The following document was submitted "for the record" to the Intermodal Container Transfer Facility (ICTF) Joint Powers Authority (JPA) during the Notice of Preparation/Initial Study (NOP/IS) comment period for the ICTF Modernization and Expansion Project.

The document was submitted by:

Andrea M. Hricko
Assoc Prof Prev Med
Keck School of Med &
Director, Community Outreach and Education
Southern CA Env Health Sciences Ctr
1540 Alcazar Street CHP 236
L.A. CA 90033
323-442-3077

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Results from the Research of the Southern California Particle Center and Supersite (SCPCS)

Part I: Atmospheric Measurements and Development of Instrumentation

Constantinos Sioutas
Associate Professor
USC School of Engineering
Civil and Environmental Engineering
Deputy Director of Southern California Particle Center and Supersite

Presented to the California Air Resources Board

Wednesday, June 18

Summary:

-Why Are We Interested in Ultrafine PM

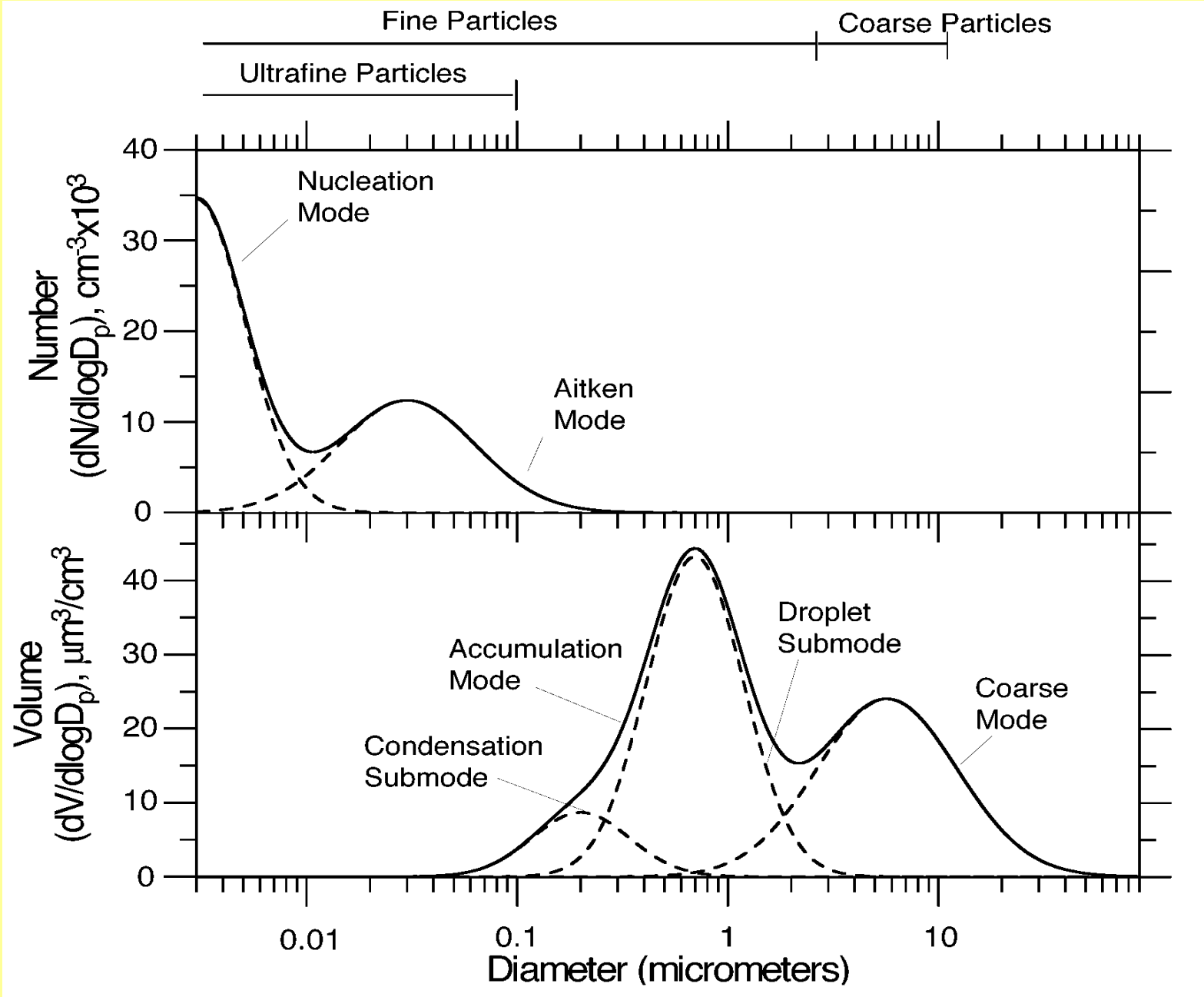
- What do we know about their toxicological properties

