Dynamic Energy and Emissions Management (DEEM)

PEMS Workshop 2018

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Presented By

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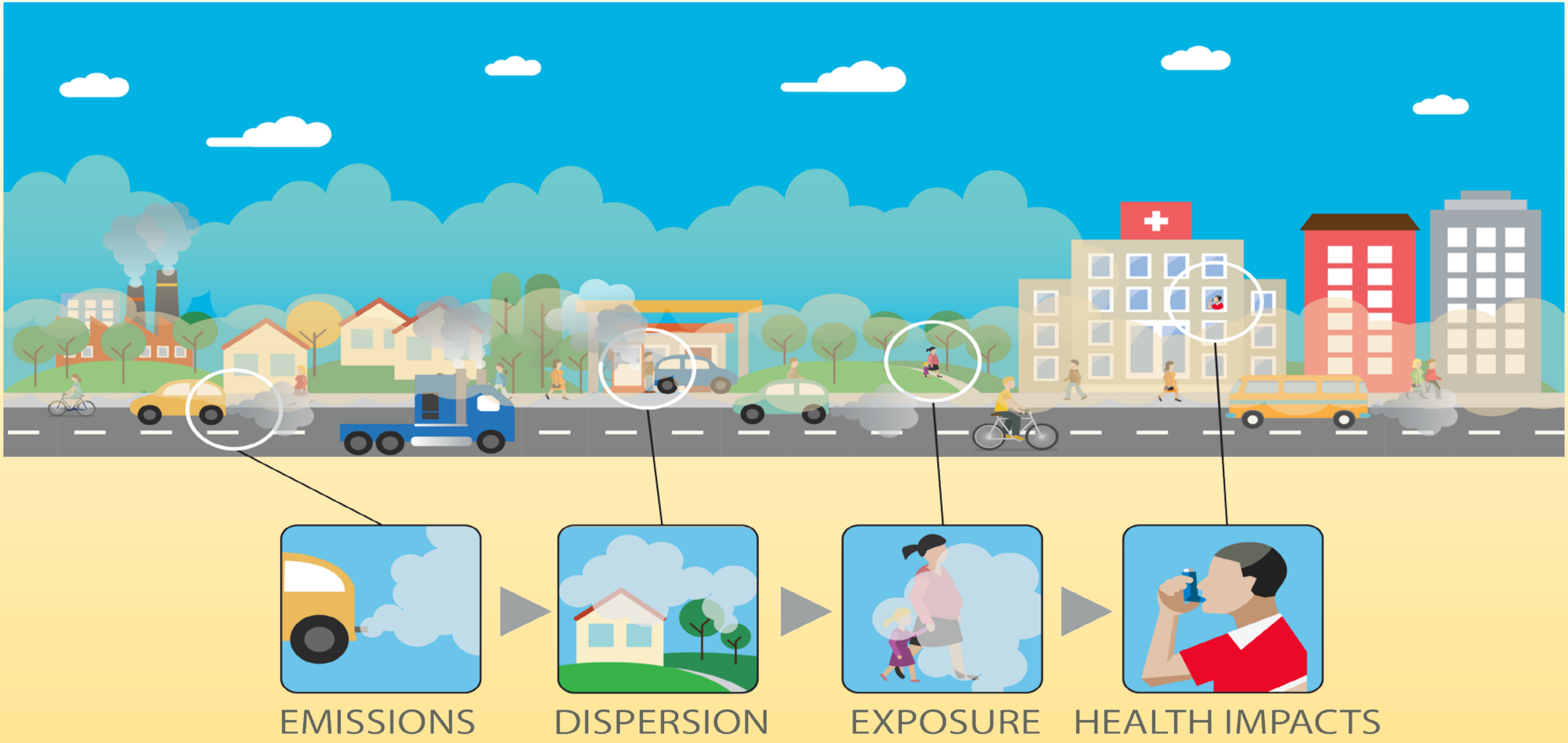
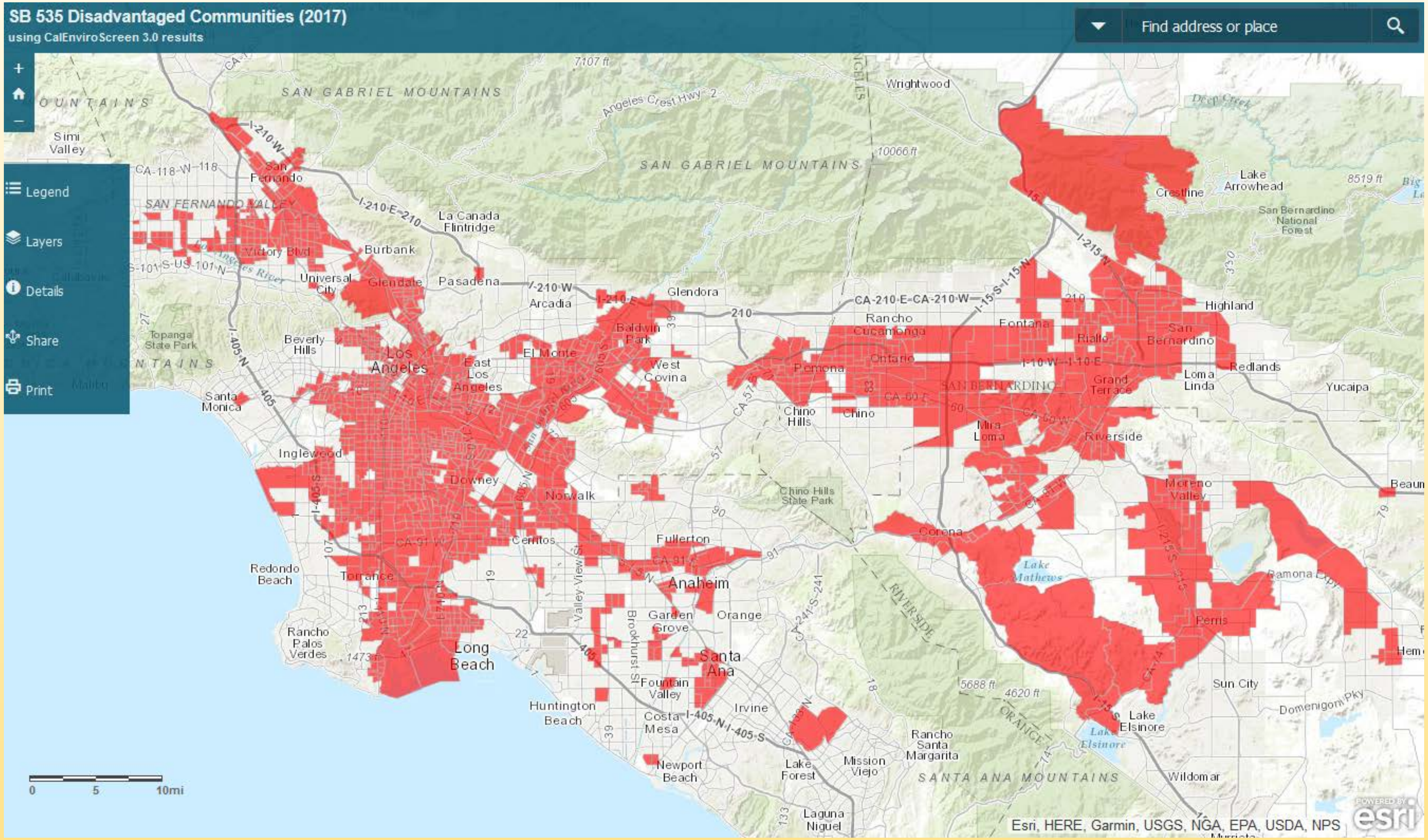
Emissions and Their Impact



