Real-World Tire and Brake Wear Emissions

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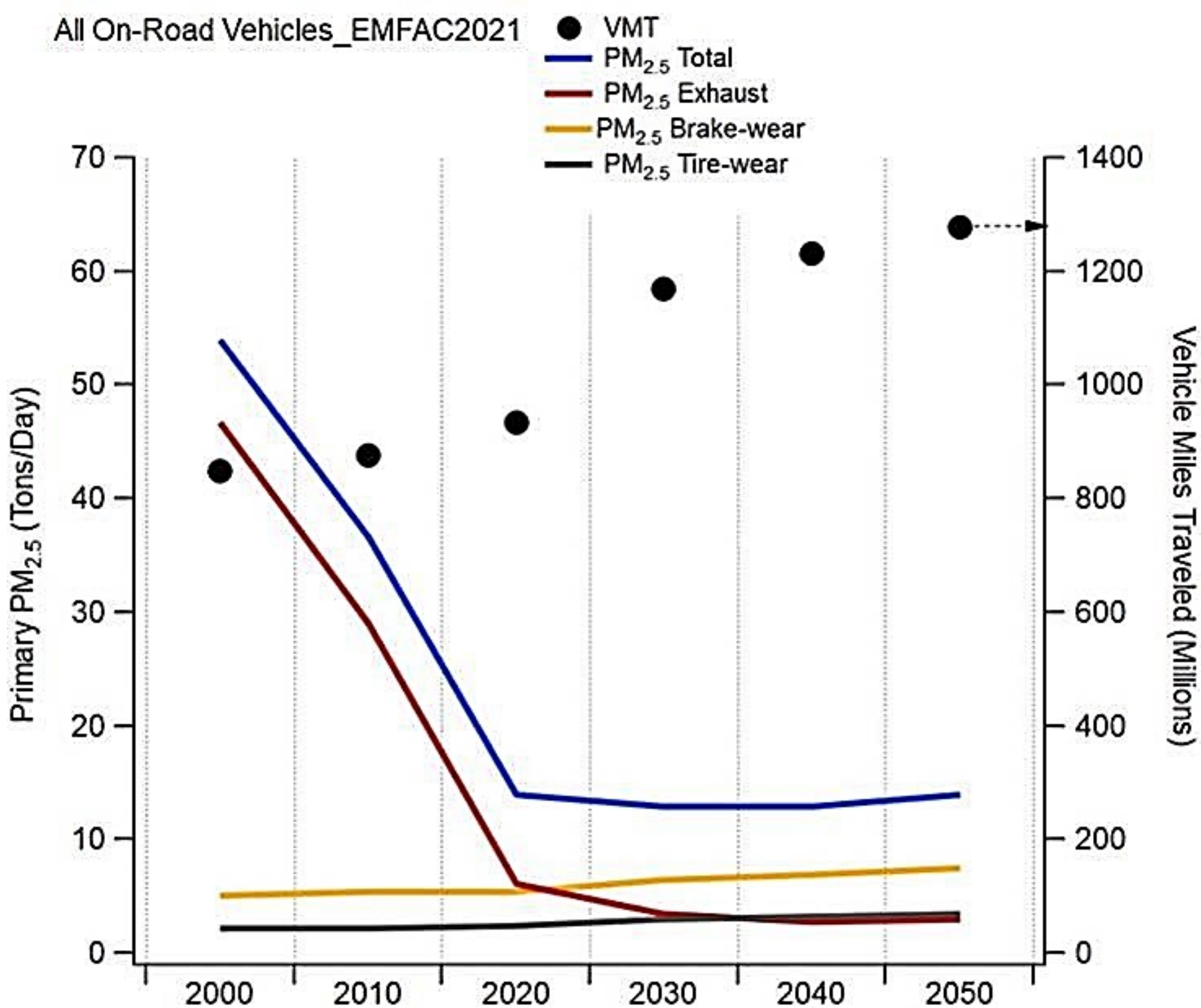
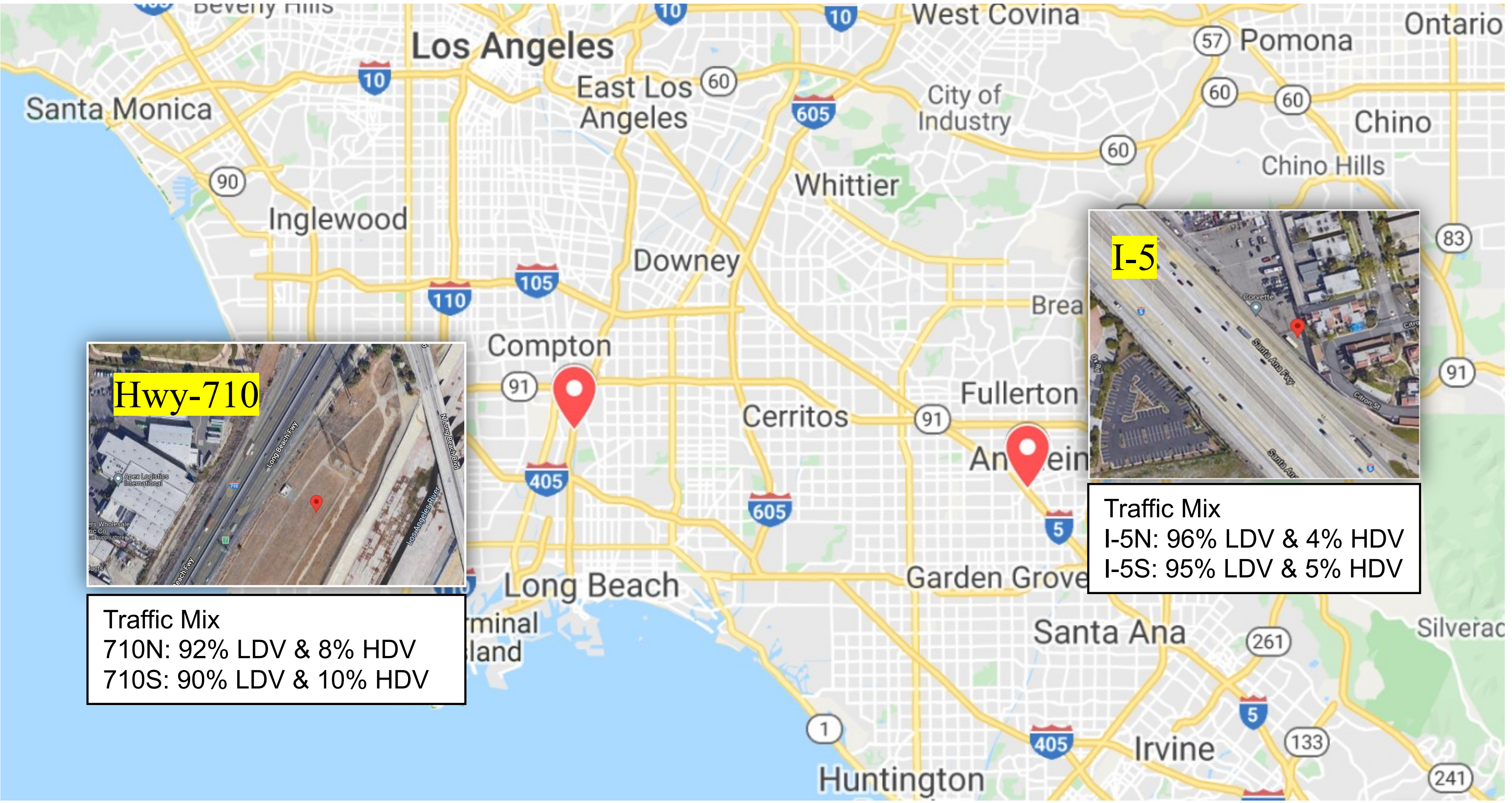
Non-tailpipe emissions are becoming a larger fraction of total vehicle emissions



Study Objectives

- Measure time-resolved $PM_{2.5}$ and PM_{10} mass at near road locations to quantify exposure at near road locations.
- Conduct source apportionment analysis to determine contribution of brake and tire particles to $PM_{2.5}$ and PM_{10}.

