Evaluation of a NO_x Tracking Concept Using Heavy-Duty Truck OBD Data

Yi Tan, Paul Henderick, Seungju Yoon, Tom Montes, Jorn Herner
California Air Resources Board

Kanok Boriboonsomsin, Kent Johnson, George Scora, Daniel Sandez, Tom Durbin
University of California, Riverside

In-use NO_x Emission – NO_x Tracking Concept

- The NO_x tracking concept is recently proposed to the heavy-duty OBD amendment.
- In-Use NO_x emissions could be better understood along with binned engine power and vehicle speed

	Vehicle Speed (mph)				
% of rated power	***Idle***	***1 - 10***	***10 - 25***	***25 - 40***	***40+***
<25	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5
25 - 50	Bin 6	Bin 7	Bin 8	Bin 9	Bin 10
50+	Bin 11	Bin 12	Bin 13	Bin 14	Bin 15

NTE

HD Activity Data Collection

Data Logger

Data loggers automatically record OBD (on-board diagnosis) and GPS data. Loggers have 4GB internal memory and telematics option.

Vehicle Selection

CE-CERT selected 90 heavy duty diesel/CNG/hybrid vehicles, representing 10 vocations. Most vehicles are 2010+ MY MHDD and HHDD trucks and buses.

Activity Collection

The real world activity of each vehicle was recorded for at least one month.

Vehicle Statistics

- The analysis only included trucks with valid data from NO_x sensors
- 72 vehicles from 16 vocational groups
- Data from SCR inlet NO_x sensor were missing from 4 vehicles

Vehicle Types	Vocation ID	Vocation Type	Veh. Num.
Long Haul	1a	Line haul - out of state	3
Long Haul	1b	Line haul - in state	3
Short Haul	2a	Drayage - No. Cal.	1
Short Haul	4a	Construction - heavy	6
Short Haul	4b	Construction - small	5
Pick-up and delivery	5a	Food distribution	5
Pick-up and delivery	5b	Beverage distribution	6
Pick-up and delivery	5c	Local moving	1
Pick-up and delivery	6	Shuttle	5
Pick-up and delivery	7	Refuse	6
Pick-up and delivery	8a	Urban buses	6
Service-oriented	9a	Freeway work	5
Service-oriented	9b	Sweeping	5
Service-oriented	9c	Municipal work	3
Service-oriented	9d	Towing	7
Service-oriented	10	Utility repair	5
		Total	***72***

