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

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

Air Quality Measurement Methods and Technology
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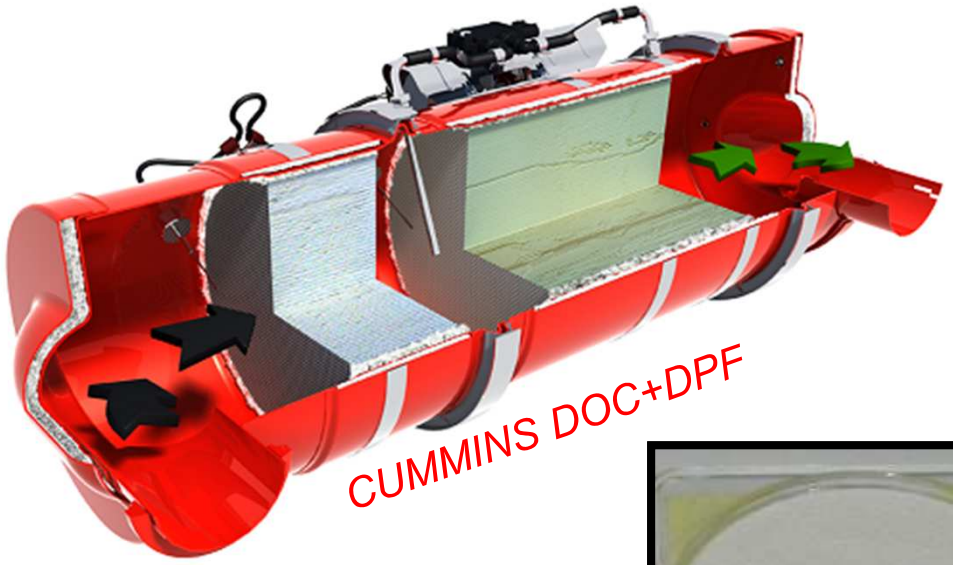
Background

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



CUMMINS DOC+DPF

BASELINE

DOC+DPF
(no regeneration)

