

BLACK CARBON IN THE SF BAY AREA: TRENDS IN AMBIENT CONCENTRATIONS AND EMISSIONS

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BAAQMD Advisory Council

Acknowledgments

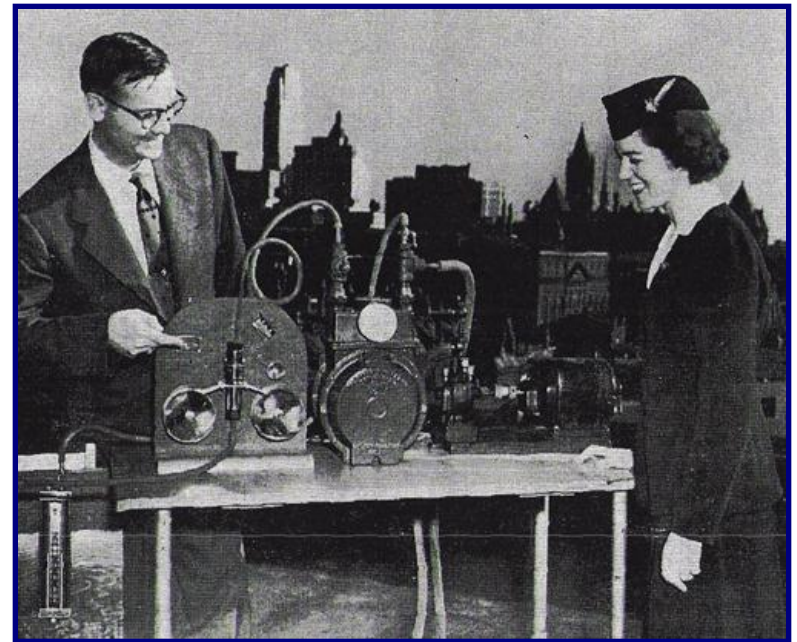
- **UC Berkeley:** Tom Kirchstetter (also at LBNL), Tim Dallmann, George Ban-Weiss, Chelsea Preble
- **Aerosol Dynamics:** Susanne Hering, Nathan Kreisberg
- **Aerodyne Research:** Tim Onasch, Ed Fortner, Doug Worsnop
- **BAAQMD:** Eric Stevenson, David Fairley, Amir Fanai, Phil Martien, Gary Kendall

Black Carbon Introduction

- BC = strong **absorber** of solar radiation
- BC correlated with adverse human health effects, more than other components of PM_{2.5}
- BC is a product of incomplete combustion
 - ▣ poor air-fuel mixing and/or very fuel-rich conditions
- Measurement methods include light absorption and thermal-optical analysis

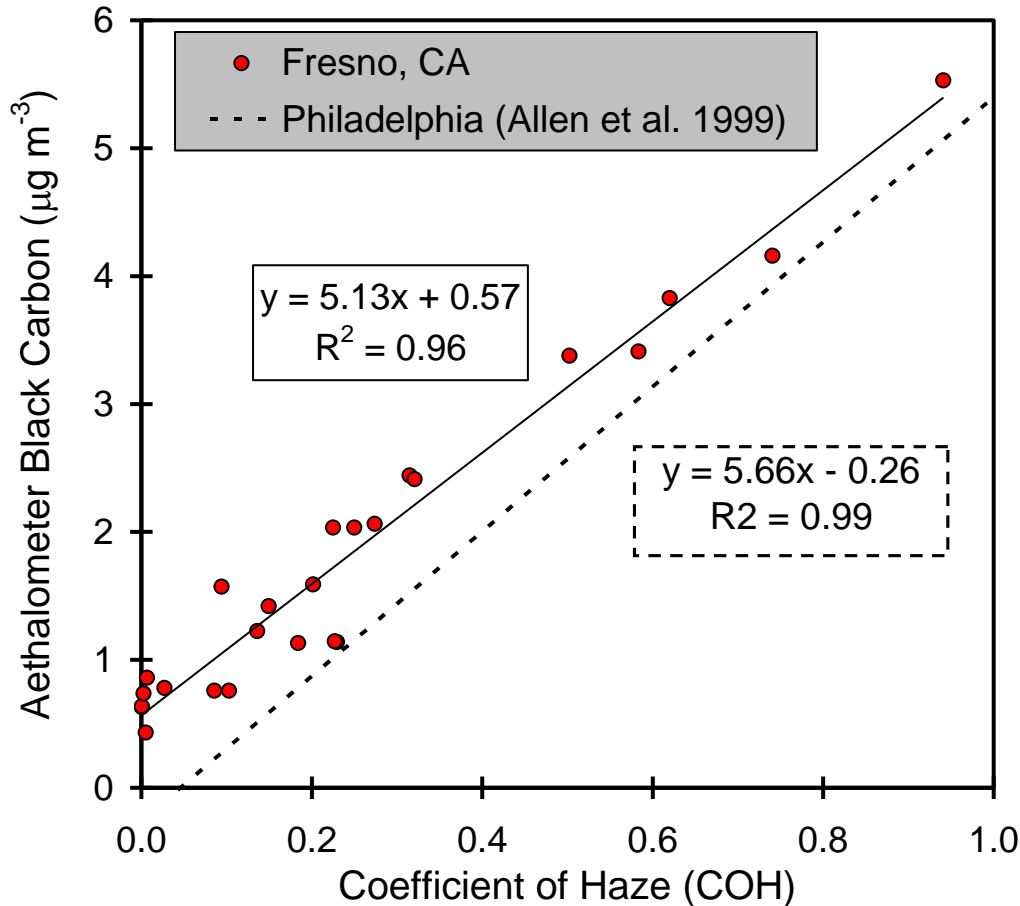
Coefficient of Haze (COH) Sampler

- Measures light transmitted through particles collected on white paper filter
- Bay area COH data available for 1968-2003



Hemeon et al. (*Air Repair*, 1953). Determination of haze and smoke concentrations by filter paper samples

