Engine Exhaust Particle Sizer (EEPS) Improvement for Engine Emission Measurement

Xiaoliang Wang[1] (xwang@dri.edu), Judith C. Chow[1], John G. Watson[1], Melissa A. Grose[2], Robert Caldow[2], Brian L. Osmondson[2], Jacob J. Swanson[3], David B. Kittelson[4], Yang Li[5], Xue Jian[5], and Heejung Jung[5]

[1]Desert Research Institute, 2215 Raggio Pkwy, Reno, NV 89512; [2]TSI Inc., 500 Cardigan Road, Shoreview, MN 55126; [3]Minnesota State University-Mankato, 9700 France Ave S., Bloomington, MN 55431; [4]University of Minnesota-Twin Cities, 111 Church St. S.E., Minneapolis, MN 55455; [5]University of California-Riverside, 1084 Columbia Ave, Riverside, CA 92507

Motivations

1. EEPS does not agree well with the Scanning Mobility Particle Sizer (SMPS) for some engine exhaust particle size distributions.
2. EEPS size distributions usually begin to roll-off at 200 nm as compared to SMPS.

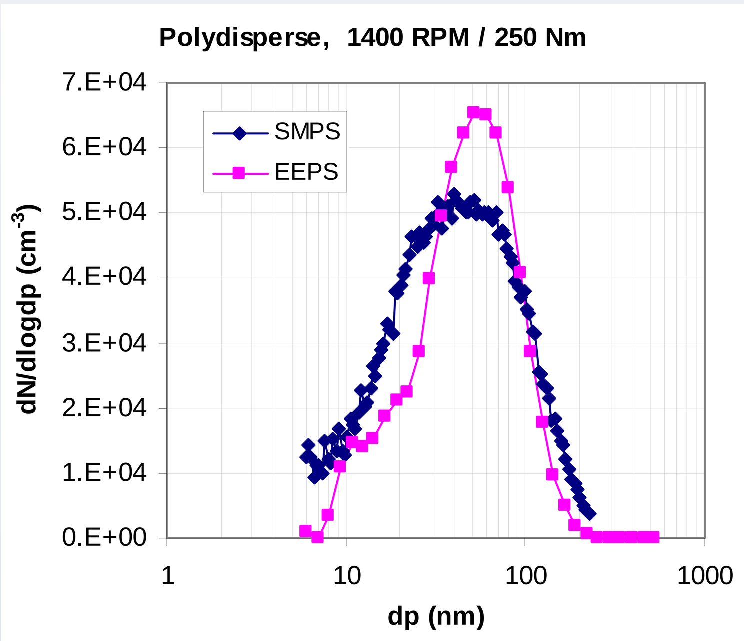


Fig. 1. An example of EEPS/SMPS particles size distribution comparison for the exhaust from a John Deere 4045H diesel engine under steady state conditions.

Objectives

1. Characterize the EEPS performance using mono- and polydisperse engine exhaust aerosols.
2. Improve size distribution agreement between the EEPS and SMPS when measuring vehicle exhaust aerosols.