DYNAMOMETER TESTING ON OTHER VEHICLES

REGENERATION

THIS STUDY
2007 MY

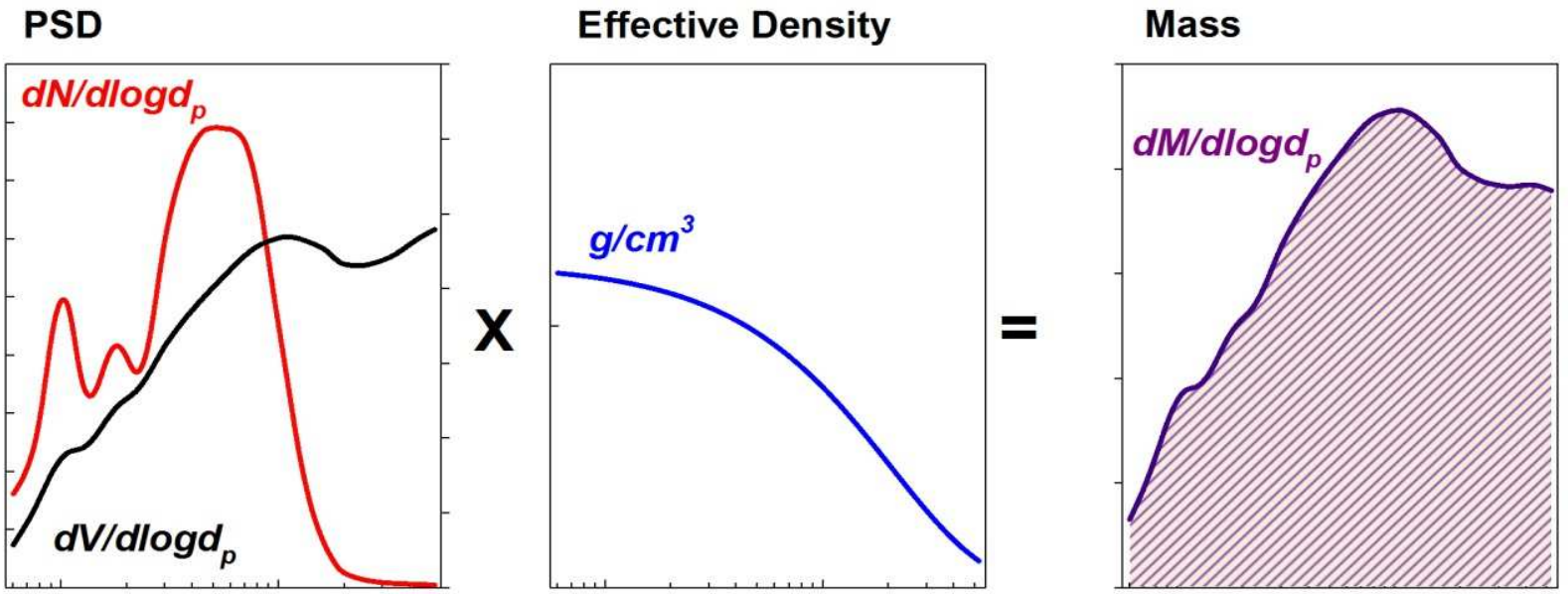
Objective

- **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

Filter

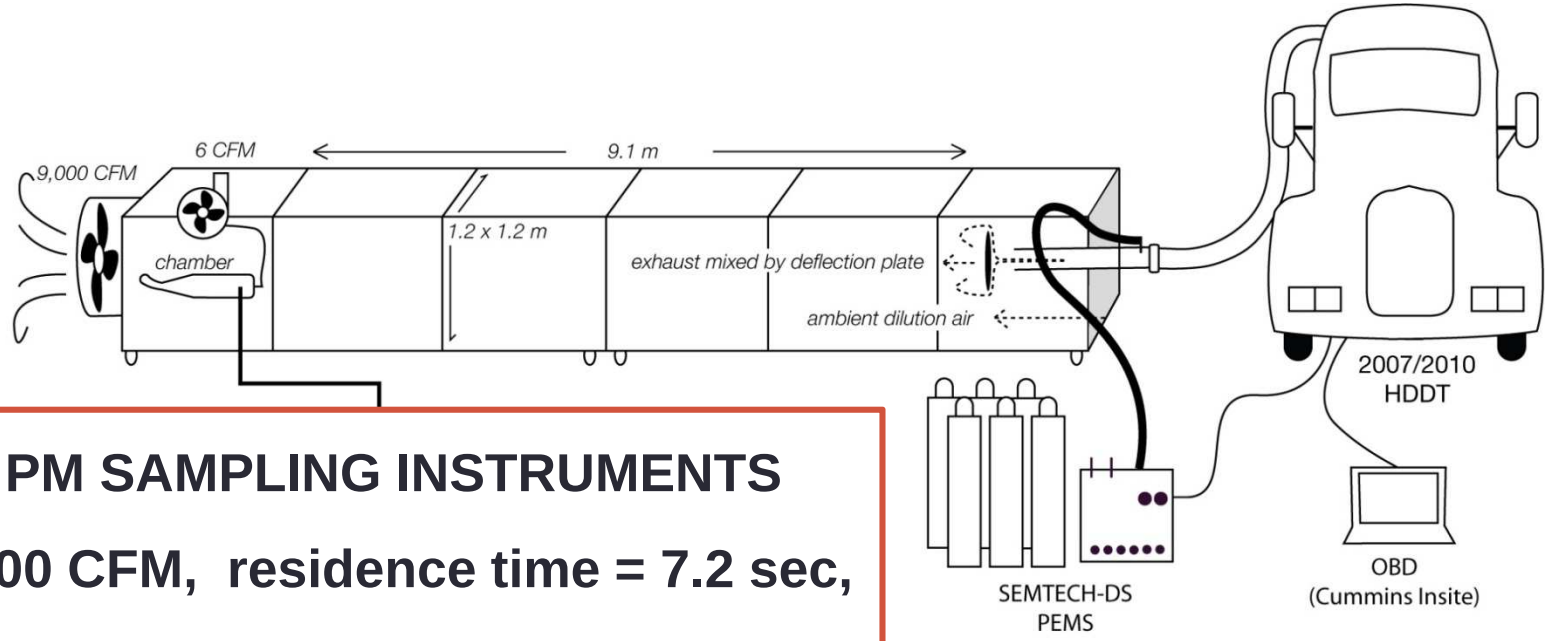
DMM
0.01-1.3 µm

DustTrak
PM_1, $PM_{2.5}$, PM_{10}

EEPS
5.6-560 nm

Study Design

Truck	Engine + Aftertreatment	Tests
2007 Kenworth	Cummins DOC+DPF	3
2010 Kenworth	Cummins DOC+DPF+SCR	2