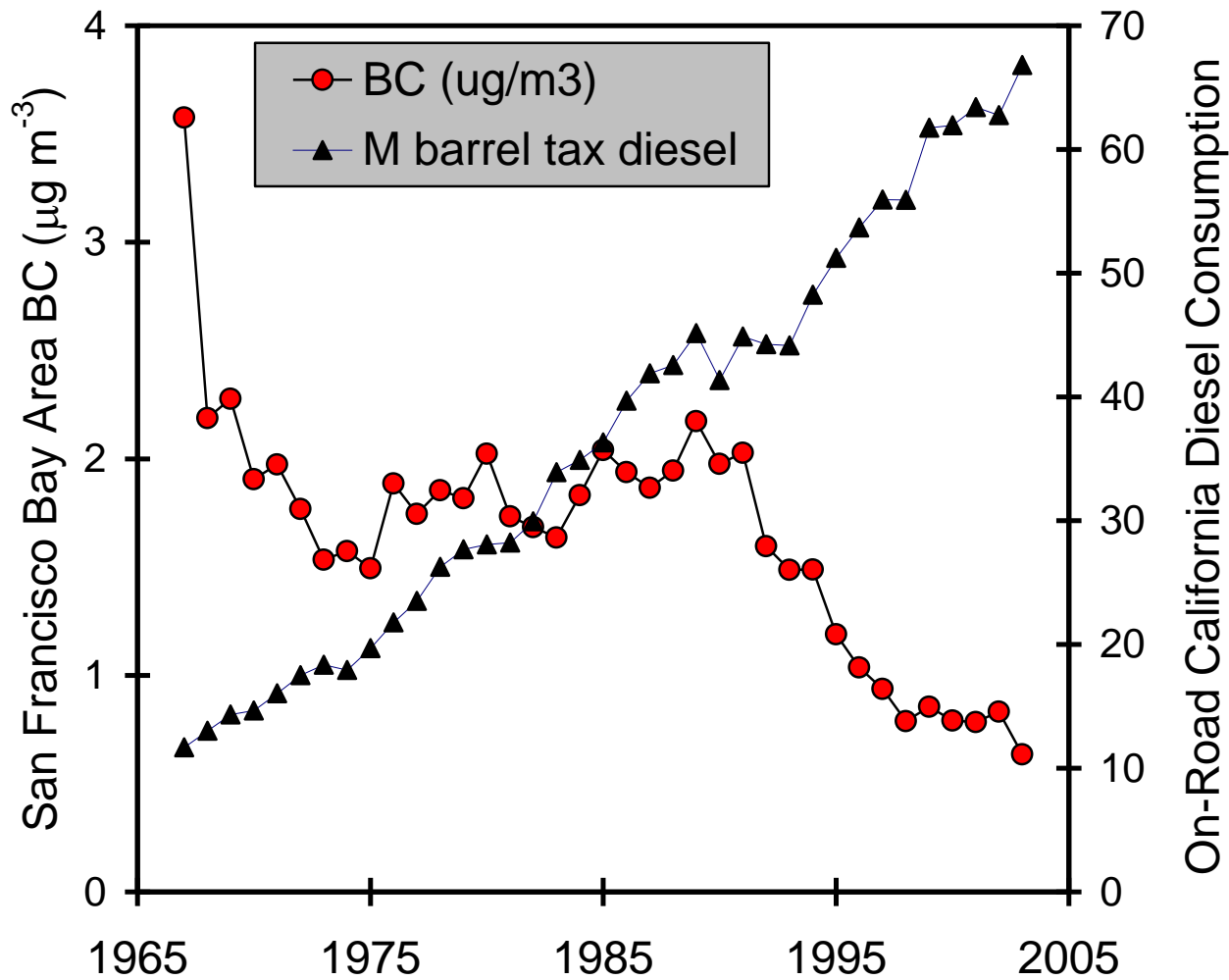
COH Highly Correlated with BC



COH and
aethalometer BC
measurements in
Fresno, CA and in
Philadelphia, PA
indicate
 $BC = 5.4 \cdot COH$

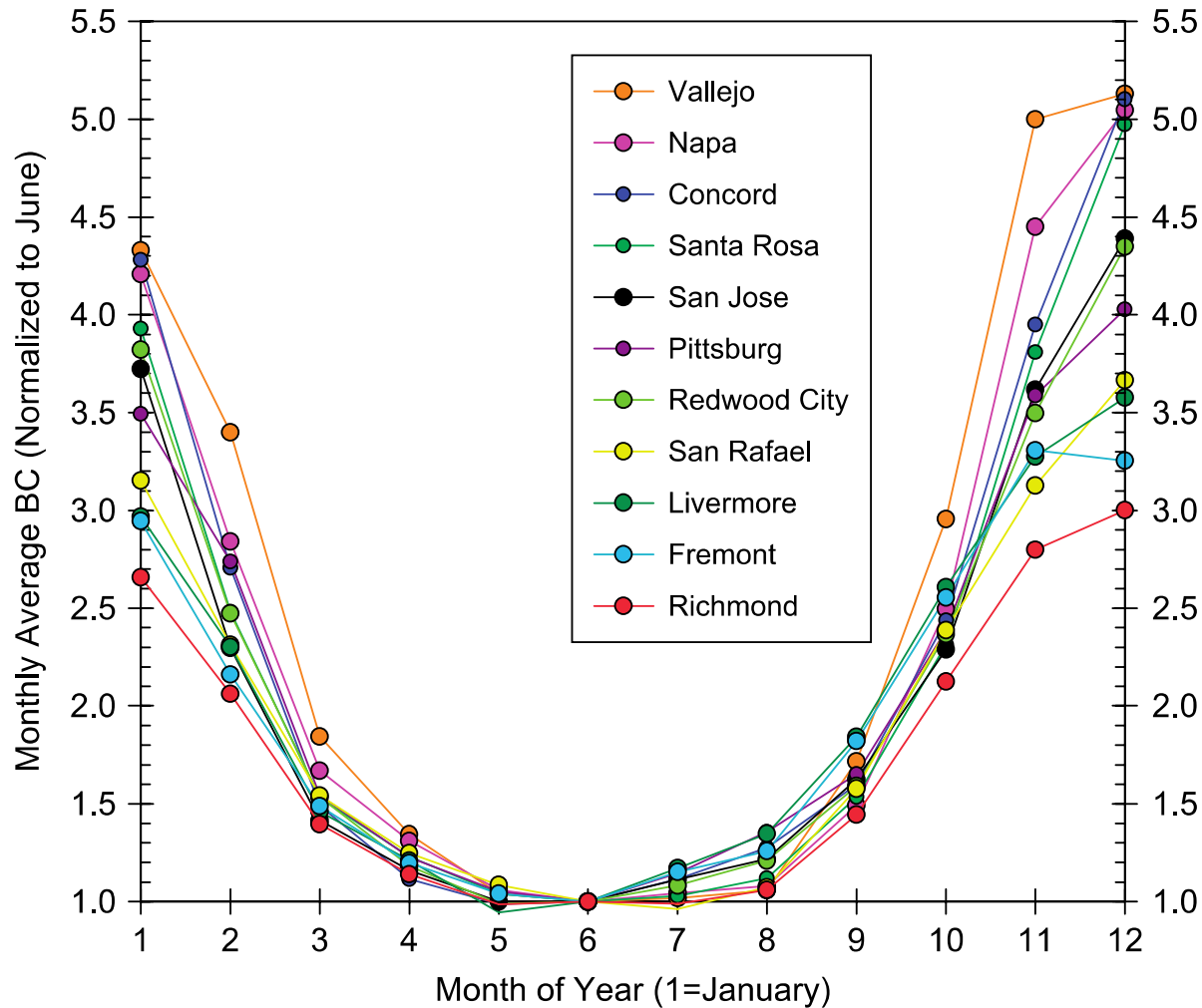
Long-Term Trend in Ambient BC

(Data from 11 Bay Area COH Monitors)



Seasonality in Ambient BC

(Bay Area Monthly BC Ratios to June; 1980-1990 Data)



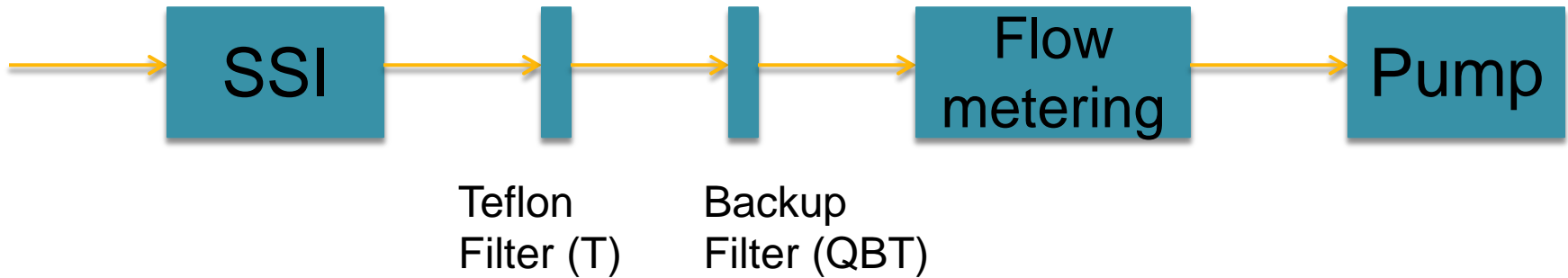
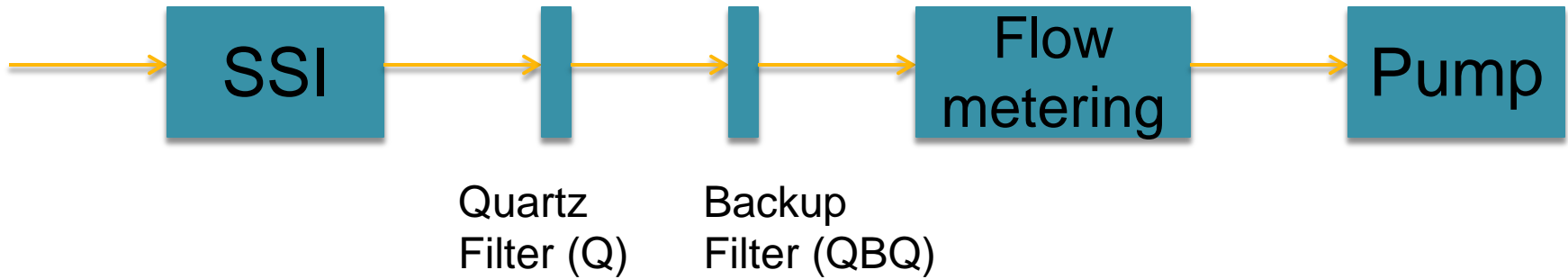
Bay Area Air Monitoring Network

