Using Partnerships to Gather Real-World Vehicle Activity and Emissions to Support EPA's Modeling Efforts

Carl Fulper

7th PEMS Conference

University of California, Riverside , CE-CERT

March 30-31, 2017

US Environmental Protection Agency, Office of Transportation & Air Quality
National Vehicle and Fuel Emissions Laboratory, Ann Arbor, MI

Outline

- Overall Research and Development Goals
- Partnerships
- Approach: Integrated “Real World” Test Design
- Developing a “Suite of Tools”

Research & Development

- Goal: Assess and gather mobile source activity and emission data to better understand the “real-world”
- Focus efforts on improvements in
  - Data gathering efforts
  - New sampling methodologies
  - Measurement equipment
  - Testing procedures and protocols
  - Modeling efforts

Working Together

Partnerships

Governments, Universities, Regulated Community, International Regulators, & others

Testing

Laboratory	"Real World"
Chassis Dynos Engine Dynos Evap SHEDs	Portable Emission Measurements Portable Activity Measurements Remote Sensing

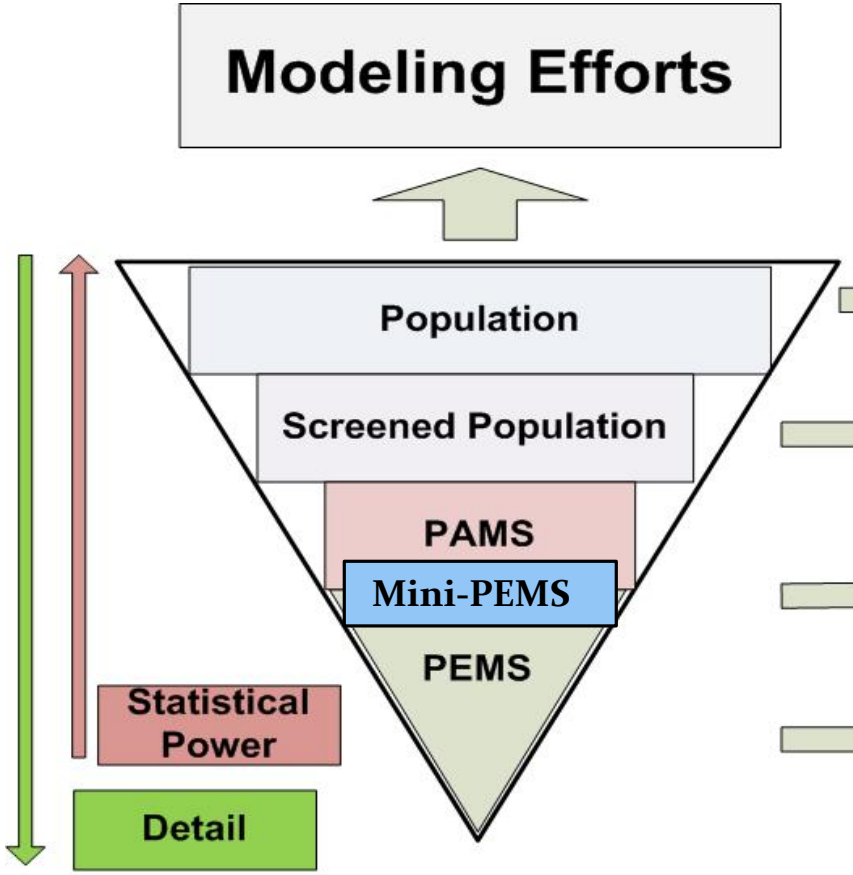
Support Mechanisms:

- CRADAs – a cooperative research and development agreement is an agreement between a government agency and a private company or university to work together on research and development.
  - **Can include: Staff Expertise, Equipment Loan & Laboratory Time**
- IAG - Interagency Agreements
- Contractor Support

Partnerships

- Sample EPA Partnerships
  - IAGs with DOE's National Renewable Energy Laboratory and Oak Ridge National Laboratory
    - Heavy-duty vehicle activity data, heavy-duty engine emissions
  - CRADA with University of California's CE-CERT
    - Gather heavy-duty vehicle activity and emissions data
  - CRADA with Texas Transportation Institute (TTI)
    - Gather heavy-duty vehicle activity and emissions data
  - CRADA with Colorado's Department of Public Health and Environment
    - Gather light-duty emissions data