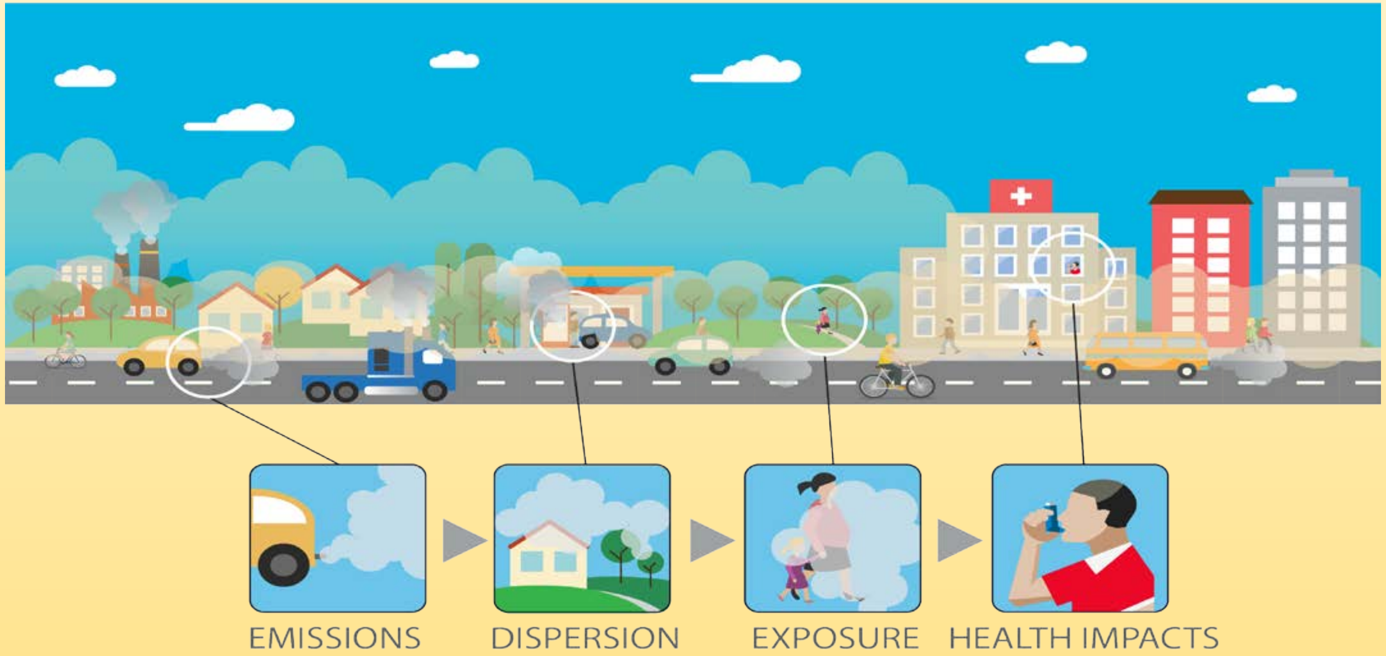
High Impact Areas and Focuses

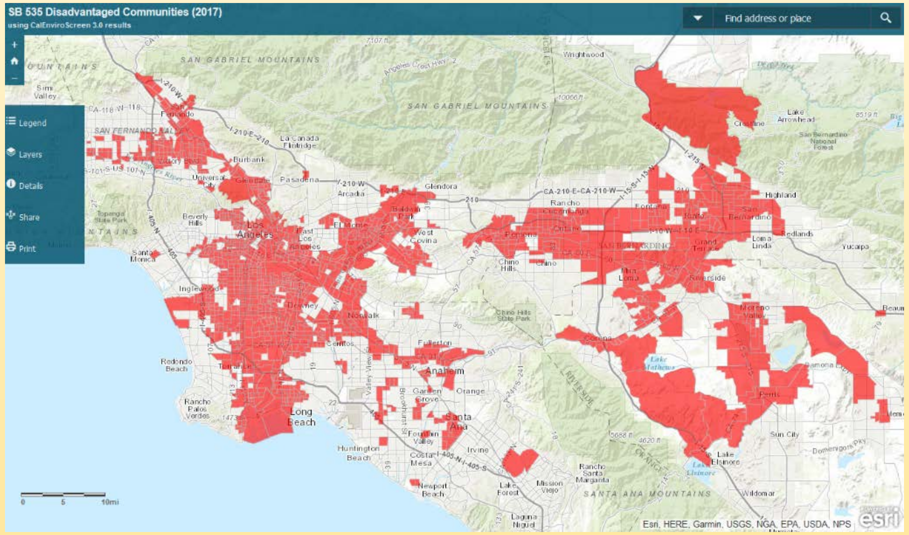
- For California, focus on disadvantaged communities.



Dynamic Energy and Emissions Management (DEEM)

- ***Managing Energy Consumption and Emissions in Real-Time***
  - Dynamic in terms of both spatially and temporally
  - Management from both industry and regulatory perspectives
  - Emissions of greenhouse gases, criterial pollutants, and air toxics
- Objectives of DEEM strategies

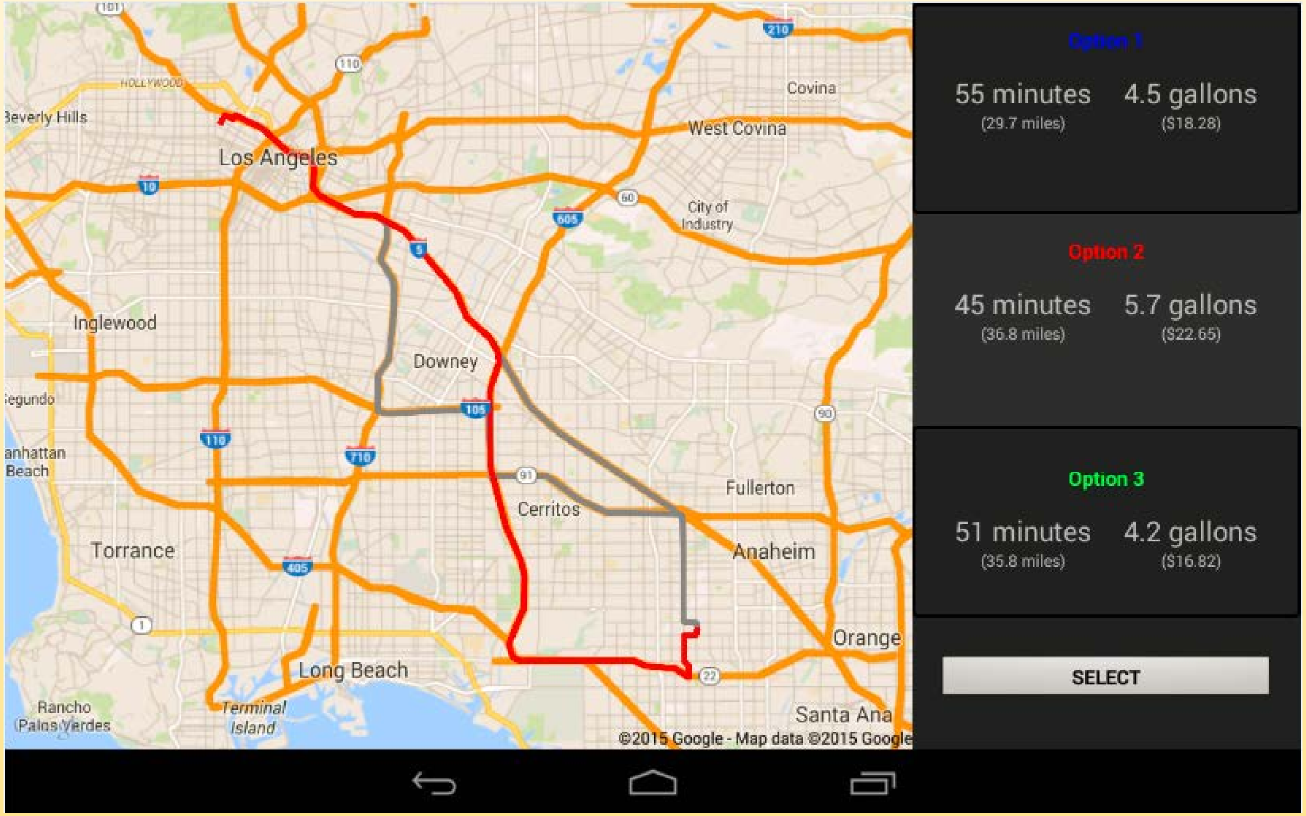




Disadvantaged Communities

VEHICLE & INFRASTRUCTURE INTEGRATION: TRAFFIC SYSTEMS

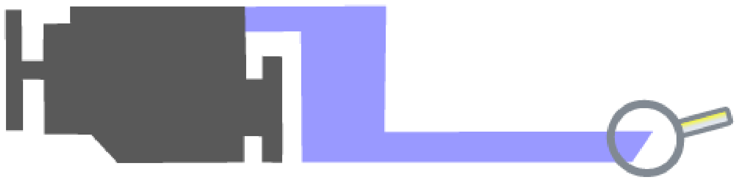
Improved traffic systems using intelligent vehicles and infrastructure to maximize safety, health benefits, mobility and efficiency



Connected Vehicles and Infrastructure (above) feed into mapping tools (left) that improve routing for congestion and fuel use

Modern Compliance Concepts

1. Sensor-Based Tailpipe Compliance evaluations would enable simple real-time in-use compliance assessment during powertrain development and vehicle operation