Pollutant	Method	# of Sites	Averaging Time	Sampling Frequency
PM _{2.5} mass	β-attenuation	14	hourly	Continuous
PM _{2.5} speciation*	Lab analysis of Q/T filters	4	24 h	1/6 days**
Light absorption*	Aethalometer	3	hourly	Continuous
Light scattering	Nephelometer	2	hourly	Continuous
Ultrafine particles	Water CPC	4	hourly	Continuous
PM ₁₀ mass	Weigh filters	8	24 h	1/6 days

* BC reported explicitly using these techniques

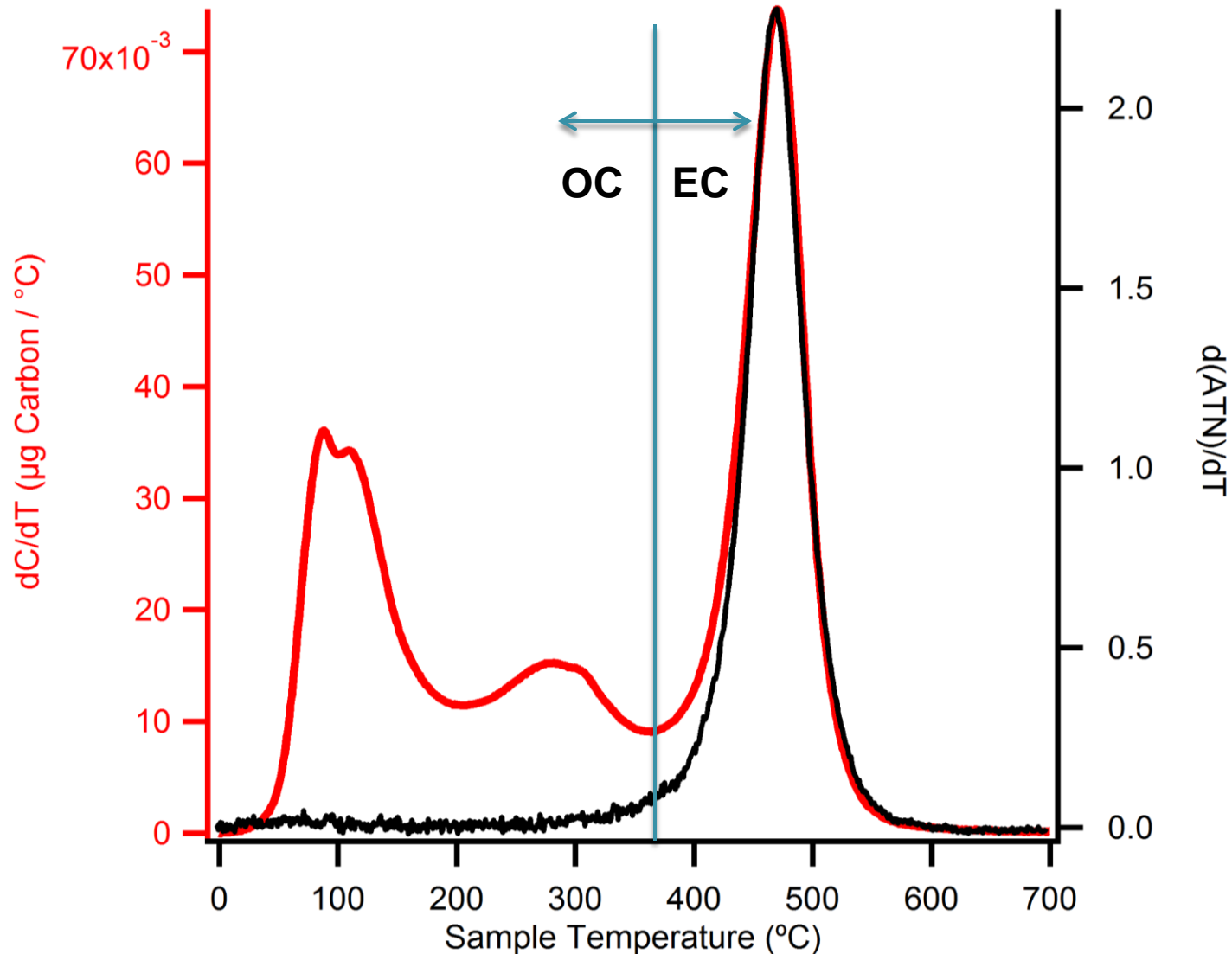
** More frequently (once every 3rd day) at San Jose

BC, OC & PM by Filter Sampling



Sample Quartz Filter Thermogram

(TOA = Thermal-Optical Analysis)

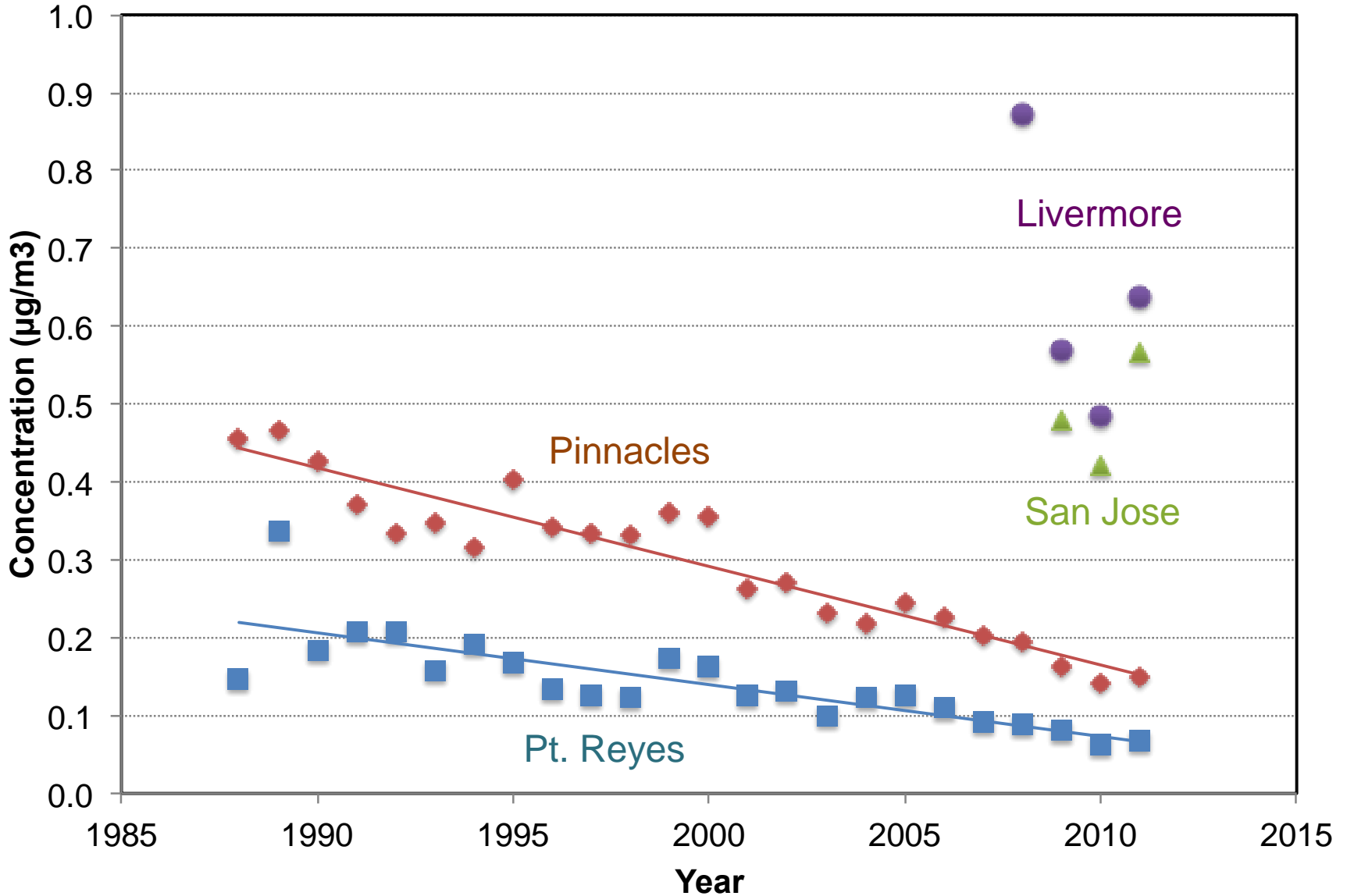


Thermal-Optical Analysis (TOA)

