

# Measuring particulate matter emissions during parked active diesel particulate filter regeneration of heavy-duty trucks

David C. Quiros<sup>1</sup>, Seungju Yoon<sup>1</sup>, Mark A. Burnitski<sup>1</sup>, Harry A. Dwyer<sup>2</sup>

<sup>1</sup> California Air Resources Board

<sup>2</sup> University of California, Davis

Mobile Sources 5E | **Control #42**

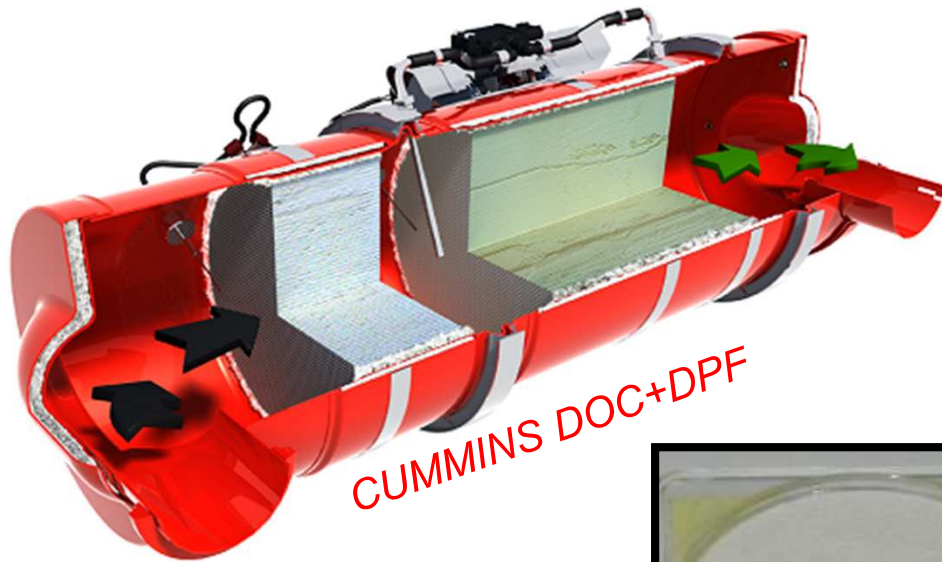
Air Quality Measurement Methods and Technology  
A&WMA, Sacramento, CA - November 20, 2013



In support of ARB Research Division Contract #11-329

# Background

2007 model year (MY) particulate matter (PM) standard, 0.01 g/bhp-hr, is achieved by diesel particulate filter (DPF)



**BASELINE**



**DOC+DPF**  
*(no regeneration)*

*DYNAMOMETER TESTING  
ON OTHER VEHICLES*



**REGENERATION**

*THIS STUDY  
2007 MY*

# Objective

- Evaluate PM mass measurement when challenged with active parked regeneration emissions:
  - TSI Scanning Mobility Particle Sizer (**SMPS**) 3936L88
  - TSI Engine Exhaust Particle Sizer (**EEPS**) 3090