Monitoring Sites in Southern California (January – February, 2020)

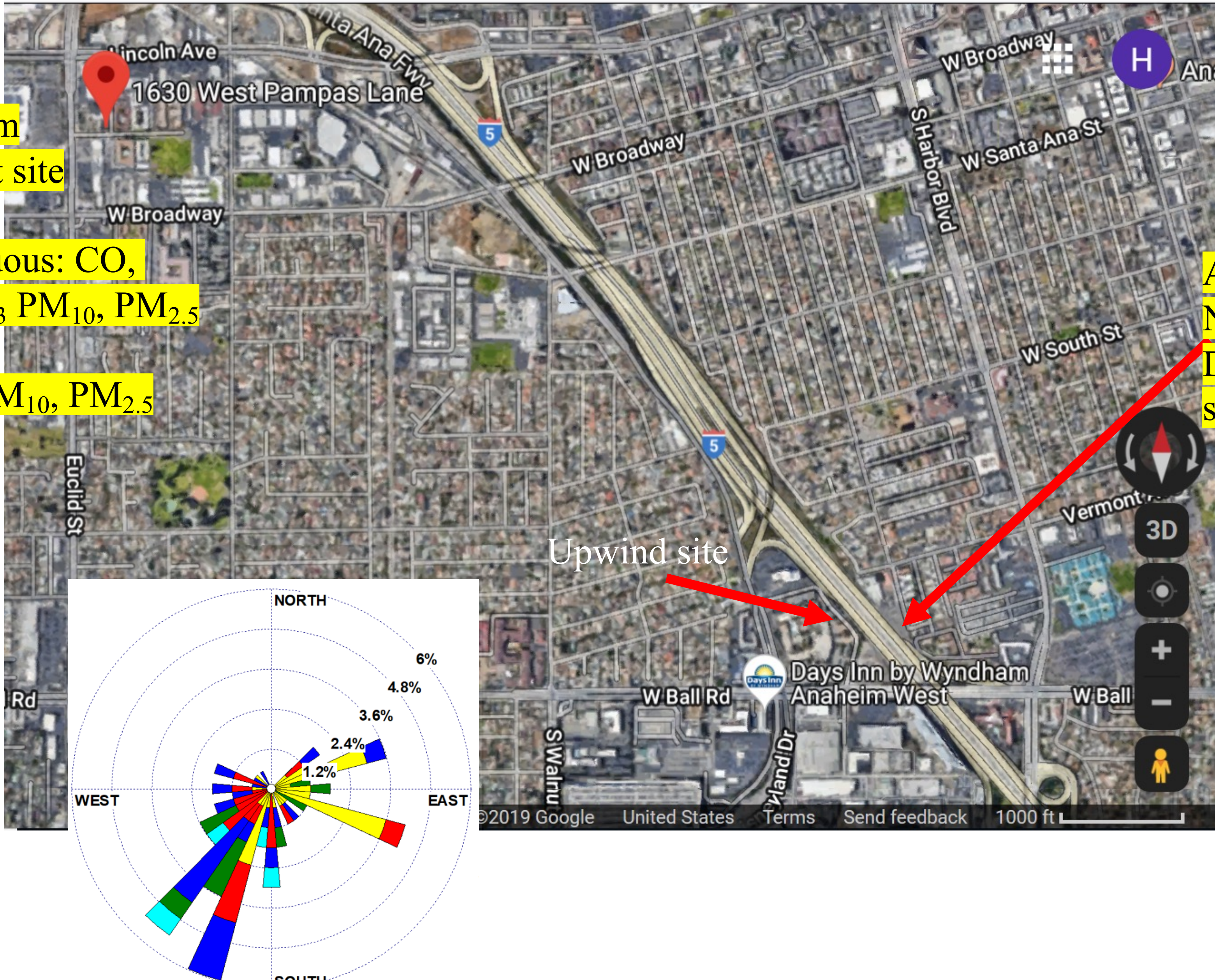


Anaheim sites

Anaheim ambient site

Continuous: CO, NO_2, O_3 PM_{10}, $PM_{2.5}$

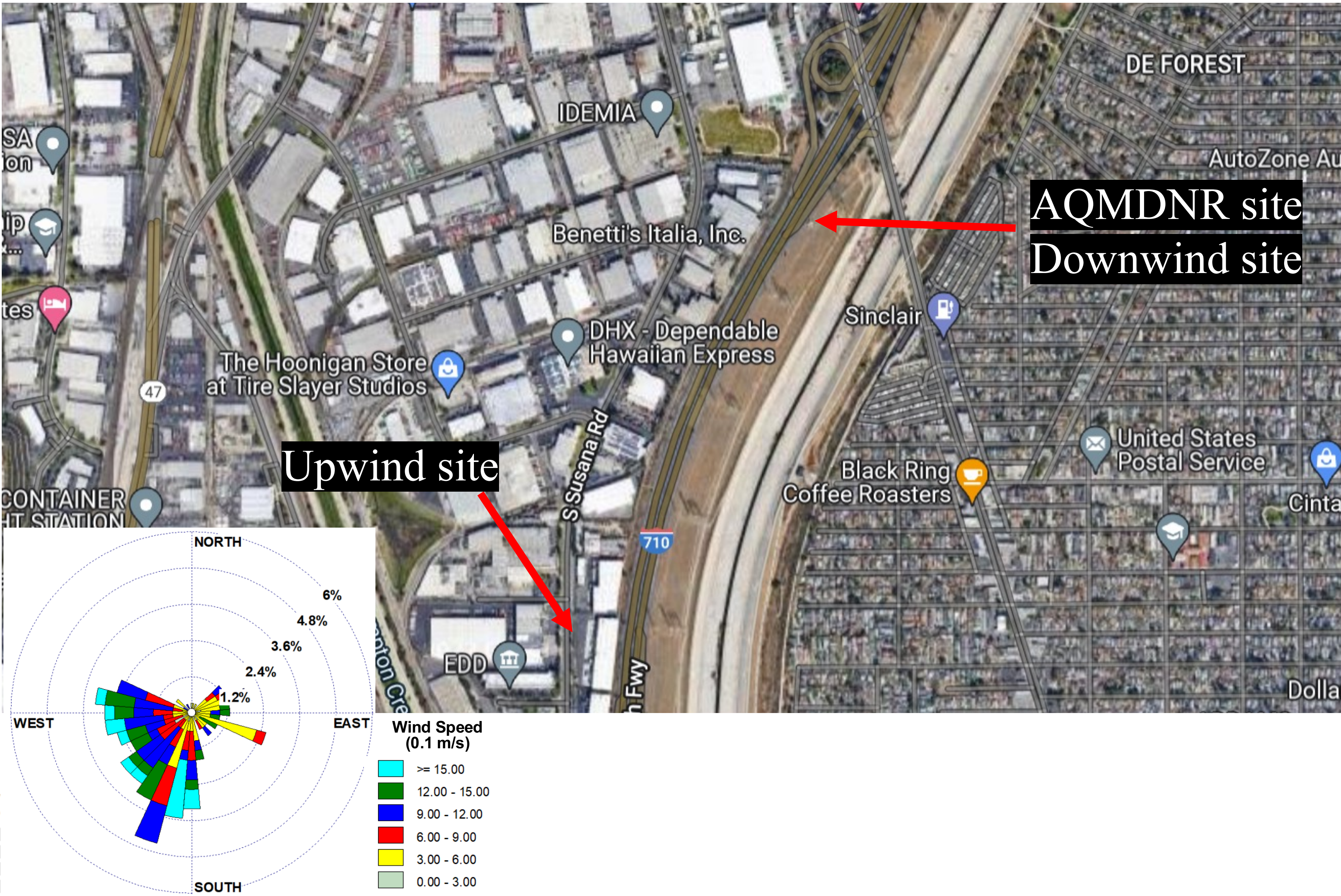
24hr: PM_{10}, $PM_{2.5}$



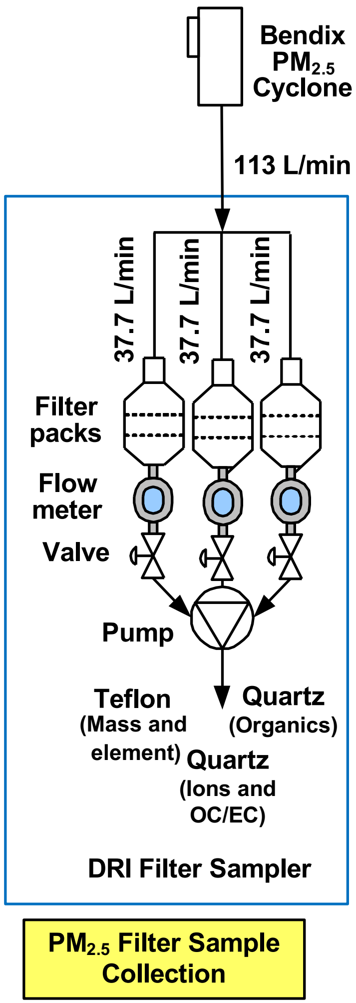
Anaheim NR site

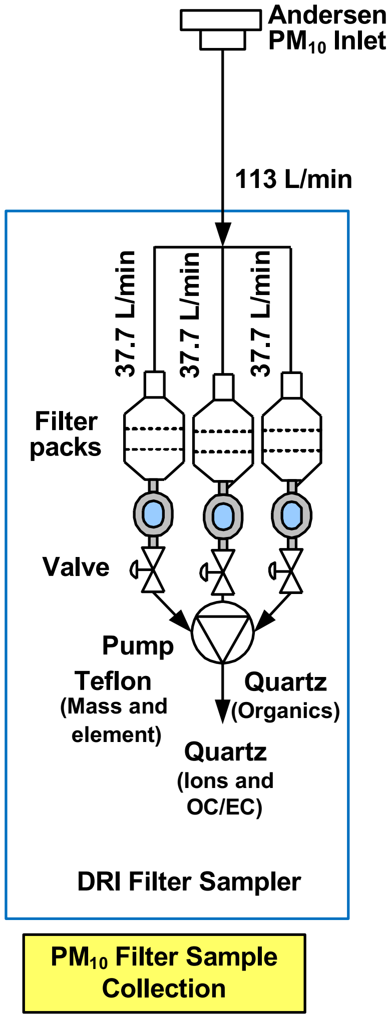