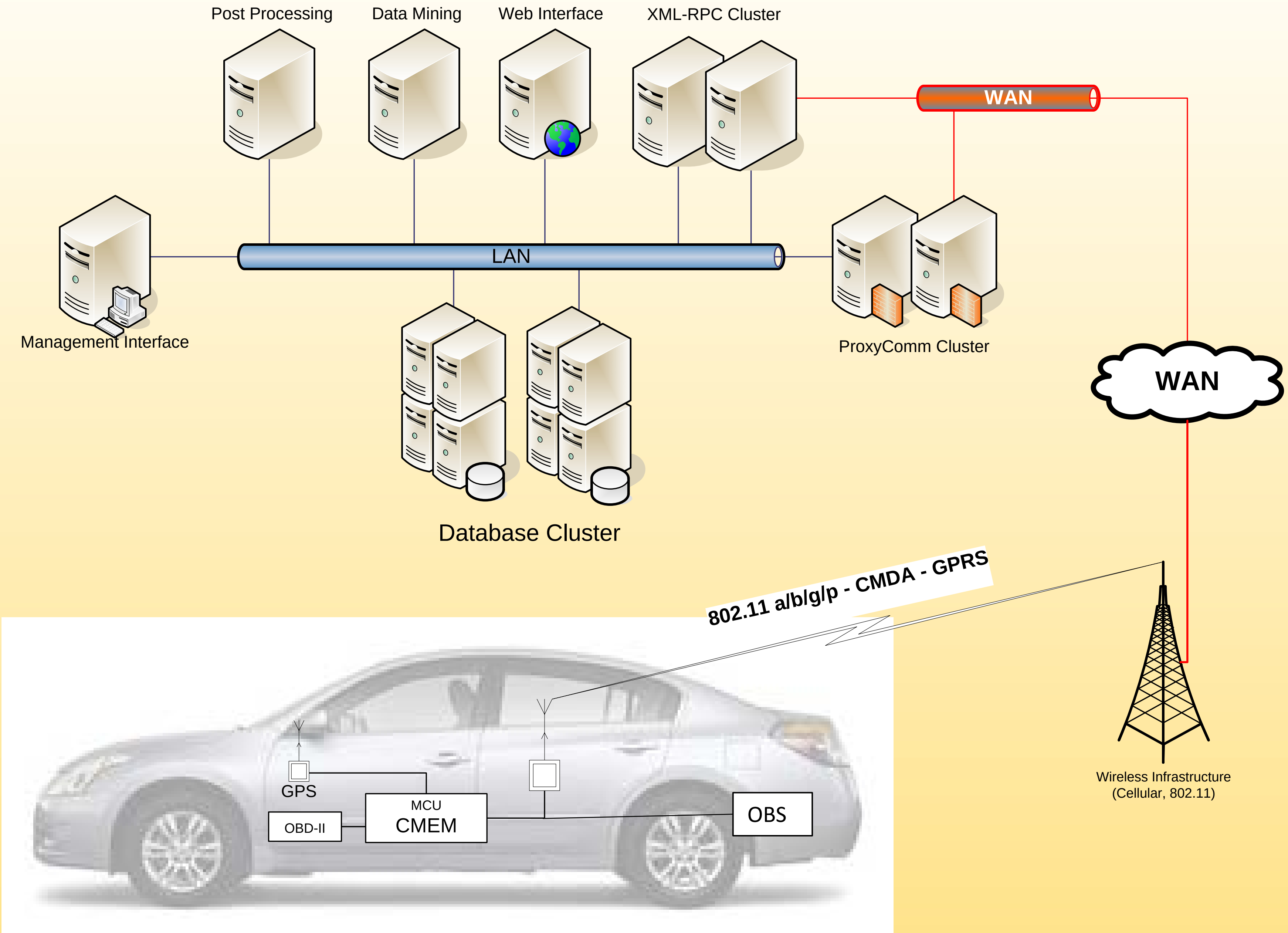
Consider New Compliance Units: NOx ppm / Fuel Consumption

2. Independent Sensor-Based PEMS-Light would discourage defeat devices while enabling cost effective compliance data over-check

Consider New Compliance Units: NOx ppm / CO_2 ppm

3. Telematic Compliance Summaries periodically submitted to regulators from manufacturer would provide engine family compliance tracking while minimizing 3rd party tampering and data ownership concerns

On-Board Sensing and Compliance

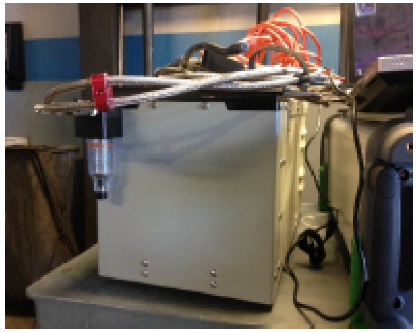


Low Cost Measurement Systems

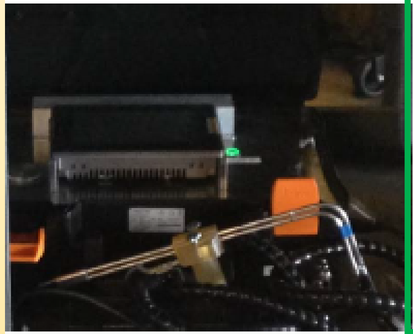
Maha

Pegasor Mi3

TSI NPET



Testo



parSYNC

NTK

ECM

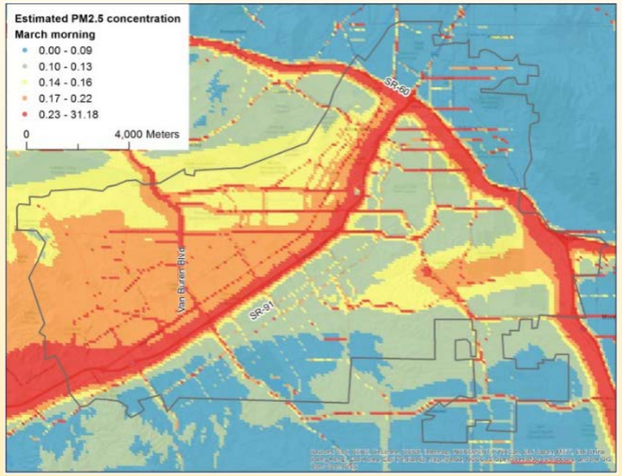
Axion/Montana

Instrument List

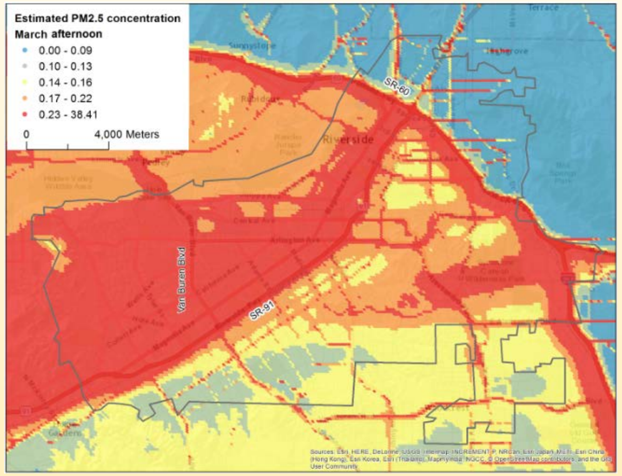
Instrument	Measure
Maha	NOx, CO_2, PM
Pegasor	PM
TSI NPET	Solid PN
Testo	PN
parSYNC	NOx, CO_2, PM
NTK	NOx, PM, AFR, PN ECM
ECM	NOx, CO2/CO, NH3, O2/AFR,ECM
Axion	Nox, CO2, CO, THC, PM, ECM

DEEM - Temporal Application

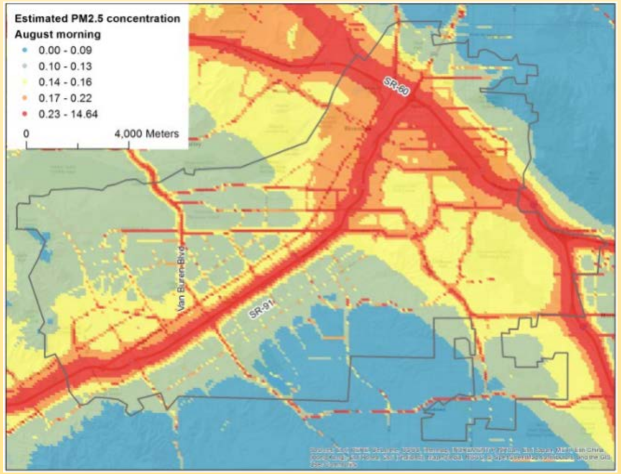
- Based on real-time or historical air quality patterns.
- Figures show modeled fine particle concentration from on-road mobile sources in Riverside, California