Integrated "Real World" Test Design



Population Data:
- Department of Motor Vehicles
- Port Gate Data
- Fleet Data
- Obtain population and temporal allocation

Emission Screening:
- Remote Sensing tools: HEAT, Portable tent, mini-PEMS
- Random population evaluated for days to months
- Obtain emission "snap shots" to identify high emitter population through license plate

Portable Activity Measurements:
- Hundreds of vehicles measured over several weeks to months in real world
- Obtain activity and temporal allocation

Portable Emission Measurements:
- Less than 100 vehicles measured for one day of operation in real world
- Obtain activity, emissions, and temporal allocation

EPA Examples:
- Colorado's Light Duty Vehicle Deterioration and High Emitter Programs
- Houston-Galveston Port Study
- Kansas City Light-Duty Vehicle Test Program
- Nonroad Construction Test Program

Development of Suite of Tools

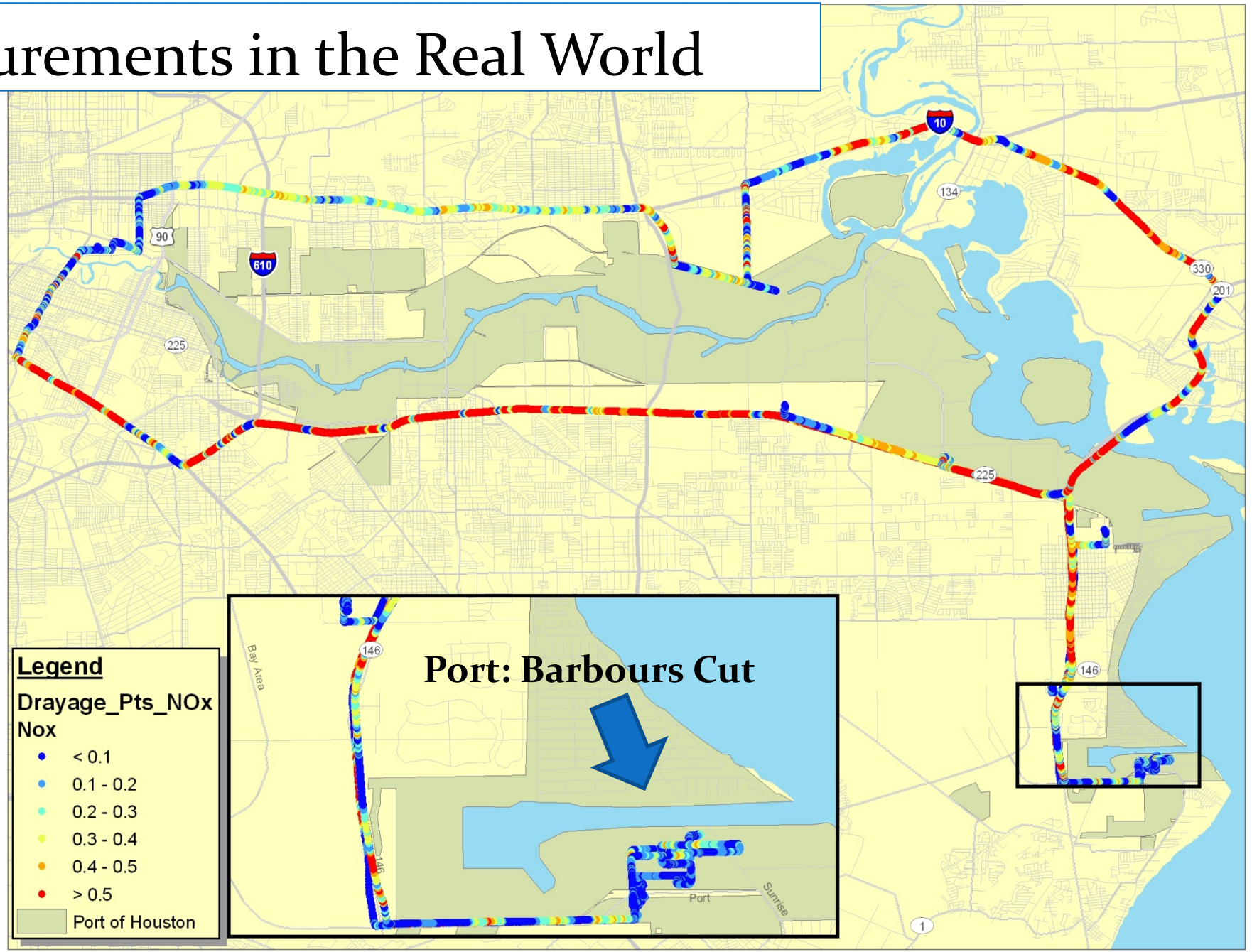
- Portable Emissions Measurement Systems (PEMS)
- Portable Activity Measurement Systems (PAMS)
- Remote Sensing Devices
  - ESP
  - Heat
  - Mini-Pems (non 1065)