Downwind site

Long Beach sites



$PM_{2.5}$ and PM_{10} filter pairs were collected upwind and downwind of highways

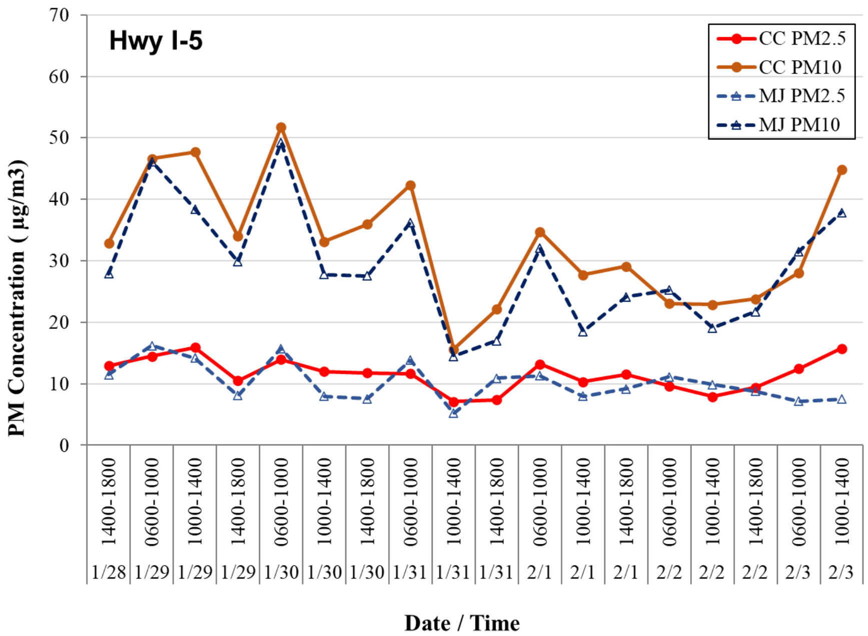


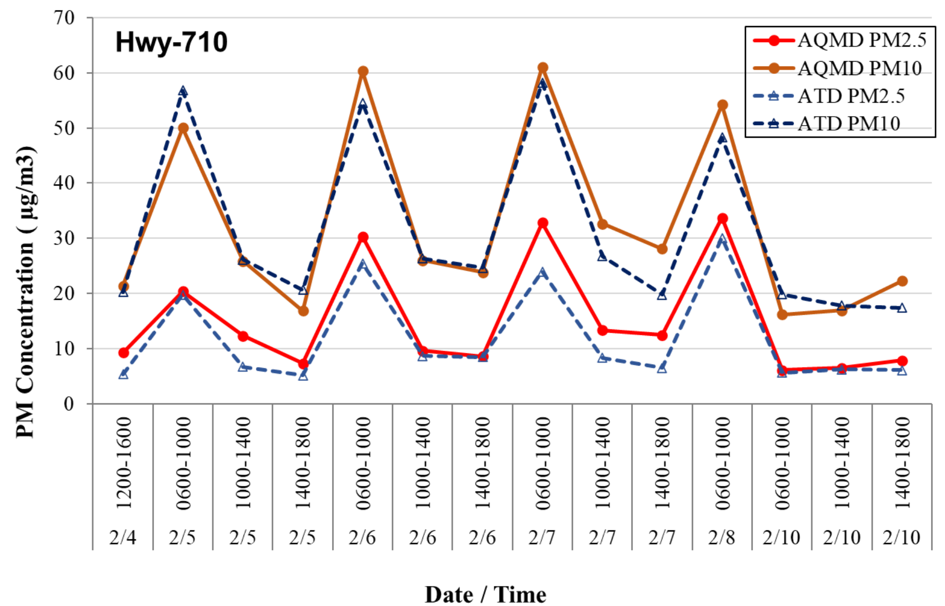


Typical sampling periods:

- 0600-1000; 1000-1400; 1400-1800
- 1/28/2020–2/3/2020 (I-5); 18 sets
- 2/4/2020–2/10/2020 (I-710); 14 sets
- A total of 128 filters.