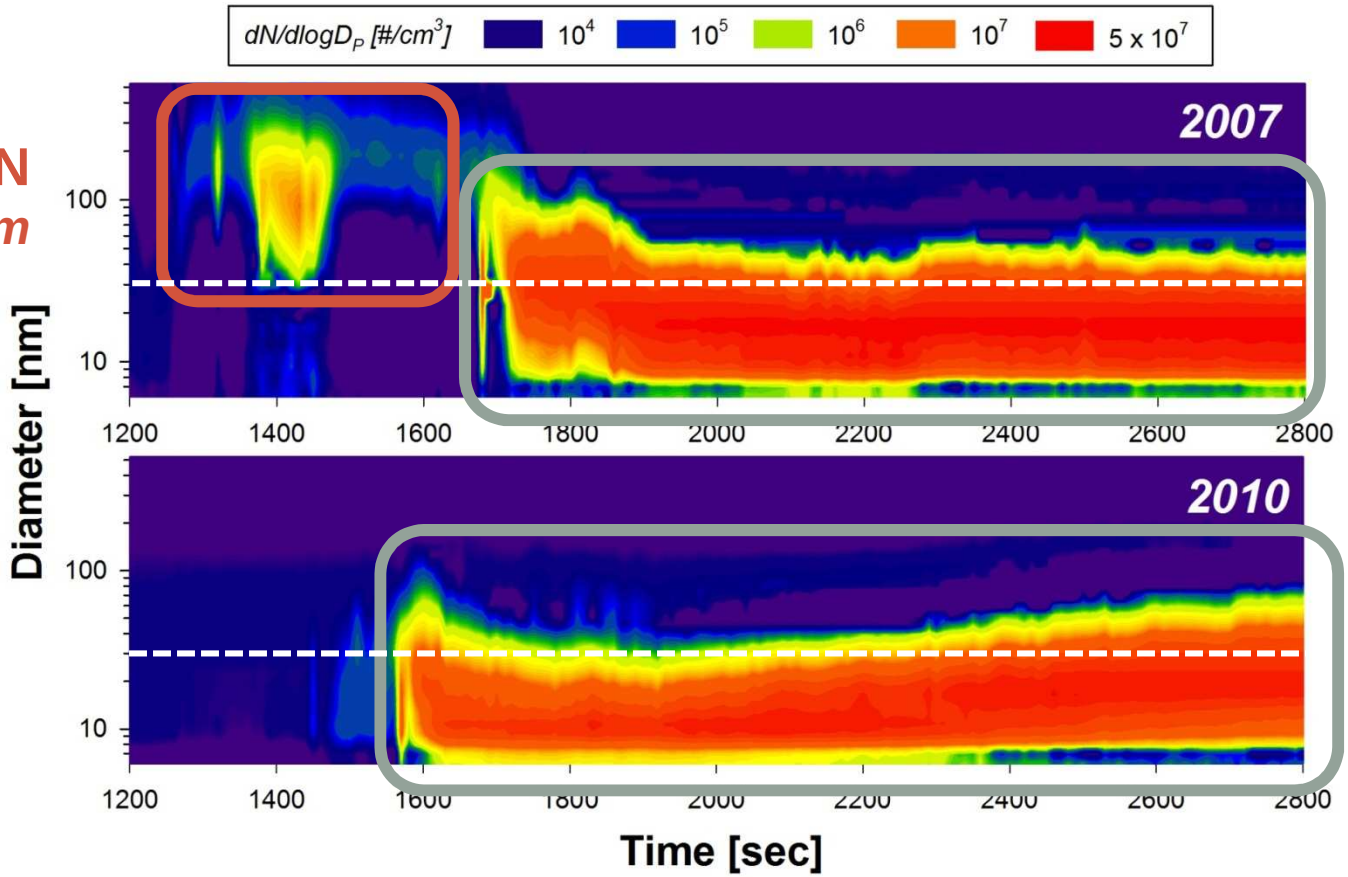
PM SAMPLING INSTRUMENTS

9000 CFM, residence time = 7.2 sec,

dilution ratios: 31 (2007) & 36 (2010)