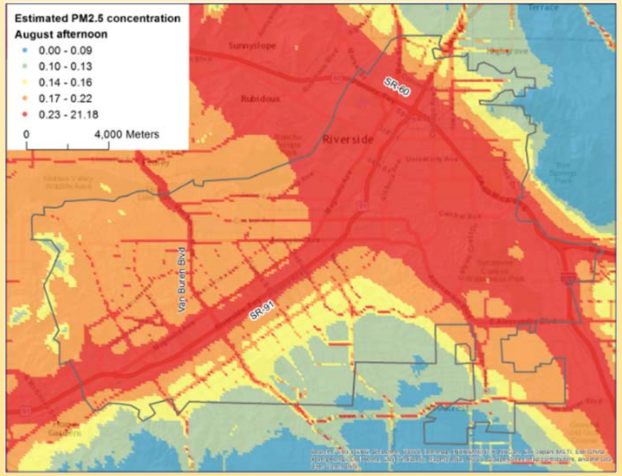
(a) March 2012, AM period



(b) March 2012, PM period



(c) August 2012, AM period



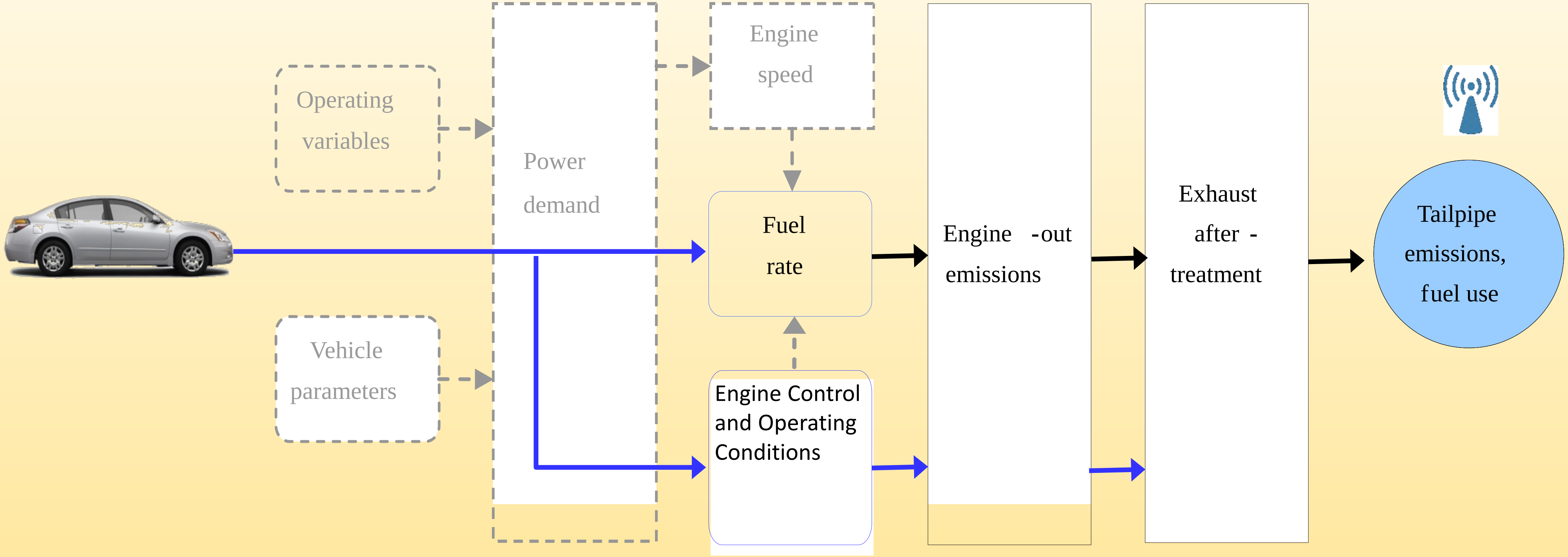
(d) August 2012, PM period

DEEM Strategies

- Transportation system level
  - √ Routing and navigation
  - √ Lower speed limits (*aka*, intelligent speed adaptation or speed harmonization)
- Vehicle/driver level
  - √ Eco-driving
- Engine/powertrain level
  - √ Energy management for HEVs and PHEVs
  - √ Engine tuning
  - Aftertreatment tuning

Real-time Emission Modeling

Comprehensive Modal Emissions Model (CMEM)



Verification and Assurances

Summary Thoughts

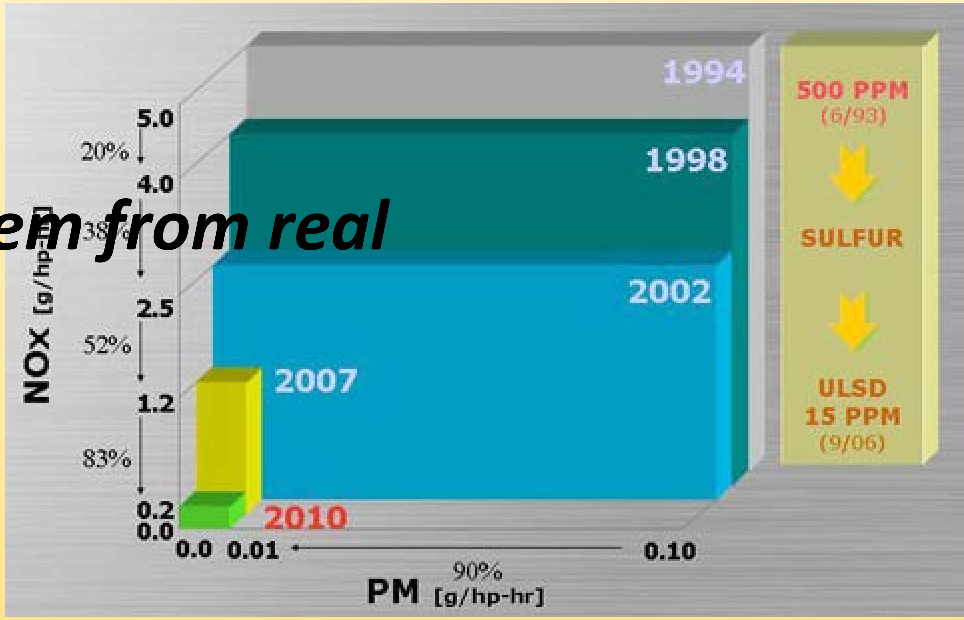
- *Vehicle system design shift from a laboratory focus to a in-use focus*
- *Take advantage of technology (sensors, connectivity, database, public)*
- *Revise regulation for DEEM concept (simple levers to control future regulation decreases)*
- *New regulation approach will provide:*
  - o *Vehicle activity*
  - o *Measured/predicted in-use emissions*
  - o *Vehicle active population*
  - o *Spatially and temporal information*

QUESTIONS

Vehicle Design is a Laboratory Approach

- *1970s Light duty emission standards*
- *1980s Heavy duty emission standards*
- *1990s Heavy duty in-use "Not-to-Exceed" standards and Light duty OBD*
- *2000s Heavy duty compliance testing protocol developed*
- *2010s Heavy duty OBD introduced*

What about for 2020s we design the vehicle system from real world requirements under actual conditions?



Heavy Duty Standards

What Tools Are Available for Emissions: Design

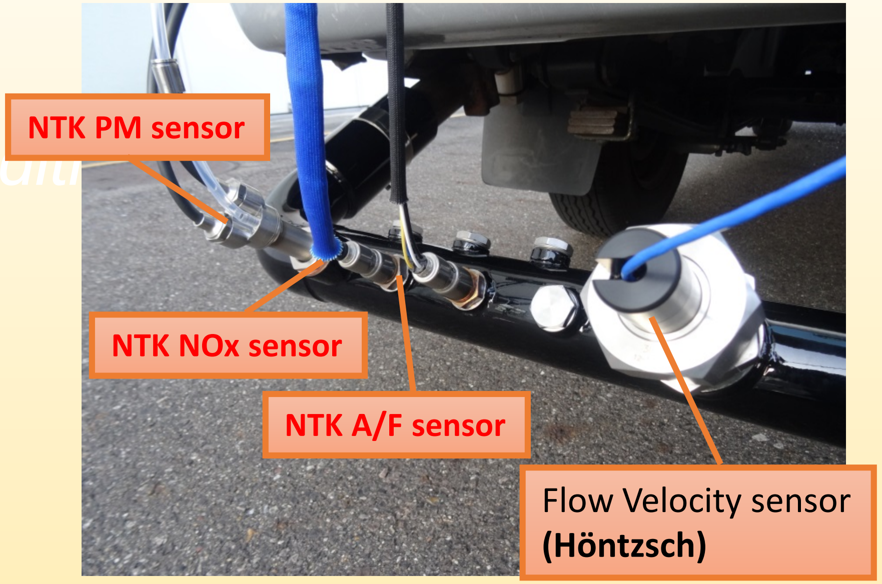
- *Telematics*
- *Seasonal weather adjustments*
- *Location-specific emissions (geo-fencing)*
- *On-board sensing for control and reporting*
- *Advanced sensing for compliance*
- *Mapping and self-learning algorithms*
- *Predictive thermal management*
- *Model based control*

WHAT TOOLS ARE AVAILABLE FOR EMISSIONS: COMPLIANCE

- ***Telematics and big data queries***
- ***Seasonal weather adjustments***
- ***Location-specific emissions (geo-fencing)***
- ***Independent low cost high frequency measurements and reporting***

Micro Portable Emissions Measurement Systems (uPEMS)