- What do we know (or do not) about their sources, formation mechanisms

- What do we know about their diurnal, seasonal and spatial characteristics

- Technologies developed by the Aerosol Laboratory at USC by funds through the SCPCS to measure physical, chemical and toxicological properties of ultrafine PM

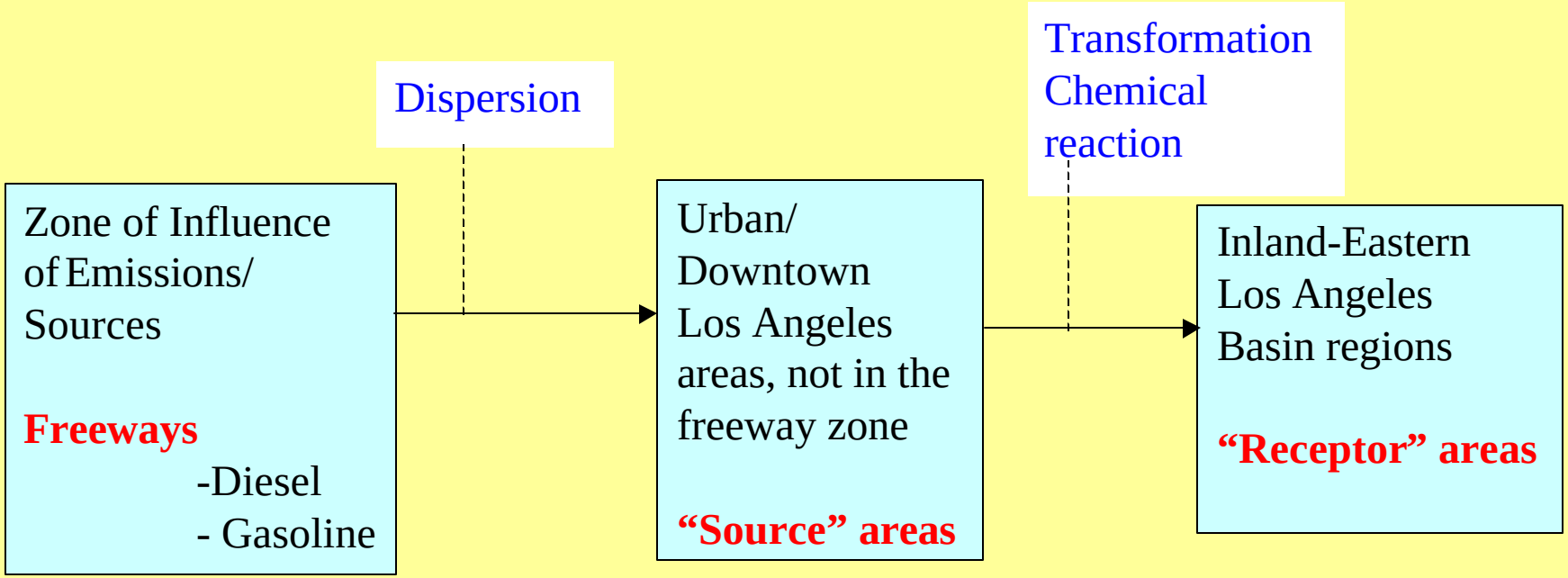
Ambient Aerosol Size Distribution



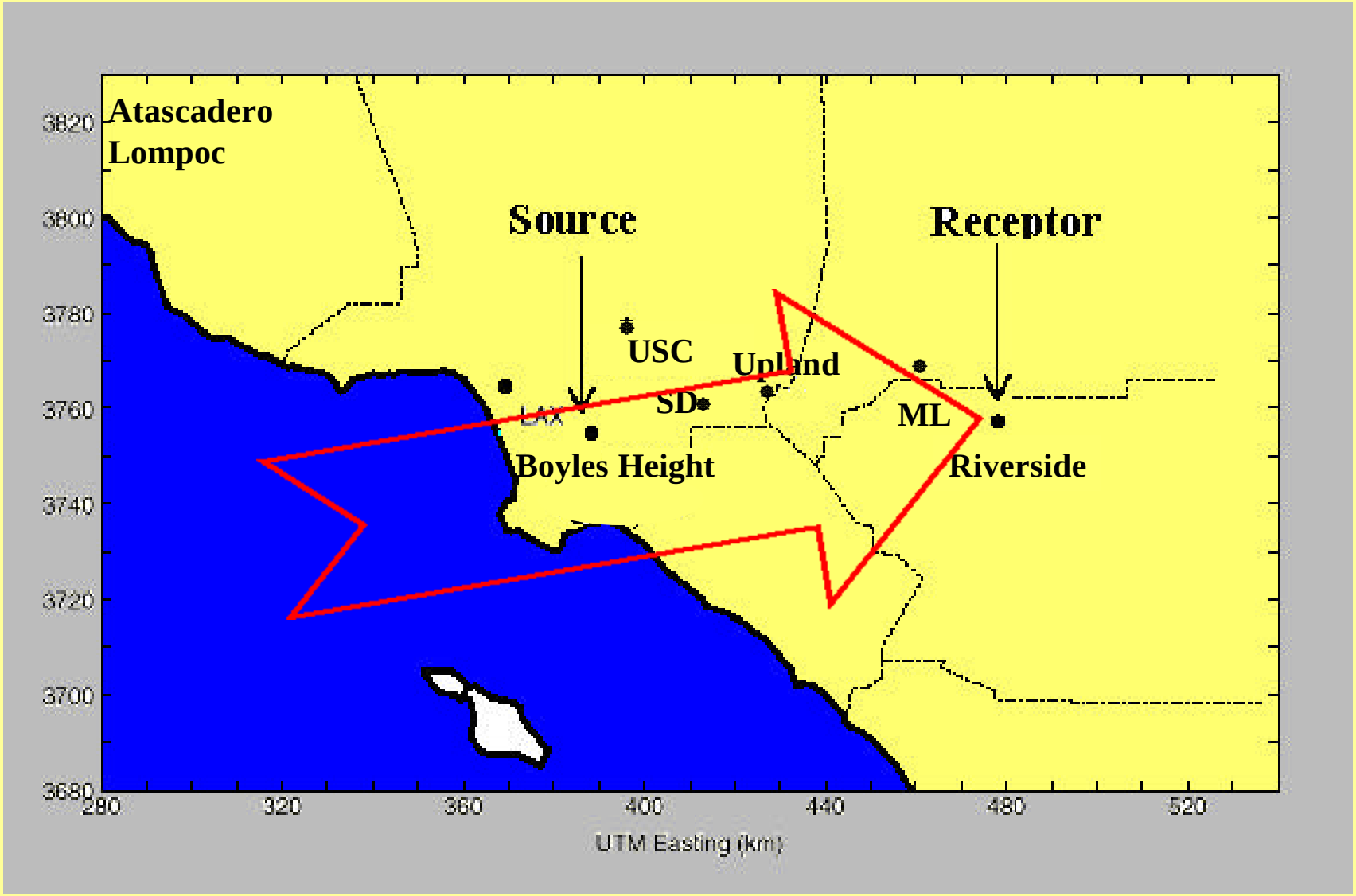
Los Angeles is a Very Unique Air Basin

- Distinct areas of different meteorological conditions result in spatial variation of PM2.5
- Predictable, well-defined and consistent meteorology; suitable for "controlled", laboratory-style experiments using real-life air pollutants as test aerosols.
- The distinct sources affecting specific areas of the LAB provide an ideal testing ground for hypotheses driven health studies.