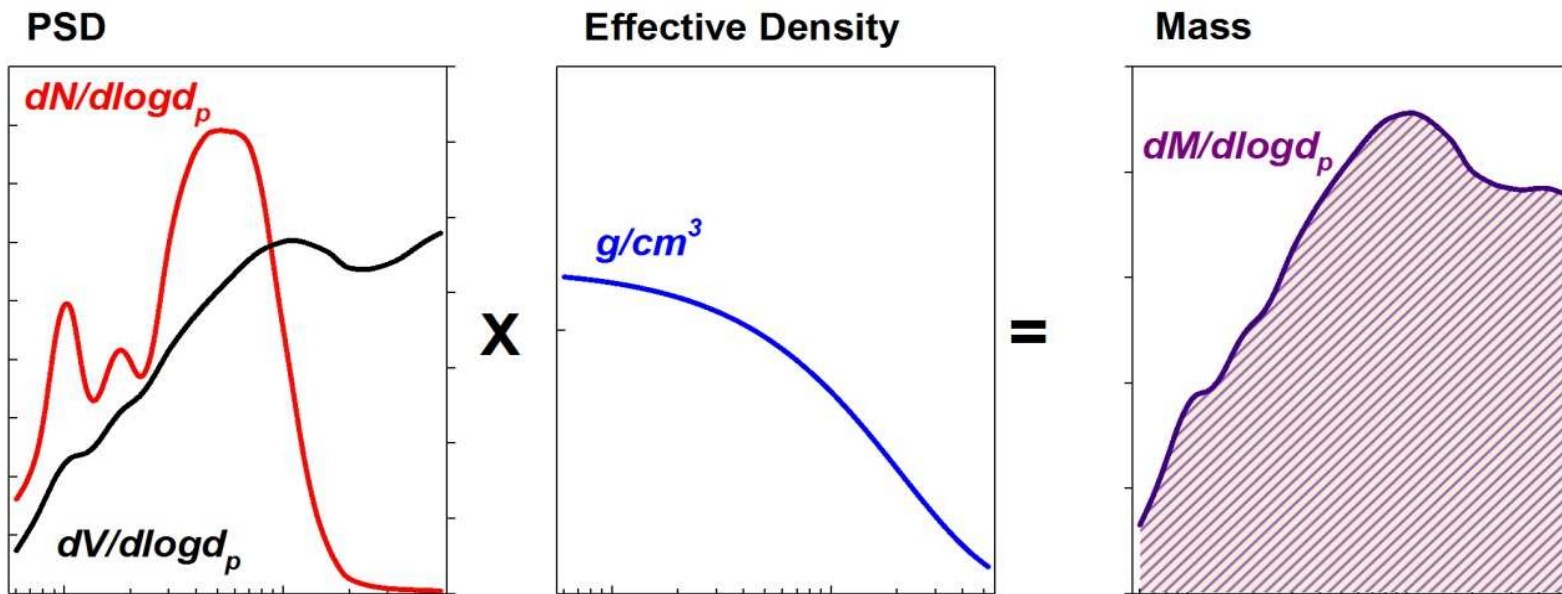


**SMPS**  
5.4-198 nm



**EEPS**  
5.6-560 nm

# PM Mass for EEPS and SMPS



$$\rho_{eff} = 1.2378 \cdot e^{-0.0048 \cdot D_p}$$

Liu, et al. (2009) and Maricq and Xu (2004)

**Liu, et al. (2009).** Comparison of Strategies for the Measurement of Mass Emissions from Diesel Engines Emitting Ultra-Low Levels of Particulate Matter. *Aerosol Science and Technology*, 43, 1142-1152.

**Maricq and Xu. (2004).** The effective density and fractal dimension of soot particles from premixed flames and motor vehicle exhaust. *Journal of Aerosol Science*, 35, 1251-1274.

# Objective

- Evaluate PM mass measurement when challenged with active parked regeneration emissions:
  - TSI Scanning Mobility Particle Sizer (**SMPS**) 3936L88
  - TSI Engine Exhaust Particle Sizer (**EEPS**) 3090
  - TSI **DustTrak** DRX 8533
  - Dekati Mass Monitor (**DMM**) 230-A
  - Gravimetric analysis of 47-mm filters