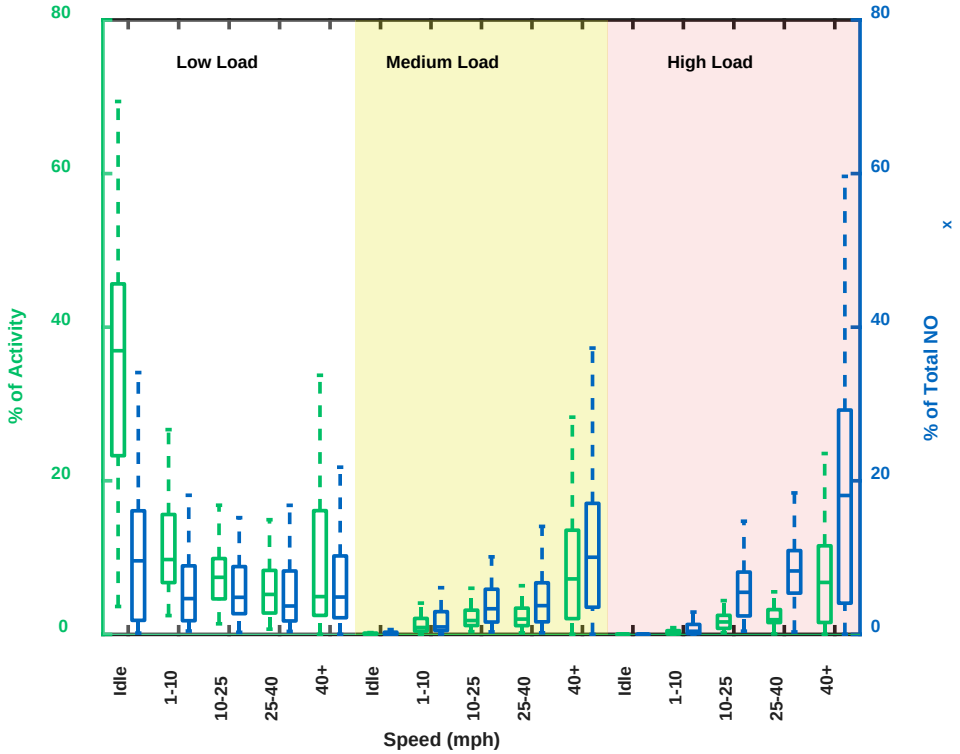
NO_x Emission Estimation Using OBD Data

- Exhaust flow rates were estimated from engine fuel rate and intake air mass flow rate.
- Engine-out and tailpipe NO_X emission factors were calculated from NO_X readings at the inlet and outlet of the SCR system.
  - Data when the NO_x sensors were turned off or warming up were not used for this analysis.
- Brake power was calculated from torque values and engine RPM.

$$NO_x\left({}^{g}/_{bhp-hr}\right) = \frac{\sum NO_x\{Exhaust\ flow\ rate, NO_x\ conc.\}}{\sum Brake\ Power\{actual\ torque, friction\ torque, RPM\}}$$

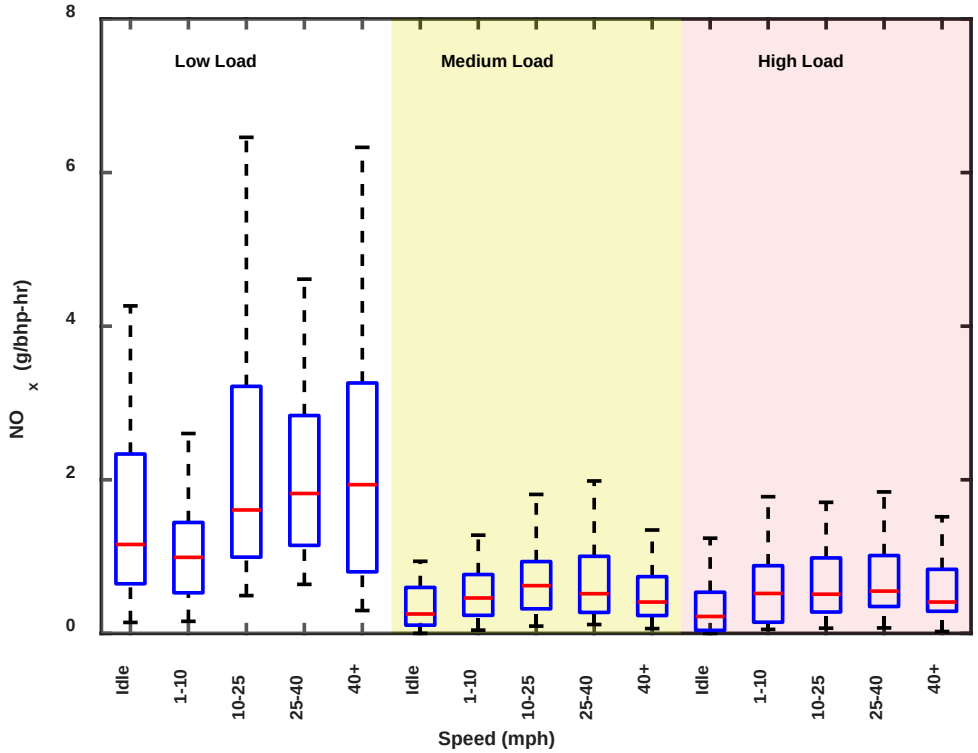
Low Load Operations in Real-World Activities

- Low load operation constitutes substantial portions of activity and NO_x emissions
  - Low load: 63% and 34% of total activity and NO_x, respectively
  - Low load idling: 34% and 13% of the total activity and NO_x, respectively