- Total Carbon = Elemental + Organic Carbon
 - ▣ units of TC, EC & OC are $\mu\text{g C per m}^3$ of air

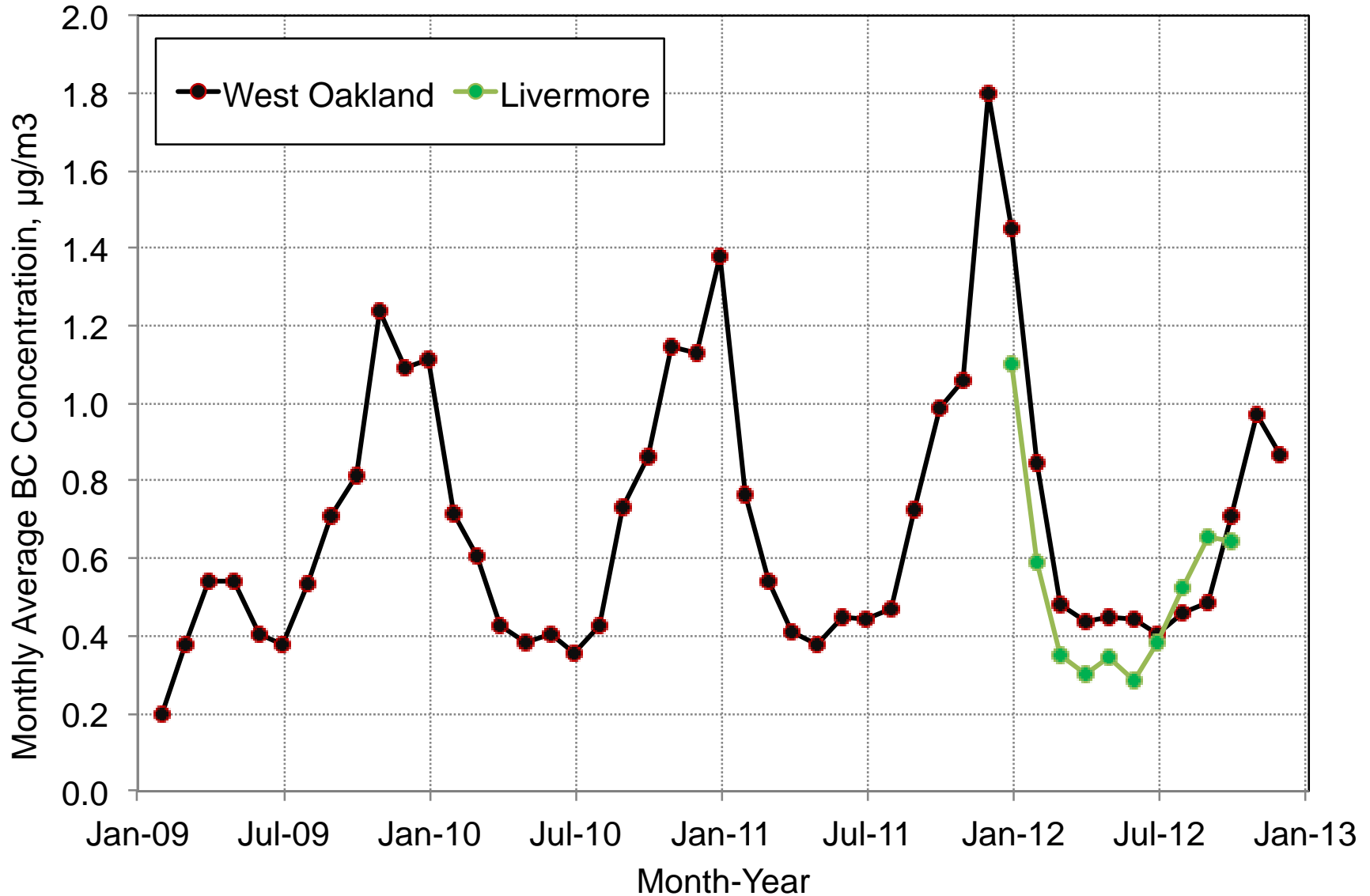
- Vexing issues with EC & OC measurements:
 1. OC can convert to EC during analysis (“charring”)
 2. Organic vapors can adsorb on quartz surfaces (positive sampling artifact for OC)
 3. Poorly defined conversion of OC ($\mu\text{g C}$) to OA (μg) (need to know H/C, O/C, N/C ratios in the OA)
 - ❖ secondary organic aerosol (SOA) is highly oxygenated

Ambient EC Data for the Bay Area (IMPROVE and BAAQMD Data)



Ambient BC at West Oakland

(BAAQMD Data; Also Showing Livermore)

