

DOE's Gasoline/Diesel PM Split Study

Eric M. Fujita, Barbara Zielinska, David E. Campbell,
William P. Arnott, and Judith C. Chow



Division of Atmospheric Sciences
Desert Research Institute
Reno, NV

California Air Resources Board
Chairman's Air Pollution Seminar Series
Sacramento, CA
September 7, 2005

Gasoline/Diesel PM Split Study

Objective:

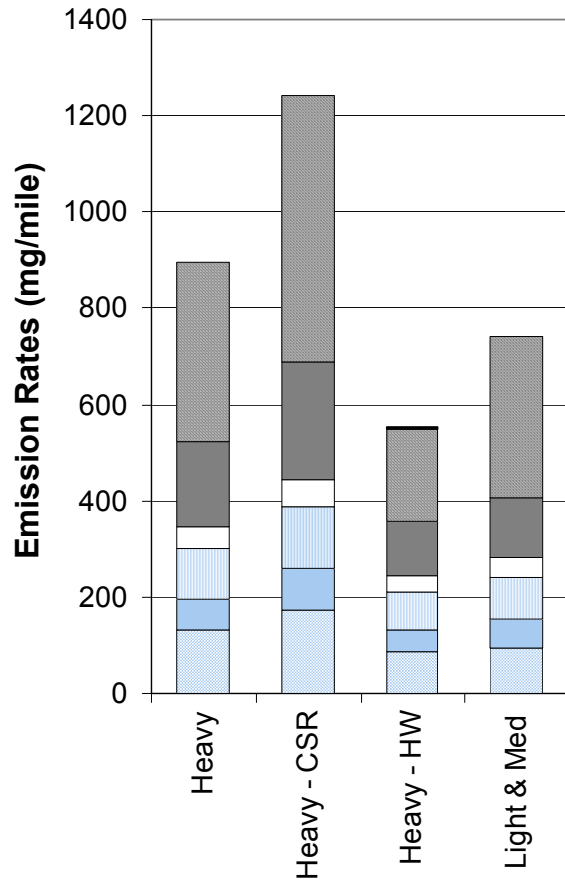
- To quantify the relative contribution of PM emissions from gasoline- and diesel-powered engines in the South Coast Air Basin
- Examine range of uncertainties that may be associated with sample collection, chemical analysis and source apportionment

Sources of Uncertainty and Variations in CI/SI Apportionment:

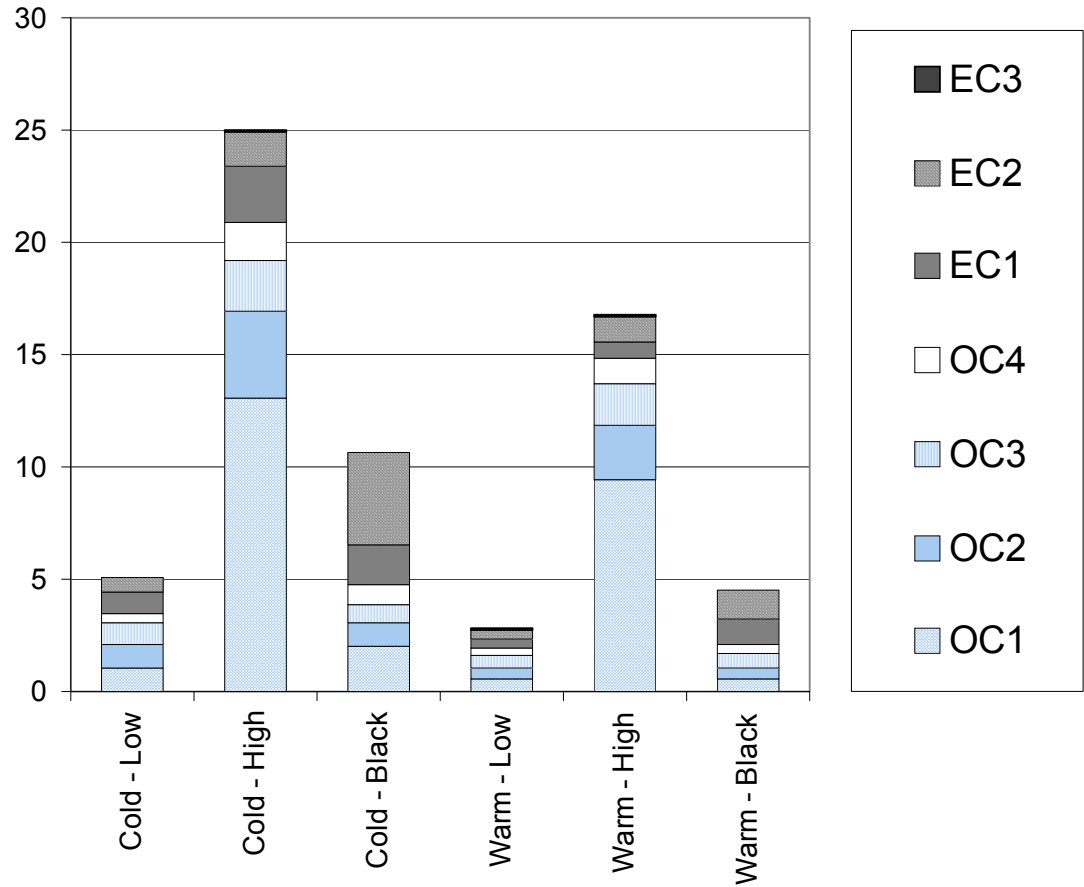
- Emissions Characterization
 - Variability in abundance of “marker species”, normal versus high emitter
 - Test cycle and condition (ambient temperature)
- Ambient Measurements
 - Spatial variations and temporal variations (diurnal, weekday and seasonal)
 - Atmospheric transformations
- Measurement Methods
 - Sampling methods
 - Analytical methods (e.g., thermal/optical OC and EC)
- Application of CMB Receptor Model
 - Derivation of composite profiles and uncertainties
 - Choice of source profiles
 - Choice of fitting species
 - Presentation of results