PM_{10} concentrations were 2-3 times of $PM_{2.5}$; Up/downwind differences were small





Average PM Concentrations (µg/m³)				
Site	Upwind $PM_{2.5}$	Upwind PM_{10}	Downwind $PM_{2.5}$	Downwind PM_{10}
I-5	9.56	28.47	10.88	32.49
I-710	11.00	30.37	14.36	31.87

High correlations were found among elements from common sources

(a) I-5 Δ PM_{10}

	Fe	Si	Ca	Al	K	Zn	Ti	Cu	Ba	Sb	Sr	Cr	Mn	Zr
Fe														
Si	0.31													
Ca	0.41	0.79												
Al	0.26	0.81	0.68											
K	0.56	0.33	0.22	0.24										
Zn	0.69	0.32	0.46	0.39	0.29									
Ti	0.90	0.27	0.30	0.21	0.49	0.70								
Cu	0.90	0.14	0.23	0.13	0.39	0.69	0.90							
Ba	0.69	0.07	0.17	0.07	0.32	0.63	0.76	0.80						
Sb	0.01	0.17	0.09	0.30	0.01	0.00	0.01	0.04	0.02					
Sr	0.53	0.22	0.23	0.12	0.27	0.38	0.43	0.46	0.28	0.00				
Cr	0.29	0.02	0.08	0.11	0.26	0.21	0.20	0.29	0.22	0.01	0.03			
Mn	0.67	0.25	0.34	0.12	0.43	0.26	0.48	0.49	0.26	0.07	0.50	0.08		
Zr	0.87	0.15	0.25	0.13	0.35	0.70	0.89	0.94	0.81	0.04	0.37	0.28	0.43	
Mo	0.01	0.03	0.01	0.00	0.01	0.01	0.01	0.06	0.00	0.02	0.00	0.25	0.00	0.04

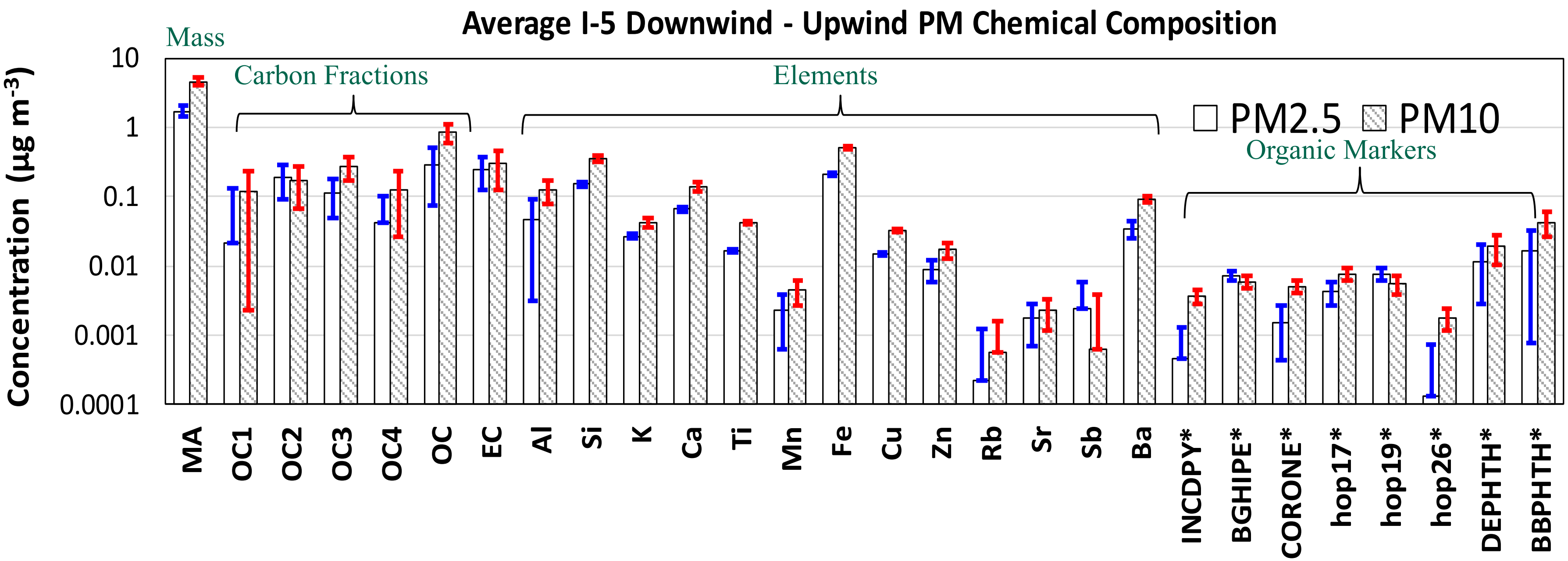
(b) I-710 Δ PM_{10}

	Fe	Si	Ca	Al	K	Zn	Ti	Cu	Ba	Sb	Sr	Cr	Mn	Zr
Fe														
Si	0.40													
Ca	0.64	0.38												
Al	0.34	0.70	0.35											
K	0.46	0.94	0.32	0.61										
Zn	0.42	0.74	0.43	0.64	0.62									
Ti	0.08	0.20	0.39	0.49	0.10	0.38								
Cu	0.75	0.07	0.32	0.11	0.14	0.08	0.01							
Ba	0.44	0.03	0.38	0.10	0.04	0.11	0.15	0.40						
Sb	0.15	0.31	0.27	0.26	0.30	0.33	0.17	0.01	0.05					
Sr	0.19	0.07	0.35	0.13	0.04	0.11	0.22	0.12	0.01	0.14				
Cr	0.35	0.30	0.07	0.29	0.30	0.45	0.00	0.15	0.09	0.07	0.02			
Mn	0.37	0.38	0.23	0.29	0.34	0.24	0.05	0.14	0.17	0.19	0.00	0.09		
Zr	0.50	0.01	0.16	0.02	0.04	0.05	0.00	0.76	0.31	0.04	0.03	0.12	0.07	
Mo	0.01	0.10	0.02	0.13	0.09	0.07	0.01	0.01	0.03	0.23	0.07	0.17	0.30	0.05

Darker green $R^2 \geq 0.8$; Light green: R^2=0.6-0.8.

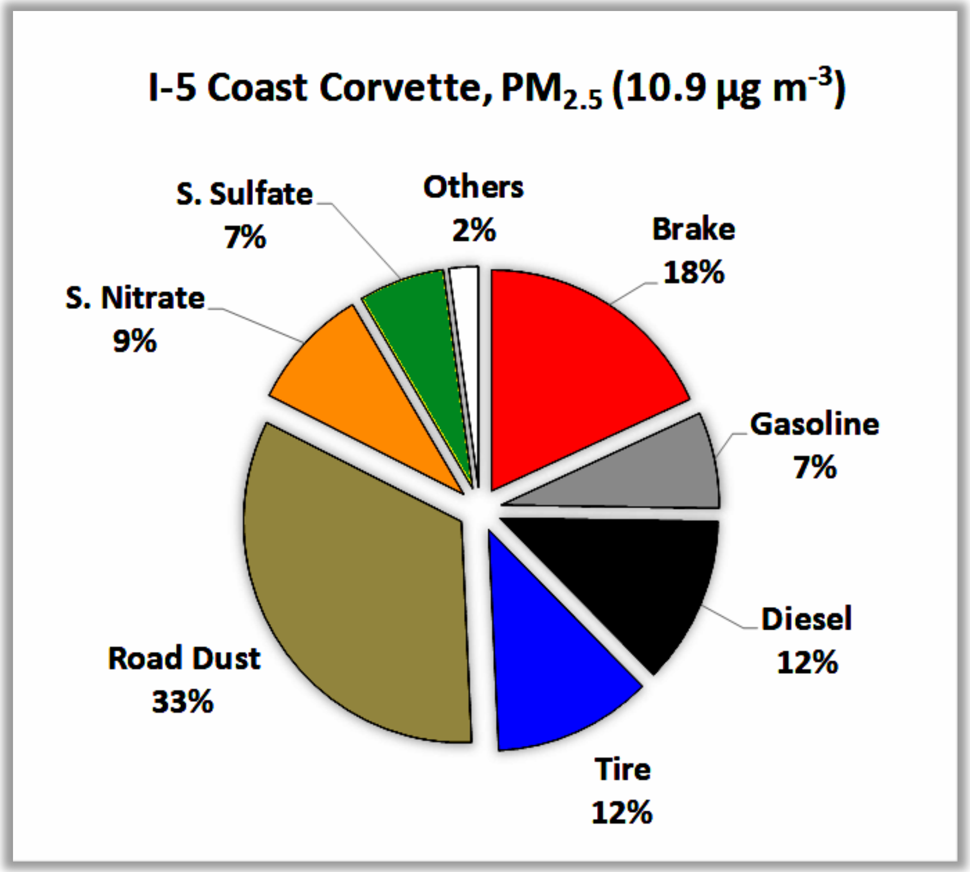
Brake wear: Ba, Cu, and Zr
Road dust: Al, Si, K, and Ca
(Measured by XRF)

