- ▶ **ARB** (in-use PEMS testing validation), in-kind (**kick off meeting March 2022**)
- ▶ **CARTEEH (changed to binning, 50% completed)**
- ▶ **EPA** (started first set of sensors)
  - ▶ Bring sensors back to CERT and evaluate
  - ▶ Evaluate at 0, 3, 6, 9, and 12 mo
  - ▶ Evaluate up to 5 sensors from in-use
  - ▶ Evaluate (TEM, Impedance, interference, accuracy..)

## EPA Project: Status

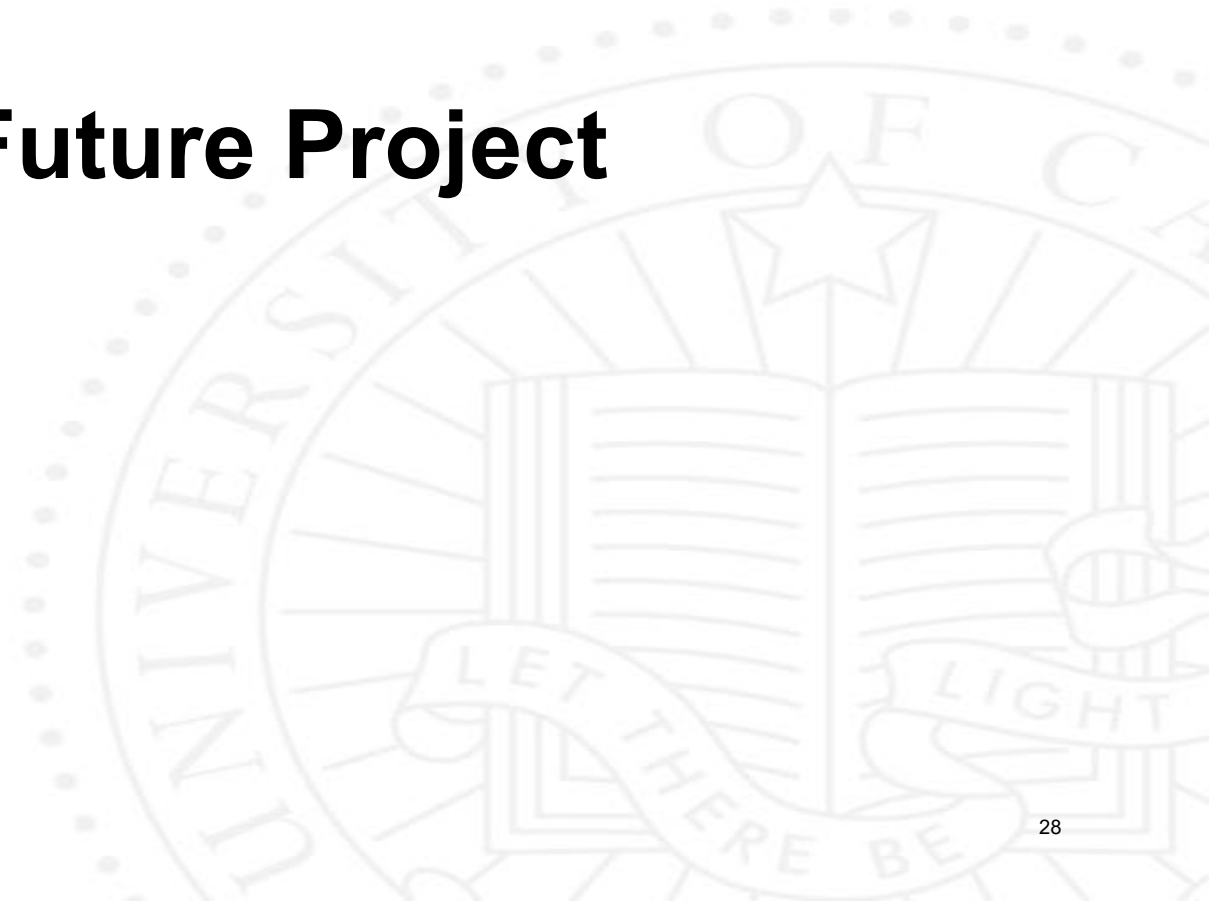
- › Contract renewal approved and work started
- › CAN data messaging did not follow standard outputs.
- › Working on CAN messaging for OEM specific NOx sensors.



The OSAR laboratory is in partner ship with EmiSense



# OSAR: New and Future Project



# New and Future Project

- ▶ **ARB OSAR** sensor study started (**Kick off meeting March 2022**)
  - ▶ Testing 40 OBD sensors (NOx, CO2, and others as available PM, NH3, and N2O)
    - ▶ Include current and future OBD versions
    - ▶ Advanced versions (lasers) and other startups
  - ▶ Deploy systems on up to 100 **on-road** trucks and 20 large **off-road** diesel engines
  - ▶ Possible co-funding to expand the study (EMA and EPA)
- ▶ **Attorney General (AG) VW Funds 1.6Mil OMEGA** (**Kick off meeting Feb 2022**)
  - ▶ Work a local fleet (changed from Amazon to DHE)
  - ▶ Instrument 40 trucks with OSAR for extended period of time
  - ▶ Tom will present more on this
- ▶ **DOT** (Awarded and in preparation)
  - ▶ CA Locomotives, low carbon fuels, Amtrak

# How the projects fit together

- ▶ **System development**
  - ▶ SC-AQMD phase 1
  - ▶ Lights ZANZEFF
  - ▶ CARTEEH
- ▶ **Aging evaluation**
  - ▶ EPA
- ▶ **New Sensors and Advances**
  - ▶ ARB Research
- ▶ **Community impacts and mitigation and eco routing**
  - ▶ Attorney General (AG) VW Funds  
1.6Mil OMEGA
  - ▶ AQMD Phase 2
- ▶ **Fuels impacts and improved efficiency engines. Compare CO<sub>2</sub> vs work metric differences**
  - ▶ DOT
  - ▶ Achates

## What is still needed

- › **Use binning method to predict local community impacts**
- › **What can be done about regulations to protect community based on binning**
- › **Databasing this data for other evaluations**
- › **What is the impact of Marine OGV and port communities**
- › **What is impact of Loco and communities**
- › **What is impact of Construction on community**
- › **Other**