Vehicle Profiles – Carbon Fractions by IMPROVE-TOR

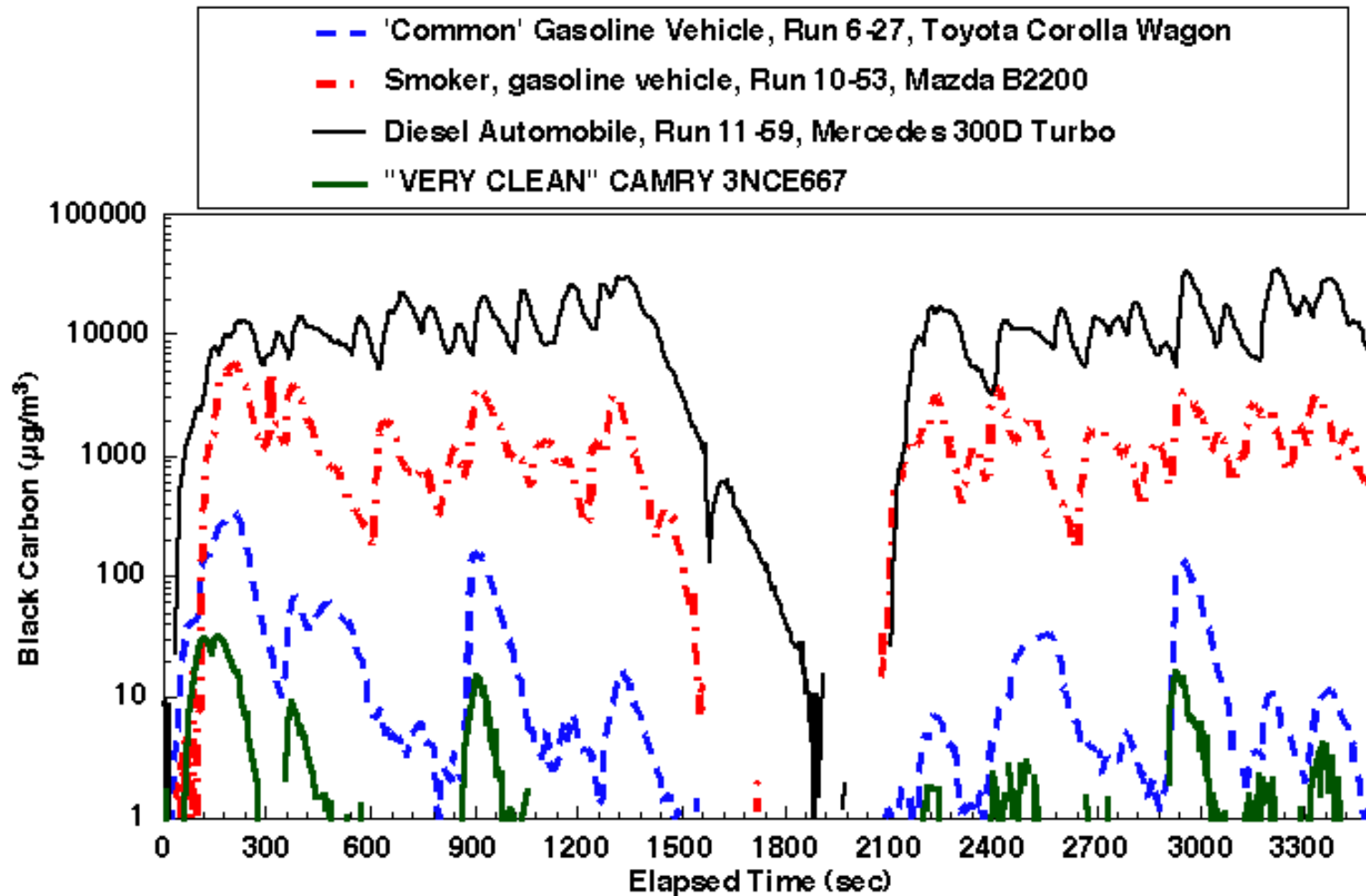
Heavy-Duty Diesel Trucks



Light-Duty Gasoline



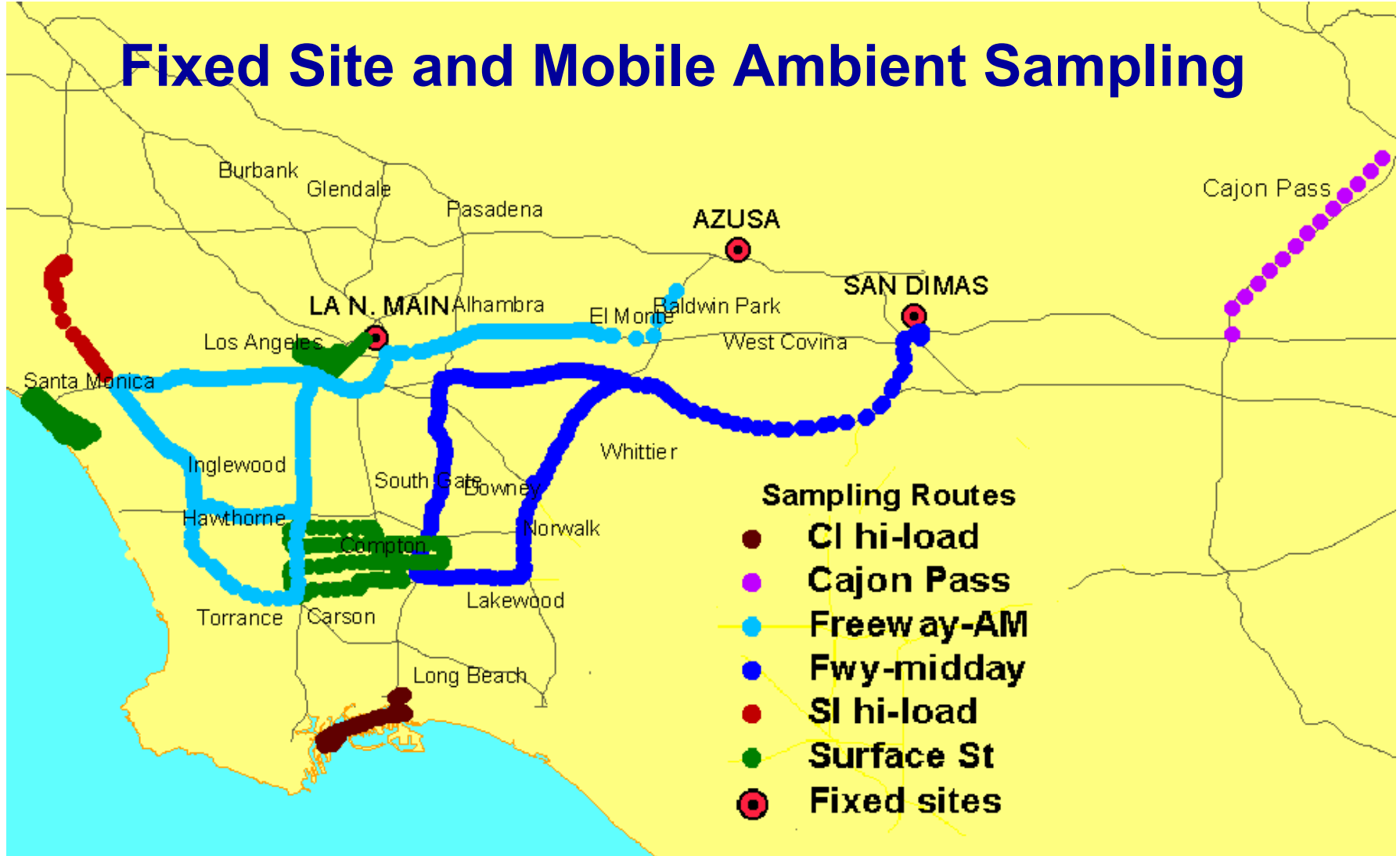
Black Carbon Emissions Rates During UDC



Source: Pat Arnott (2003)
NREL Gas/Diesel Split Study

Most PM emissions during UDC from cold start and hard accels with higher fraction of black carbon.

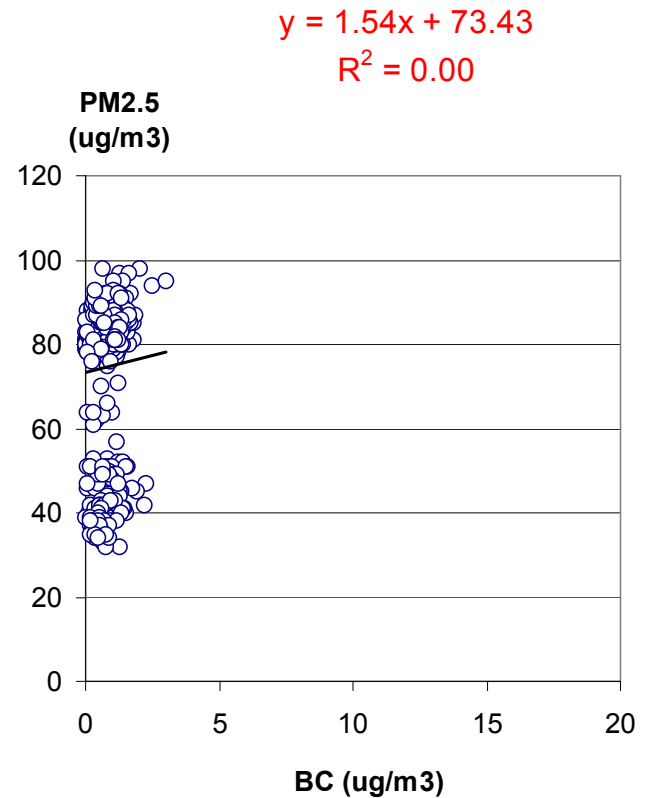
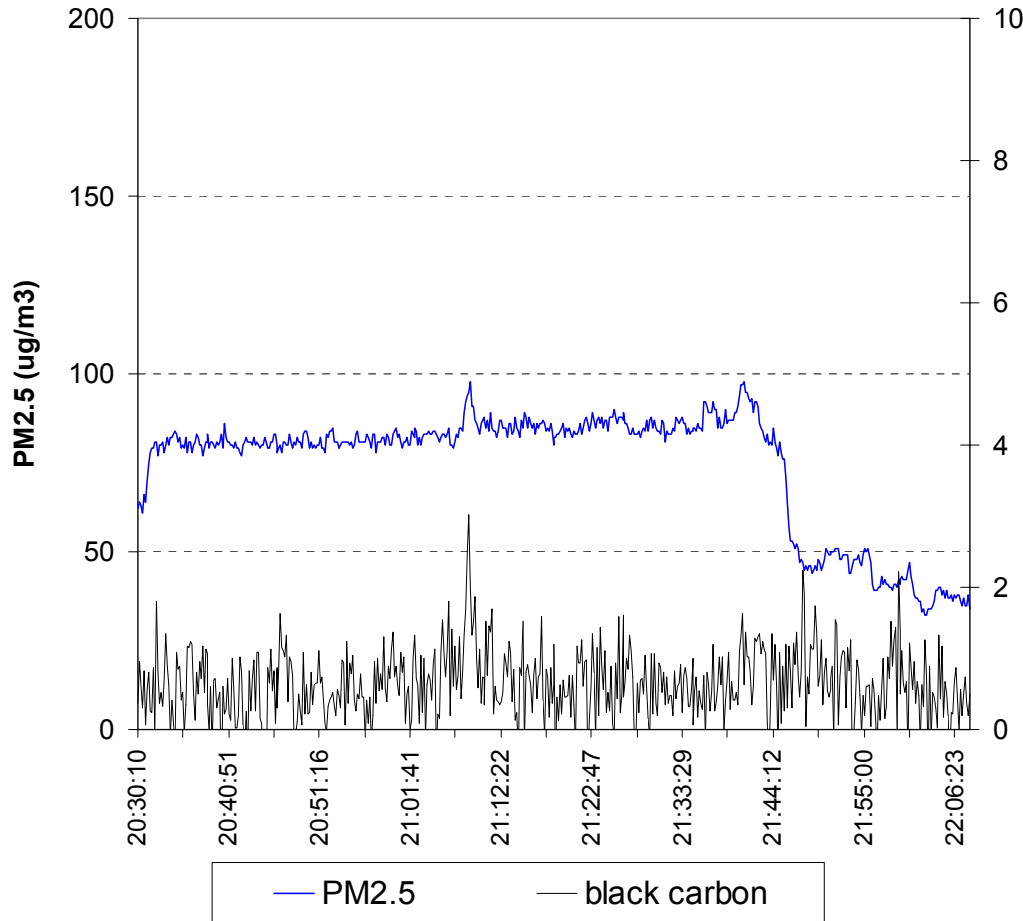
Fixed Site and Mobile Ambient Sampling



- Downtown Los Angeles and Azusa - daily 24 hour for four consecutive weeks, composite by day-of-week
- Variety of locations with variable amount of gasoline and diesel traffic

Mobile Sampling – Photoacoustic BC and DustTrak PM_{2.5} Parking Lot After Sporting Event

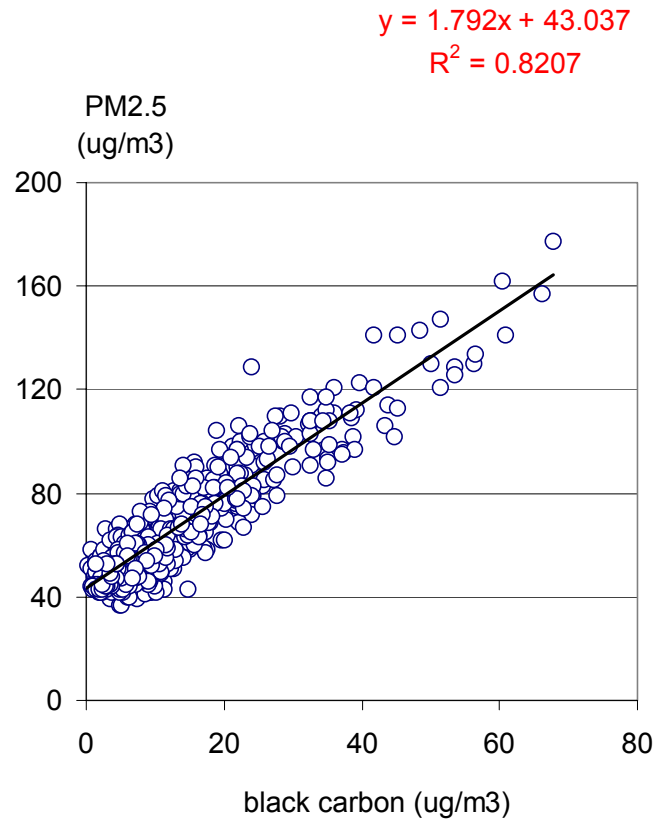
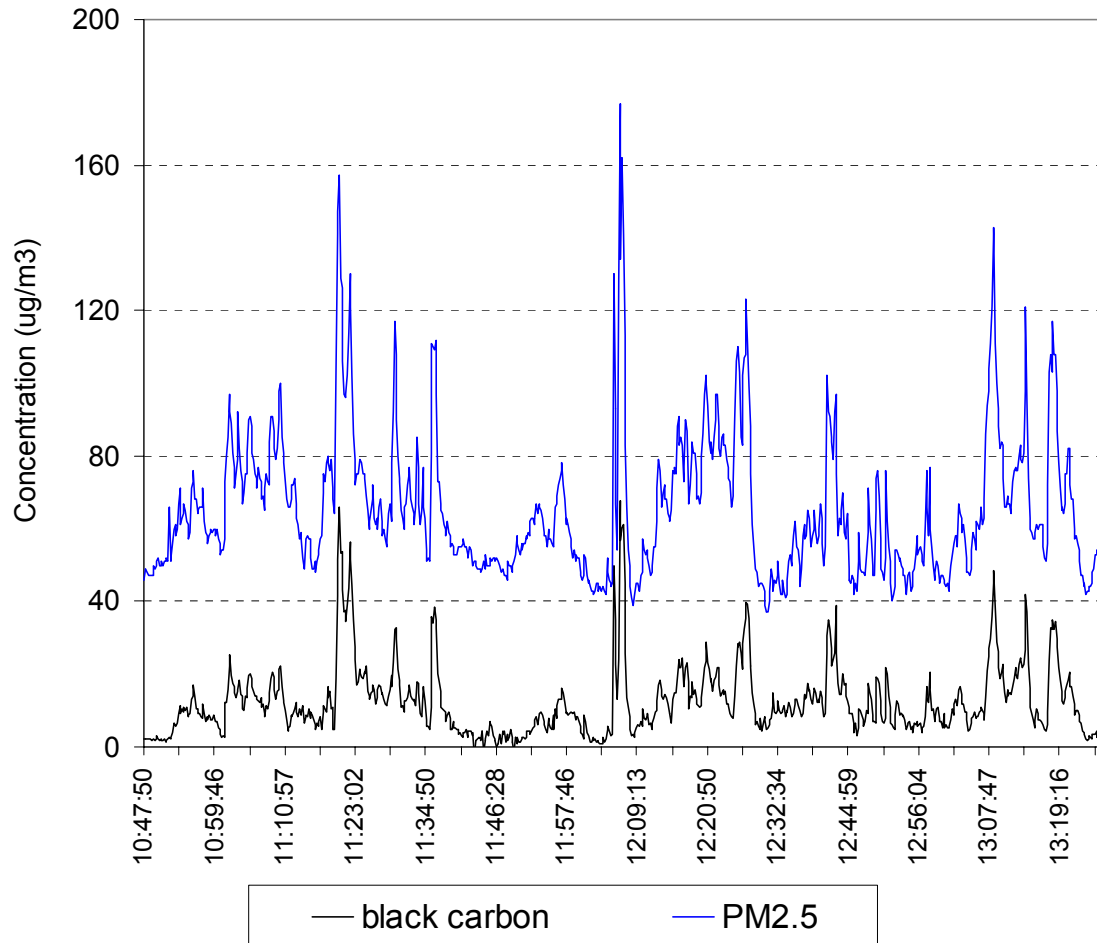
Rose Bowl after Soccer Game, Fri 7/14/01 2030-2208