**SMPS**  
5.4-198 nm



**EEPS**  
5.6-560 nm



**DustTrak**  
PM<sub>1</sub>, PM<sub>2.5</sub>, PM<sub>10</sub>

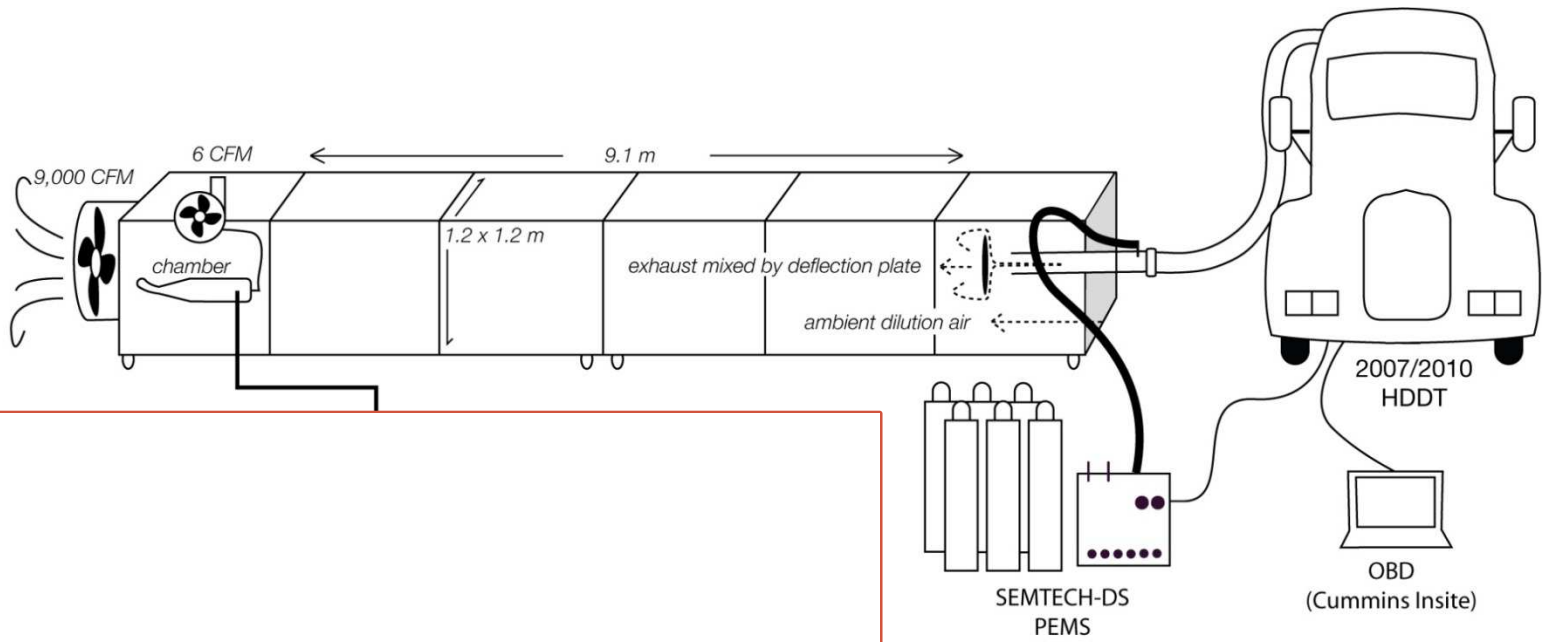


**DMM**  
0.01-1.3  $\mu\text{m}$