Principle of the EEPS

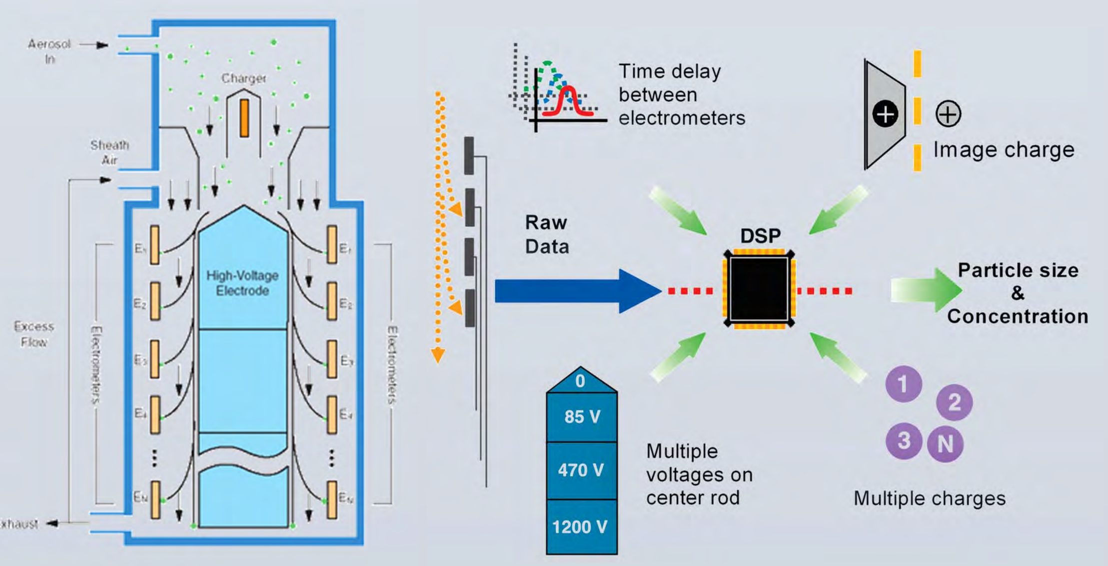


Fig. 2. Schematic diagram of the EEPS.

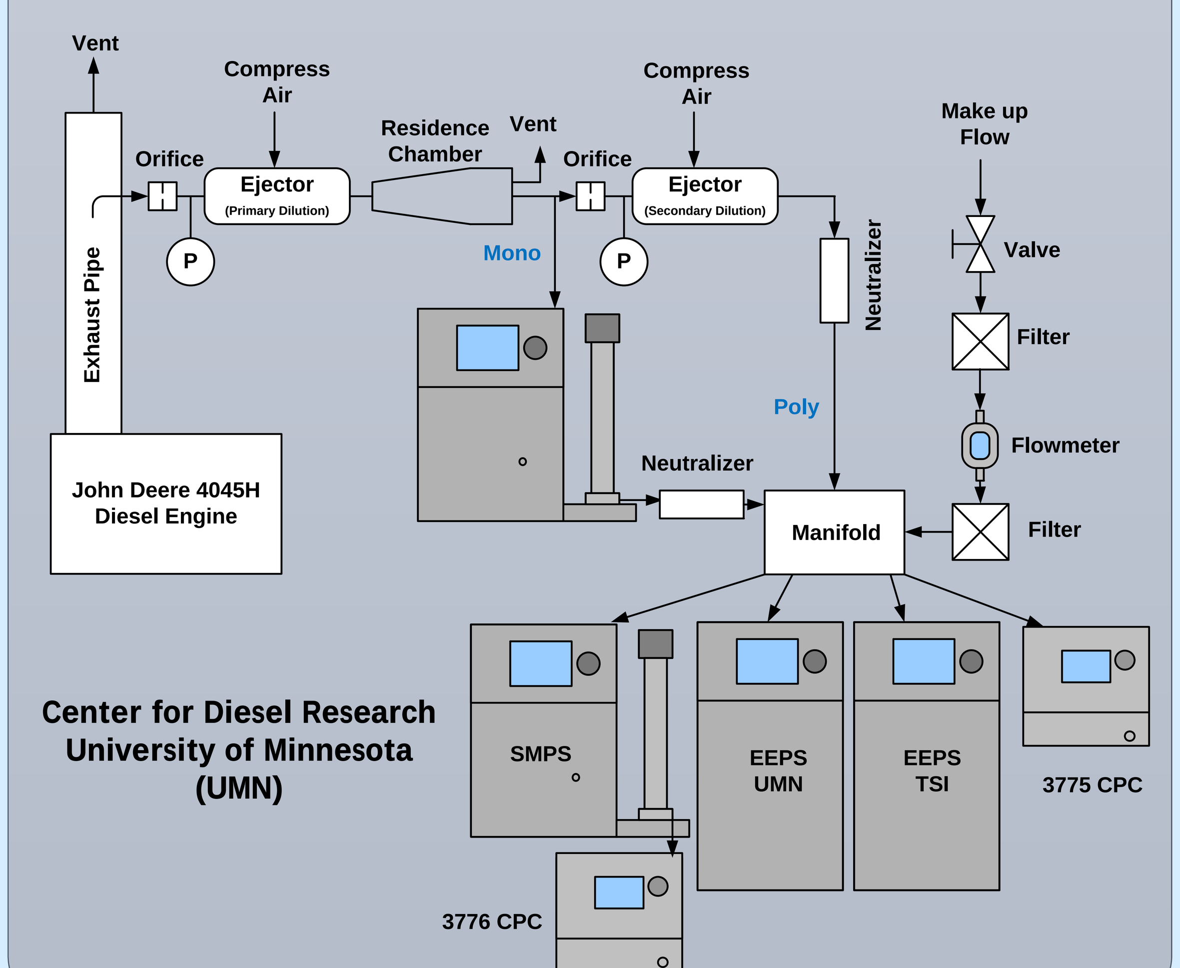
Principle: Tammet and Mirme., 2002; Johnson et al., 2004