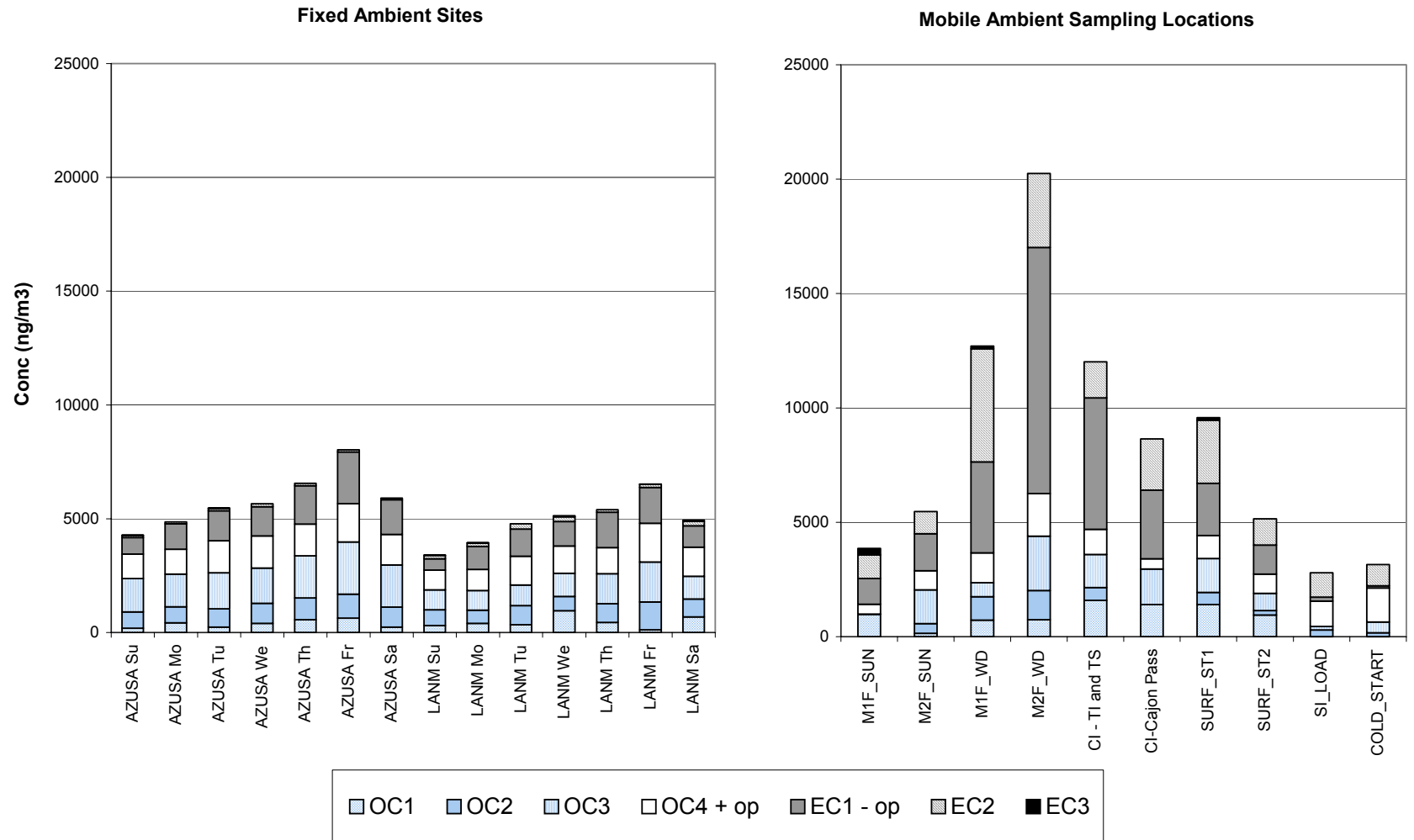
Gas Diesel PM Split Study

Mobile Sampling – Photoacoustic BC and DustTrak PM_{2.5}

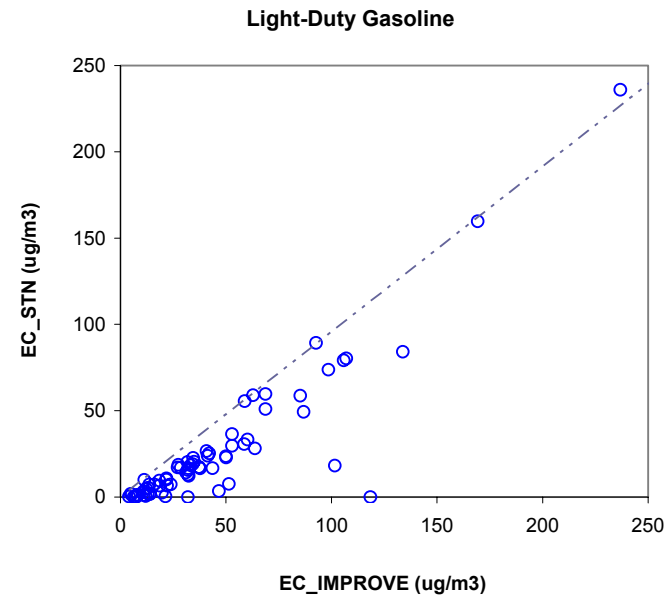
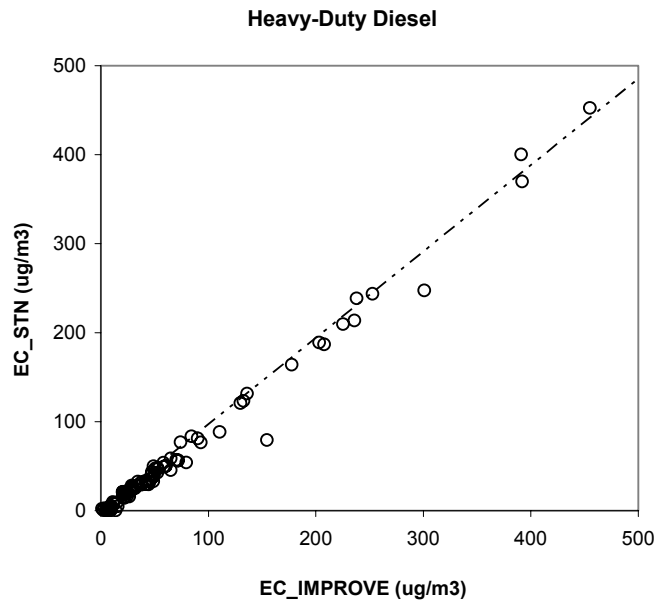
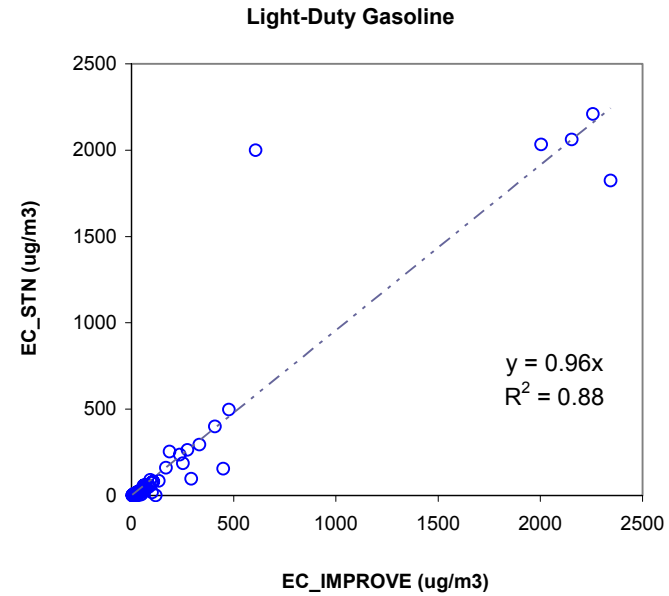
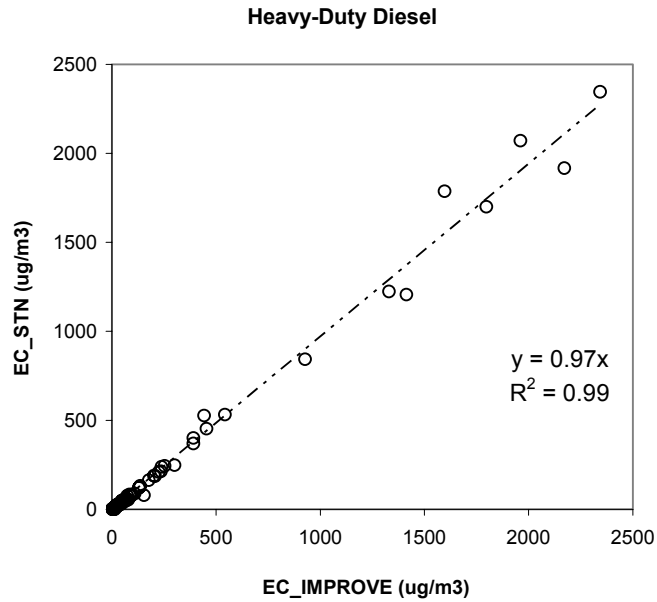
Freeway, Monday 7/9/01 1045-1326



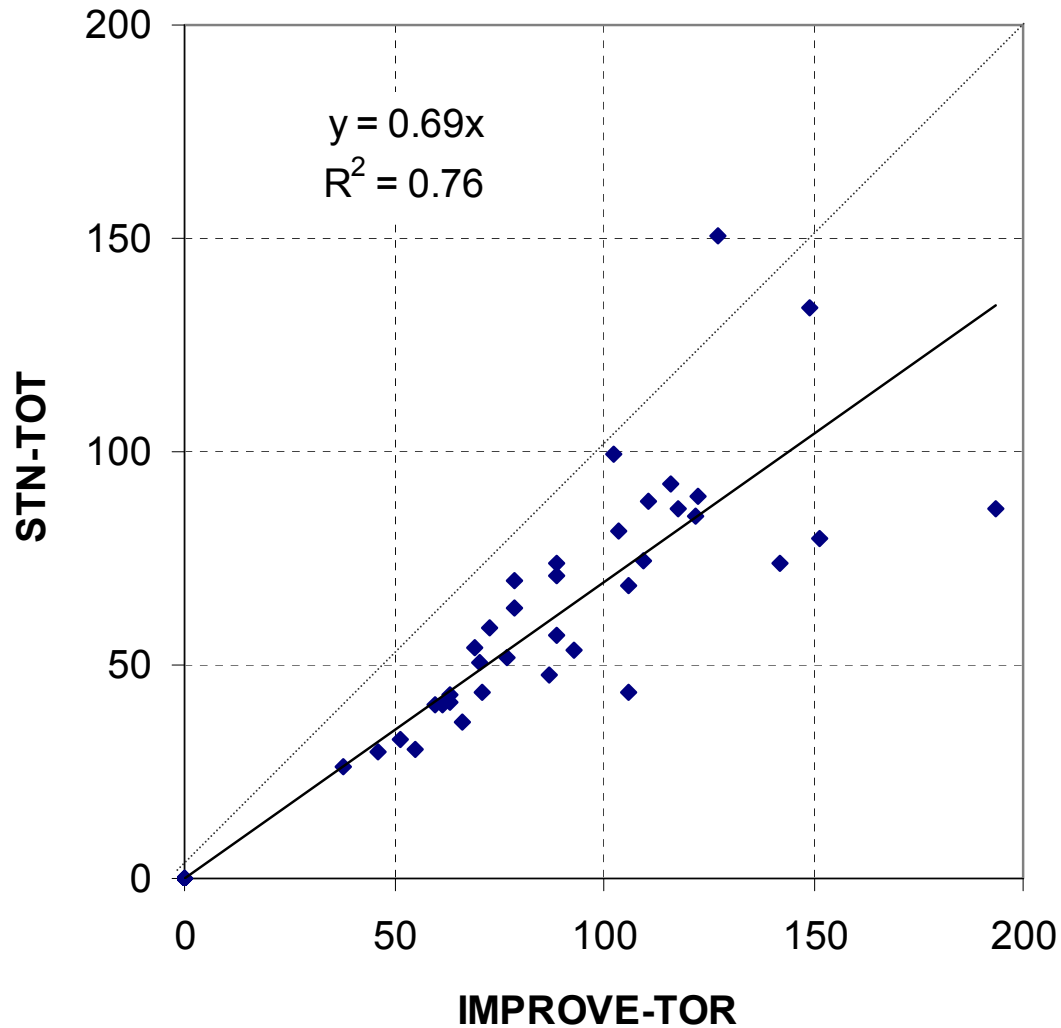
Distributions of OC and EC fractions (IMPROVE) at Azusa, Los Angeles N. Main and Source Locations