Three Different PM Exposure (or Air Pollution) Regimes in the Los Angeles Basin



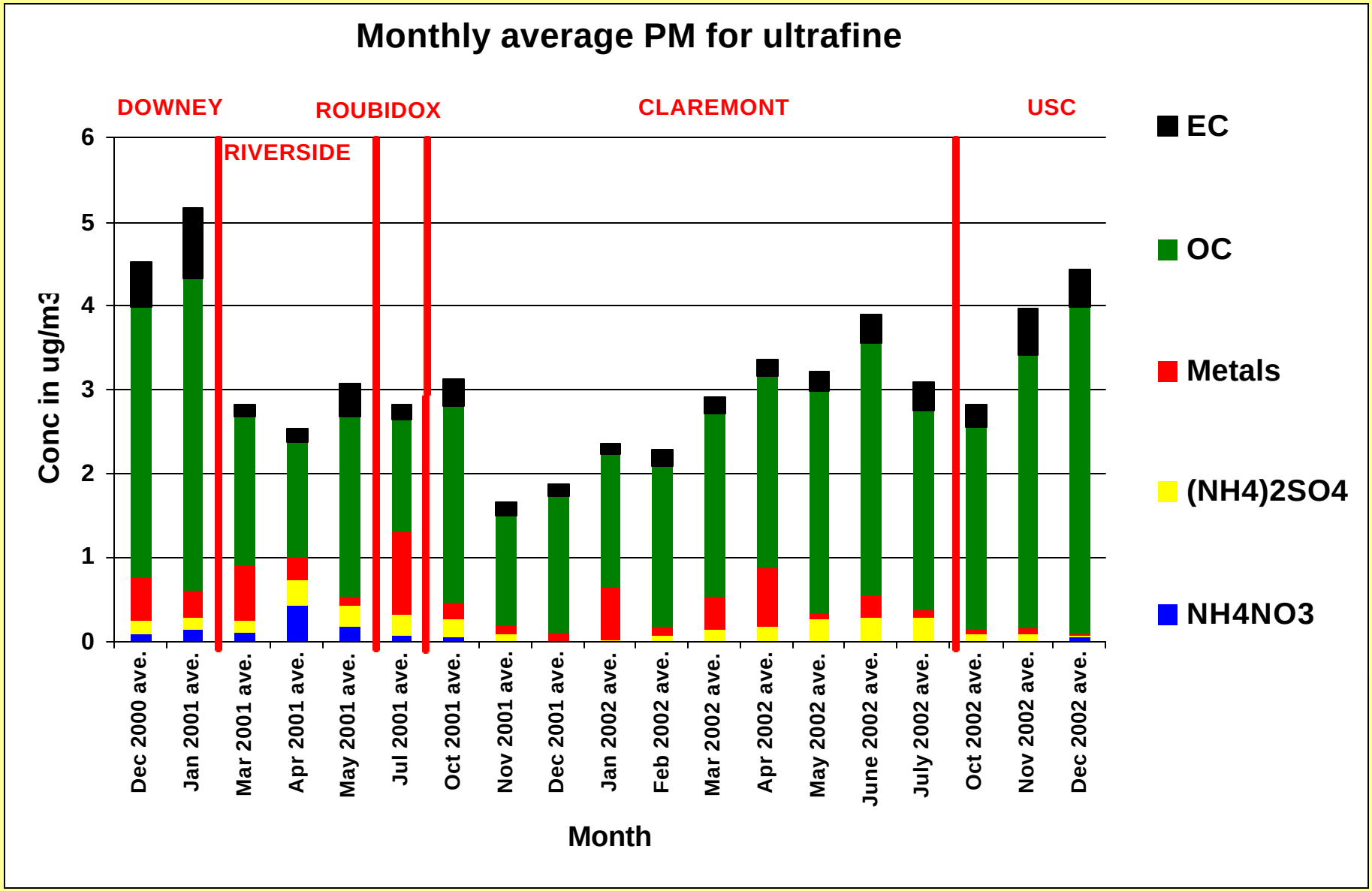
Source and Receptor Areas in the Los Angeles Basin