- Unipolar diffusion charging by two corona chargers;
- Differential electrical mobility separation under flow and electric fields;
- Electric charge detection by 22 parallel electrometers;
- Data inversion to obtain size distribution.

EEPS/SMPS Key Feature Comparison:

Parameter	EEPS	SMPS
Size range (nm):	5.6-560	e.g., 2.5–65; 5–166; 7–294
Size resolution (channel/decade)	16	64
Time resolution (s)	0.1	16–600
Concentration range (cm^{-3})	200–10^7	1–10^7

Engine Exhaust Measurement



Engine Exhaust Measurement (cont.)

Particle Sizes	Engine RPM/Torque 800/0 (idle)	1400/ 50	1400/ 100	1400/ 250	1400/ 450	2400/ 500	2400/ 475
Polydisperse	-	X	X	X	X	-	-
10 nm	X	-	-	-	-	-	-
20nm	X	X	-	-	-	-	-
30nm	-	X	-	-	-	-	-
50nm	-	-	X	X	-	-	-
70nm	-	-	X	X	-	-	-
100nm	-	-	X	X	-	-	X
150nm	-	-	X	-	-	-	X
200nm	-	-	-	-	X	X	-
250nm	-	-	-	-	-	X	-
300nm	-	-	-	-	-	X	-
350nm	-	-	-	-	-	-	X
400nm	-	-	-	-	-	-	X

Fig. 3. Experimental setup and engine conditions to evaluate the EEPS performance and generate the new inversion matrix. When measuring polydisperse aerosols, particles were sampled after the 2nd dilution stage in most cases. When measuring monodisperse aerosols, particles were sampled after the 1st dilution stage, and mobility selected by a classifier .

Polydisperse Diesel Exhaust Particles (as Found):