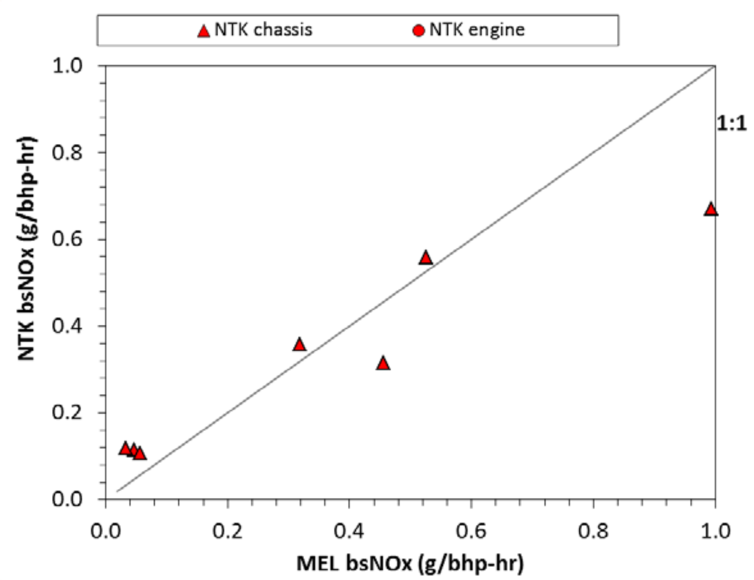
NTK NCEM System

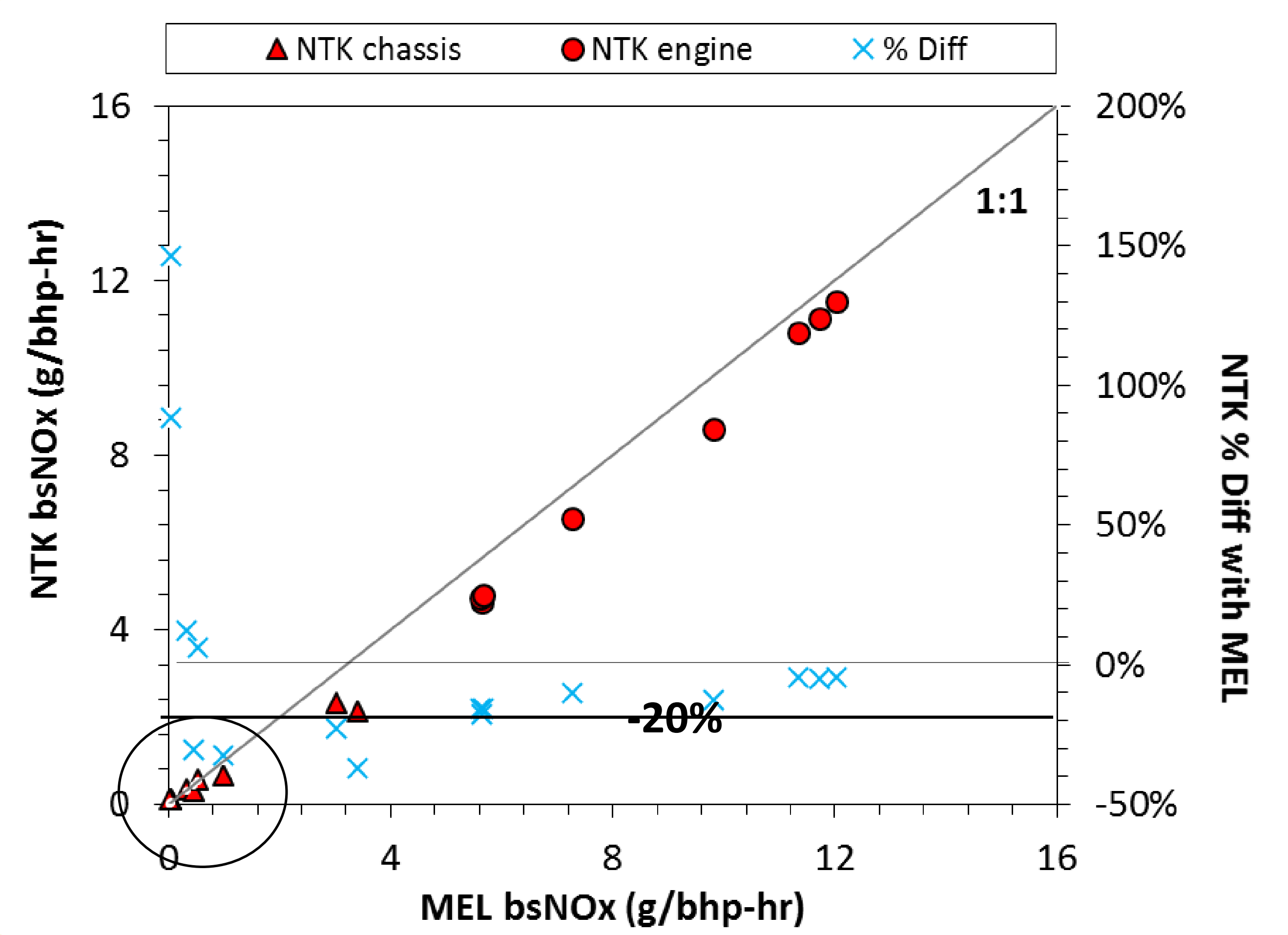


- Setup is < 1hr
- Battery powered
- Reliability is very robust
- Calibration is not needed
- Unattended operation is reasonable

ECM System

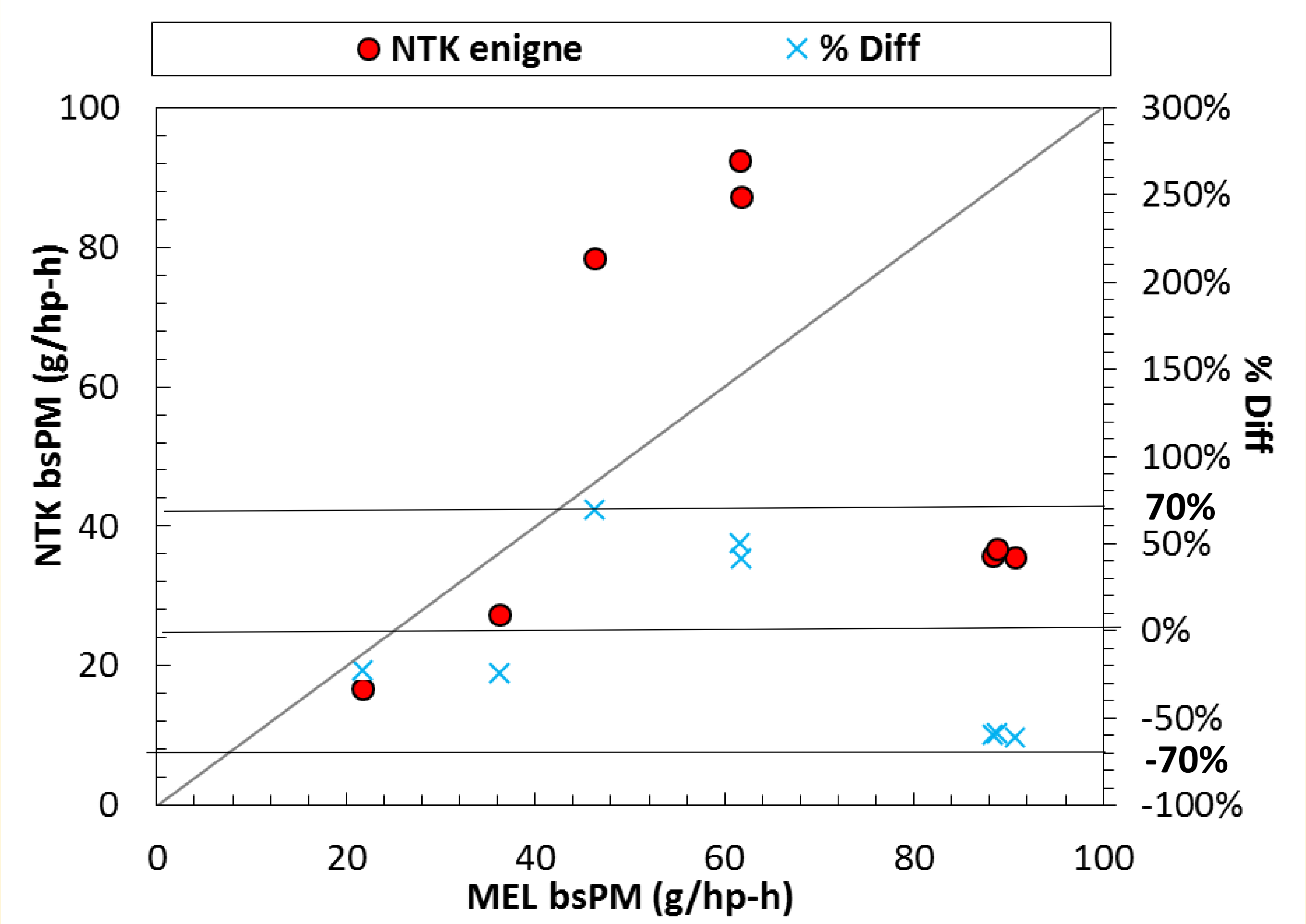
uPEMS NOx On Average ~ 20% of Reference Method