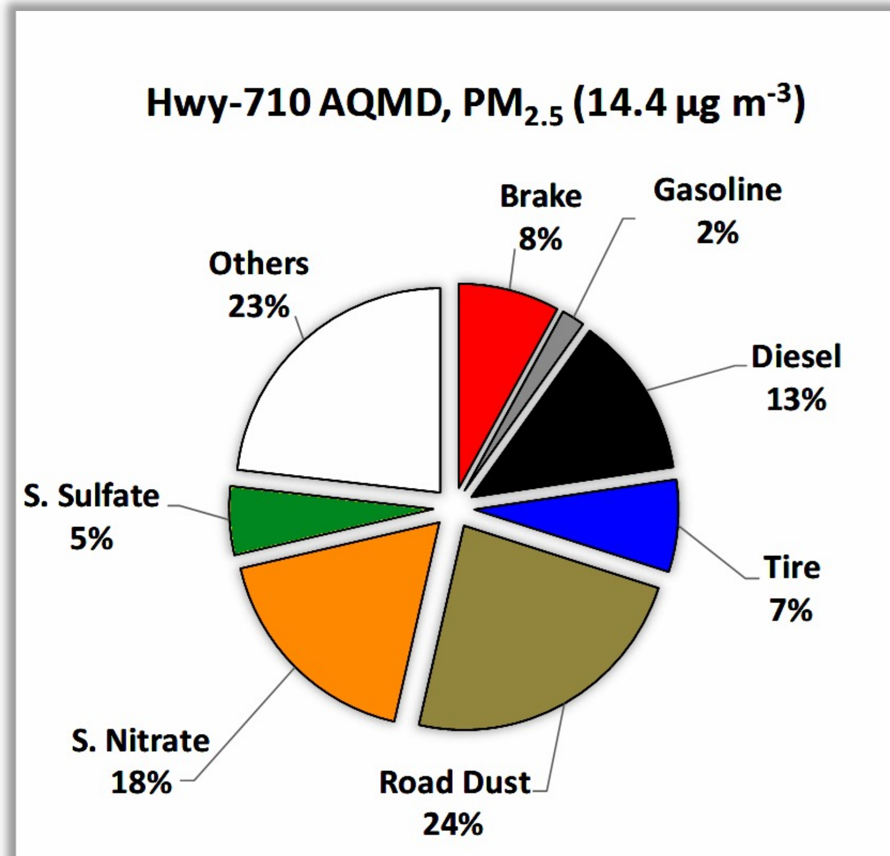
Average PM Chemical Composition (Downwind – Upwind)



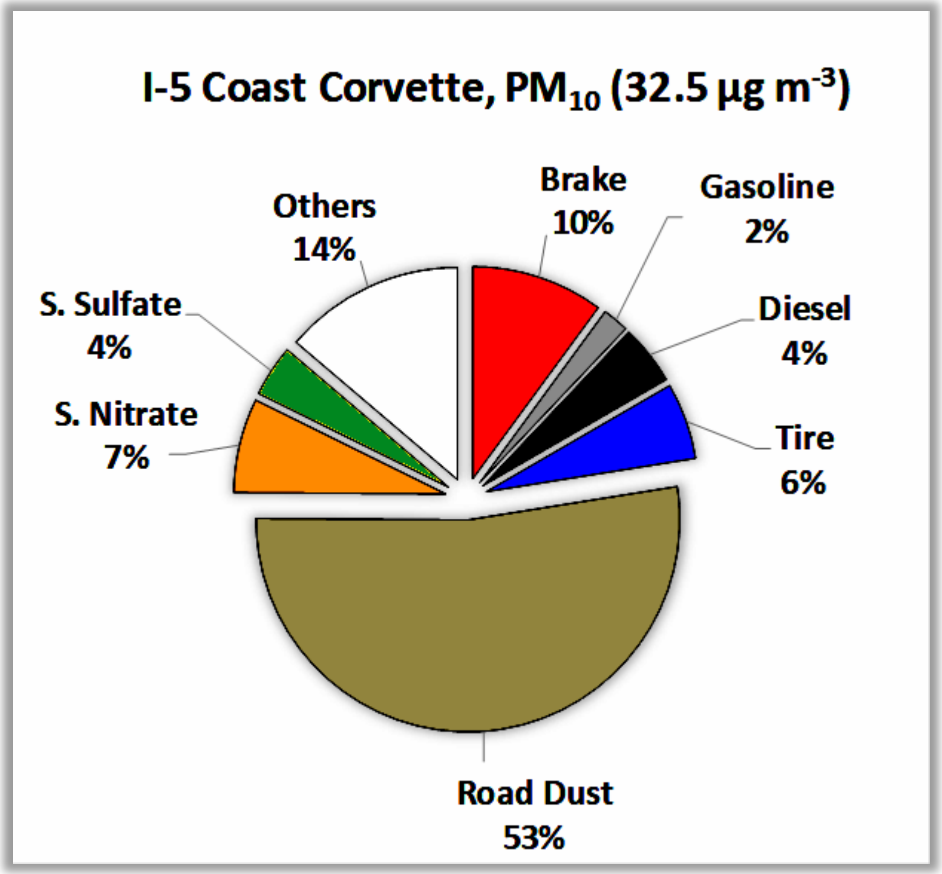
- The downwind-upwind difference may be entirely attributed to the on-road traffic emissions (exhaust + non-exhaust). It is the starting point of source apportionment

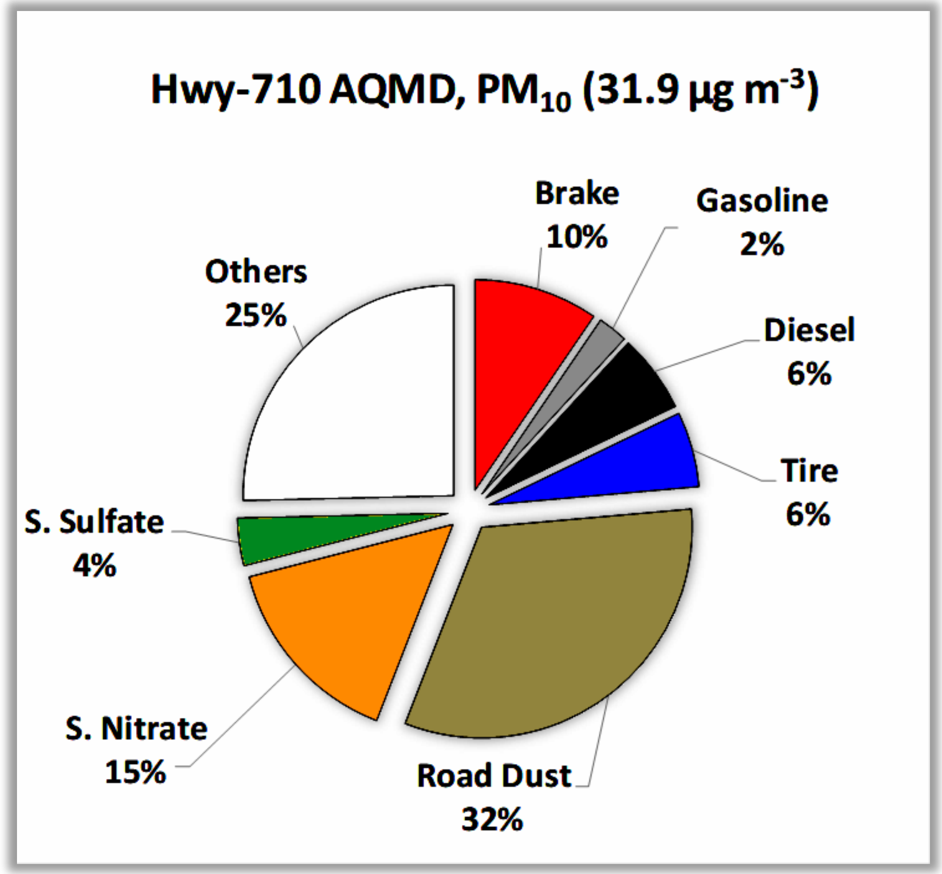
Applying CMB to Near-Road $PM_{2.5}$ Samples