Suite of Tools: PEMS

Portable Emissions Measurement Systems (PEMS)

- Gathers very detailed activity, engine parameters and emissions in “real-world” operations
- Measurement of CO_2, THC, CH_4, CO, NO, NO_2 and NOx emissions
- Gather activity data both by GPS and vehicle interface
- Major advancements over last 15 years

Emission Measurements in the Real World



Suite of Tools: PAMS

Portable Activity Measurement Systems (PAMS)

- Small data loggers interface with on-board vehicle computers to gather very detailed activity and engine parameters in "real-world" operations from light-duty, heavy-duty, and nonroad
  - Activity: vehicle miles traveled distribution, number of starts, soak periods
  - Engine: Engine RPM, engine load, aftertreatment

- Major advancements:
  - Cellular PAMS Data Loggers
  - Created a "Dashboard" to monitor data logger and vehicle
    - "Real-time" notification of issues with data logger and/or vehicle
    - Allows for "Real-time" data analysis

Vehicle Activity Datasets

- 5-State Telematic light-duty vehicle data
  - Over 45,000 vehicles representing over 45 million trips over one calendar year
  - Major modeling efforts include analysis of VMT, soaks, starts, seasonal effects, weekday/weekend, etc.

- Two CARB heavy-duty vehicle programs
  - Instrumentation of ~100 Class 5-8 vehicles covering 20 different vocations over one to four months has completed
    - Gathered over 100 engine data fields and GPS data representing over 20 Gigabytes of data
  - Major modeling efforts include analysis of VMT, soaks, starts, seasonal effects, weekday/weekend, etc.
  - CARB's HDV Greenhouse Gas Emissions Program will instrument ~ 200 vehicles during 2017

- DOE's National Renewable Energy Laboratory
  - Activity data on hundreds of heavy-duty vehicles

- Texas Transportation Institute (TTI)
  - Instrumenting ~15 buses
  - Class 8 drayage fleet data gathering starting early 2017