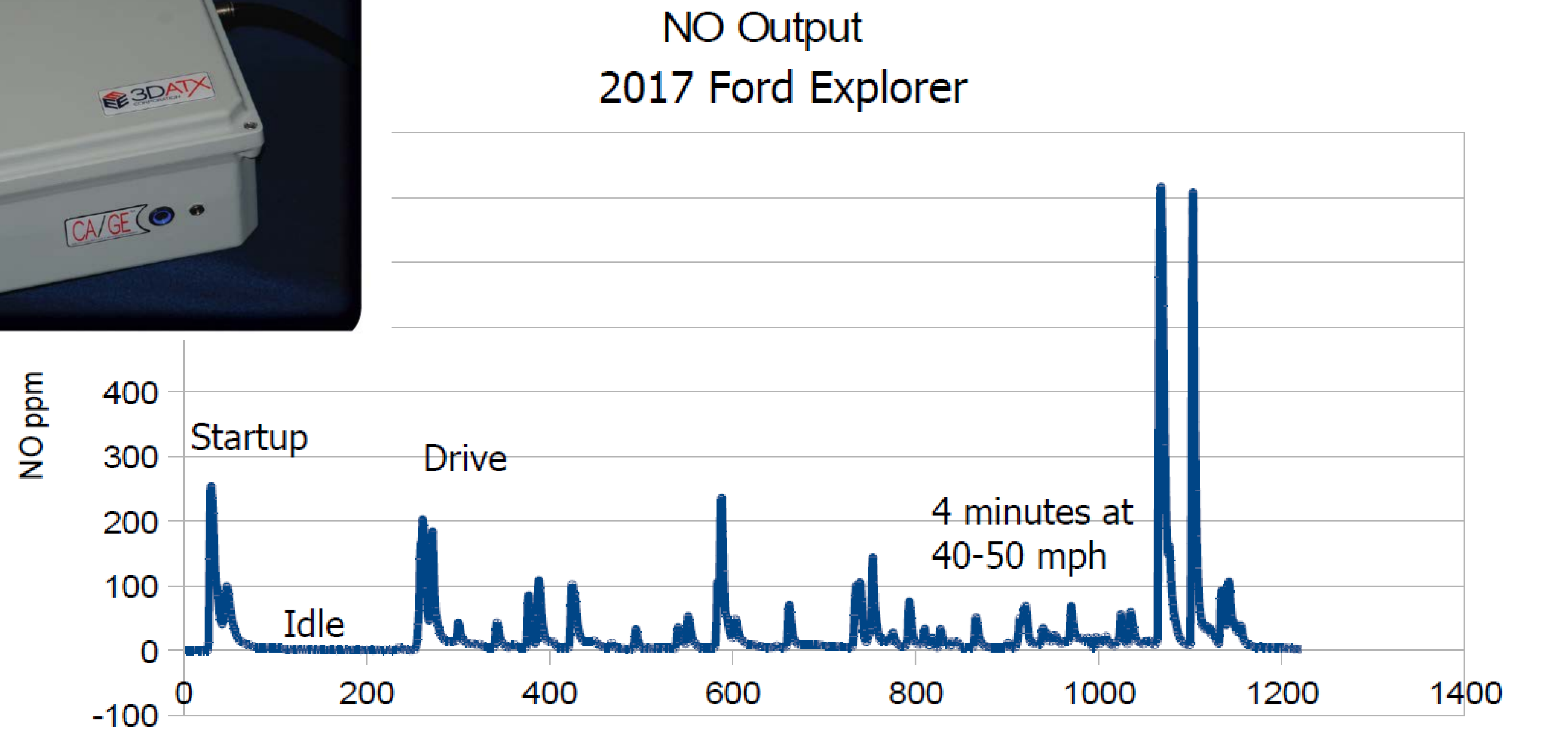
- A more simple NOx/CO2 ratio may be more reliable since exhaust flow adds to the bias.

uPEMS PM On Average ~70% of Reference Method



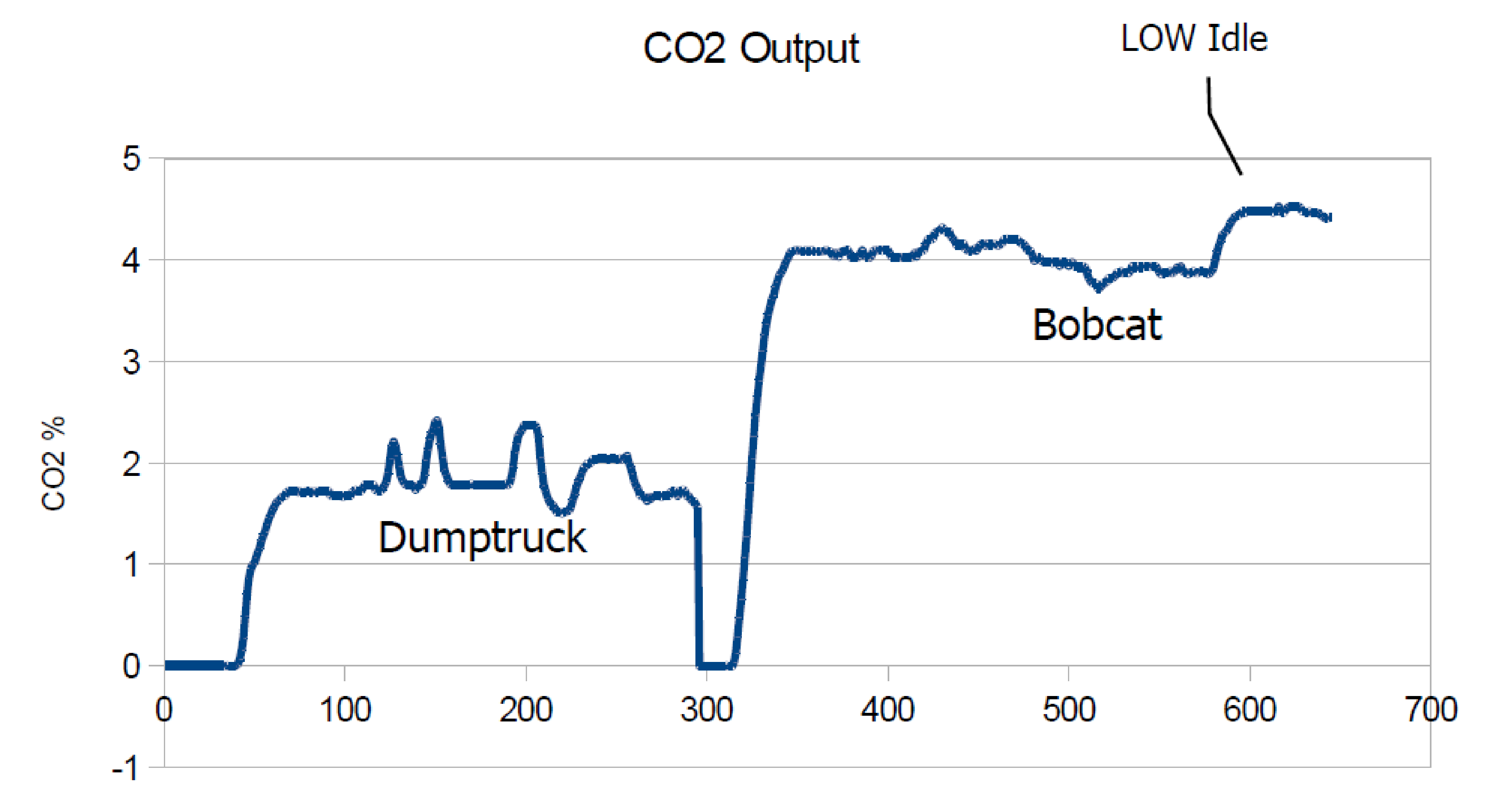
- NTK PM was measured in-situ stack, PM2.5 was measured dilute from a CVS without a catalytic stripper
- PM values were within 70% with $PM_{2.5}$ for engine dyno test