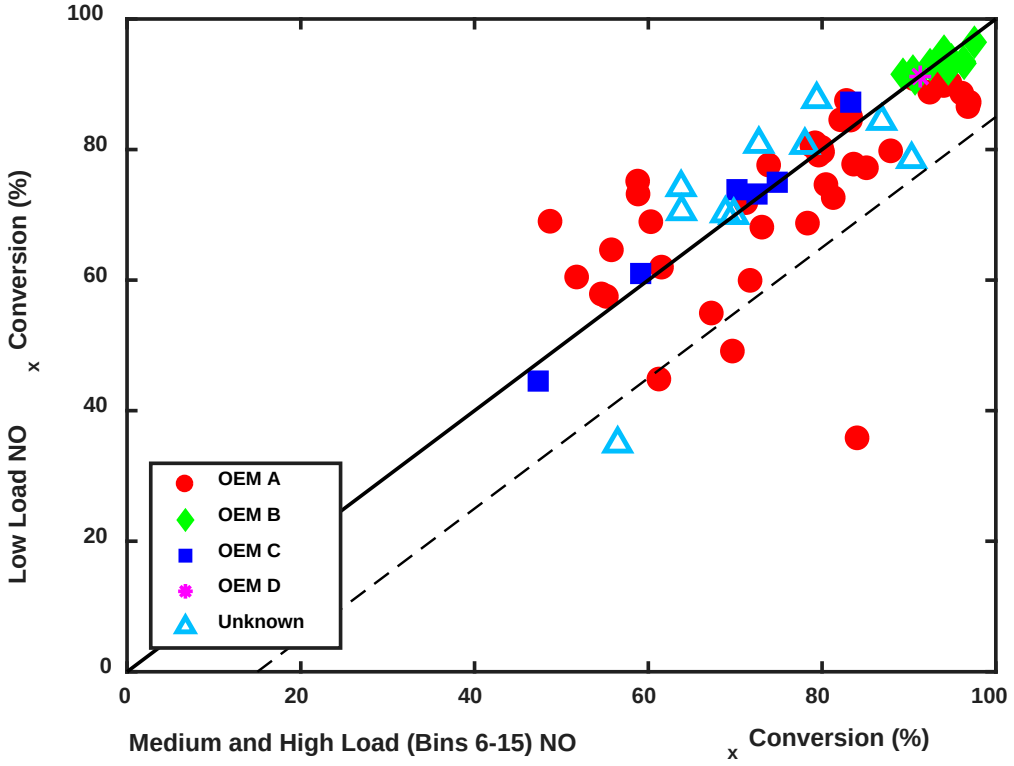
Work-Based NO_x Emission Rates

- Low load operations had much higher NO_x emission rates across all vehicle speed
- Vehicle speed had moderate effects on brake-specific NO_x emission factors



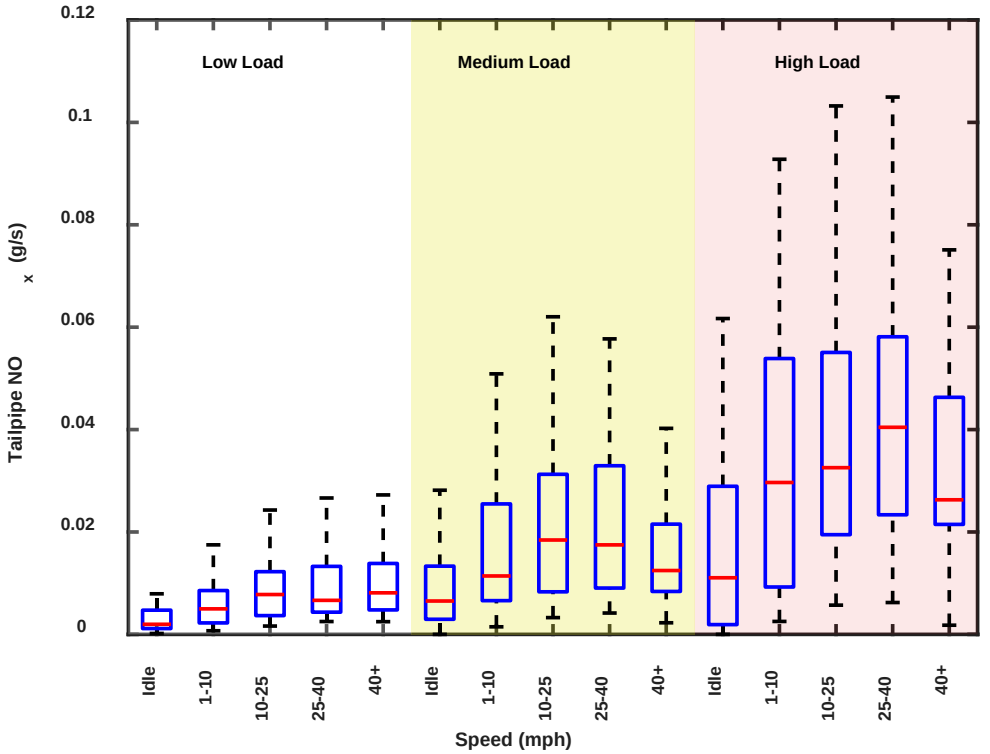
NO_x Conversion Efficiency Were Similar at Different Loads