ARB/University of California Study

Preliminary Data

Different vehicle speed bin and time of use patterns

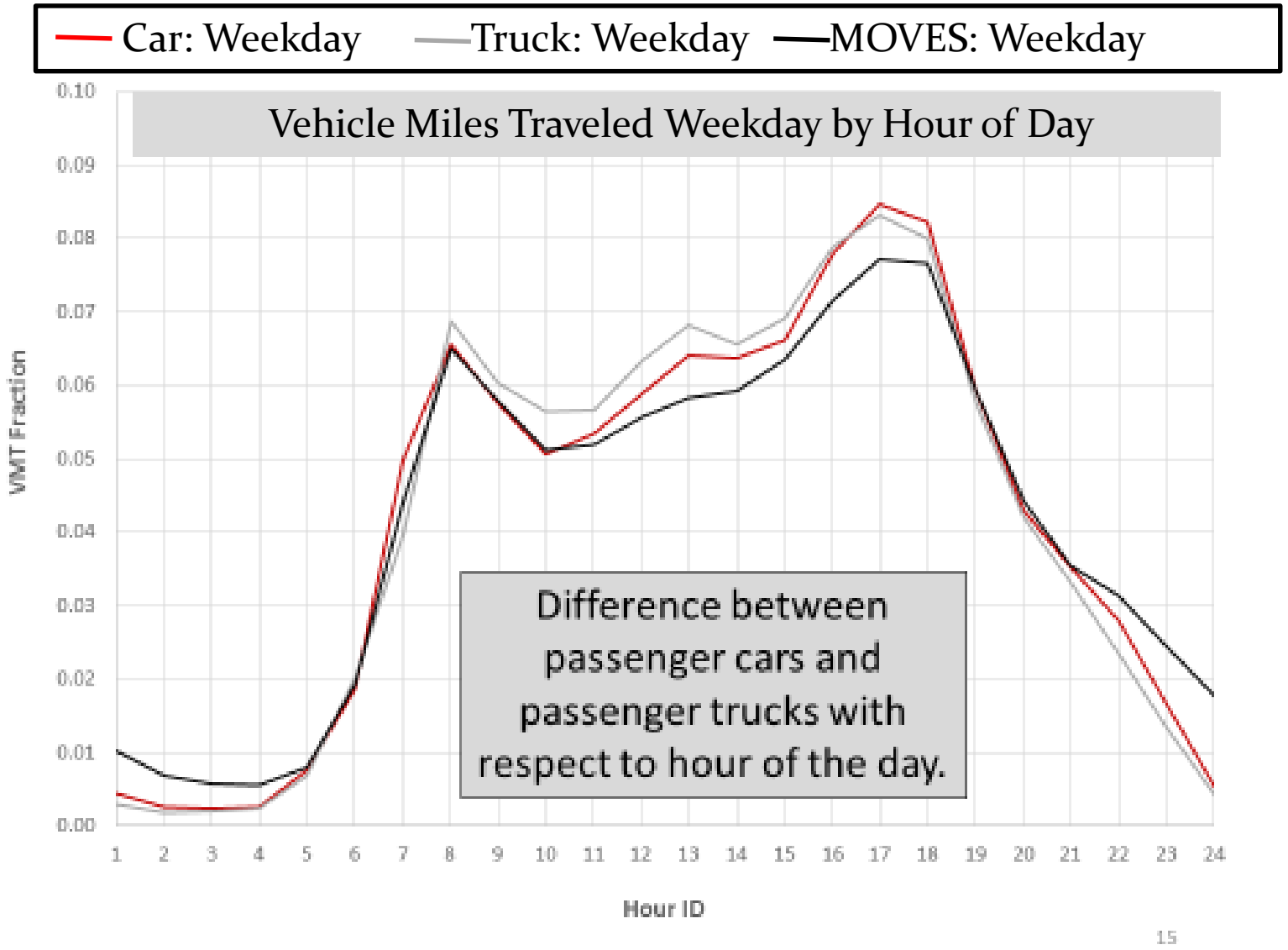
Speed Bin		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	Sum
		8.26	9.55	9.37	7.31	8.67	8.41	8.68	8.74	8.75	7.83	5.74	8.37	0.34	0	0	0	0	0	100
Hour																				
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
3	0.10	0.09	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
4	0.73	0.39	0.12	0.04	0.04	0.03	0.03	0.04	0.02	0.01	0.00	0.00	0.01	0.00	0	0	0	0	0	
5	9.49	1.14	1.65	1.61	1.11	1.19	0.83	0.65	0.46	0.28	0.18	0.13	0.25	0.01	0	0	0	0	0	
6	11.55	1.27	1.60	1.66	0.95	0.91	0.93	0.82	0.60	0.56	0.53	0.46	1.24	0.03	0	0	0	0	0	
7	17.54	1.16	1.29	1.26	0.98	1.16	1.21	1.32	1.47	1.74	1.77	1.49	2.66	0.04	0	0	0	0	0	
8	13.06	1.27	1.56	1.41	0.96	1.05	1.14	1.08	1.02	0.99	1.06	0.80	0.67	0.04	0	0	0	0	0	
9	13.77	1.23	1.55	1.39	1.03	1.22	1.24	1.32	1.25	1.03	0.87	0.59	1.01	0.04	0	0	0	0	0	
10	18.01	0.94	1.10	1.16	1.18	1.55	1.47	1.77	2.08	2.33	1.97	1.20	1.24	0.03	0	0	0	0	0	
11	10.22	0.47	0.43	0.52	0.66	1.00	0.96	1.05	1.20	1.26	1.02	0.78	0.84	0.02	0	0	0	0	0	
12	2.75	0.14	0.13	0.18	0.22	0.29	0.30	0.33	0.33	0.30	0.21	0.11	0.17	0.05	0	0	0	0	0	
13	1.35	0.07	0.06	0.07	0.08	0.12	0.15	0.18	0.17	0.14	0.11	0.07	0.11	0.02	0	0	0	0	0	
14	0.91	0.05	0.03	0.05	0.06	0.10	0.11	0.09	0.09	0.06	0.07	0.06	0.10	0.01	0	0	0	0	0	
15	0.48	0.04	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.07	0.04	0	0	0	0	0	
16	0.05	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0	0	0	0	0	0	0	0	
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Sum	100																			100