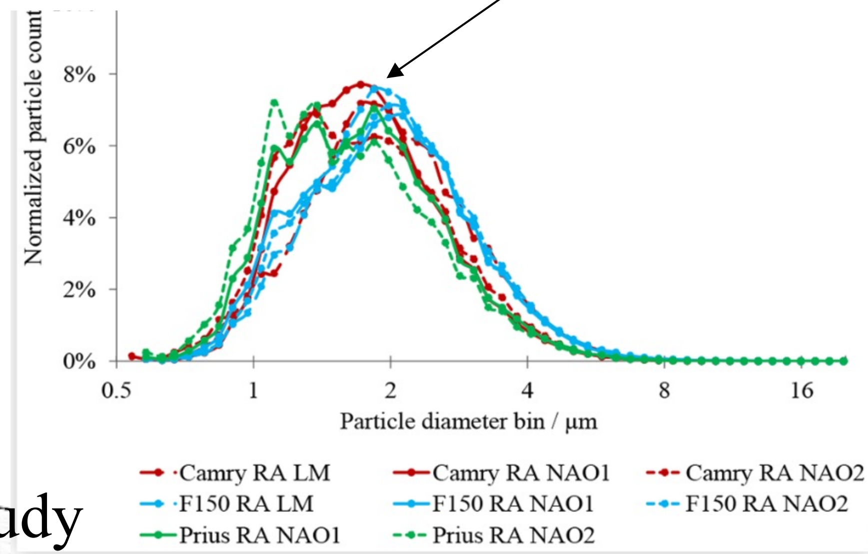
Applying CMB to Near-Road PM_{10} Samples