STN versus IMPROVE EC for CI and SI Exhaust Samples

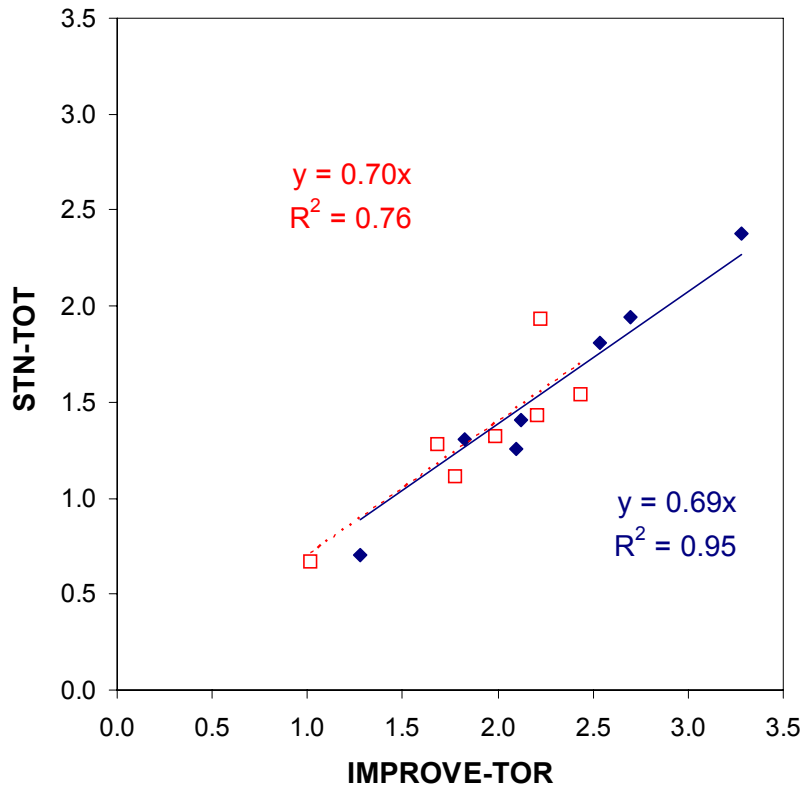


Scatterplot of STN-TOT EC Versus IMPROVE-TOR EC for Ambient Samples (ug/sample)

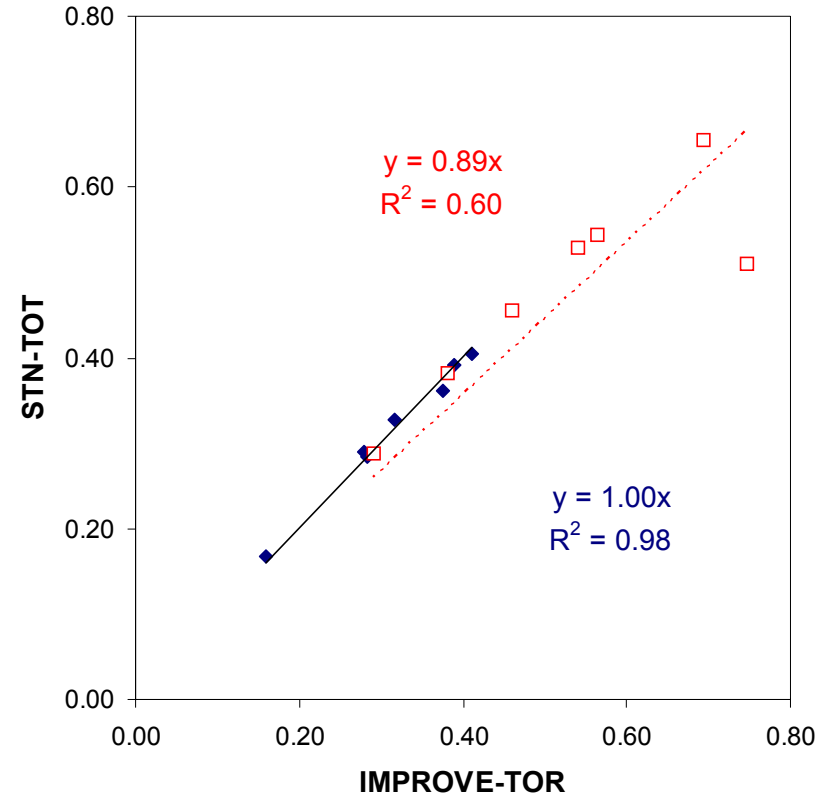


Sensitivity of CMB Apportionments to Carbon Measurement Protocol

Diesel Exhaust



Gasoline Exhaust

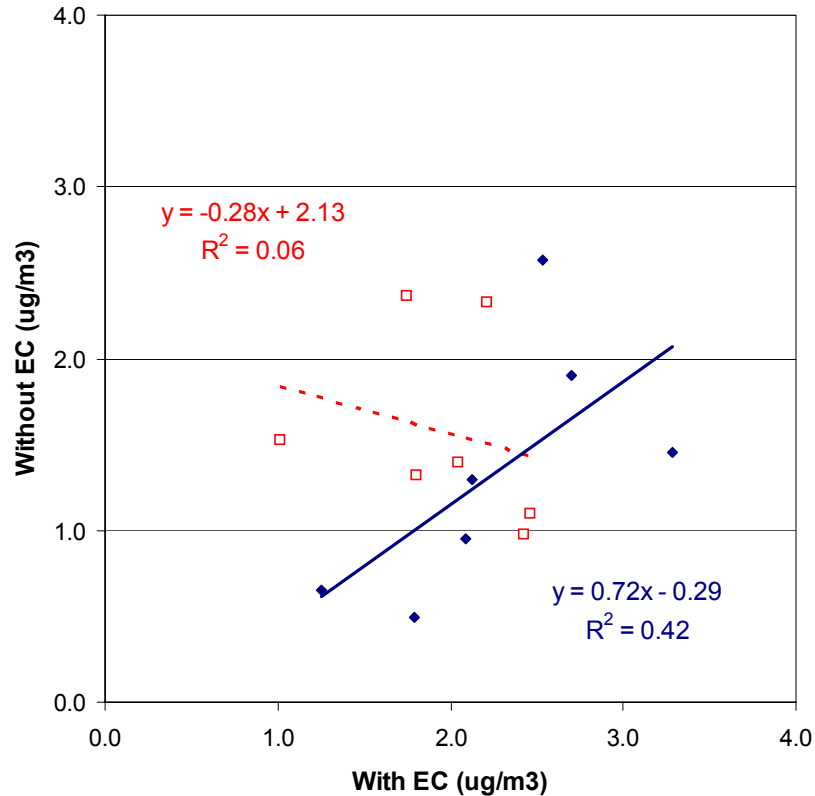


IMPROVE-TOR gave higher CI source contributions than STN-TOT.

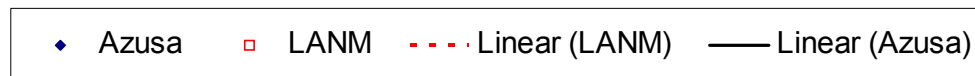
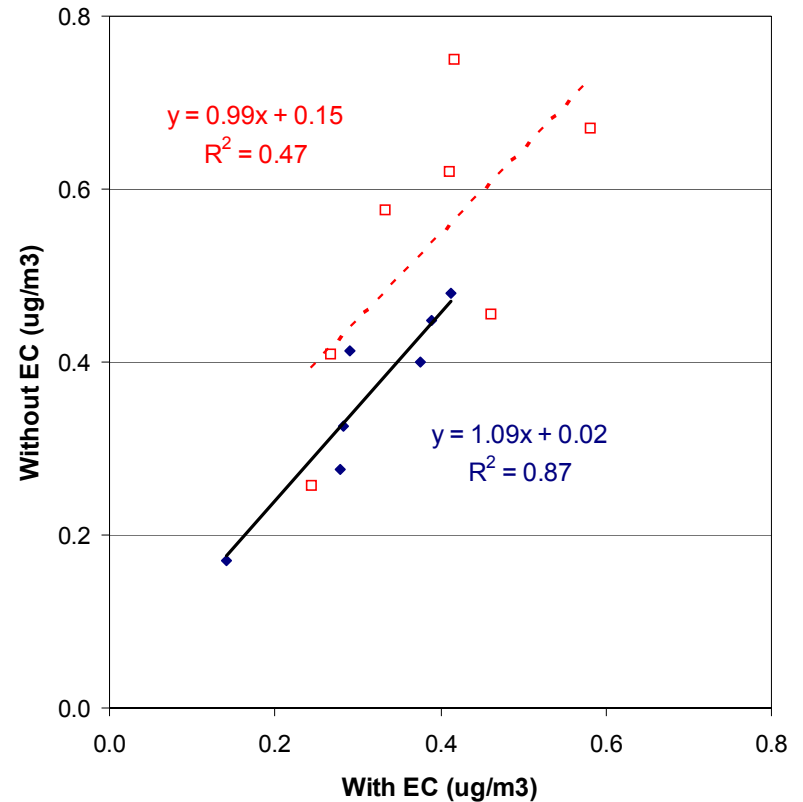
No effect on SI contributions.