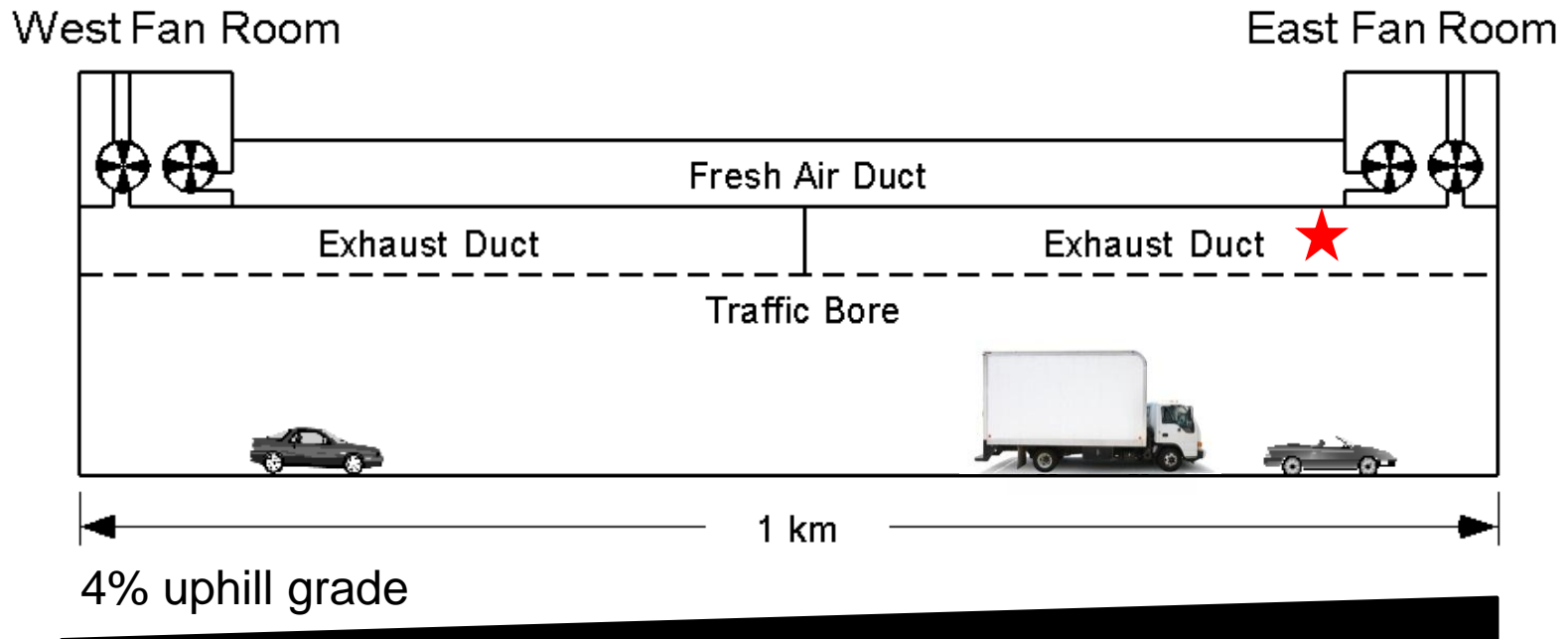


Ambient Monitoring Recommendations

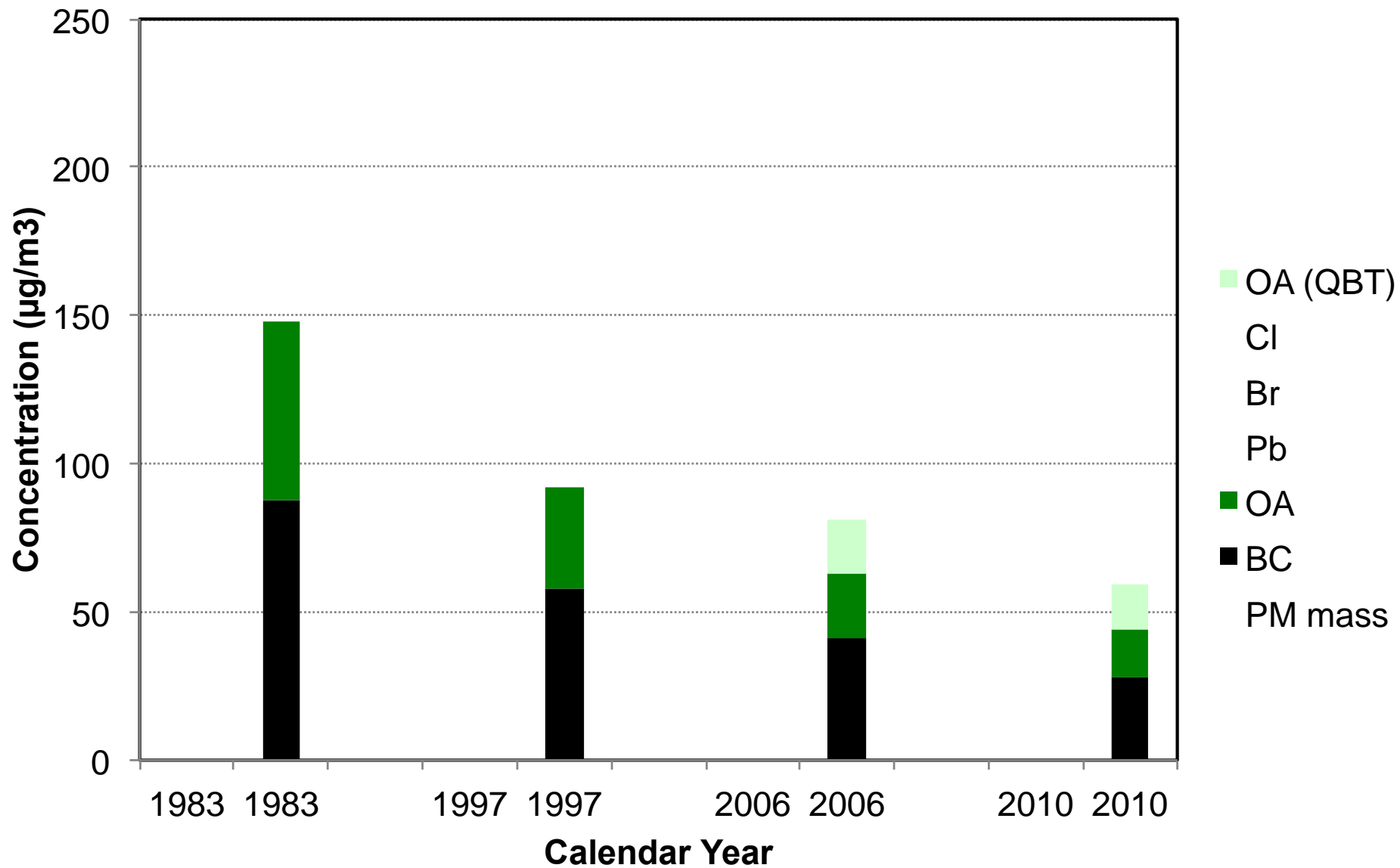
- Increase BC and speciated PM_{2.5} monitoring
 - ▣ Improve understanding of sources that contribute to PM_{2.5} problems
 - ▣ Track impact of emission control measures over next decade (big efforts on diesel control are underway)
- Align monitoring with former COH sites to extend existing long-term record of BC
 - ▣ Also continue BC monitoring at West Oakland
 - ▣ Use online measurement method for BC

Vehicle Emissions at Caldecott Tunnel

On-road vehicle emissions measured here over last 30 years...
Hering et al. (1984); Kirchstetter et al. (1999); Ban-Weiss et al. (2008); Dallmann et al. (2013)