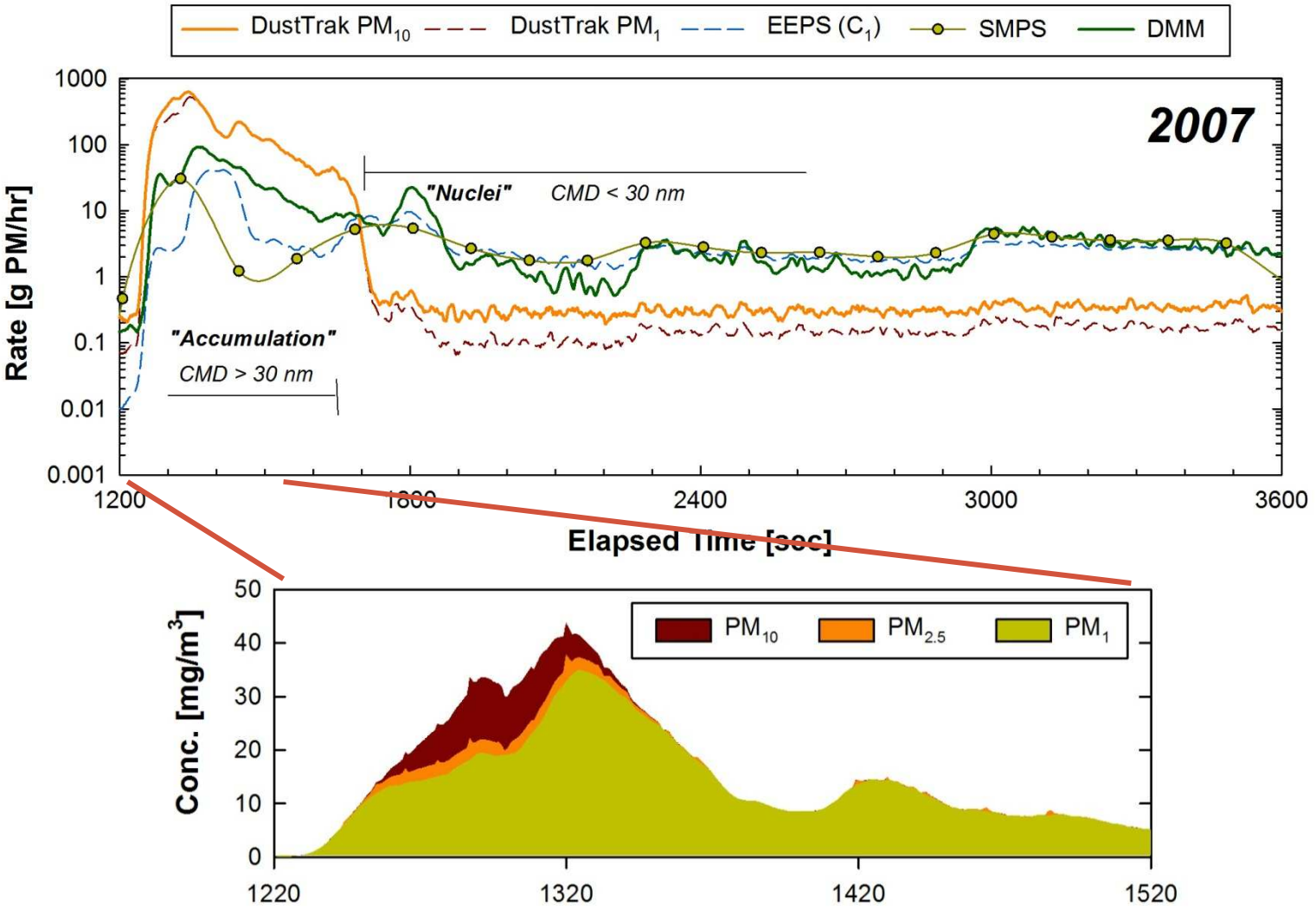
Two Regimes

ACCUMULATION
CMD > 30 nm

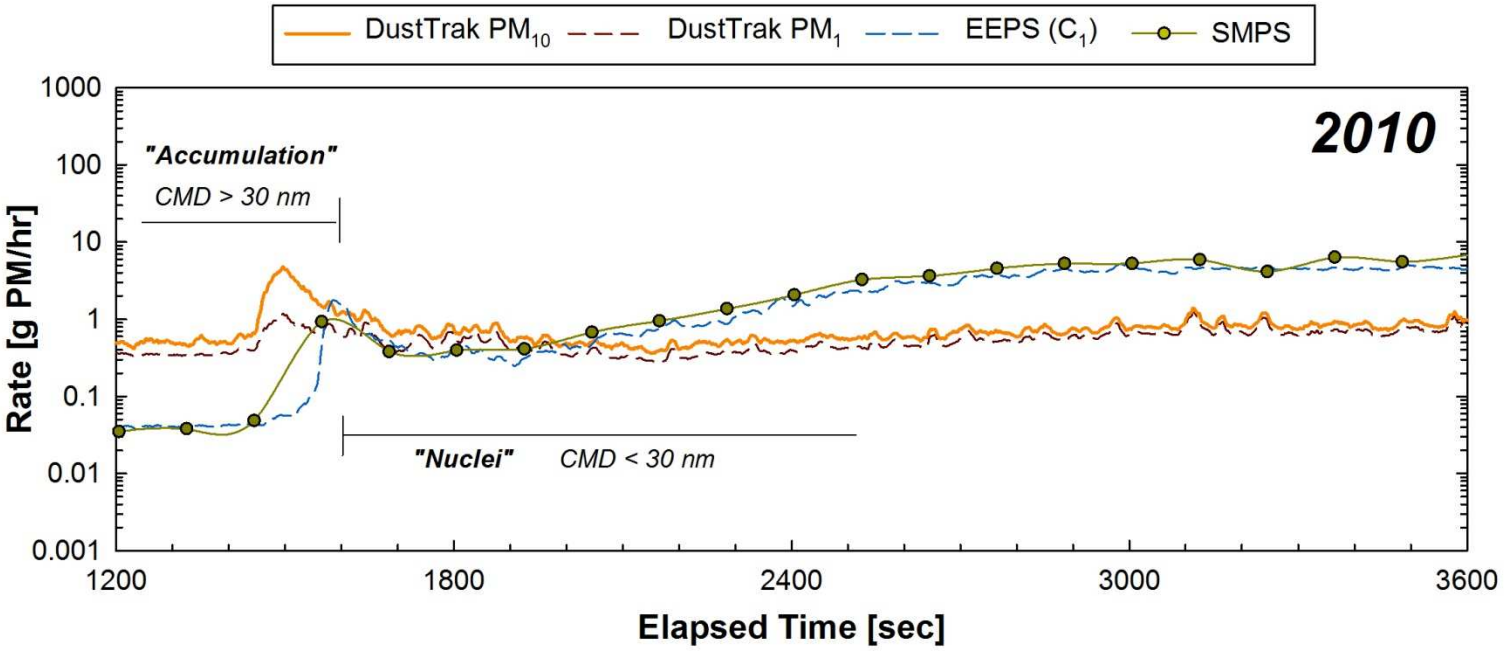


NUCLEI, ***CMD < 30 nm***

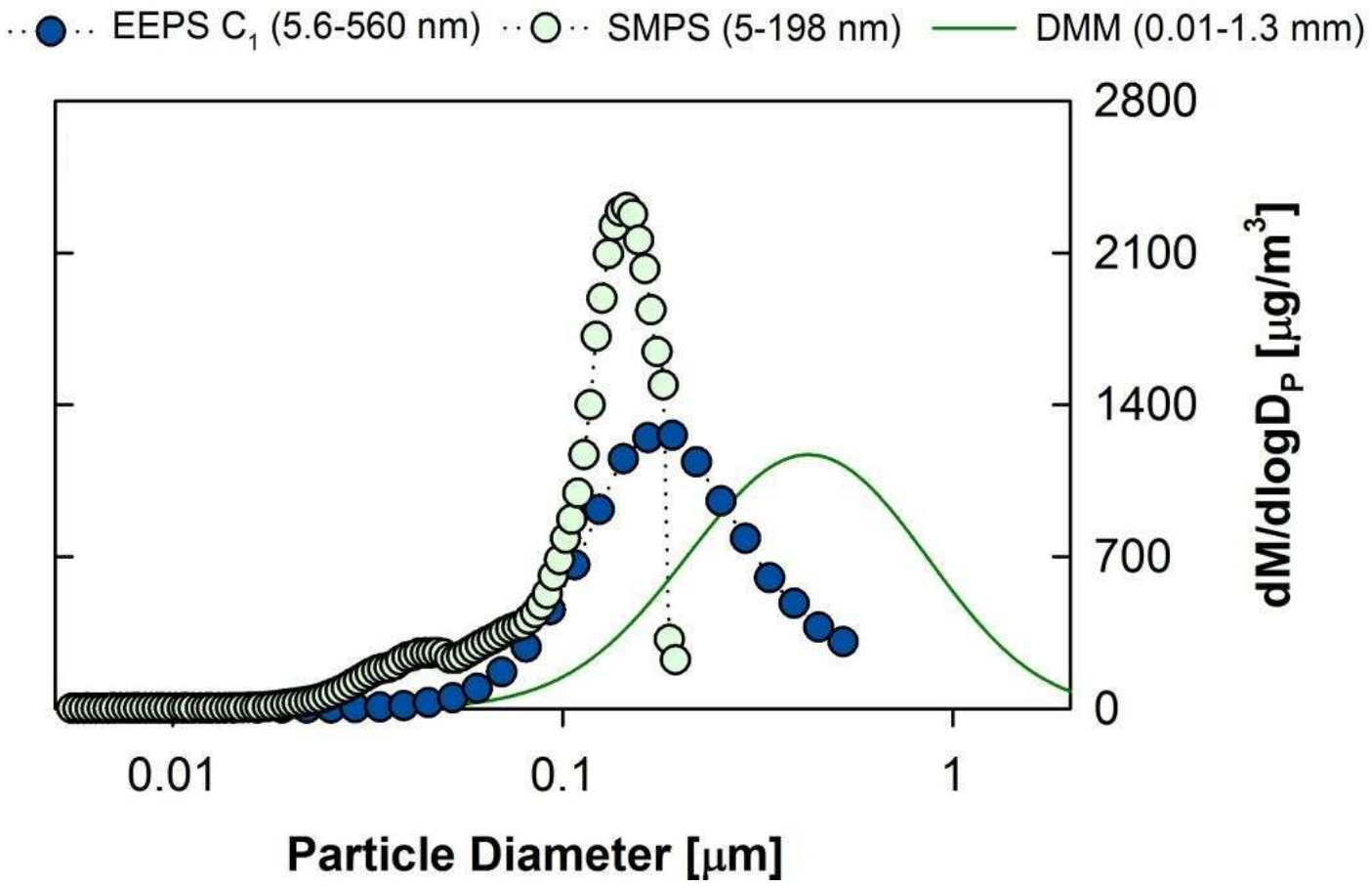
PM Mass Emissions



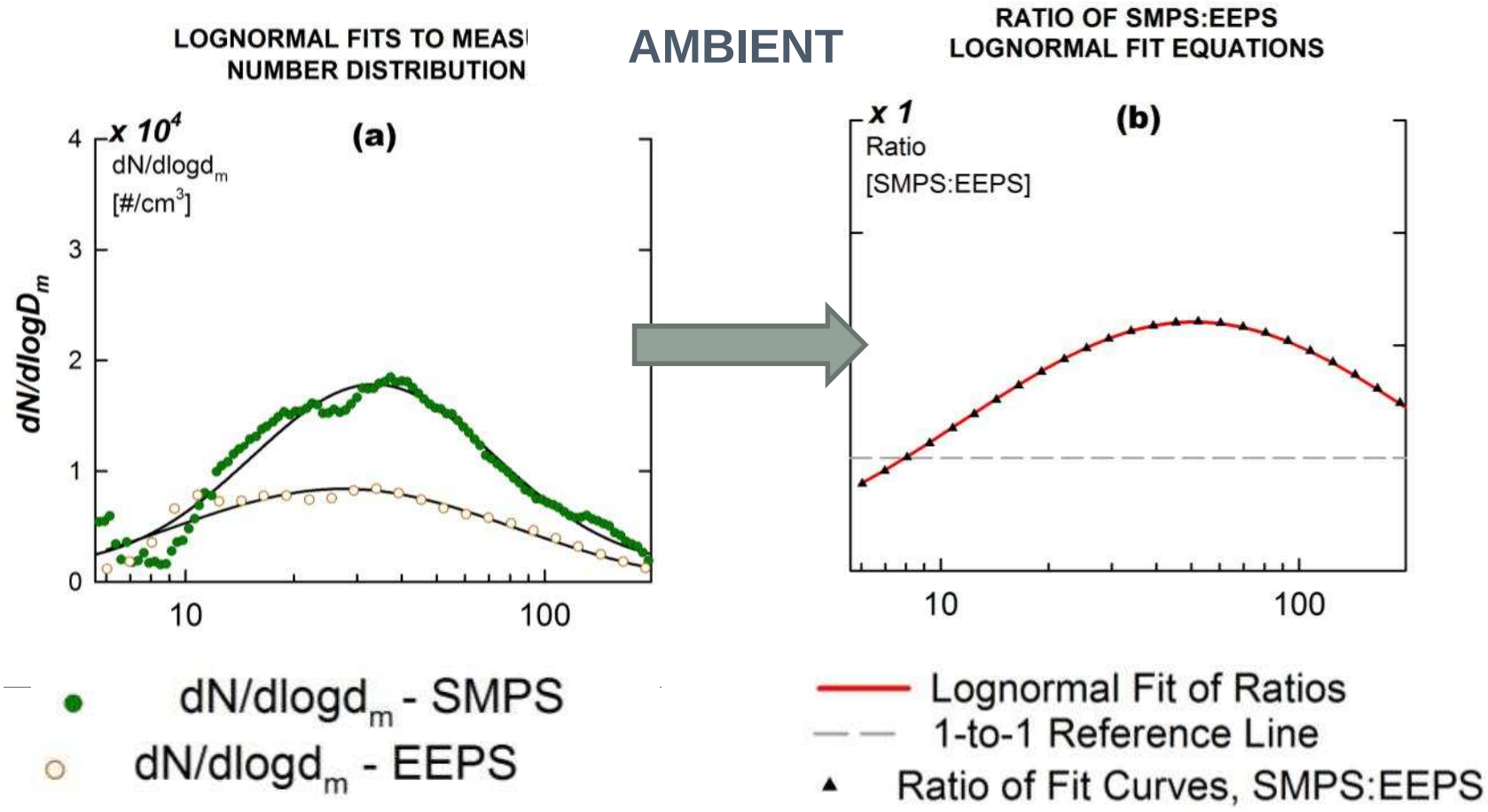