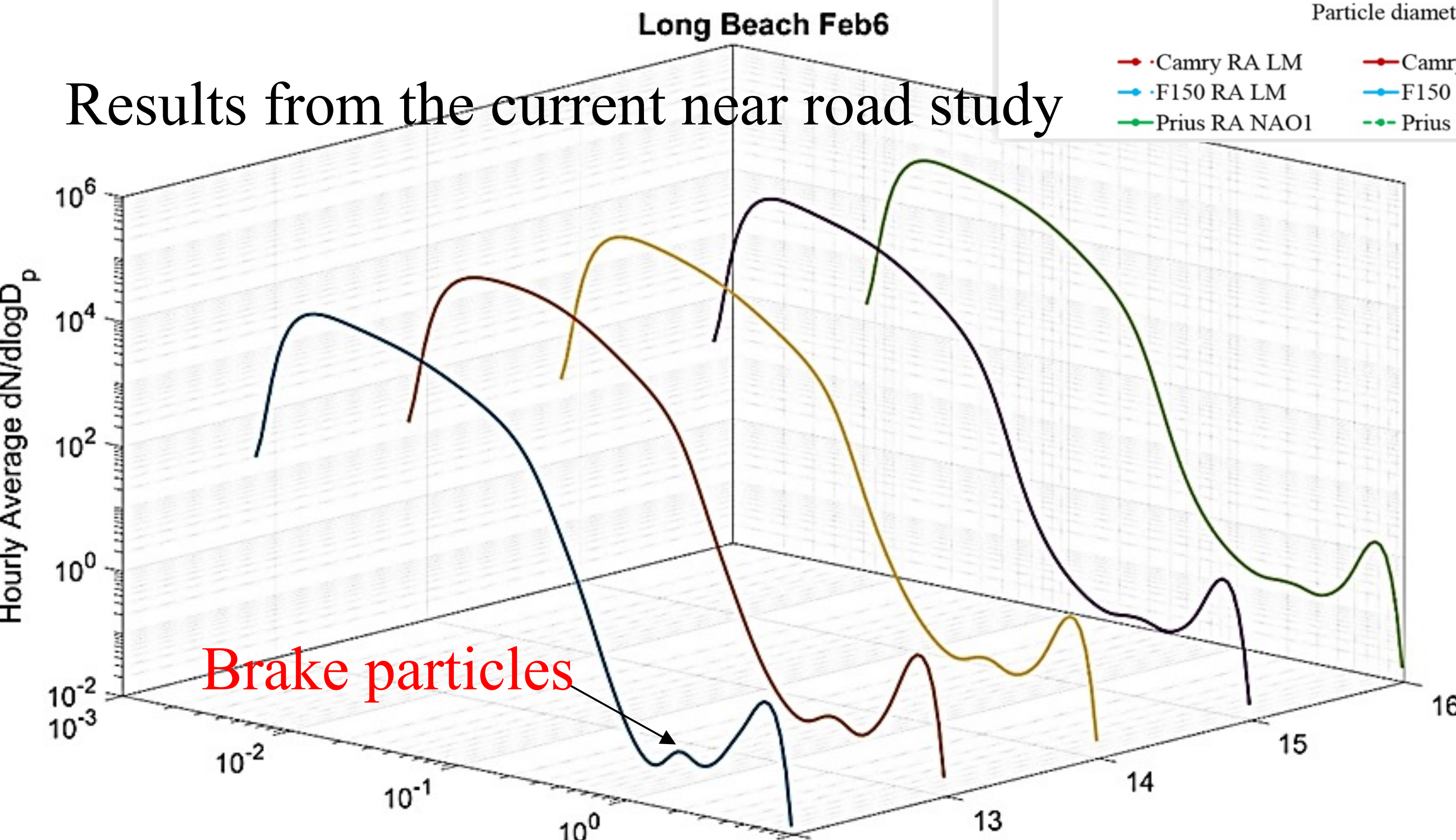


Aerodynamic particle size distribution

Results from the CARB dynamometer study, SAE 2020-01-1637

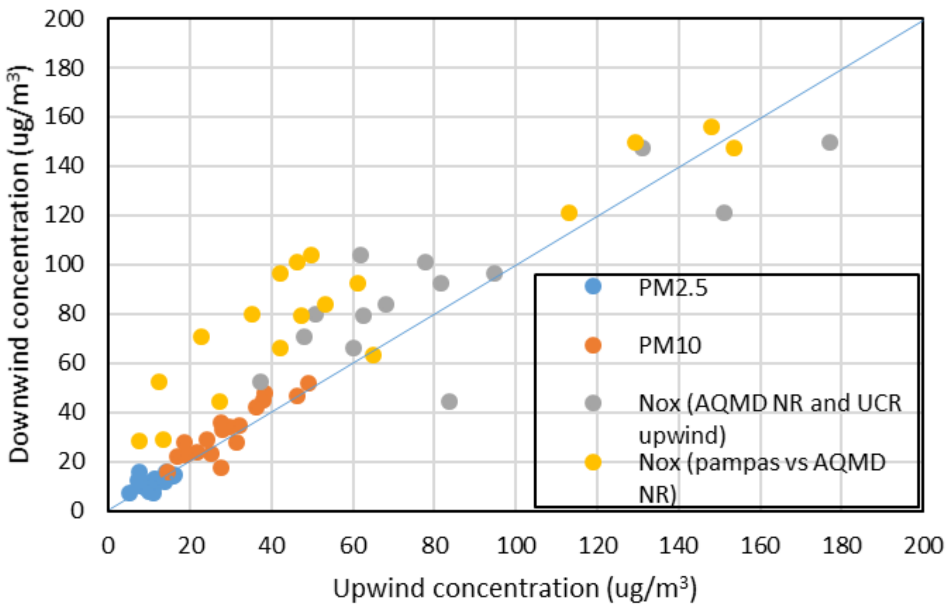


Results from the current near road study

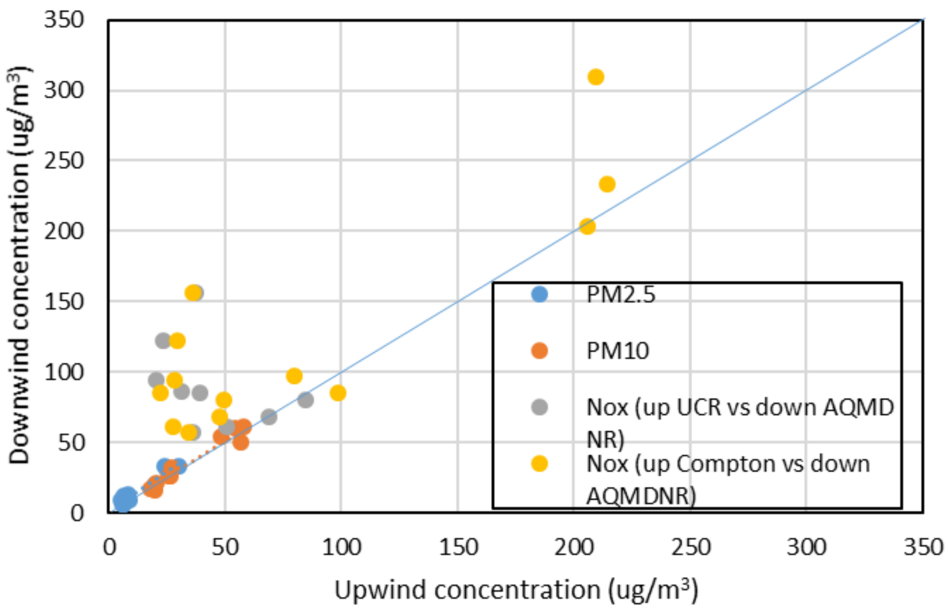


Brake particles

Background subtraction for PM



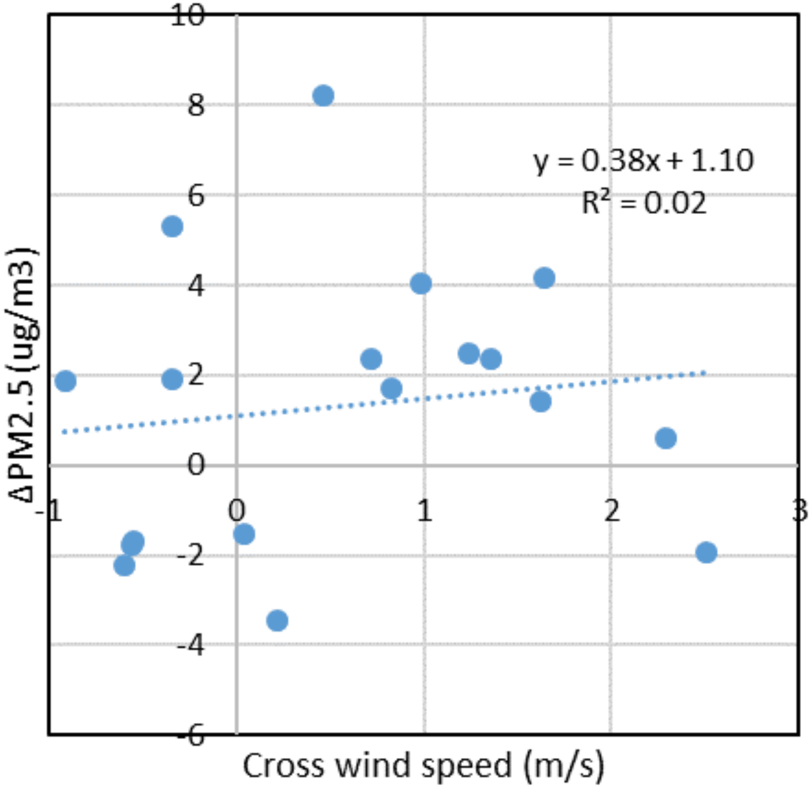
Anaheim



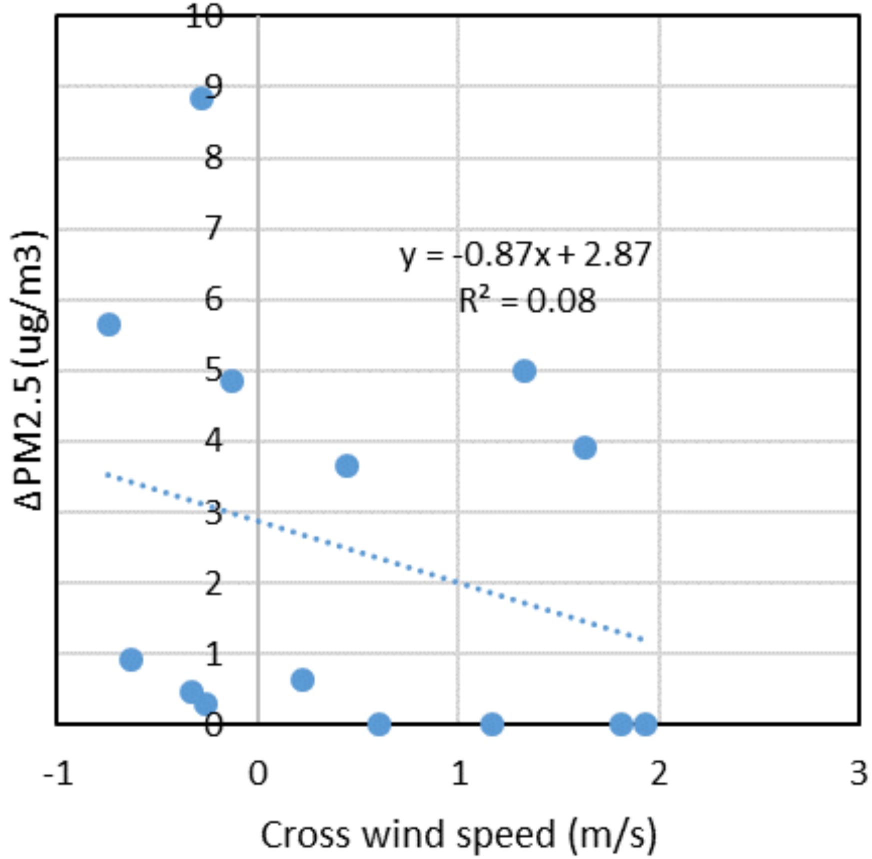
Long Beach

Background subtraction for PM2.5

Anaheim



Long Beach



Background subtraction for PM2.5$_{brake}$

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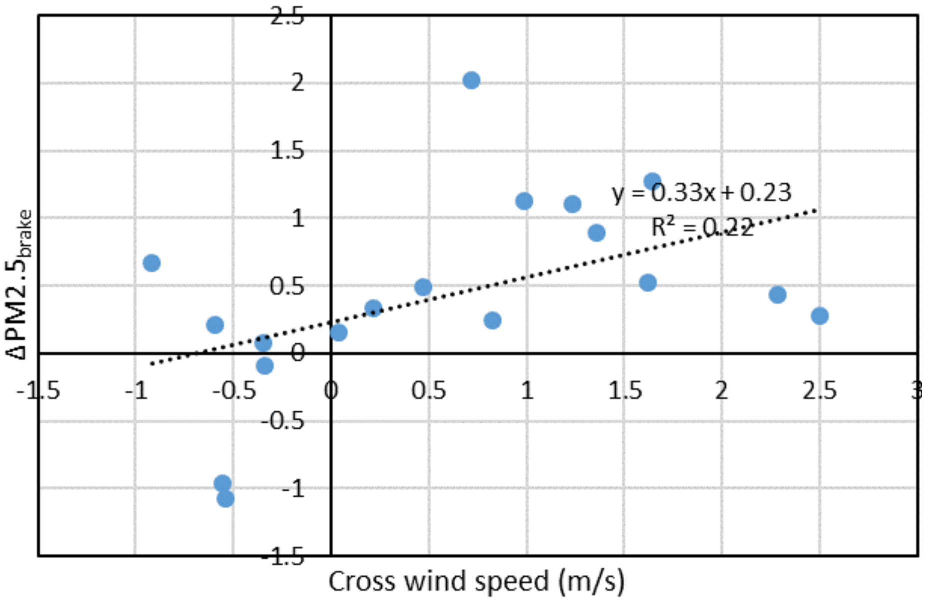
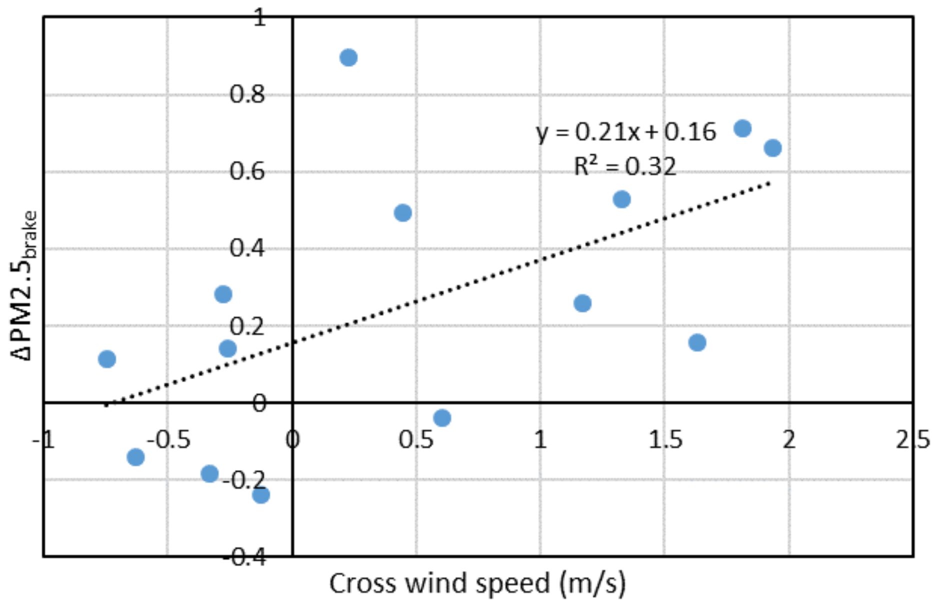


Long Beach



Comparison of $PM_{2.5}$ vs PM_{10} ratio for brake wear PM between lab and field measurements

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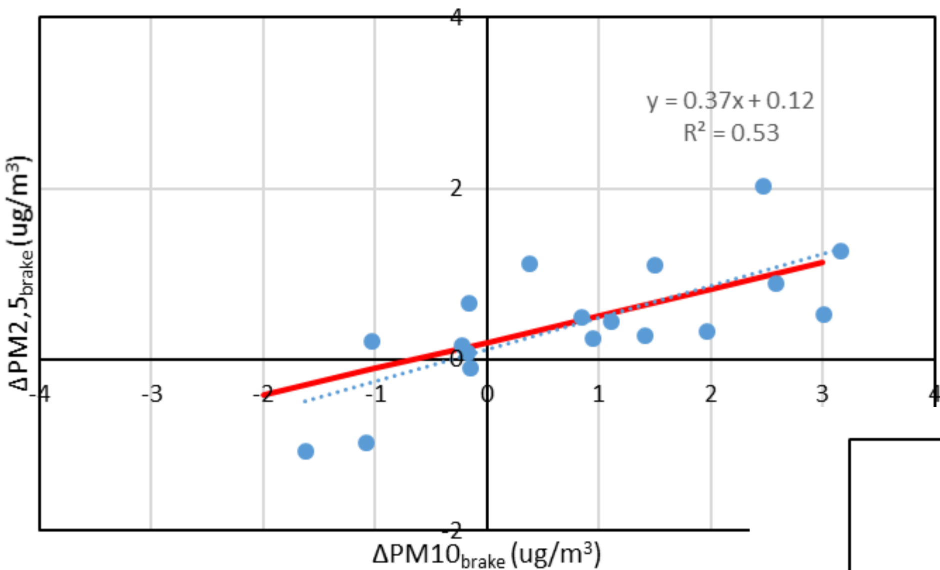