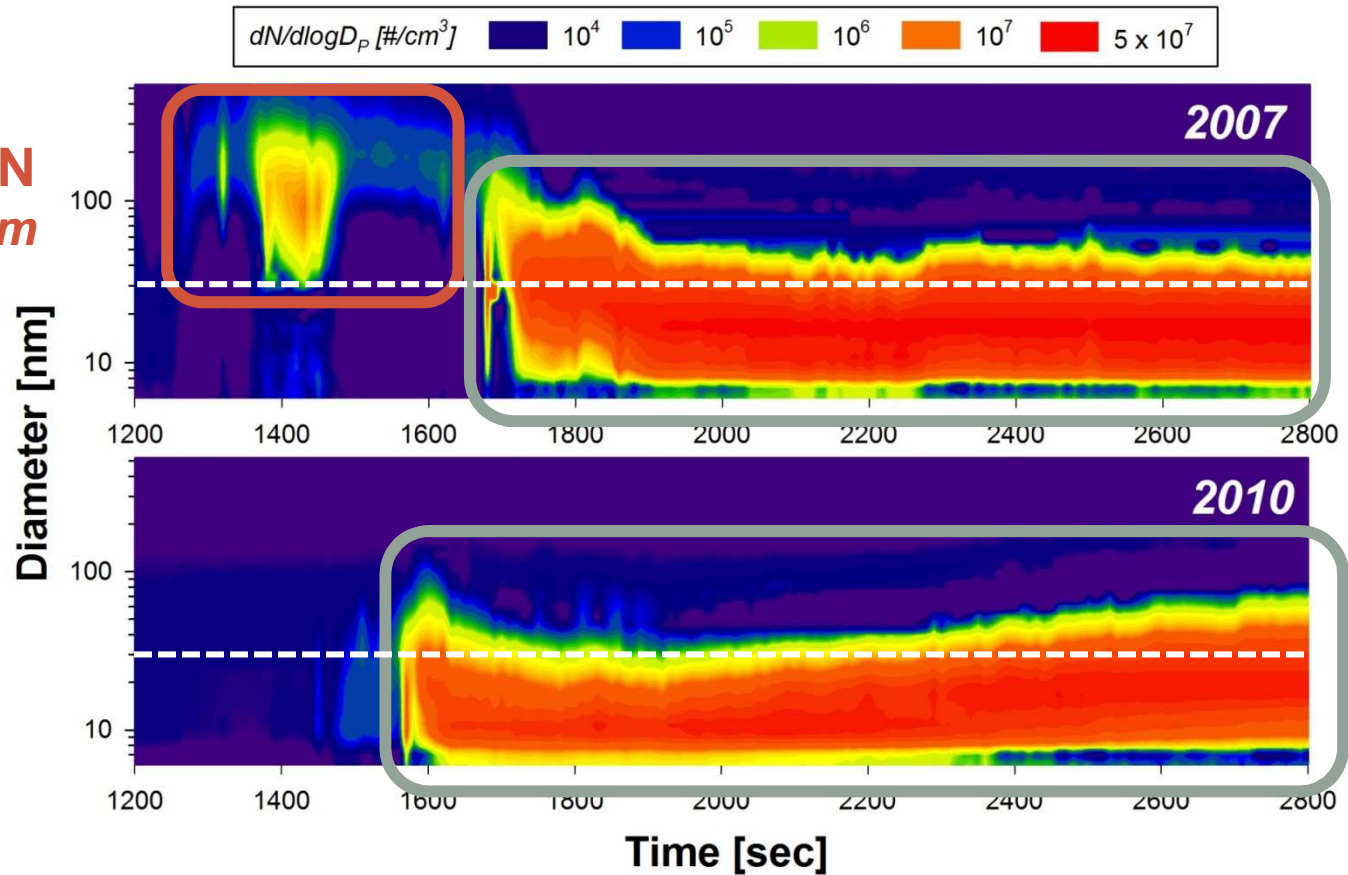
**Filter**

# Study Design

# Two Regimes

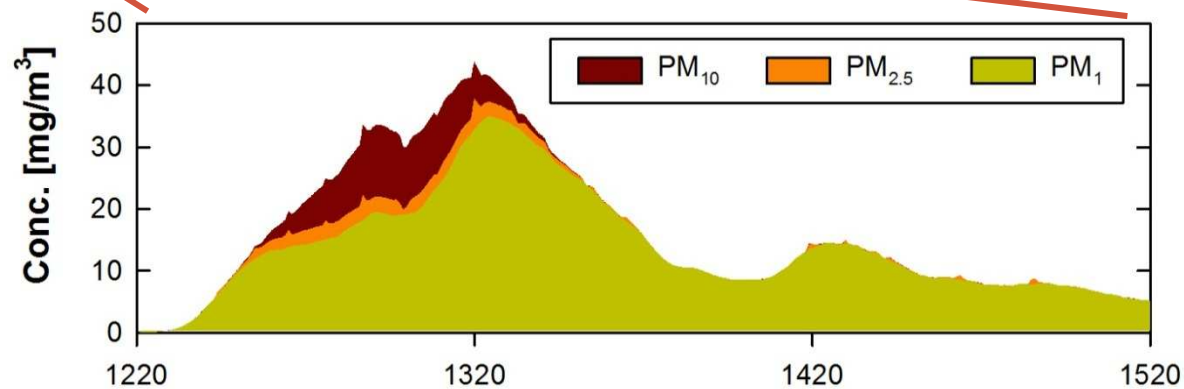
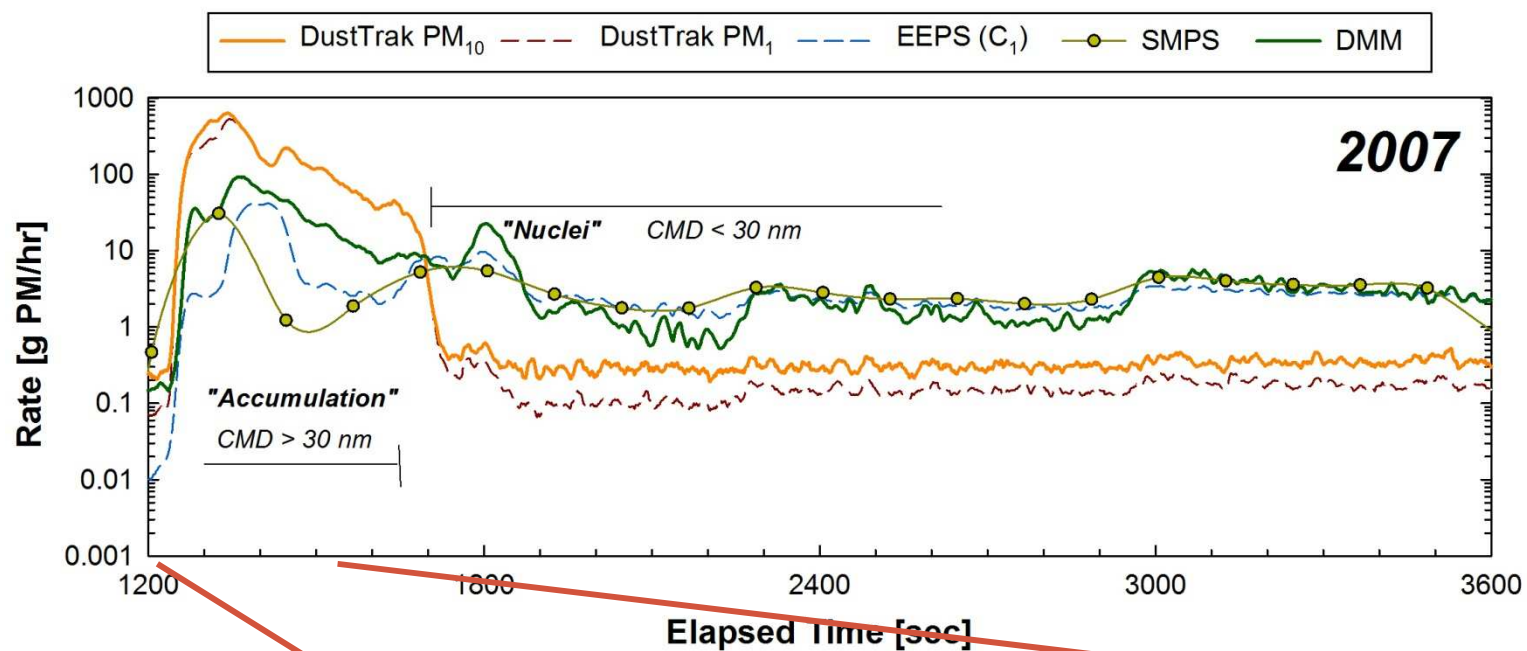
ACCUMULATION  
*CMD > 30 nm*