PM Mass Emissions



Mass-based size distributions differ



Derivation of (C_2) correction for EEPS

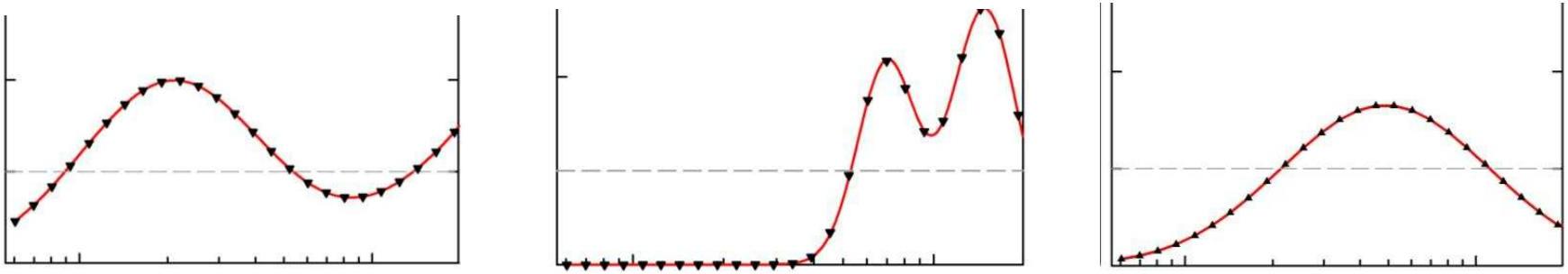


More EEPS-to-SMPS Ratios

CURB IDLE

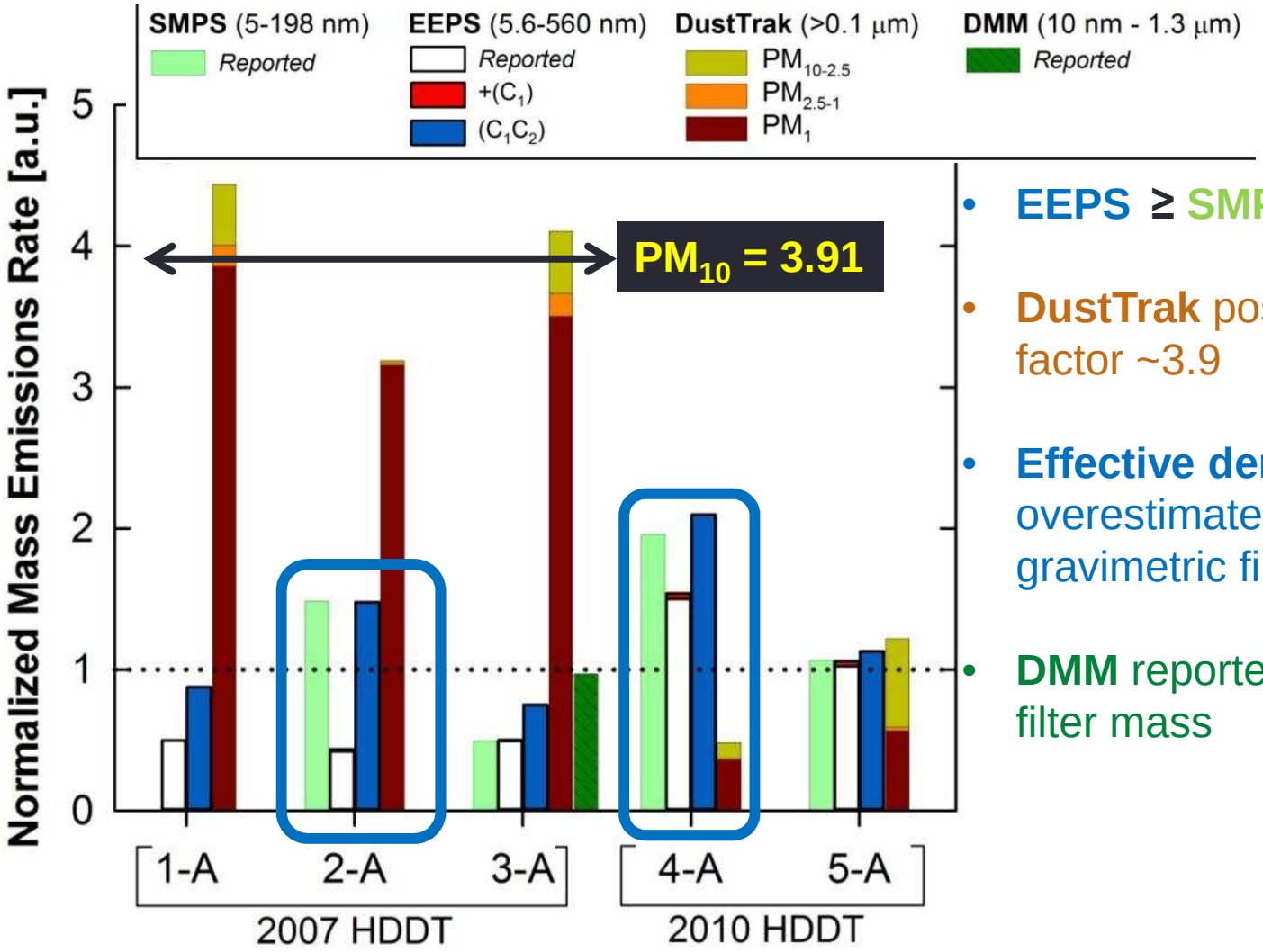
regeneration