3DATX parSync NO Measurement System



Data from 3DATX

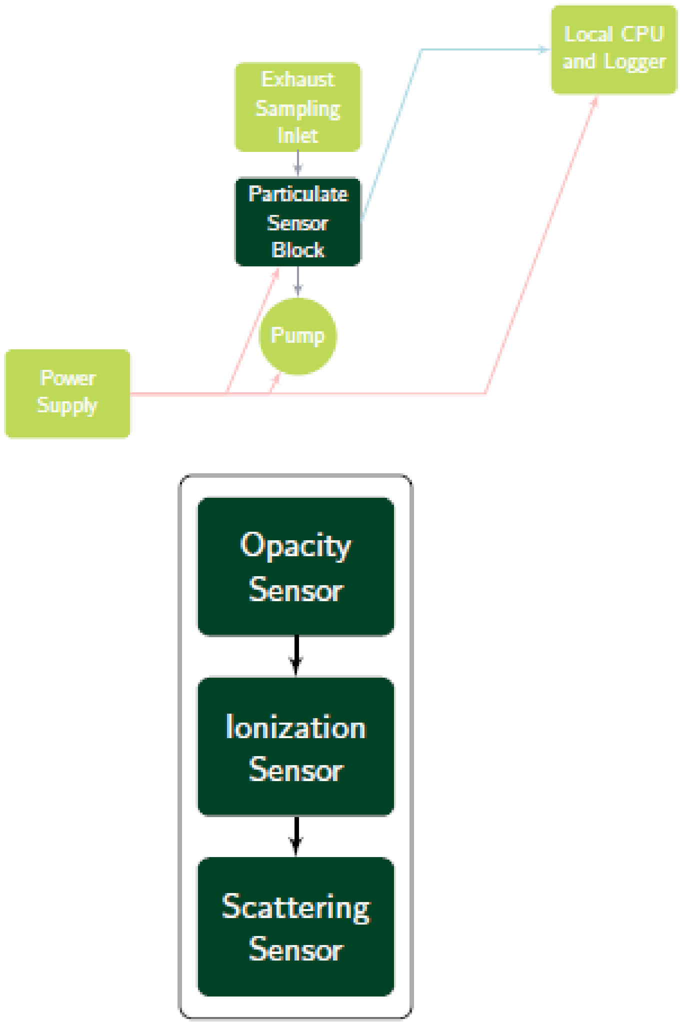
3DATX parSync CO2 Measurement System

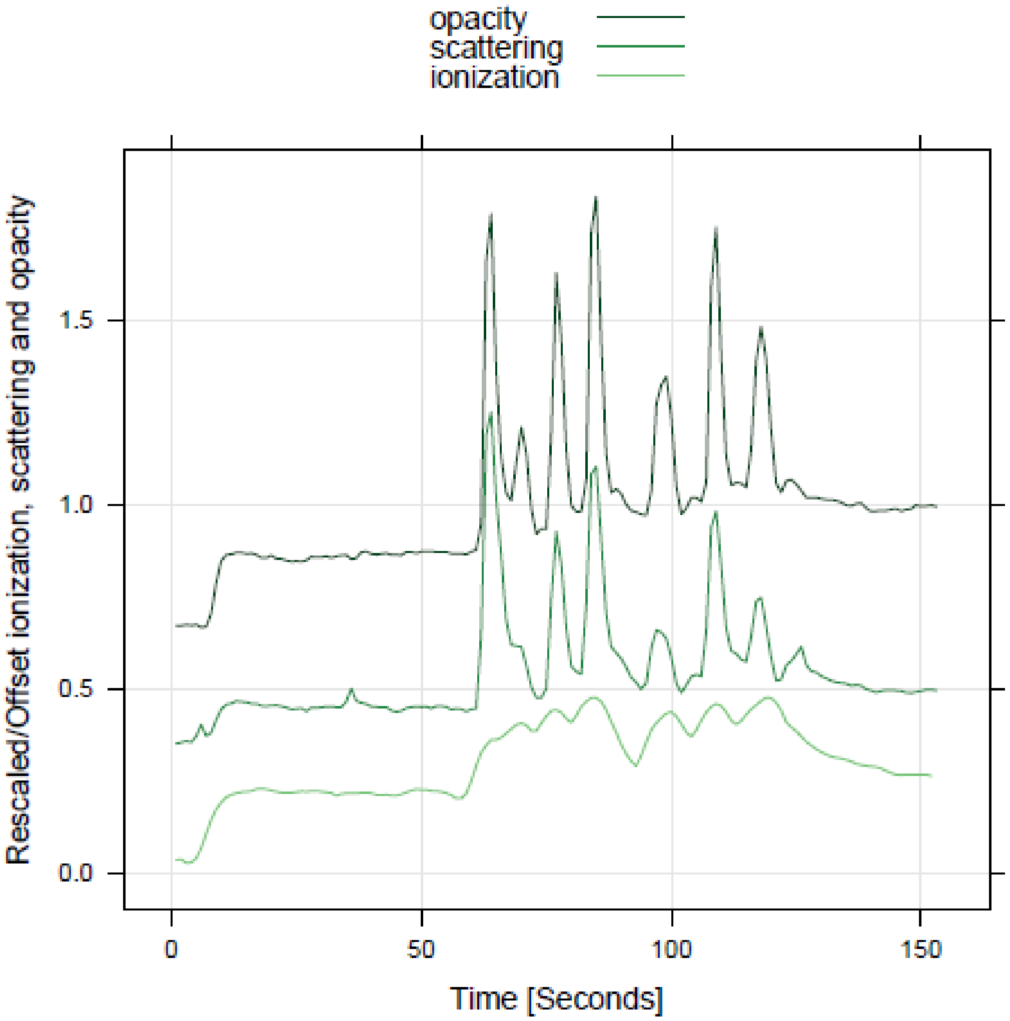


Data from 3DATX

A Sensory Array Measurement Strategy

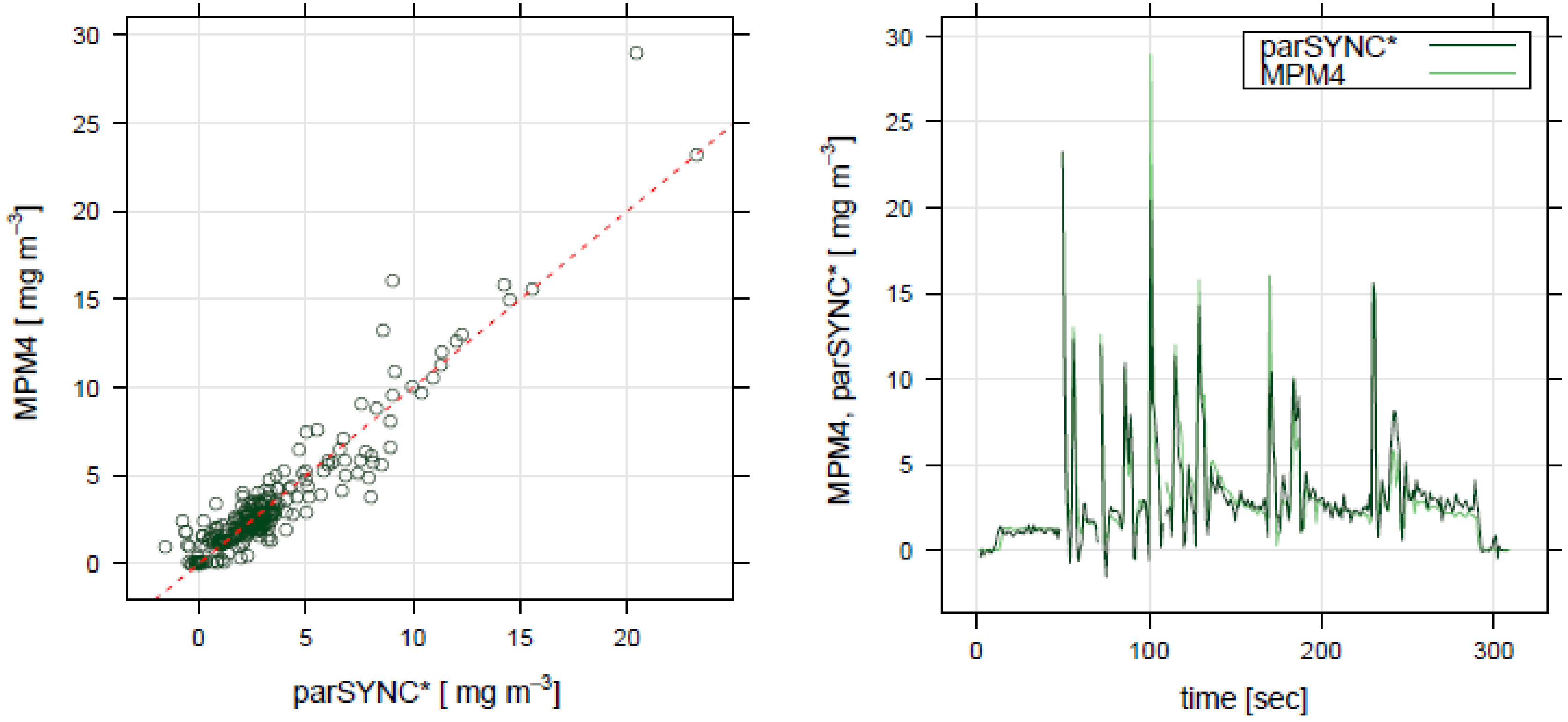
parSYNC® Sensor Module





Data from Karl Ropkins, Leeds University

Multiplex Sensor Fit

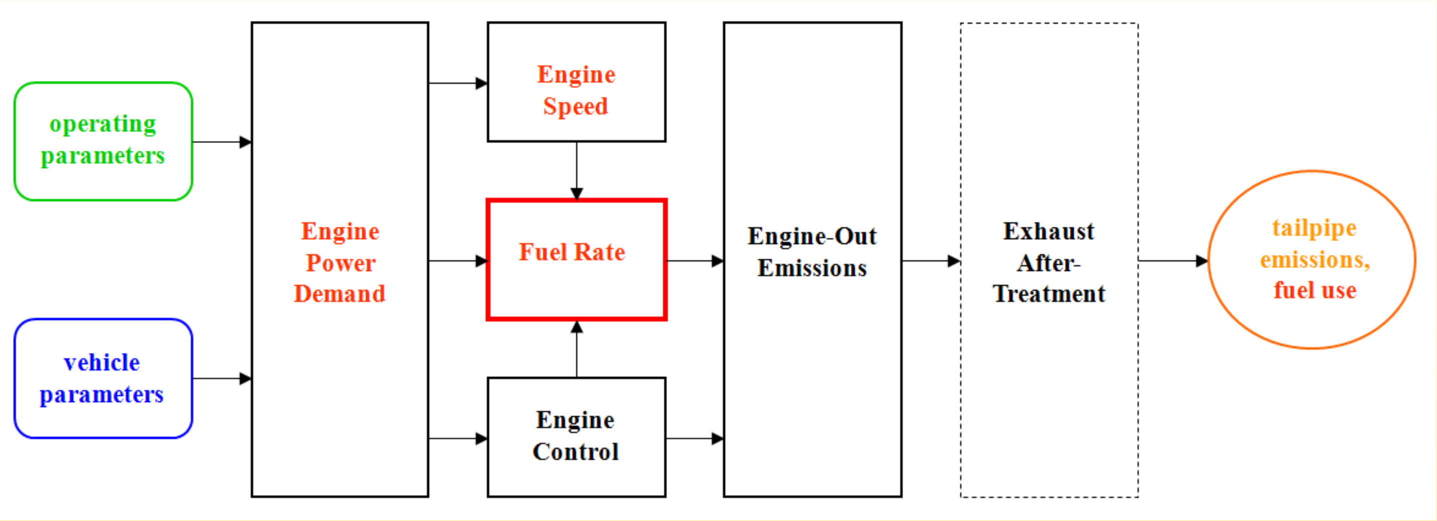


Agreement MPM4 / parSYNC® multiplex sensor $R \approx 0.92$
(two sensor, scattering and opacity, parSYNC* model)