- NO_x conversion efficiencies of most trucks were relatively similar at low and higher loads
- Three outlying trucks had unusually low NO_x conversion efficiencies at low loads (more than 15% lower compared to higher loads)



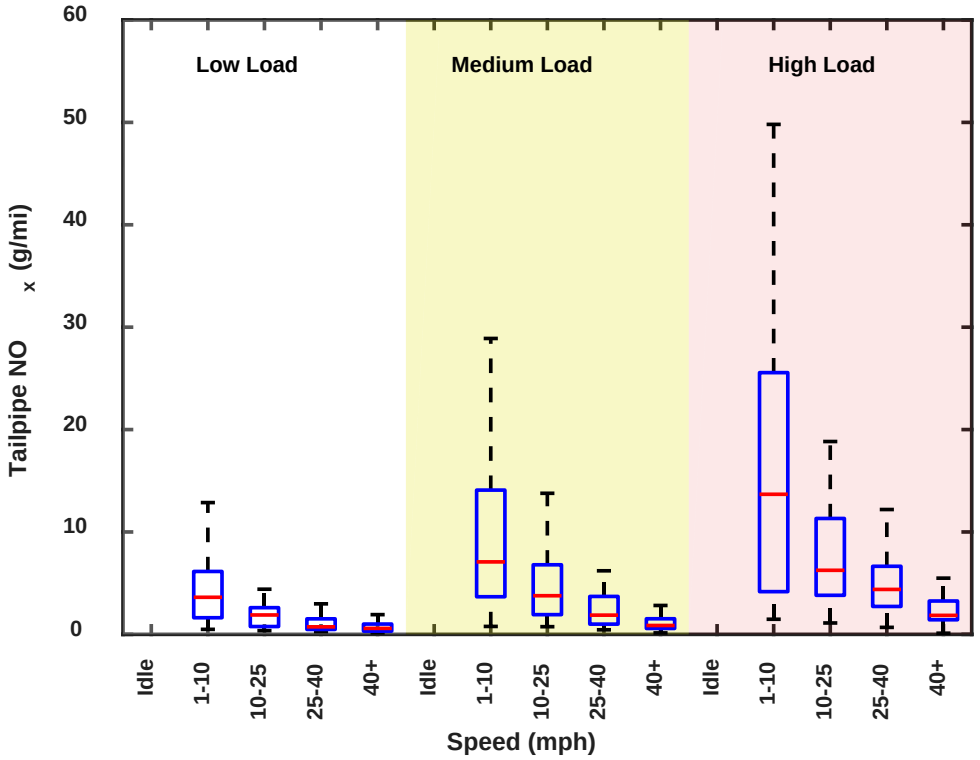
Time-Based NO_x Emission Rates

- Instantaneous emission rates increased as vehicle speed and engine power increased



Travel Distance-Based NO_x Emission Rates

- Distance-based NO_x emission rates increased when engine load increased, and decreased when speed increased
- Distance-based emissions were not calculated for idling



Conclusions

- The NO_x tracking concept can effectively monitor in-use NO_x emissions under various operation conditions
  - Work-Based
  - Time-Based
  - Distance-Based
- Comparing NO_x emissions at different loads from a large fleet could identify vehicles with unusual emission behaviors

Acknowledgement

CARB contract 13-301 with CE-CERT – raw data

Chris Ruehl, Sonya Collier, Tao Zhan – discussion on data analysis

THANK YOU