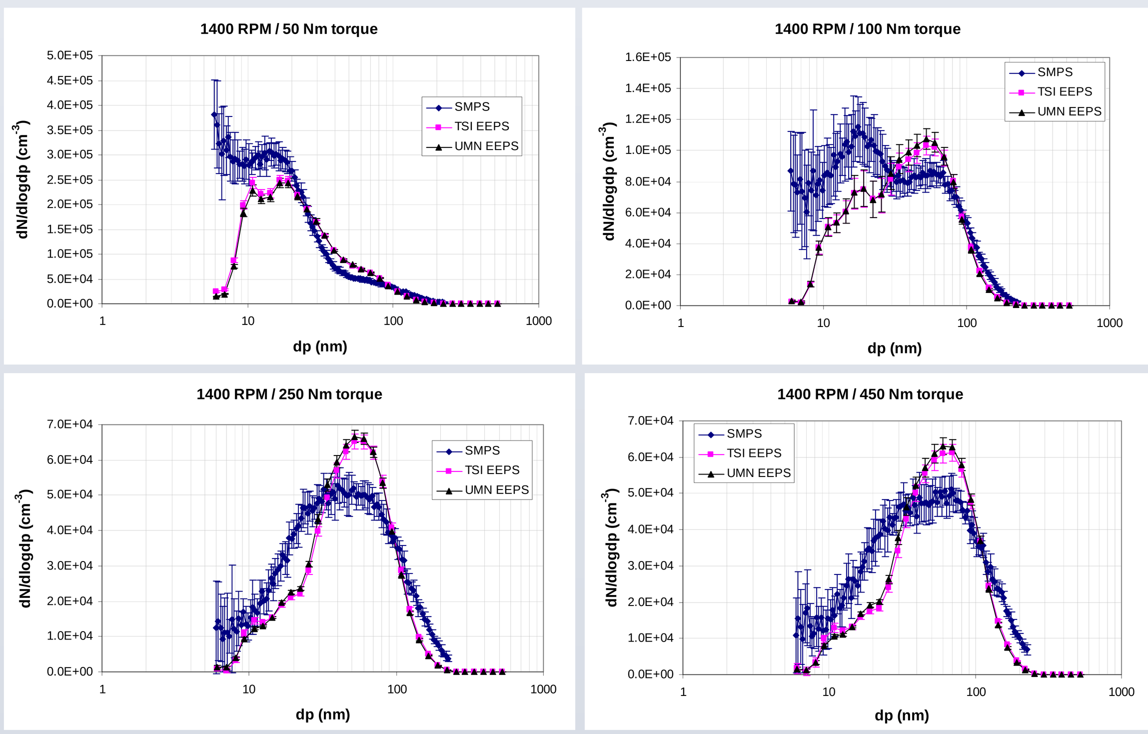


Fig. 4. EEPS and SMPS comparison for polydisperse engine exhaust aerosols. The EEPS concentration was generally higher than the SMPS for ~30-90 nm particles, but was lower for sizes >~100 nm. The lower EEPS concentration for particles >100 nm would result in underestimation of particle mass when compared to filter measurements. It is the goal of this study to reduce these discrepancies by creating an inversion matrix specific to engine exhaust aerosols (i.e. a soot matrix). The two EEPS agreed remarkably well.

Monodisperse Diesel Exhaust Particles (as Found):

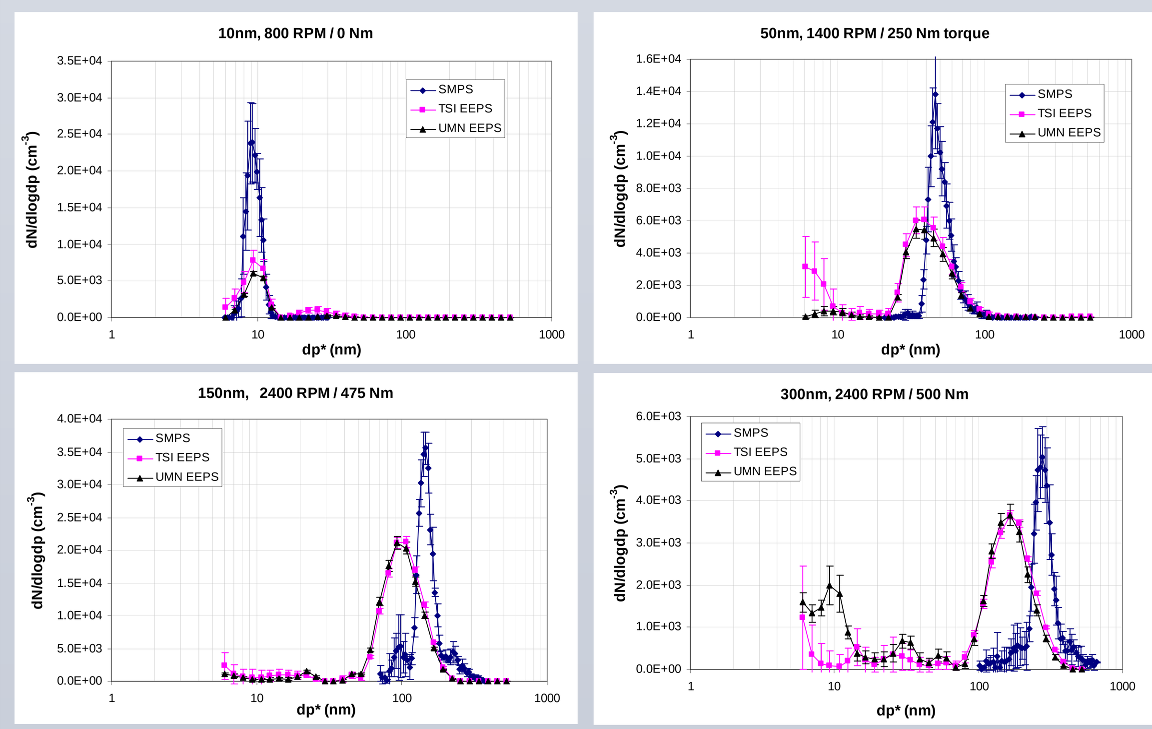


Fig. 5. EEPS and SMPS comparison for mobility classified monodisperse engine exhaust aerosols. Note that (1) EEPS distributions were wider than the SMPS; and (2) The mean sizes of EEPS agreed with SMSP for particles <30 nm, but became smaller for particles >50 nm.