NUCLEI, *CMD < 30 nm*

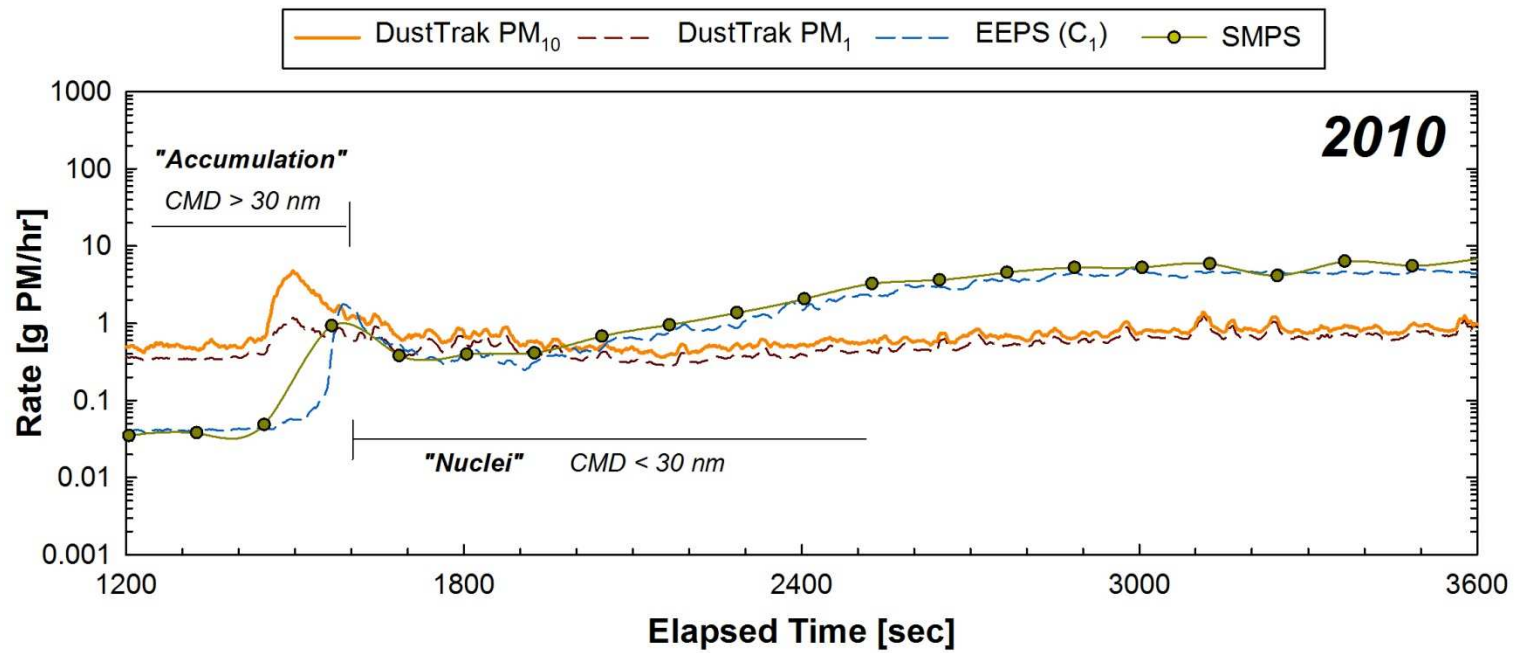


# PM Mass Emissions



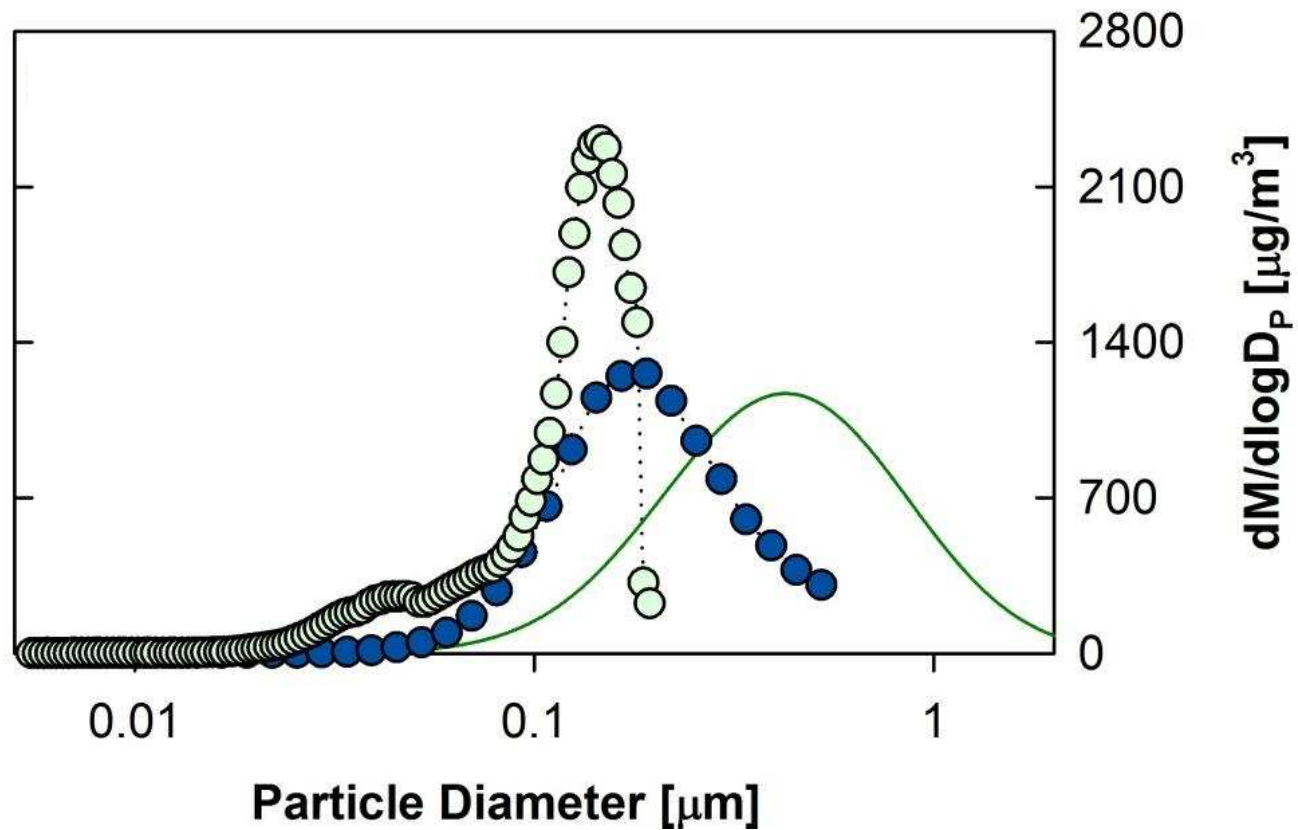


# PM Mass Emissions

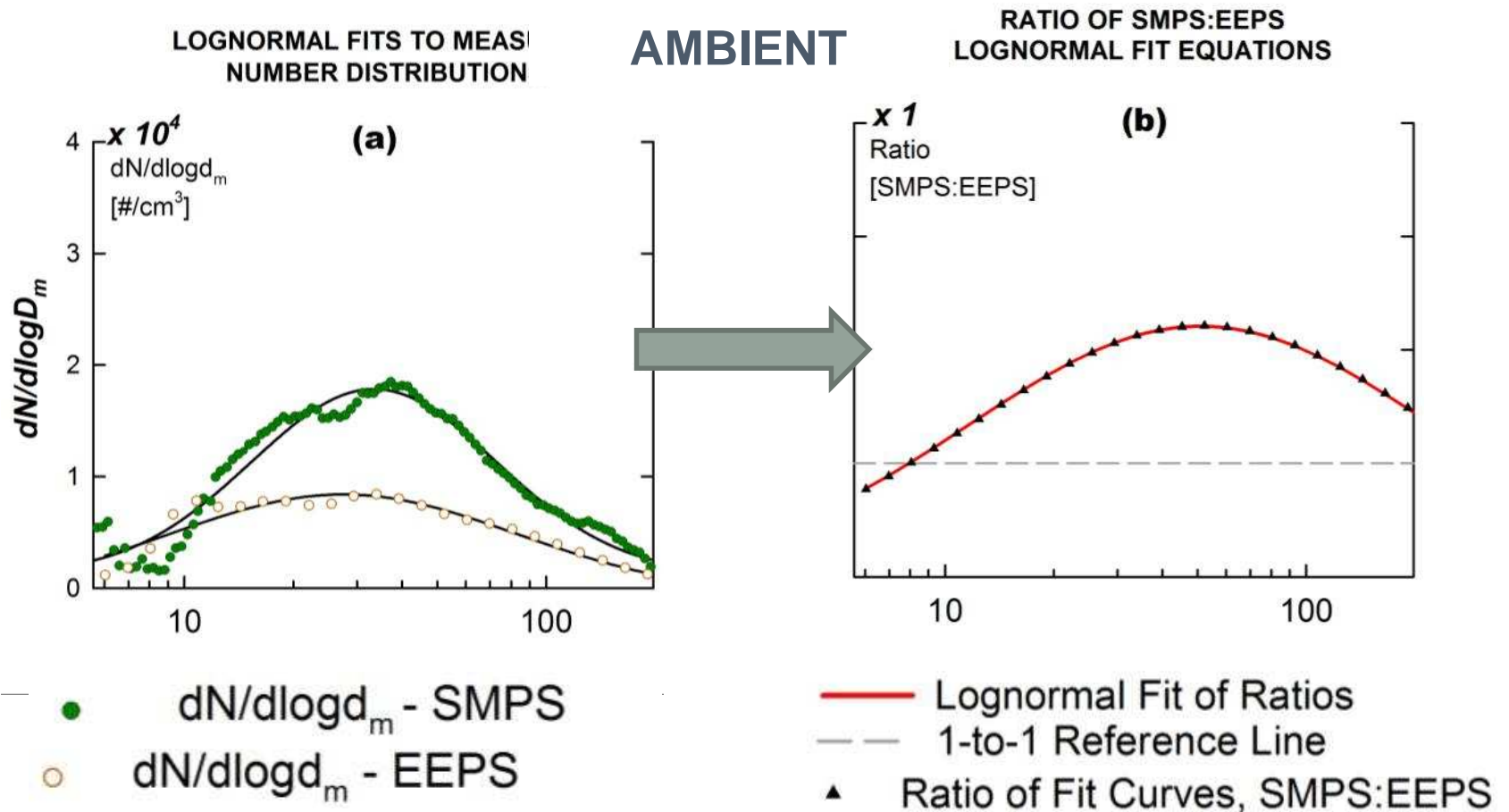