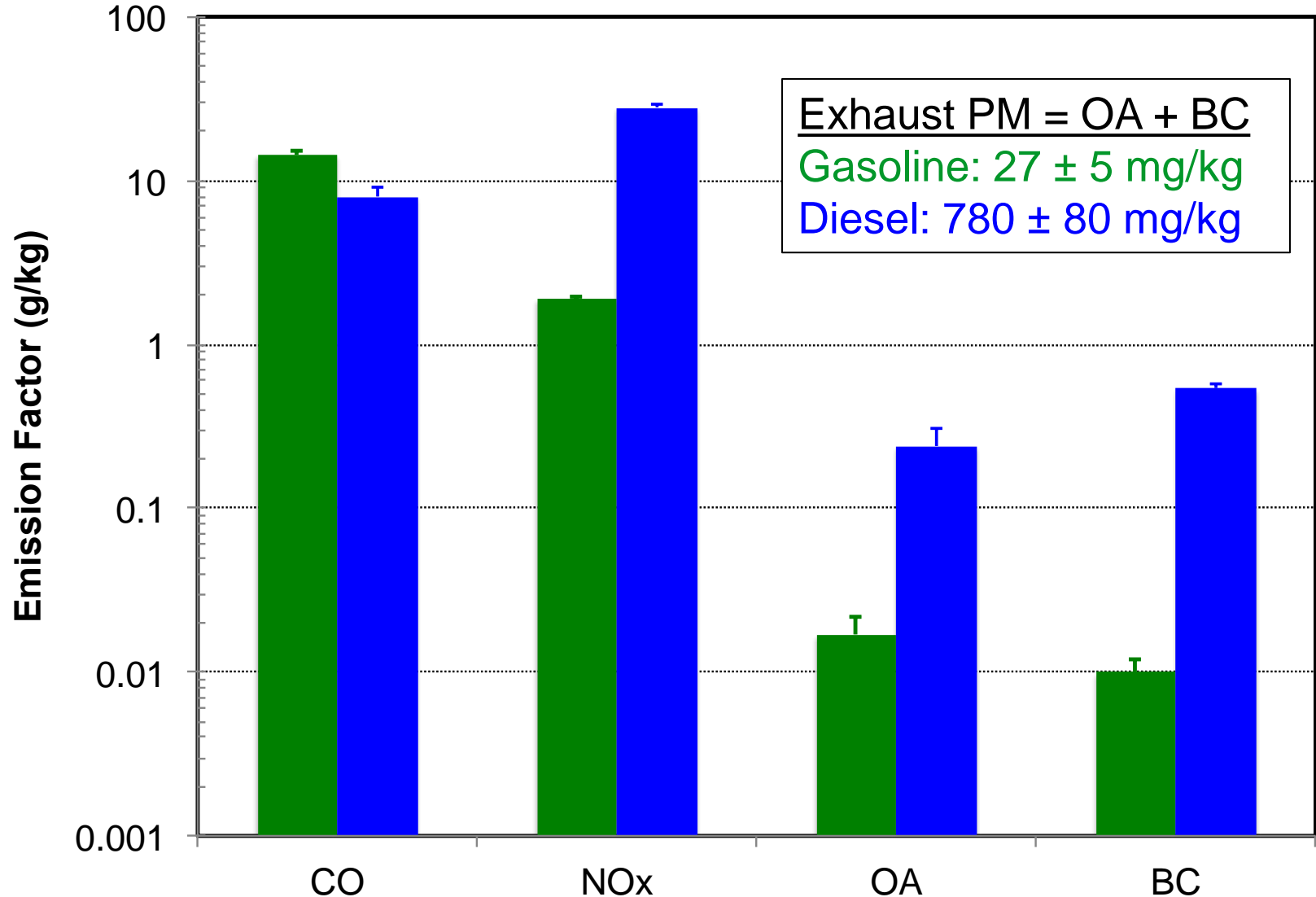


Tunnel Fine Particle Mass and Speciation



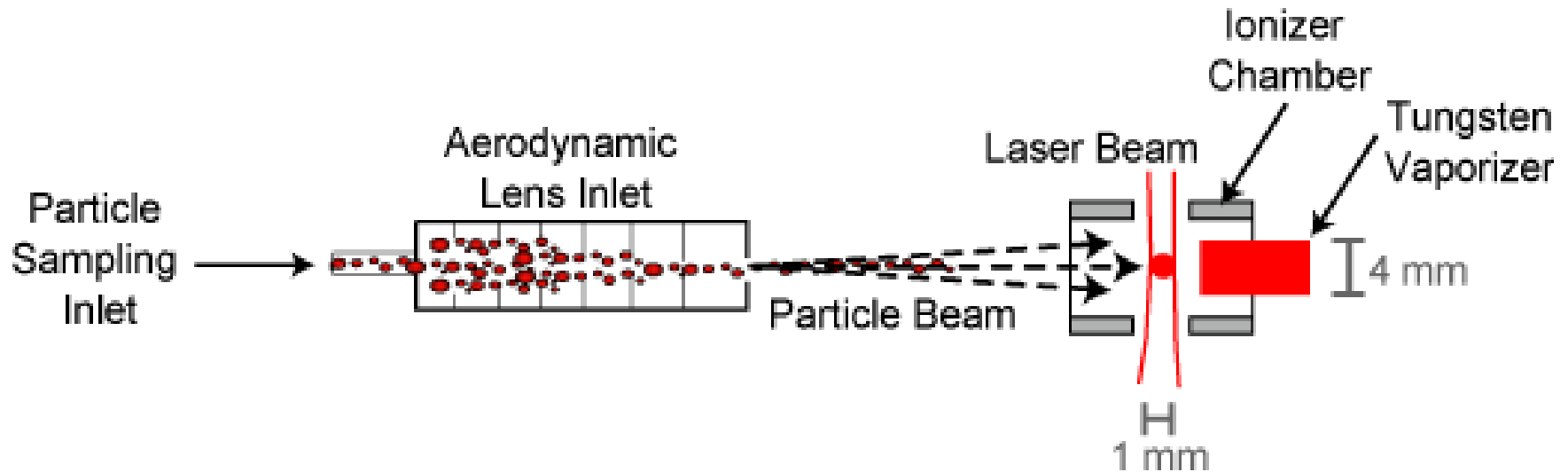
Gasoline vs Diesel Emission Factors

(Caldecott Tunnel – 2010)



SP-AMS Aerosol Mass Spectrometer

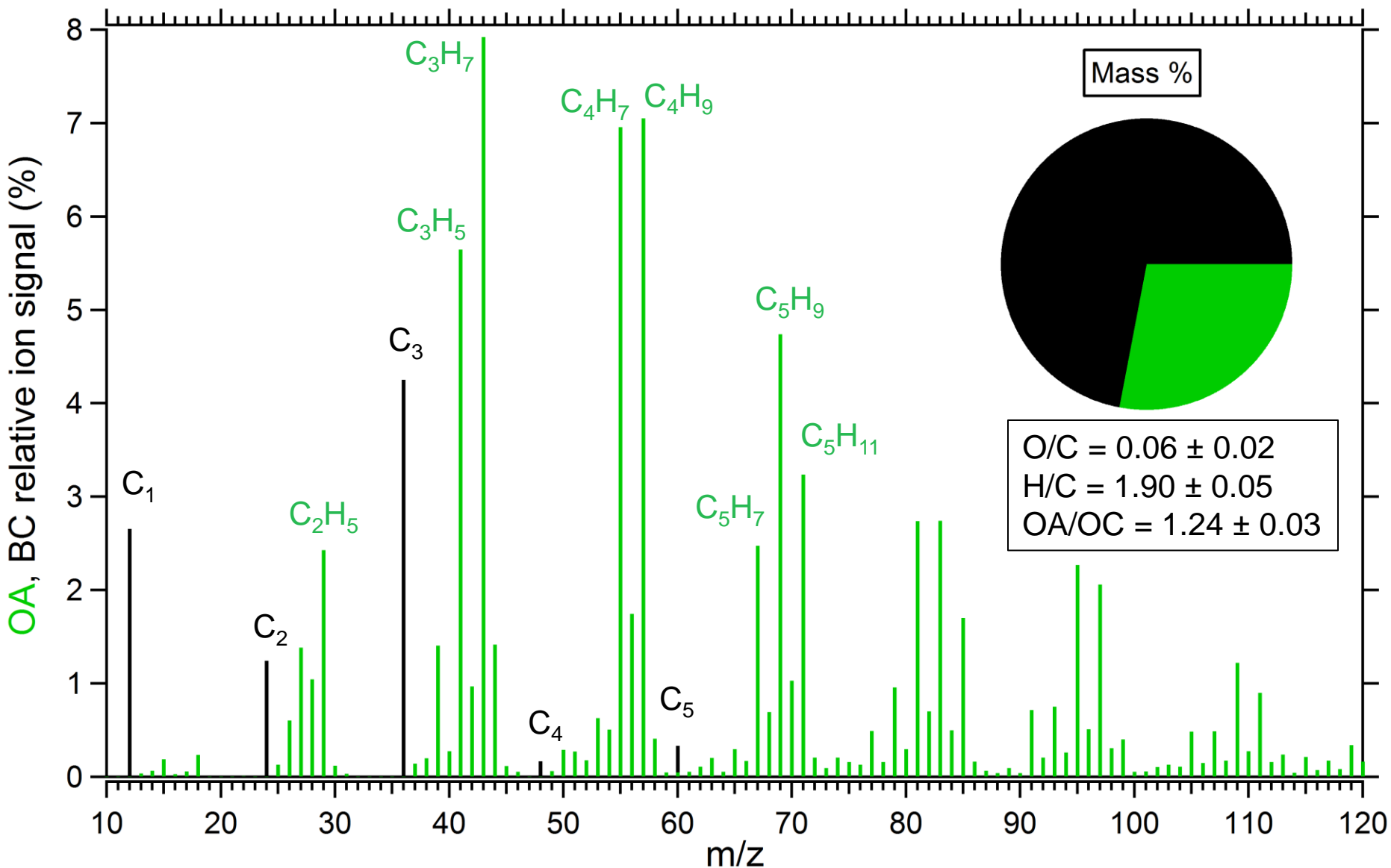
(measures refractory & organic aerosol)