Improved EEPS Inversion

Monodisperse Diesel Exhaust Particles (Improved):

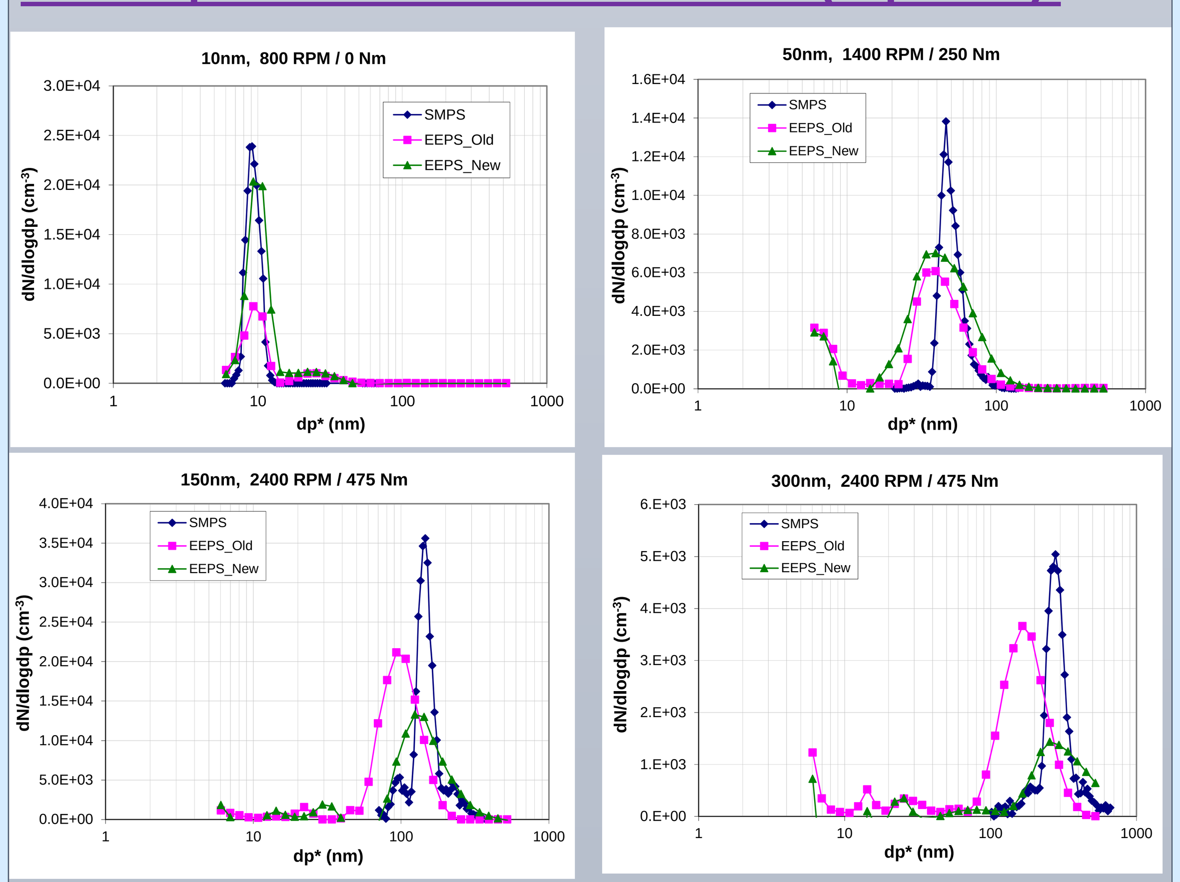


Fig. 6A. Comparison of EEPS with old matrix and new soot matrix with SMPS and CPC for monodisperse particles. The new soot matrix significantly improved EEPS agreement with SMPS and CPC.