COMPREHENSIVE MODAL EMISSIONS MODEL (CMEM)

- Microscale emission model
  - Developed at UCR CE-CERT
  - Initially developed in the 1990's
- Sponsorship
  - National Cooperative Highway Research Program (NCHRP)
  - U.S. Environmental Protection Agency (EPA)
- Developed to model vehicle emissions
  - project level (sec-by-sec)
- Accurately reflect impacts of :
  - Vehicle speed, acceleration, road grade, starting conditions, and secondary engine load

CMEM Emission Model Structure



- Fuel is a function of Engine Power Demand and Engine Speed
- Fuel rate is related to emissions through analysis based on measured data
- Model Inputs
  - Operating parameters - vehicle speed, road grade, accessory power, etc.
  - Vehicle parameters – weight, gear ratios, calibrated emission parameters, etc.
- Model Outputs
  - Second–by–second emission data and fuel use

Fuel Rate Calculation

$$FR = \frac{\left(kND + \frac{P_e}{\eta}\right)}{LHV}$$

k = engine friction term
N = engine speed
D = engine displacement

P_e = engine power
η = engine indicated efficiency
LHV = lower heating value of fuel

$$P_e = \frac{P_t}{\varepsilon} + P_{run} + P_{acc}$$

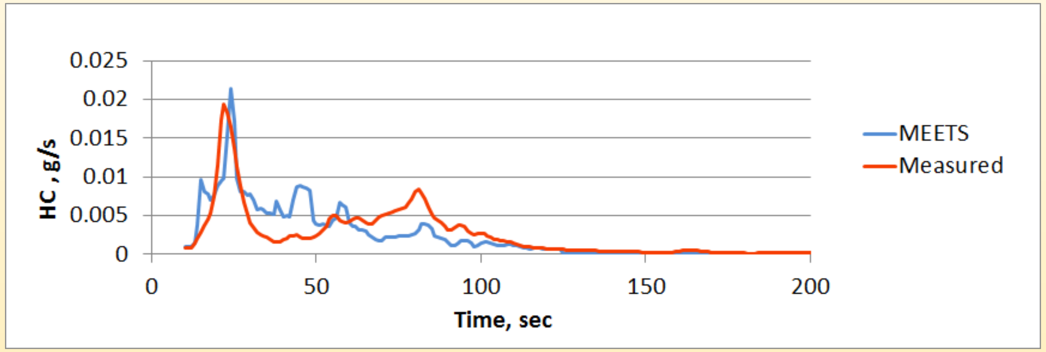
P_t = tractive power demand
ε = drivetrain efficiency
P_{run} = running losses
P_{acc} = accessory power demand

$$N = vS\frac{R_L}{R_T}$$

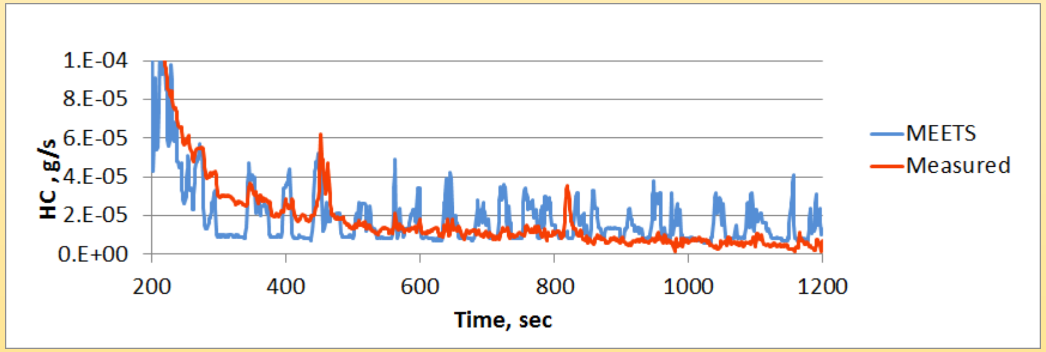
S = engine-speed/vehicle-speed in top gear
R_L = gear ratio in L^{th} gear
R_T = gear ratio in top gear
v = vehicle speed

MEETS Emission Outputs HC

Cold Start

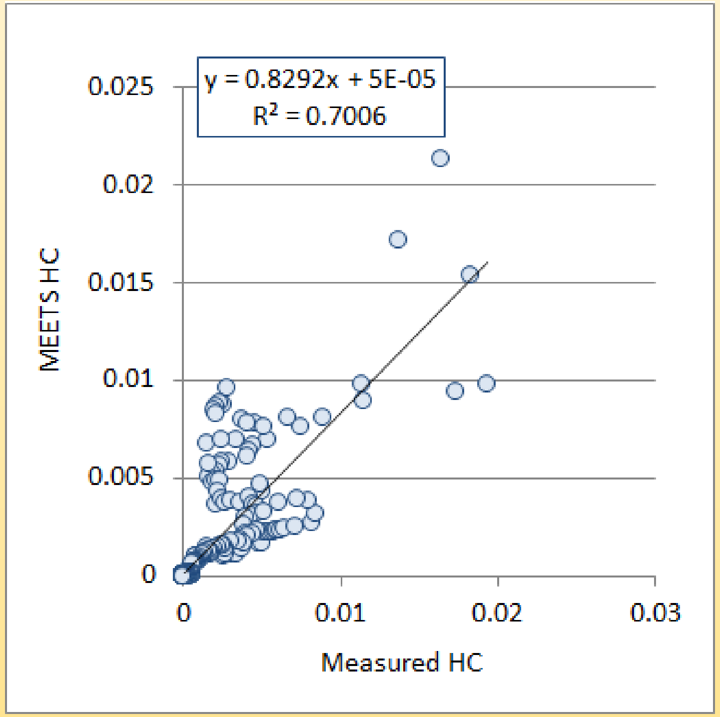


Hot Stabilized



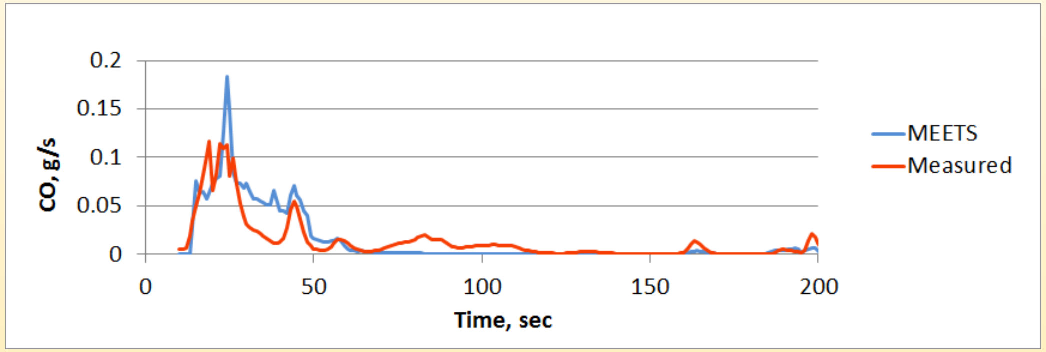
HC (g/s)

Measured	0.514
MEETS	0.483
% Difference	-5.9

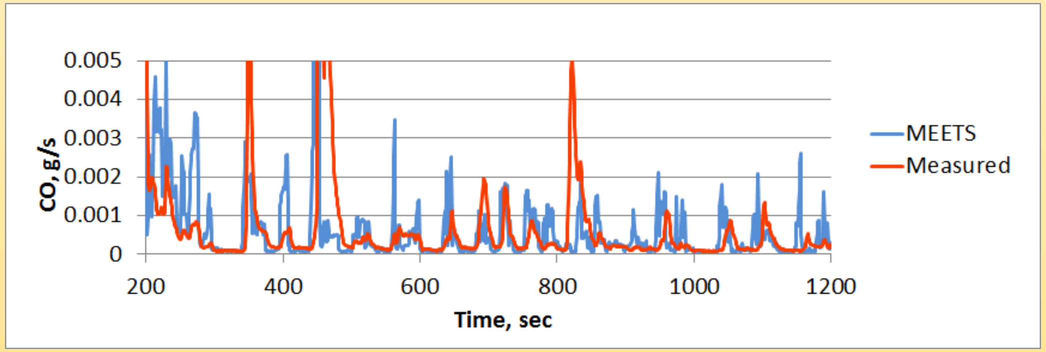


MEETS Emission Outputs CO

Cold Start



Hot Stabilized



CO (g/s)

Measured	3.927
MEETS	3.388
% Difference	2.8