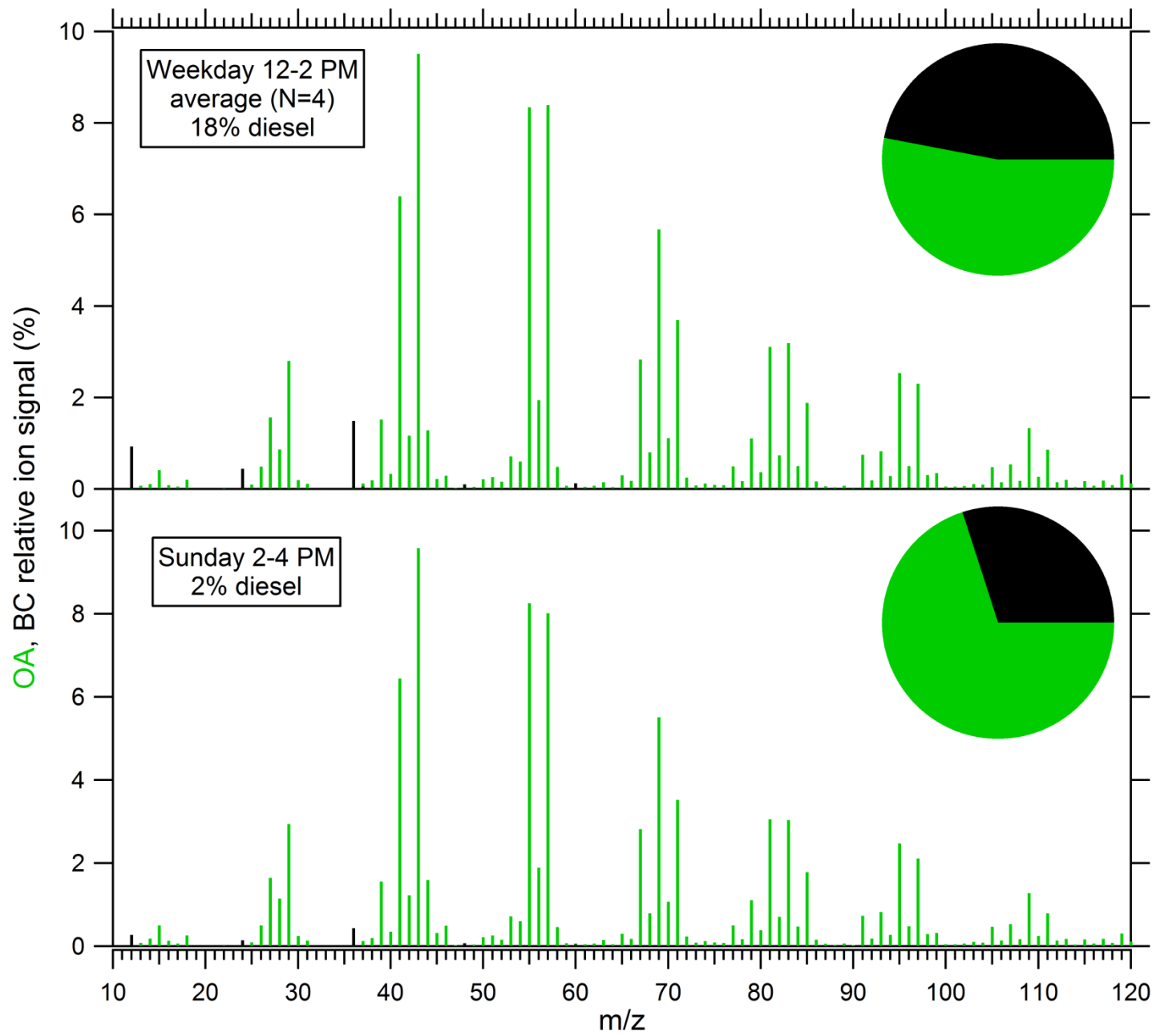
- Traditional tungsten vaporizer combined with laser to vaporize refractory aerosol (i.e., black carbon)
- Electron ionization (EI) following vaporization
- High-resolution time-of-flight mass spectrometer provides ion spectrum every second

Mass Spectrum for Diesel PM Emissions

(Composite of N=145 HD Diesel Truck Exhaust Plumes)

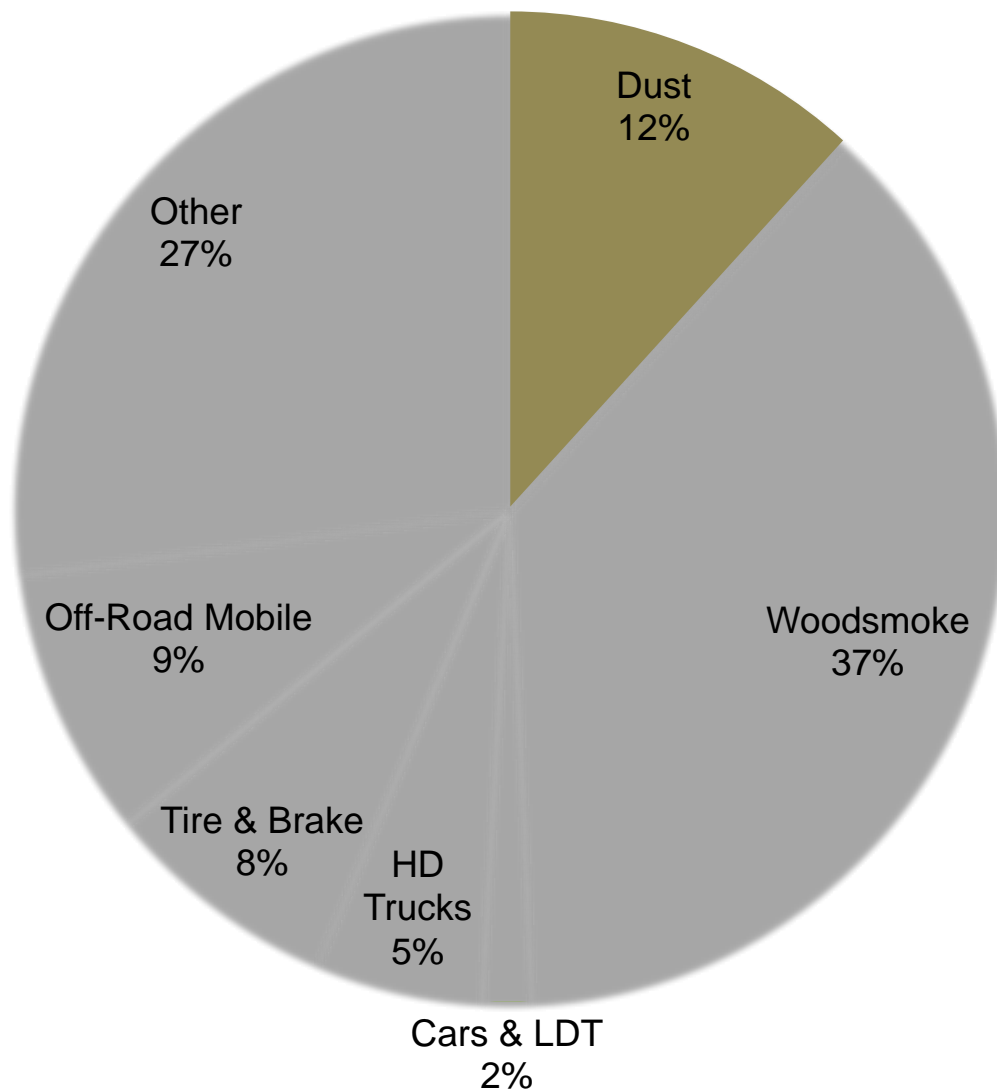


Gasoline and Diesel OA mass spectra are similar



Fine PM Emissions in the Bay Area

(Winter Inventory – 2010)