Improved EEPS Inversion (continued)

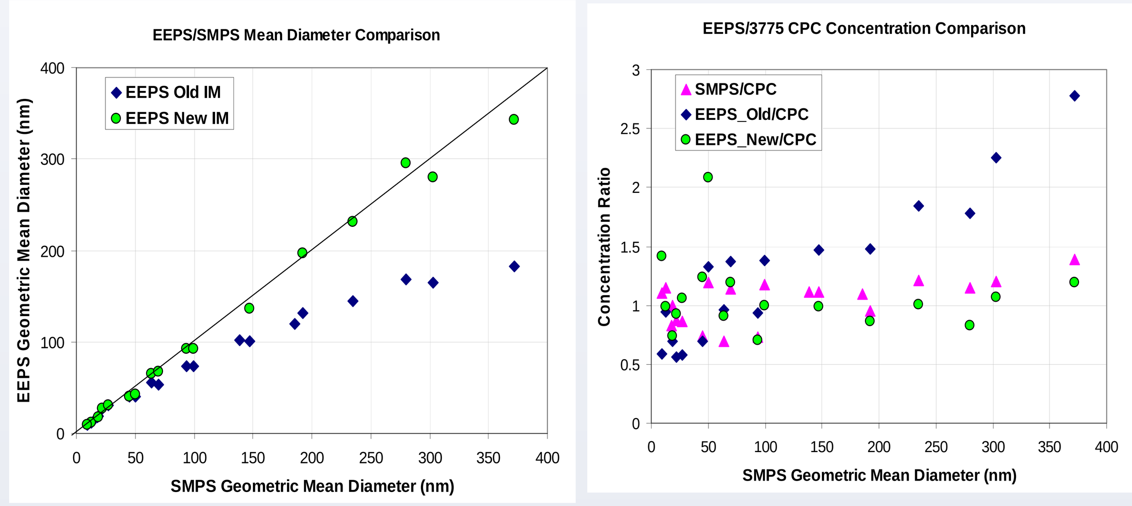


Fig. 6B. Comparison of EEPS with old matrix and new soot matrix with SMPS and CPC for monodisperse particles. The new soot matrix significantly improved EEPS agreement with SMPS and CPC.

Polydisperse Diesel Exhaust Particles (Improved):