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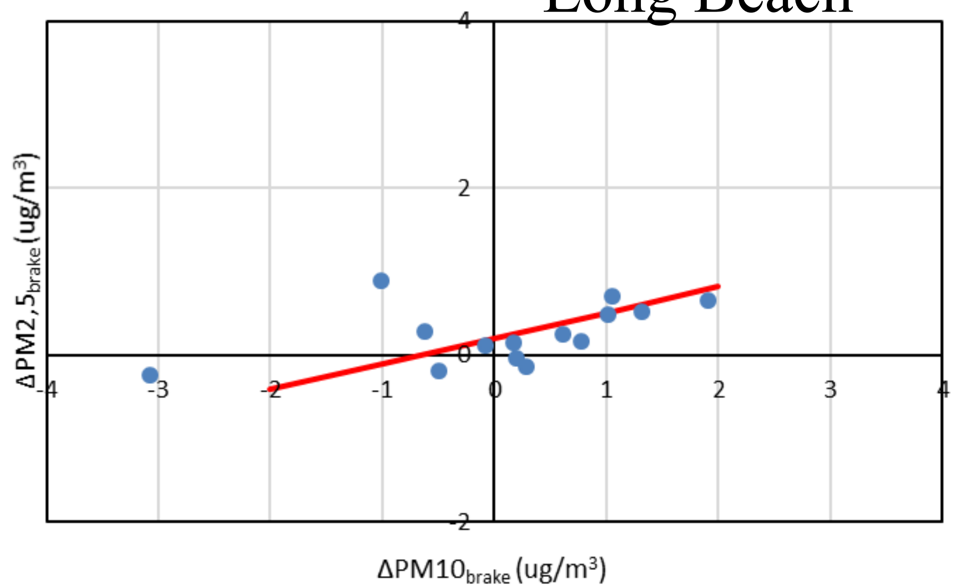

Takeaways

- Average concentrations of near-road $PM_{2.5}$ and PM_{10} were 10-15 and ~30 μg/m^3, respectively.
- Averaged over the upwind and downwind samples, contributions of the non-exhaust fractions (brake + tire) to $PM_{2.5}$ exceed those of exhaust fractions (diesel + gasoline) for I-5 (29–30% vs. 19–21%) while they are comparable for Hwy-710 (15–17% vs. 15–19%).
- For PM_{10}, the non-exhaust contributions are 2 – 3 times the exhaust contributions

Takeaways

- Particle size distribution measured at near road shows the brake mode observed in the laboratory test.
- $PM_{2.5}$ vs PM_{10} ratios of the source apportioned brake PM from the field study agree well with the lab results
- Subtracting background for PM is complicated.