Sensitivity of Apportionments to Use of EC in CMB Fit

SCE - Compression Ignition Exhaust



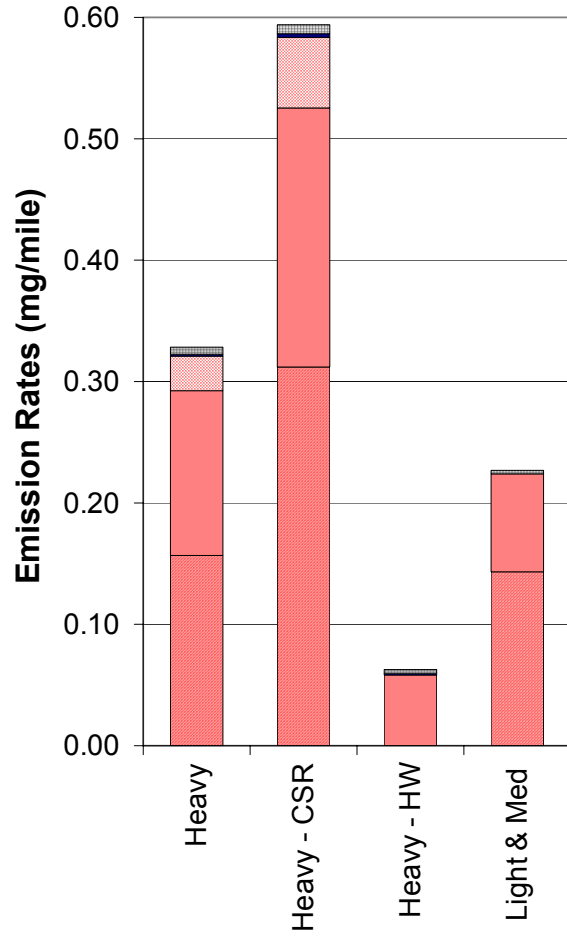
SCE - Spark Ignition Exhaust



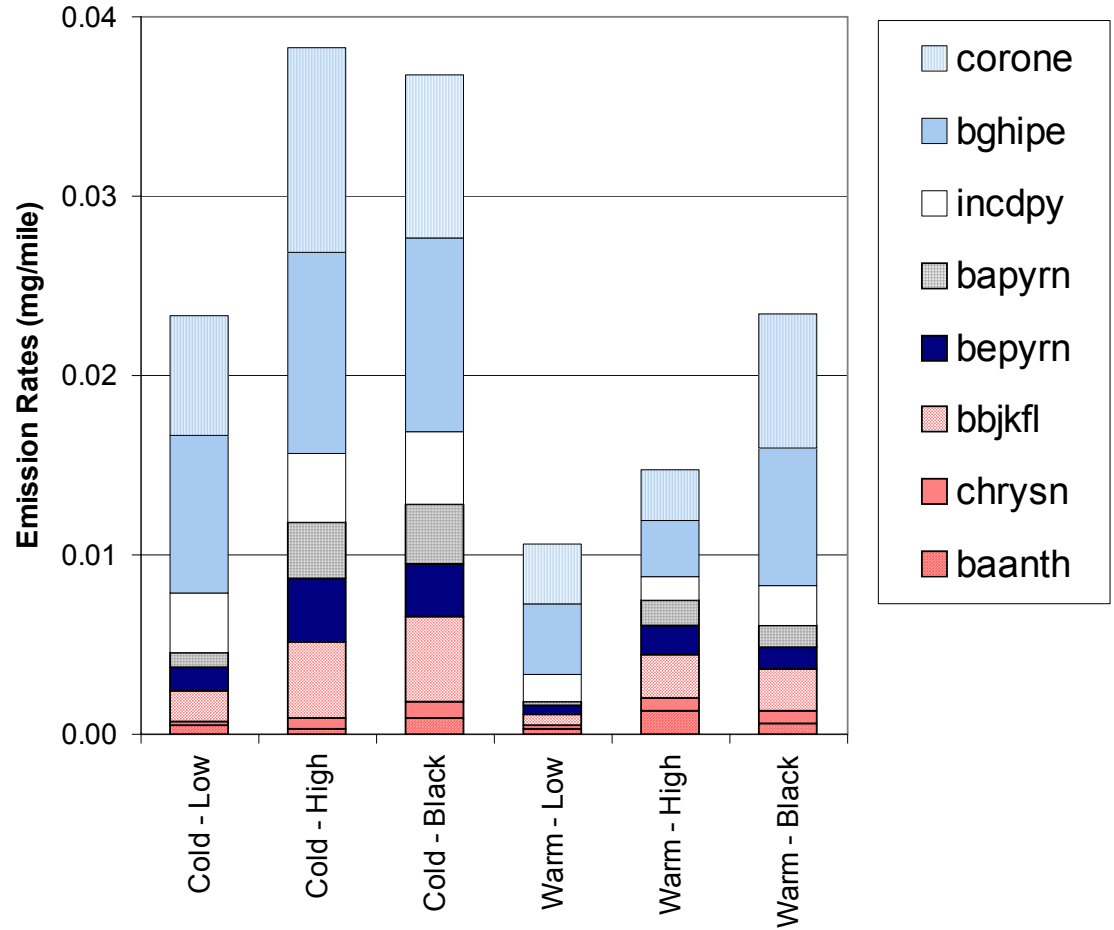
CI apportionment is dependent on EC. SI apportionment is depends on PAHs, Steranes and Hopanes rather than EC.