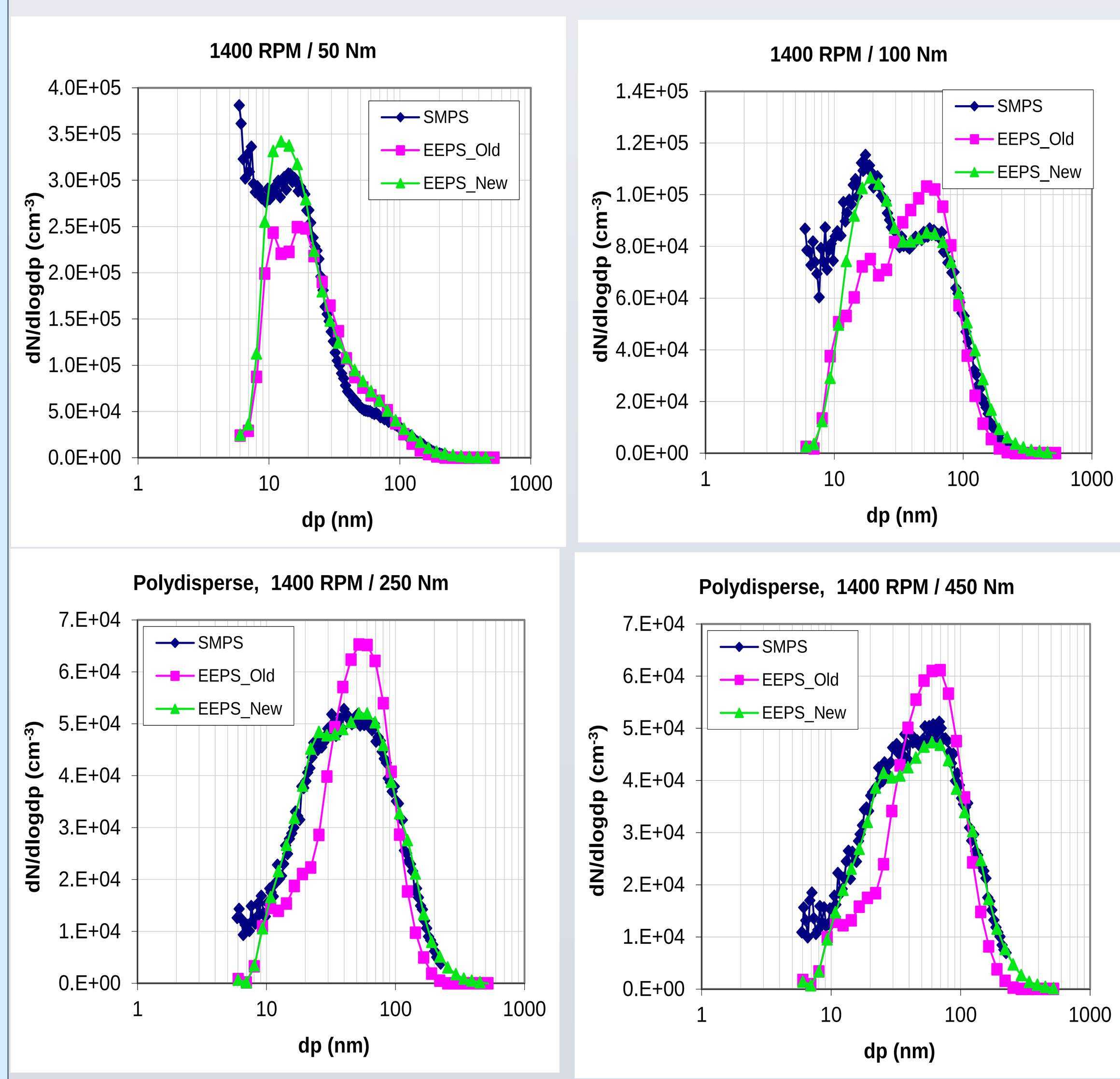


Fig. 7. EEPS with the new soot matrix significantly improved the agreement with SMPS for polydisperse diesel engine exhaust particles.

Polydisperse Gasoline Exhaust Particles (Mixed):

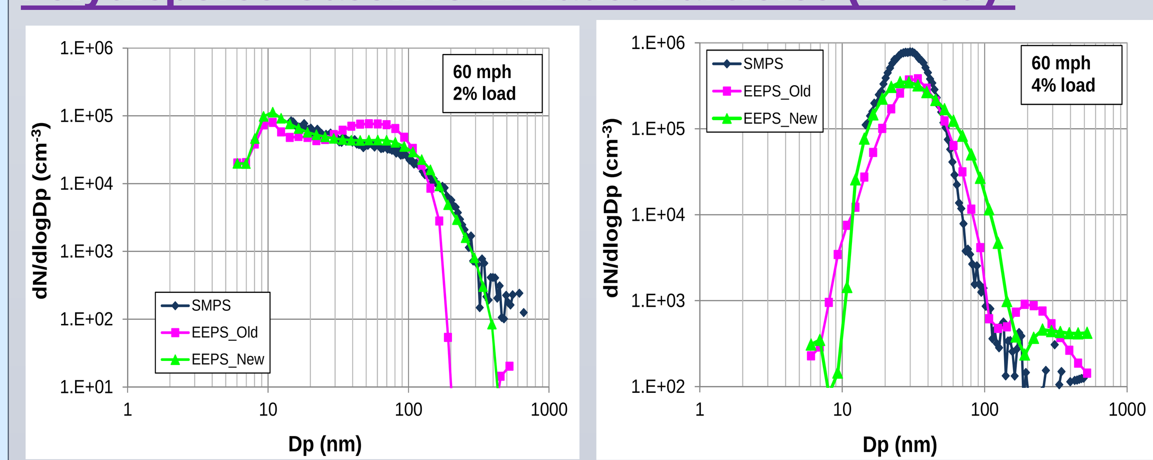


Fig. 8. EEPS with the new soot matrix improved the agreement with SMPS for one gasoline direct injection (GDI) vehicle (left panel), but did not improve for another GDI vehicle (right panel). More investigations are needed to test the applicability of the new soot matrix.

Conclusions

- The EEPS with default inversion matrix underestimates the size and concentration of >100 nm engine exhaust particles.
- Using experimentally generated soot matrix significantly improved agreement between EEPS and SMPS and CPC for many cases of diesel and gasoline vehicle emissions.
- Further testing with different engines and conditions are needed to verify the versatility or further improve the new soot matrix.

References

- Johnson, T. et al. (2004). SAE 2004-01-1341.
- Tammet,H. and Mirme, A. (2002). Atmos. Res., 62(3-4): 315-324.

Acknowledgements

The EEPS inversion matrix evaluation in the Center for Environmental Research and Technology (CE-CERT), University of California-Riverside was supported by the California Air Resources Board under contract 11-548.