# Mass-based size distributions differ

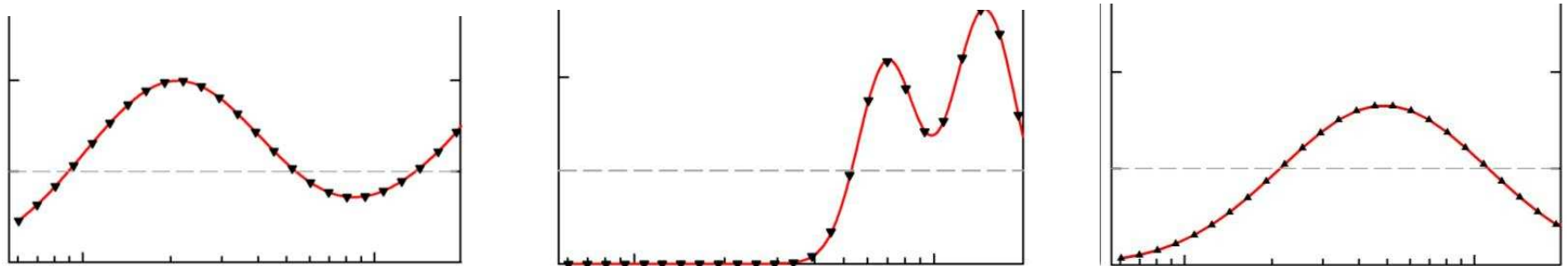
● EEPS C<sub>1</sub> (5.6-560 nm) ○ SMPS (5-198 nm) — DMM (0.01-1.3 mm)