Emission Rates of Particulate PAH

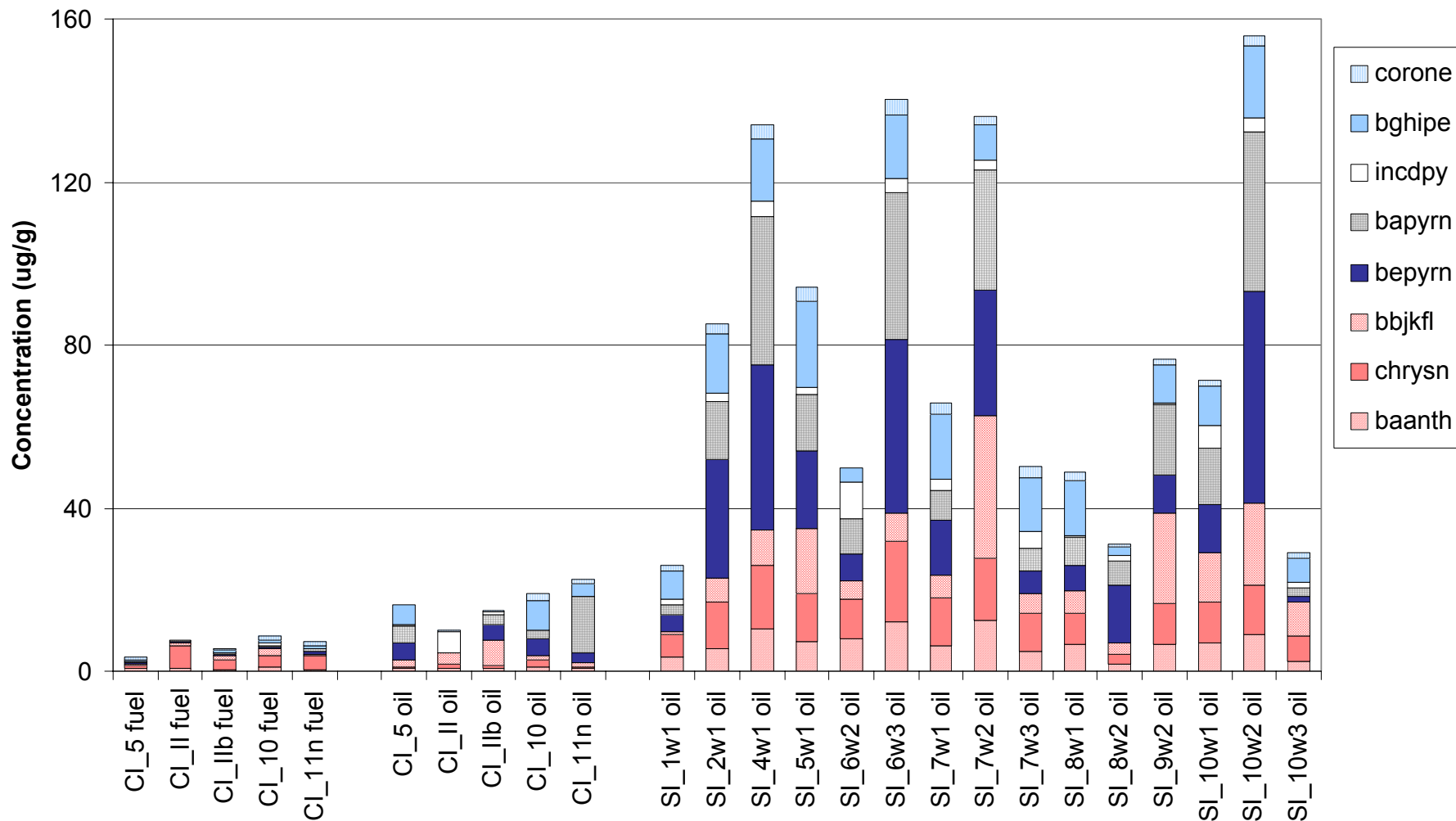
Heavy-Duty Diesel Trucks



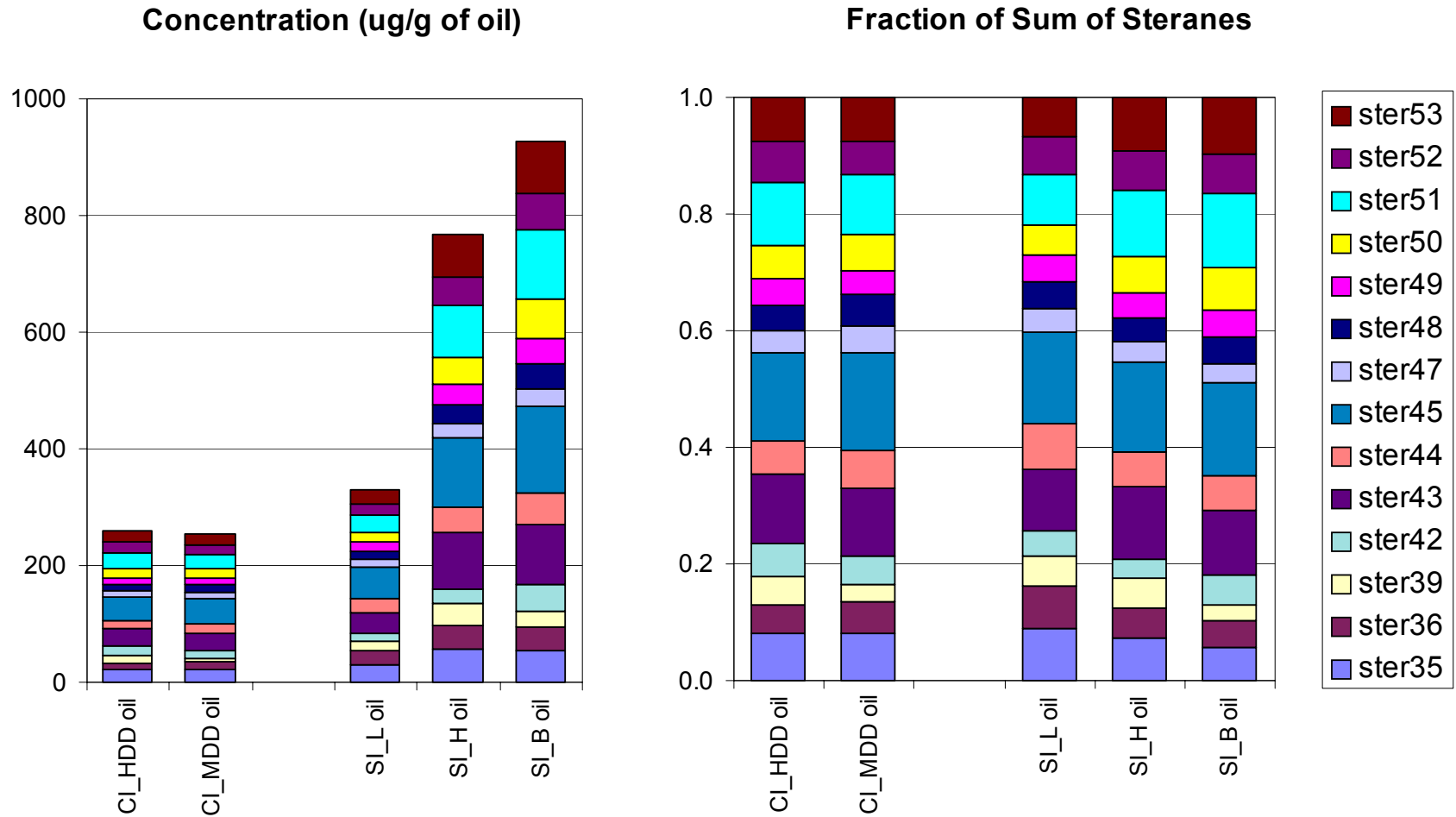
Light-Duty Gasoline



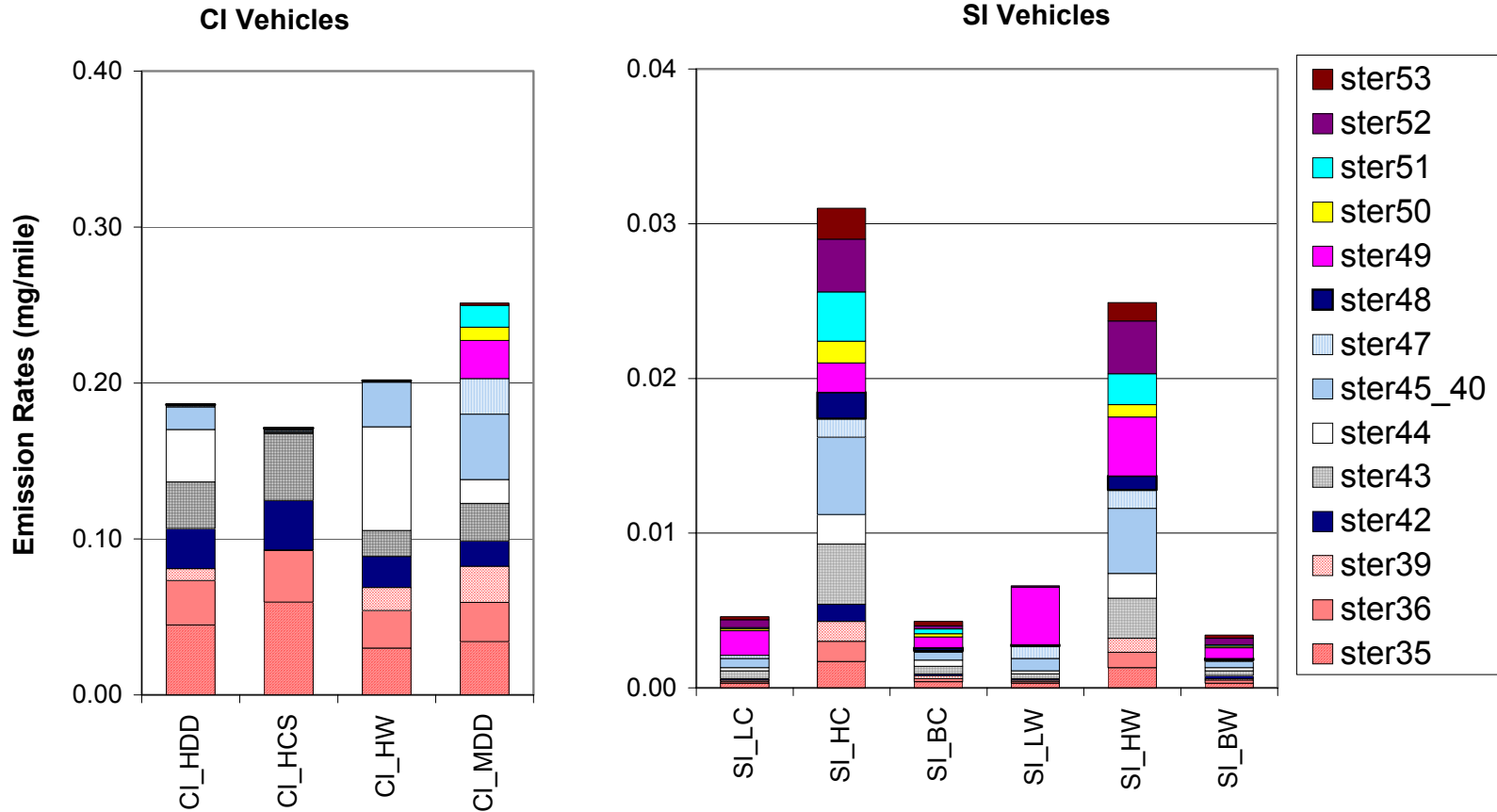
Concentrations of Particulate PAH in Lubrication Oil Samples Taken from Test Vehicles