VMT Distributions for Refuse Trucks

Speed Bin		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	Sum
		0.45	0.92	1.16	1.29	1.55	1.96	2.30	2.88	3.37	4.96	10.85	34.30	25.97	7.60	0.44	0.00	0	0	100
Hour																				
0	3.24	0.02	0.02	0.03	0.03	0.04	0.05	0.06	0.08	0.10	0.10	0.28	0.95	1.09	0.36	0.03	0	0	0	
1	3.06	0.01	0.03	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.10	0.23	0.77	1.12	0.41	0.03	0.00	0	0	
2	3.13	0.01	0.02	0.02	0.02	0.02	0.03	0.04	0.06	0.08	0.09	0.29	0.80	1.05	0.55	0.05	0	0	0	
3	2.89	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.06	0.12	0.46	1.21	0.83	0.04	0	0	0	
4	2.99	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.05	0.08	0.20	0.79	1.18	0.53	0.02	0	0	0	
5	3.70	0.02	0.04	0.04	0.05	0.06	0.09	0.10	0.10	0.12	0.17	0.37	1.18	0.94	0.40	0.01	0	0	0	
6	4.53	0.02	0.03	0.05	0.07	0.09	0.11	0.13	0.16	0.19	0.29	0.60	1.40	1.04	0.33	0.01	0	0	0	
7	4.16	0.02	0.05	0.07	0.09	0.11	0.13	0.14	0.17	0.19	0.25	0.49	1.44	0.92	0.10	0.00	0	0	0	
8	3.71	0.02	0.05	0.06	0.08	0.09	0.10	0.09	0.13	0.14	0.24	0.48	1.56	0.55	0.11	0.01	0	0	0	
9	4.36	0.02	0.04	0.04	0.05	0.06	0.07	0.10	0.10	0.15	0.30	0.76	1.96	0.69	0.04	0.00	0	0	0	
10	4.32	0.02	0.03	0.04	0.05	0.07	0.09	0.10	0.16	0.16	0.24	0.57	2.02	0.71	0.04	0.00	0	0	0	
11	4.48	0.02	0.04	0.05	0.05	0.06	0.08	0.09	0.11	0.16	0.30	0.70	1.96	0.80	0.05	0.00	0	0	0	
12	4.60	0.02	0.04	0.04	0.04	0.05	0.07	0.09	0.12	0.15	0.26	0.66	2.20	0.77	0.09	0.00	0	0	0	
13	4.92	0.02	0.03	0.05	0.05	0.06	0.08	0.10	0.12	0.13	0.21	0.58	2.38	0.95	0.14	0.02	0	0	0	
14	4.36	0.02	0.05	0.05	0.06	0.08	0.10	0.10	0.12	0.14	0.21	0.42	2.09	0.73	0.20	0.00	0.00	0	0	
15	4.86	0.02	0.06	0.07	0.09	0.10	0.11	0.13	0.16	0.18	0.28	0.55	1.78	1.23	0.09	0.00	0	0	0	
16	4.85	0.02	0.06	0.09	0.10	0.11	0.14	0.16	0.18	0.19	0.27	0.63	1.68	1.17	0.06	0.00	0	0	0	
17	3.91	0.03	0.09	0.10	0.10	0.12	0.14	0.18	0.21	0.21	0.26	0.38	1.04	0.96	0.08	0.01	0	0	0	
18	4.85	0.02	0.05	0.08	0.09	0.11	0.13	0.15	0.17	0.20	0.25	0.42	1.32	1.64	0.23	0.02	0	0	0	
19	4.87	0.02	0.04	0.05	0.05	0.07	0.08	0.10	0.16	0.17	0.24	0.46	1.42	1.58	0.39	0.03	0	0	0	
20	5.22	0.02	0.03	0.04	0.04	0.05	0.07	0.08	0.13	0.18	0.28	0.71	1.84	1.39	0.36	0.01	0.00	0	0	
21	4.69	0.02	0.04	0.04	0.05	0.06	0.08	0.09	0.12	0.16	0.22	0.44	1.38	1.35	0.59	0.03	0.00	0	0	
22	4.46	0.02	0.04	0.04	0.04	0.04	0.05	0.07	0.08	0.11	0.15	0.31	1.04	1.57	0.85	0.05	0	0	0	
23	3.83	0.02	0.03	0.04	0.04	0.05	0.07	0.07	0.07	0.10	0.13	0.21	0.85	1.32	0.78	0.06	0.00	0	0	
Sum	100																			100