# Derivation of ( $C_2$ ) correction for EEPS

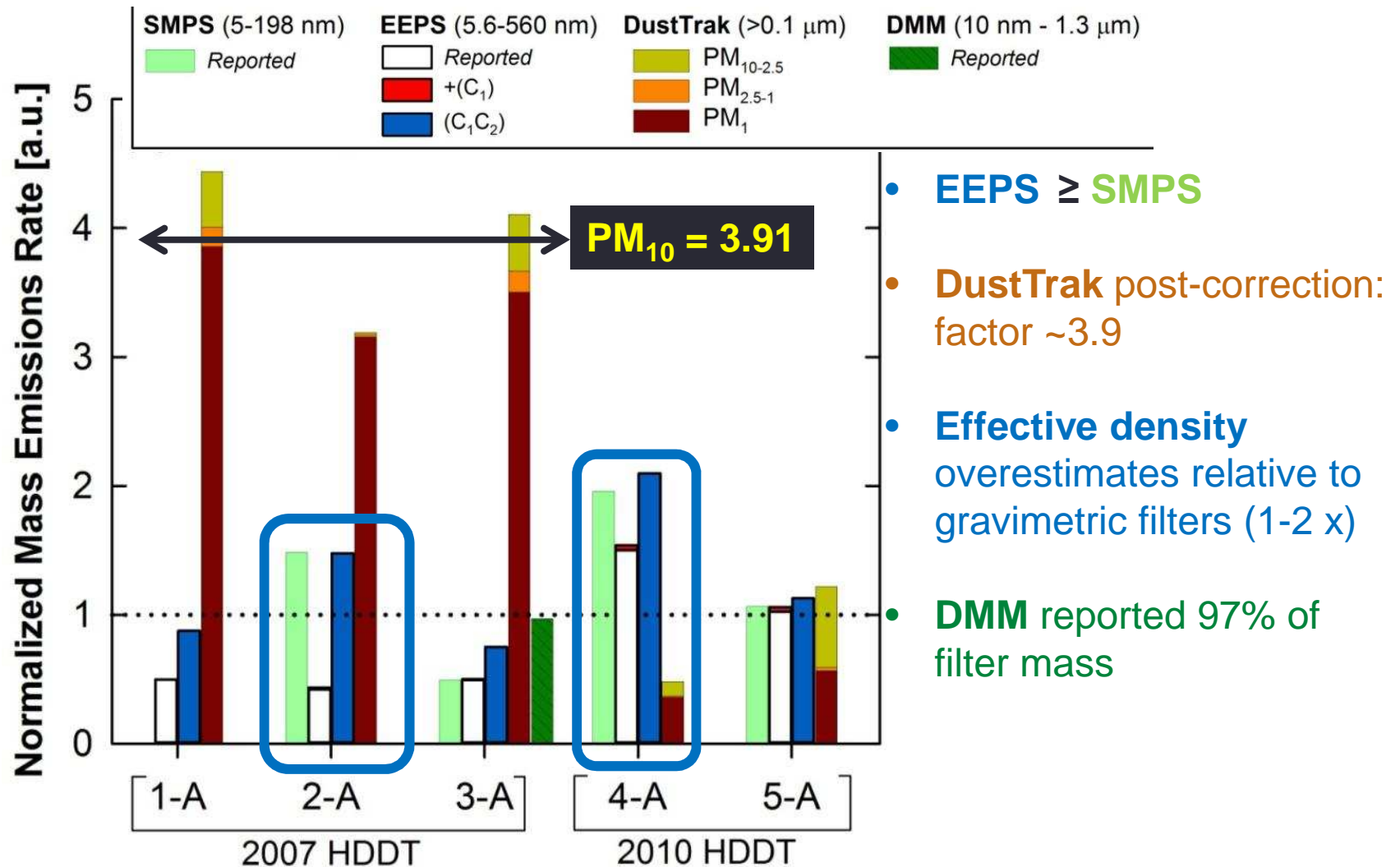


# More EEPS-to-SMPS Ratios



- Lognormal Fit of Ratios
- - 1-to-1 Reference Line
- ▲ Ratio of Fit Curves, SMPS:EEPS

# Average Regeneration Emissions



# Conclusions

- PM emissions from 2007 MY truck are substantial and should be considered when quantifying real-world emissions
- Regeneration “nuclei” emissions (CMD < 30 nm) dominated for 2010 MY, although less apparent need for active regeneration
- Real-time instrumentation findings:
  - **DustTrak DRX** reported substantial PM >1  $\mu\text{m}$  during regeneration. However, during certification following 40 CFR Part 1065, this PM would be removed by a pre-classifier. Quantitatively, instrument calibration was  $\sim 3.9$  times greater than the gravimetric equivalent, and was insensitive to all ultrafine PM.