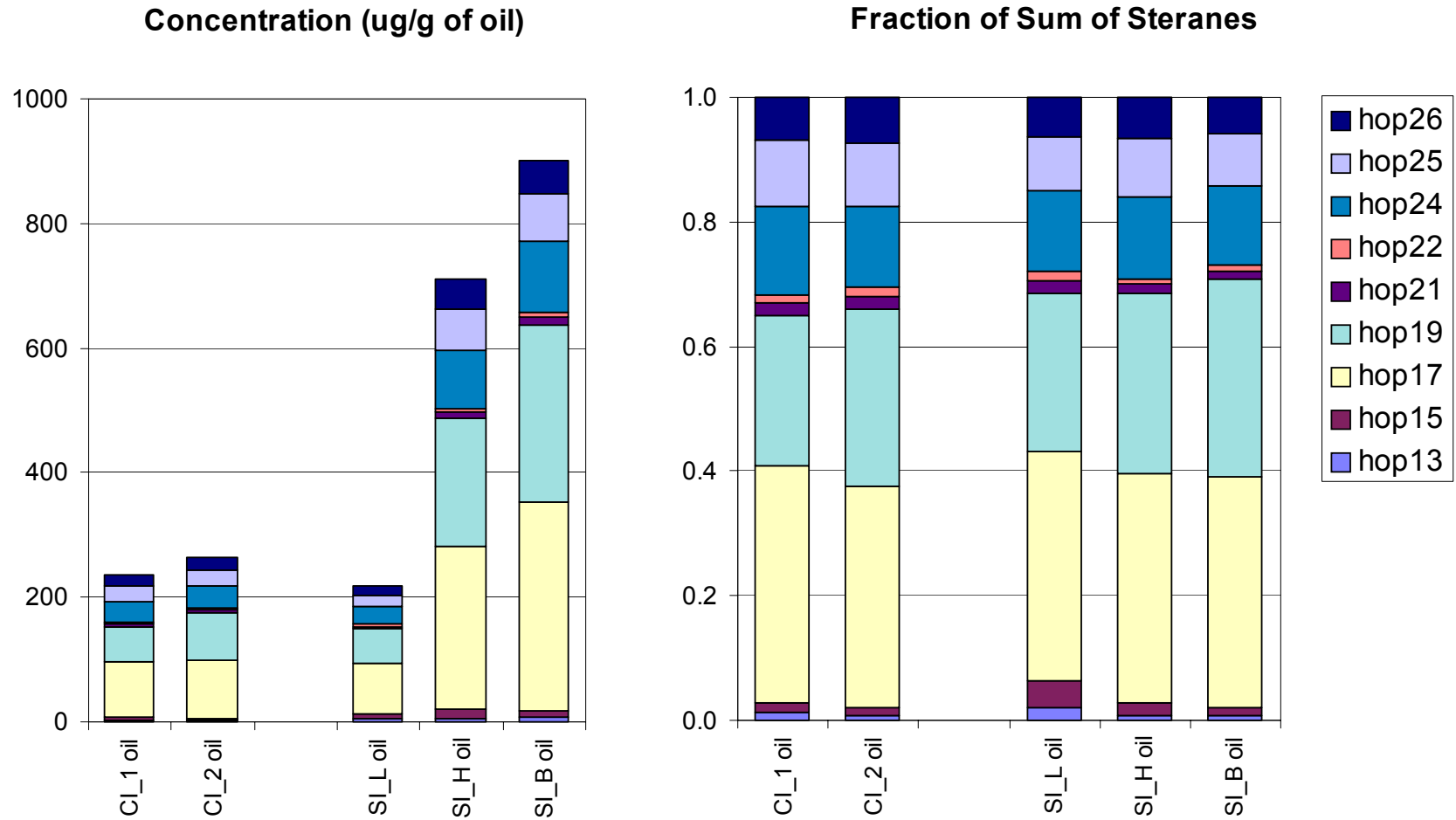
Steranes in Lubrication Oil Samples



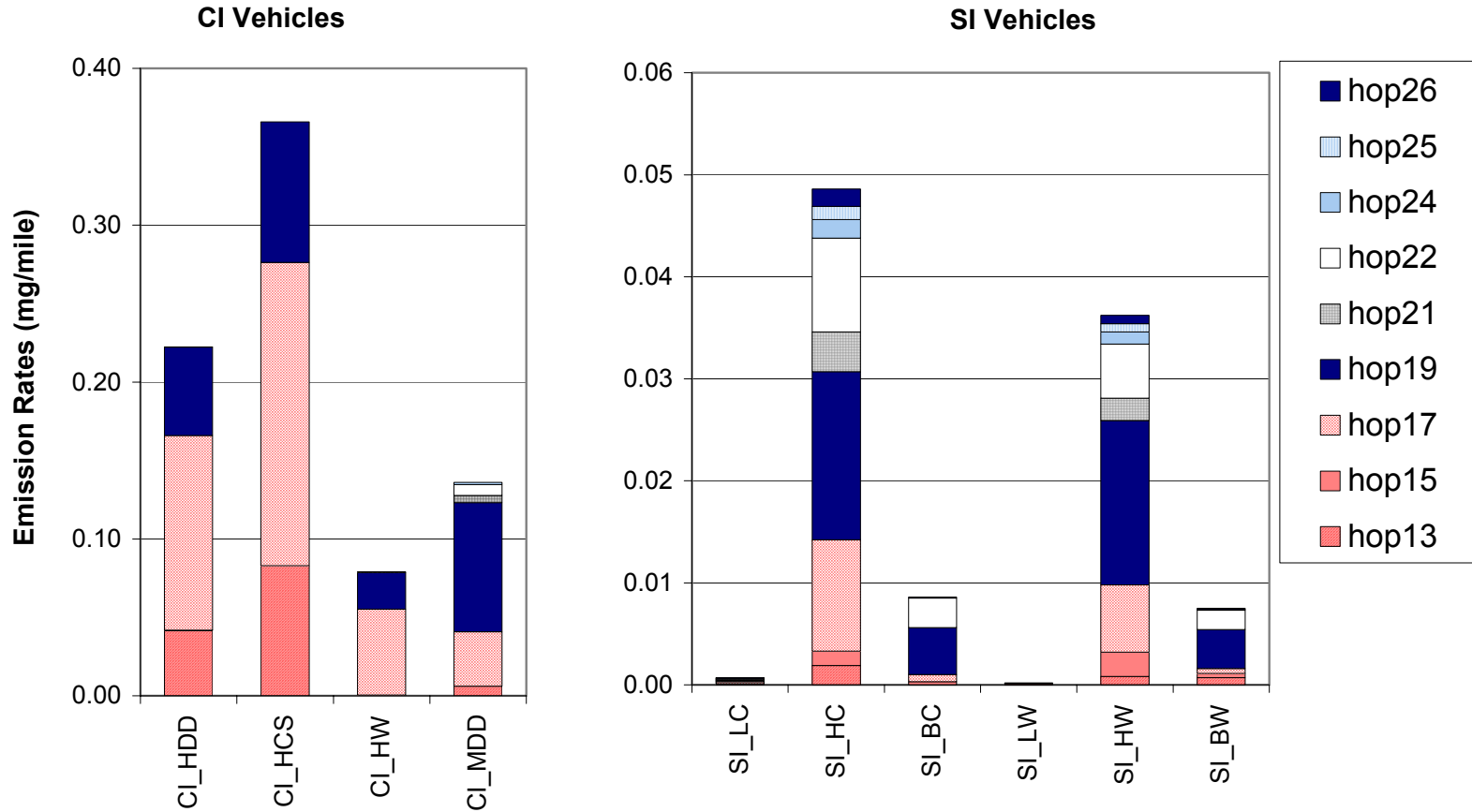
Steranes in Vehicle Exhaust Profiles



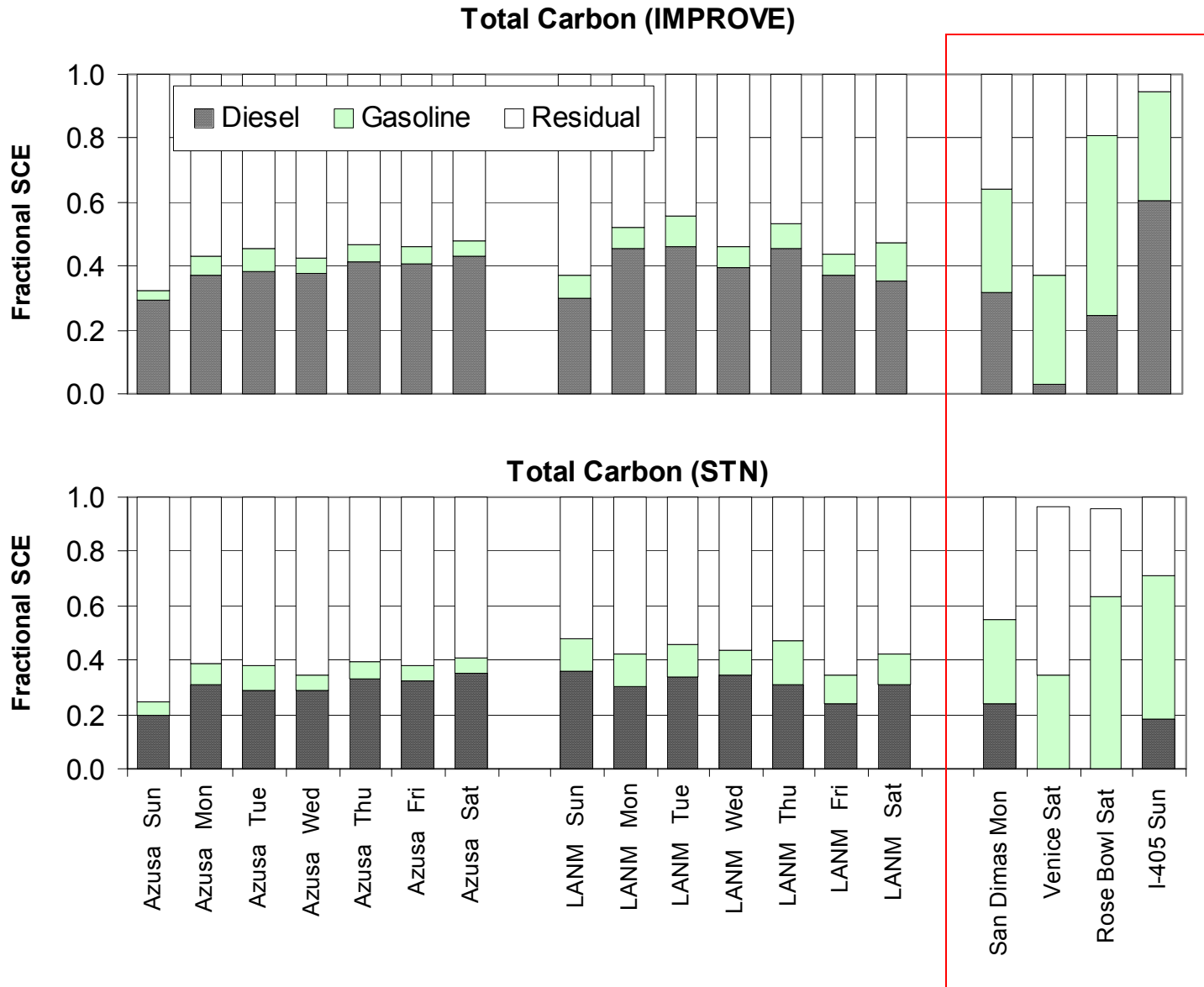
Hopanes in Lubrication Oil Samples



Hopanes in Vehicle Exhaust Profiles



Total Carbon Source Contributions



Elemental Carbon Source Contributions

CI/SI (IMP)

Azusa

Sun – 22

WD – 19-28

Sat – 31

LANM

Sun – 14

WD – 13-21

Sat – 8

CI/SI (STN)

Azusa

Sun – 22

WD – 17-31

Sat – 42

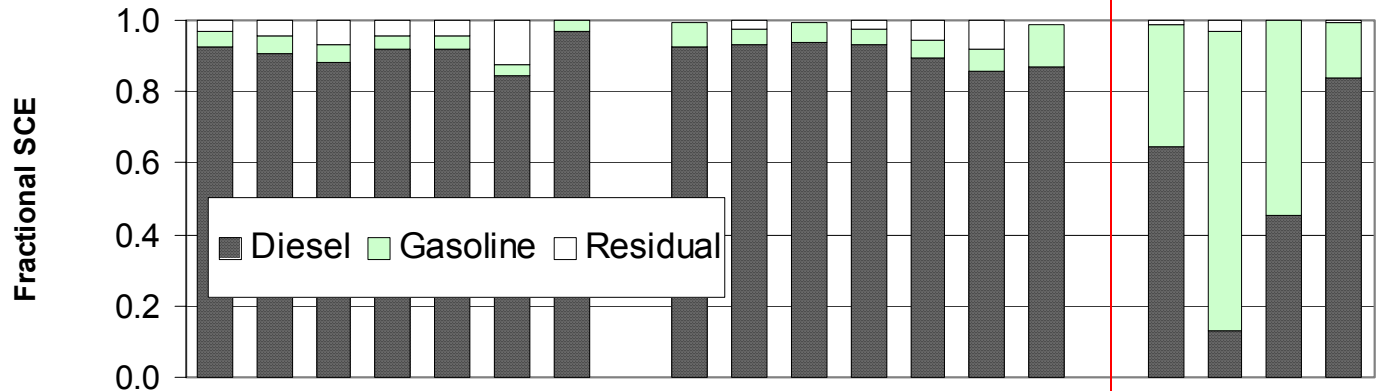
LANM

Sun – 17

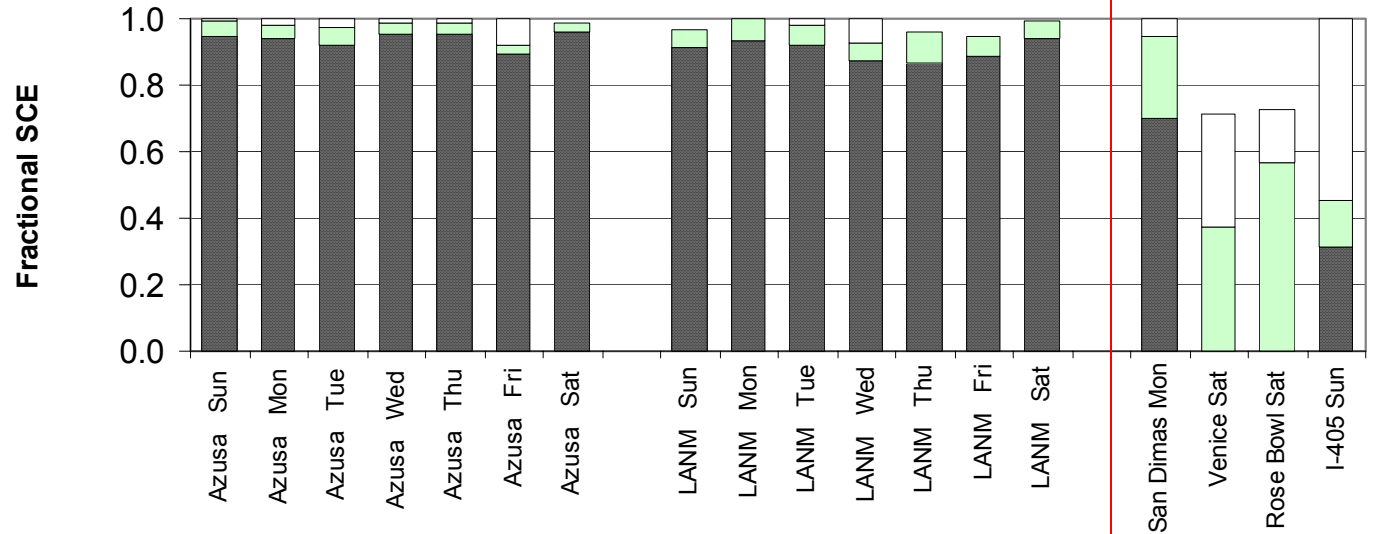
WD – 10-18

Sat – 17

Elemental Carbon (IMPROVE)



Elemental Carbon (STN)



Organic Carbon Source Contributions

CI/SI (IMP)

Azusa

Sun – 4.6

WD – 2.5-3.8

Sat – 4.3

LANM

Sun – 2.0

WD – 2.3-3.3

Sat – 1.5

CI/SI (STN)

Azusa

Sun – 1.9

WD – 1.5-2.7

Sat – 2.8

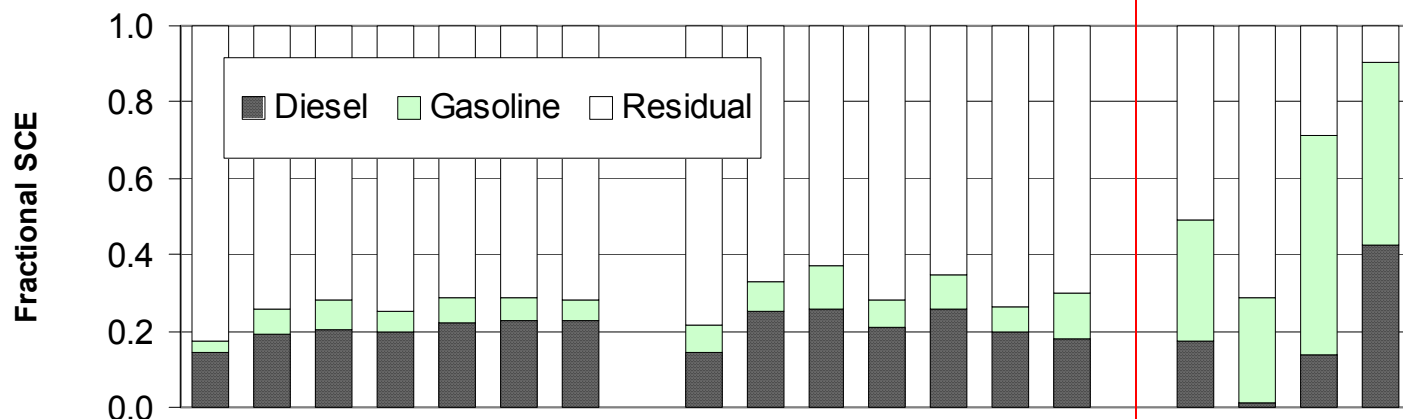
LANM

Sun – 1.5

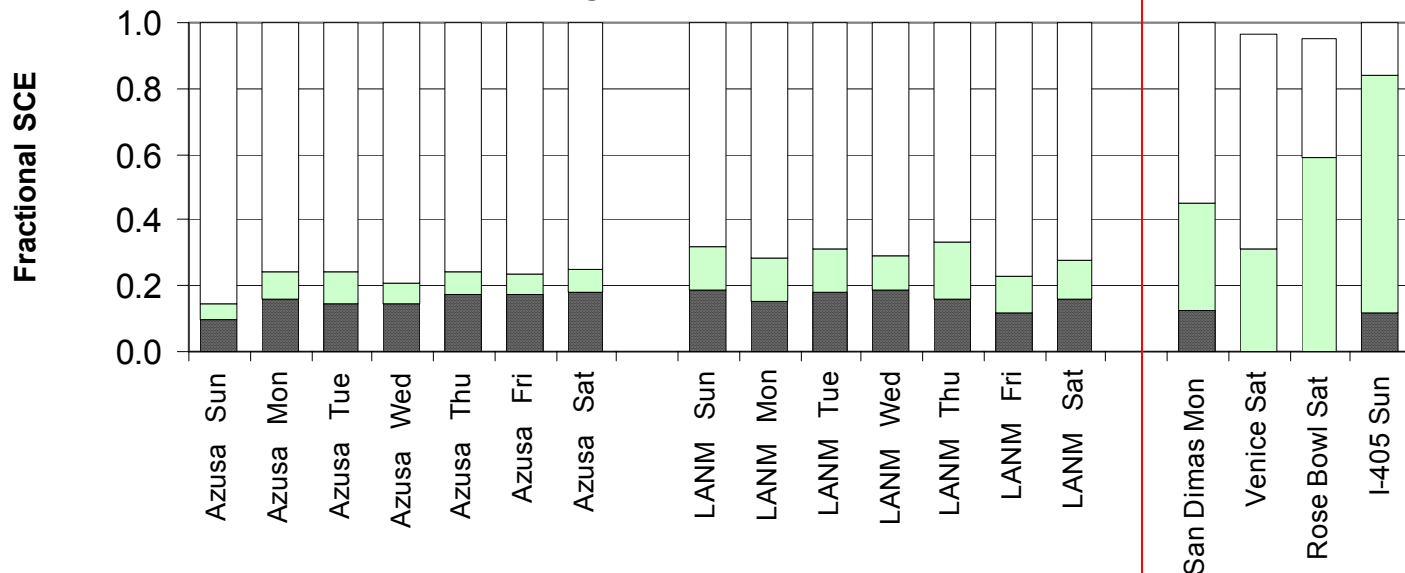
WD – 0.9-1.3

Sat – 1.3

Organic Carbon (IMPROVE)