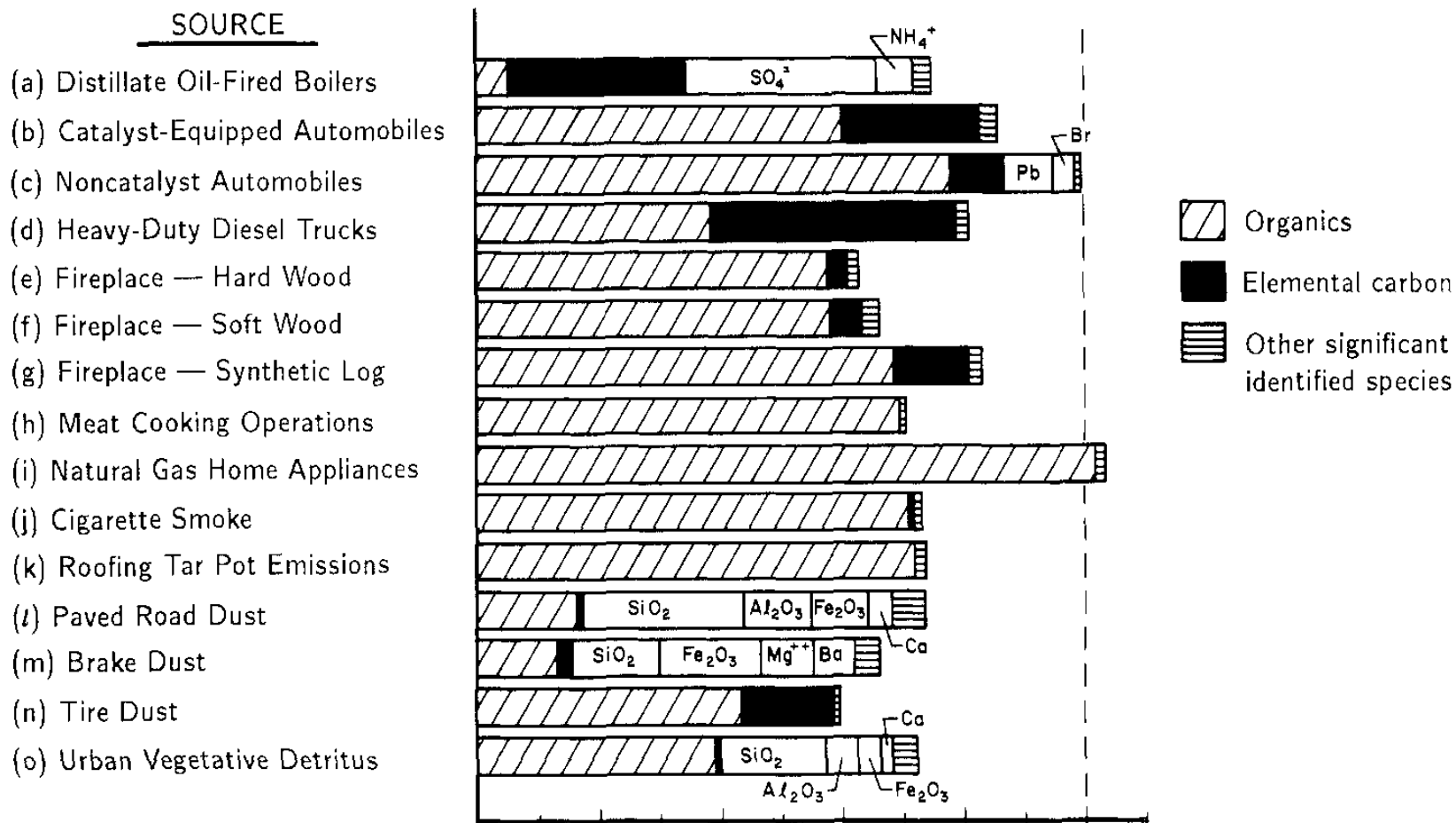
PM_{2.5} Emissions =
49 tons/day

Does not include
secondary PM that
forms from VOC,
NO_x, NH₃, and SO₂

BAAQMD Inventory
by Fanai et al. (2012)

BC Fraction in Fine PM Emissions

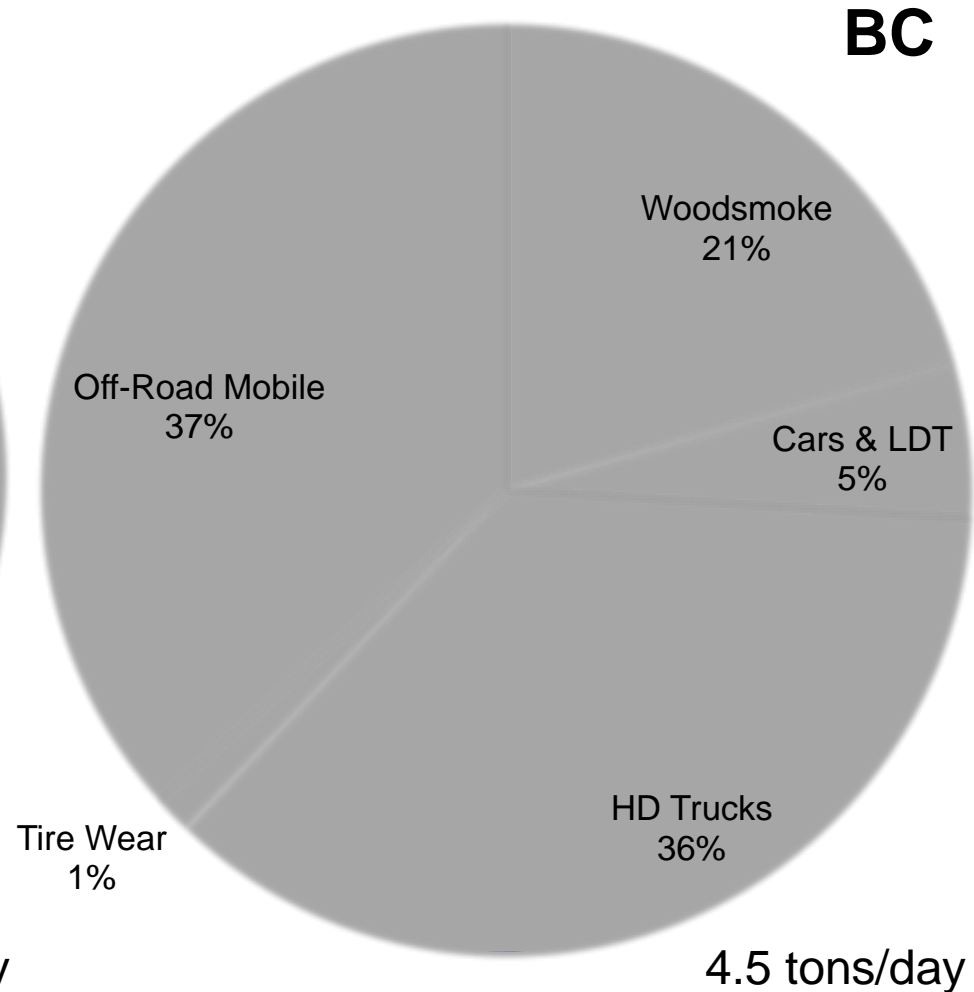
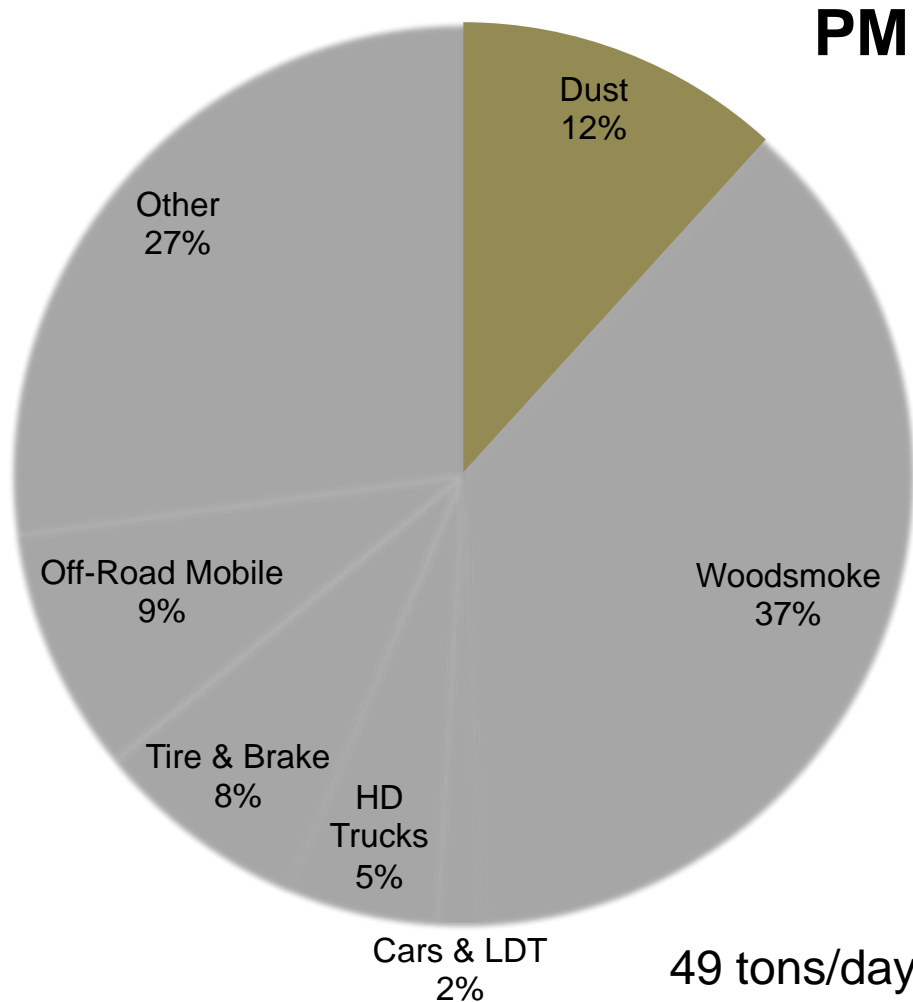
ce.



Hildemann et al. (*ES&T* 1991)

Fine PM and BC Emissions in the Bay Area

(Winter Inventory – 2010)



BC Emission Controls

- Major decreases in BC expected due to new diesel emission controls
 - ▣ Particle filters required nationwide on all **new** heavy-duty diesel engines (starting 2007)
 - Also pre-2007 engines must be **replaced** in California

- Other BC control efforts also underway:
 - ▣ Goods movement (rail, ships, drayage trucks)
 - ▣ Light-duty vehicles (gasoline direct injection)
 - ▣ Wood-burning