  - **SMPS** conferred adequate time resolution for regeneration.
  - **EEPS** accuracy was questionable due to charge inversion, but rapid measurement may be needed for transient emissions.
  - **DMM** reported mass consistent with gravimetric reference, but “black box” operation gave no indication of basis for accurate or precise PM mass measurement.
- PM density, size, and physical appearance (i.e. color on filter) is different between regeneration and engine-out conditions

# Acknowledgements

Don Chernich

Robert Ianni

Roelof Riemersma

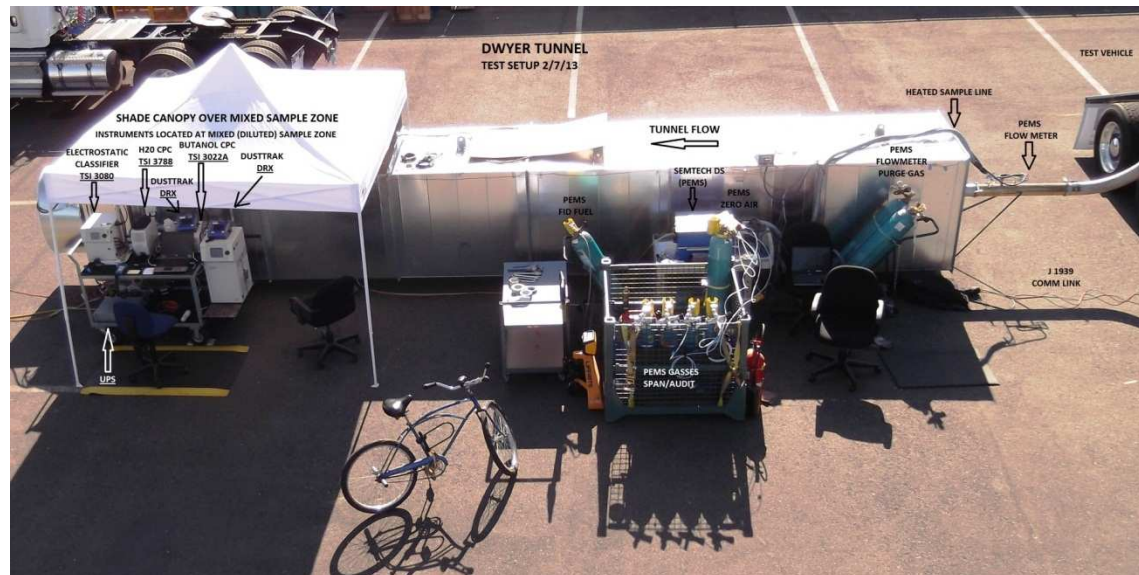
Tullie Flower

Wayne Sobieralski

John Collins

Tao Huai

Michael Werst



# Contact

David C. Quiros

Monitoring & Laboratory Division | CA Air Resources Board

e. [dquiros@arb.ca.gov](mailto:dquiros@arb.ca.gov) | p. 916-445-9370