VMT Distributions for Line-Haul Trucks

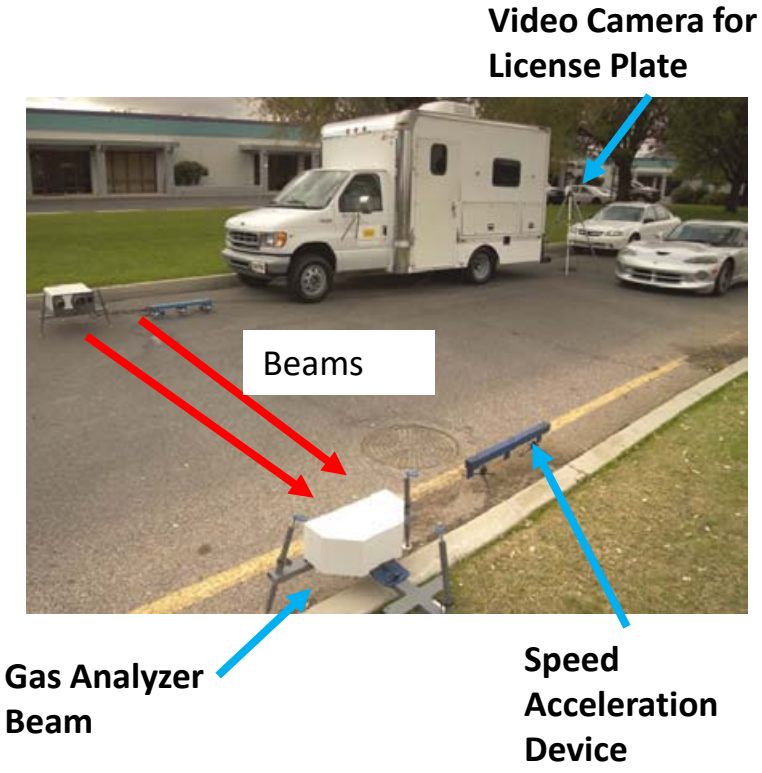
Light-Duty Telematics: Preliminary Data



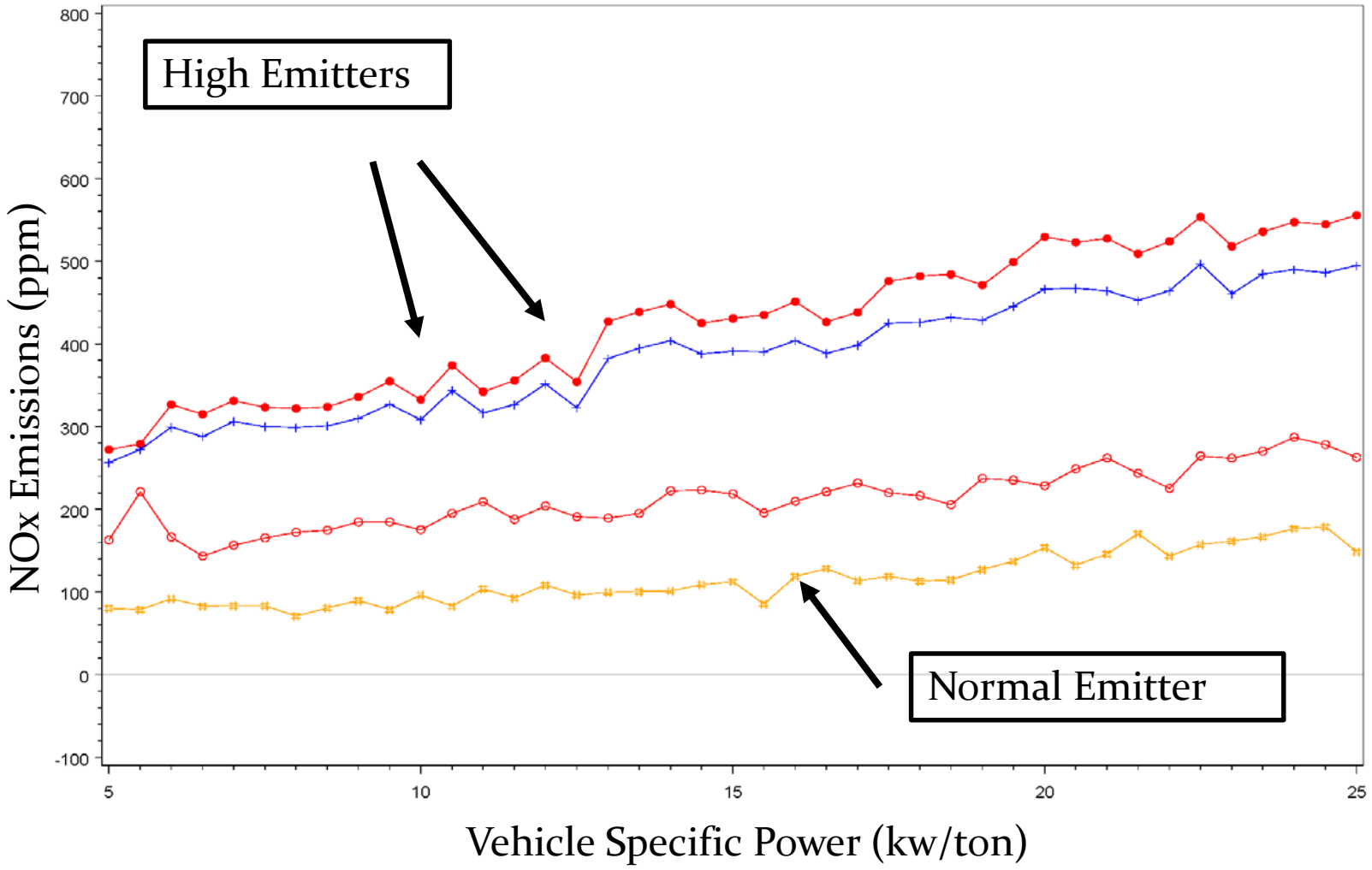
Suite of Tools: RSD

Remote Sensing Devices (RSD)

- A “snap shot” of emissions are measured by infrared (IR) and ultraviolet (UV) light beam across roadway
- Screens hundreds of vehicles per day in a semi-invisible manner
- Specific concentrations of HC, CO, CO_2, NO and smoke are measured and then reported as ratios to CO_2
- Colorado uses RSD to reduce the number of vehicles requiring a traditional I/M inspection through their Clean Screen Program



Light-Duty RSD Results



Improvements to Data Analysis:

QA/QC Procedures

- Goal: Quicker QA/QC and then quicker analysis of the data

- Currently developing and implementing an open database and open data analysis structure with our partners
  - Standard database structure: MySQL
  - Standard data analysis and QC/QA techniques: modular designed Scripts in Python and MySQL
  - Standard graphics: R

Improvements to Data Analysis

- Modular QA/QC Design

Step 1	Step 2	Step 3	Step 4
Data Structure & Nomenclature Checks	Date/Time & Vehicle Speed Checks	Engine Parameter Checks	GPS Parameter Checks
Define field names, definitions, etc.	Proper fields defined and validation	Proper field	

Additional Analysis

Allows for immediate data analysis on a per trip and aggregate basis

Soak times, starts, idle times, VMT, speed distributions, drive cycle development, use patterns, etc.

Engine load, SCR operation, DPF operation, Engine RPM, etc.

GPS Fencing (ports, hoteling, county, city boundaries), road types, etc.

Outcomes

- EPA is actively seeking partnerships to help gather better data to address present and future research.
- EPA wants to enhance local data gathering efforts to improve our models
- EPA is actively developing tools and methodologies to further support gathering activity and emissions data.
  - PEMS, PAMS and RSD
- This includes improvement and support:
  - Better integration and understanding "real-world" emissions on different vehicle and engine technologies
  - Better understanding of engine parameters to emissions in "real-world" operations
  - Better understanding of fleet "high emitters" by screening vehicles
    - Mini-PEMS/SHEDs/HEAT (EDAR)

Contact Information

Carl Fulper
US Environmental Protection Agency
Office of Transportation and Air Quality
Assessment and Standards Division
National Vehicle and Fuel Emission Laboratory
2000 Traverwood Drive
Ann Arbor, MI 48105
734-214-4400
fulper.carlr@epa.gov

Questions