ACCUMULATION

regeneration
NUCLEI



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

Average Regeneration Emissions



- **EEPS** ≥ **SMPS**
- **DustTrak** post-correction: factor ~3.9
- **Effective density** overestimates relative to gravimetric filters (1-2 x)
- **DMM** reported 97% of filter mass

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 µm during regeneration. However, during certification following 40 CFR Part 1065, this PM would be removed by a pre-classifier. Quantitatively, instrument calibration was ~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

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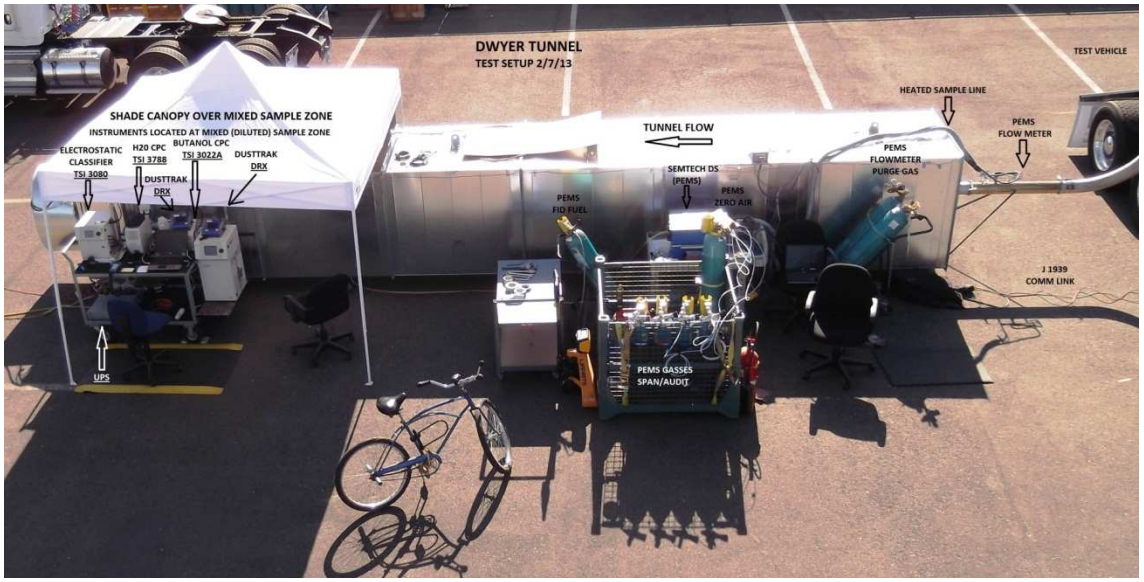

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