Organic Carbon (STN)

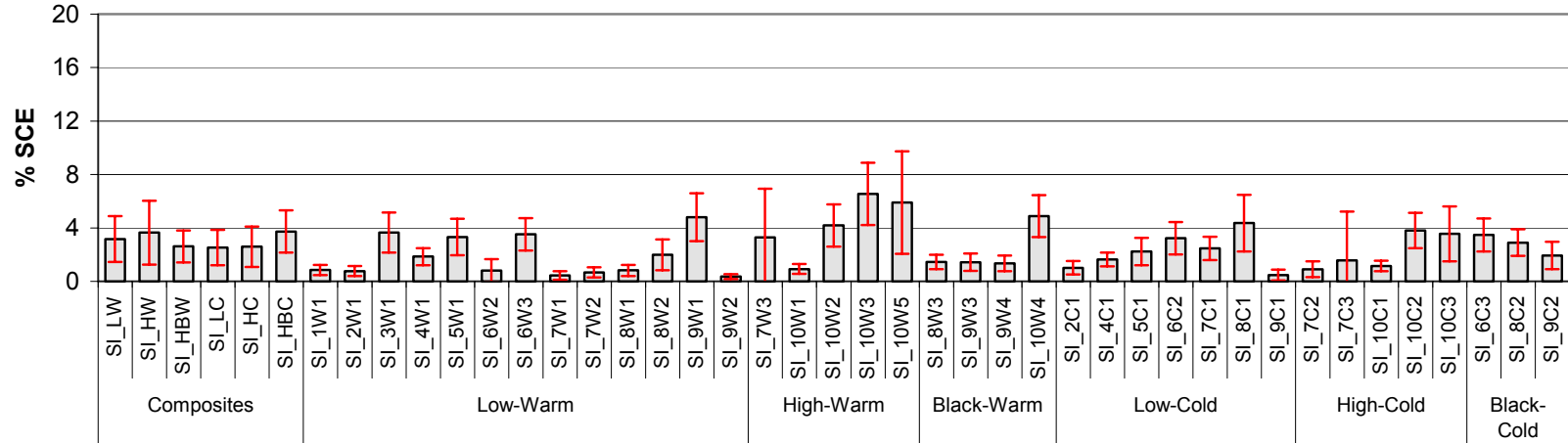


Variations in Source Contribution Estimates (Percent of Total) Azusa and Los Angeles Weekday Ambient Samples

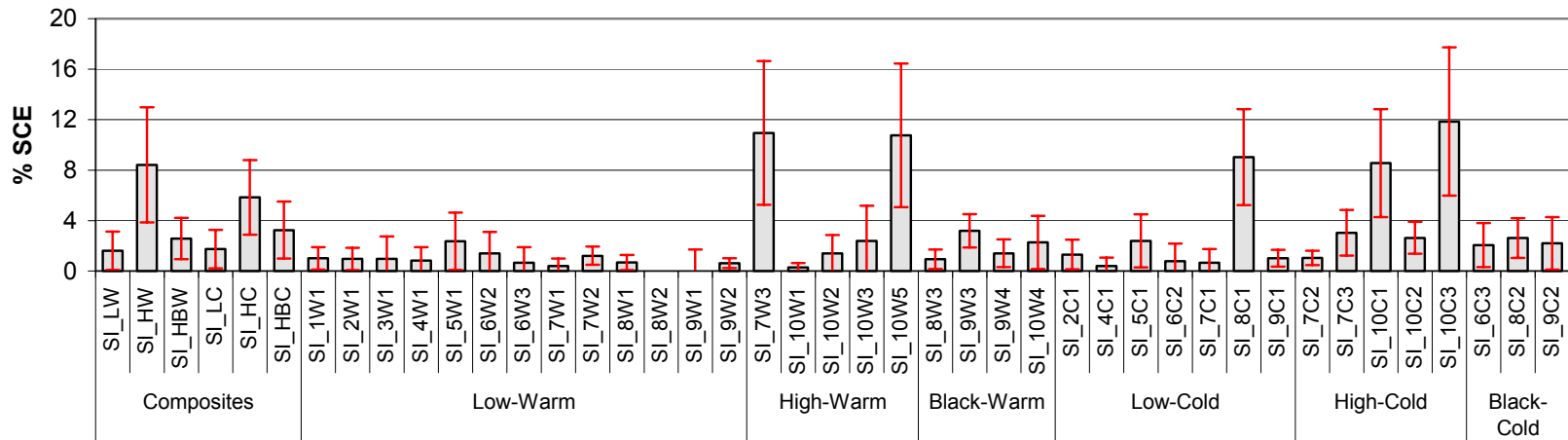
	Compression-Ignition			Spark-Ignition		
	IMPROVE	STN	STN no PAH	IMPROVE	STN	STN no PAH
TC						
Mean	40.9	30.8	31.3	6.6	9.4	11.4
Std Dev	3.7	3.0	2.7	1.3	3.3	3.5
Std Err	1.2	1.0	0.9	0.4	1.0	1.1
OC						
Mean	22.1	15.8	16.1	7.4	10.4	12.2
Std Dev	2.6	2.0	1.9	1.7	3.6	3.7
Std Err	0.8	0.6	0.6	0.5	1.1	1.2
EC						
Mean	90.3	93.3	65.9	4.5	5.2	7.2
Std Dev	3.3	3.4	5.9	1.0	2.1	2.0
Std Err	1.0	1.1	1.9	0.3	0.7	0.6

Variations in SI Exhaust Contributions to TC by Profile

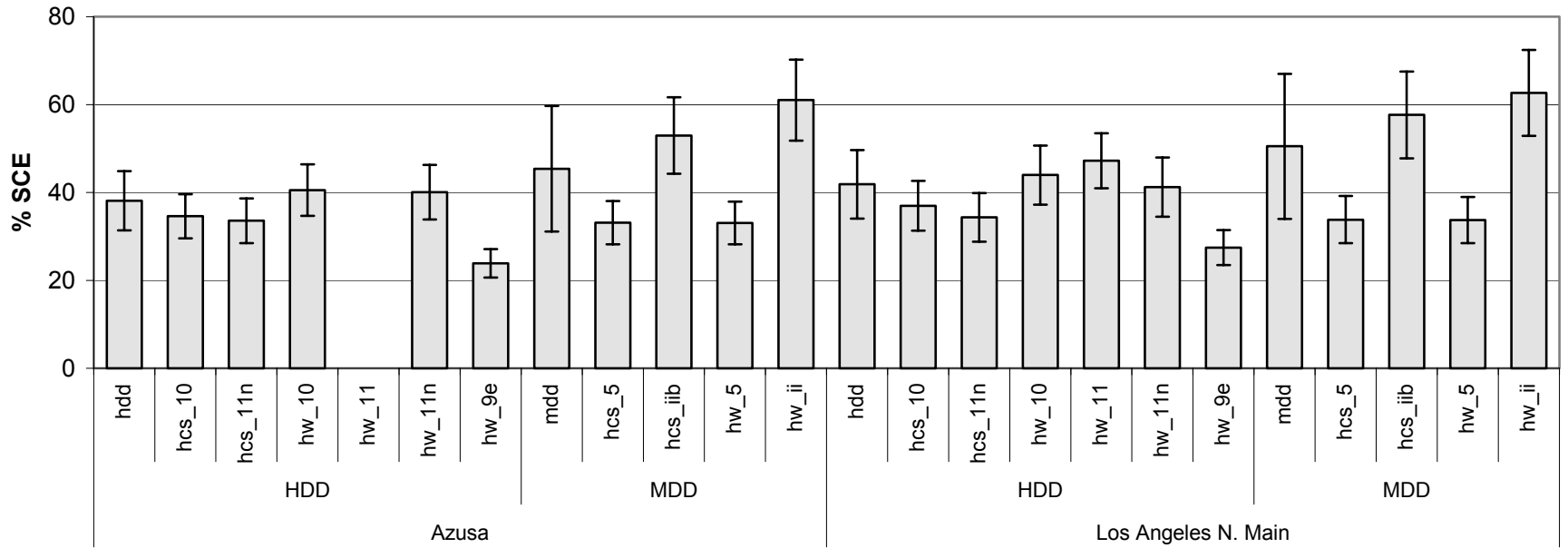
Azusa



Los Angeles N. Main



Variations in CI Exhaust Contributions to TC by Profile



Factors Affecting Apportionment of CI/SI Exhaust

- CI apportionments were mainly dependent upon EC. CI contributions were greater with IMPROVE.
- SI apportionments were most sensitive to PAHs (indeno[123-cd]pyrene, benzo(ghi)perylene, and coronene) and steranes and hopanes. EC had little effect on SI apportionment.
 - EC emission for SI vehicles were minimal except in cold start and hard accels.
 - “Marker” PAHs were present in used SI engine lubrication oil in similar proportions but concentrations tended to increase with age of the oil.
 - Most of the SI apportionment was associated with the high emitter profile. Apportionment varied with specific high-emitter profile.
 - Removing PAHs from the fit increased SI contributions relative to CI.
- CI and SI apportionments varied with location and time.
 - CI vehicles were the dominant mobile source of EC and TC at Azusa and LANM.
 - More equal apportionment at other locations that are more regionally representative.
 - SI vehicles were the dominant mobile source of OC and EC in locations and times with minimal truck traffic.
- Alternative methods for deriving composite profiles and uncertainties had minor effect on apportionment.

Implications

- Emissions of black carbon and PM were low for most SI vehicles except in cold start mode and during hard accelerations. **Effect of test cycle?**
- CI vehicles were the dominant source of EC. **EC is a reasonable surrogate of PM emissions from CI vehicles in the SoCAB.**
- A larger fraction of the SI source contribution to OC was attributed to high emitters. **Existing control programs do not address high PM emitting vehicles.**
- Spatial and temporal variations in relative CI and SI apportionments were large. **Must consider purpose of sampling and source apportionment** (compliance with ambient standards, reconciliation with emission inventory data, exposure assessment).

Implications

- PM concentrations and exposures were higher on and adjacent to major roadways with high volume of diesel truck traffic. Exposures were also higher when following high-emitting gasoline vehicles. **Existing monitoring programs do not account for these higher exposures.**
- Motor vehicles were significant contributors to semi-volatile organic compounds. **These compounds are not routinely measured.**
- Significant fraction of the organic carbon during summer in the SoCAB could not be apportioned to directly-emitted PM emissions from motor vehicles. **What are the relative contributions of SI and CI exhaust to secondary organic aerosols?**

Acknowledgments

Sponsor

DOE's Office of FreedomCAR and Vehicle Technologies

Dr. James Eberhardt

Additional Support

NREL - Study design and Coordination

WVU - CI vehicle testing

US EPA/BKI - SI vehicle testing

BAR and SCAQMD – Light-duty vehicle recruitment

Ralphs Grocery – Facility for vehicle testing