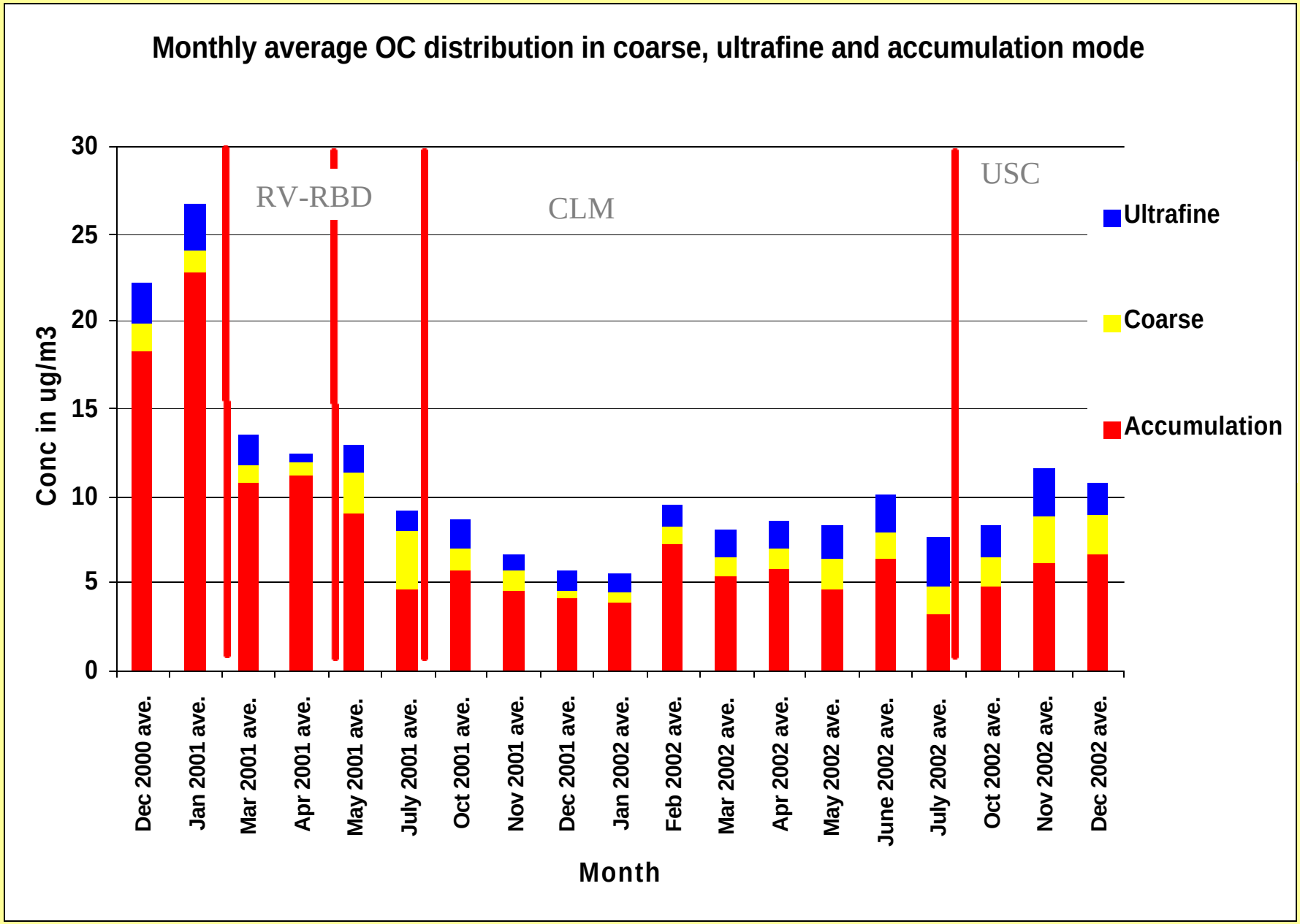
Sampling was Conducted in :

- **Downey (source) September 2000-January 2001**
- **Riverside (receptor) February – June 2001**
- **Rubidoux (receptor) June – September 2001**
- **Claremont (receptor) September 2001-August 2002**
- **USC (source) September 2002 - present**
- **Concurrently with in vivo and in vitro studies to concentrated air particulates (CAPS)**

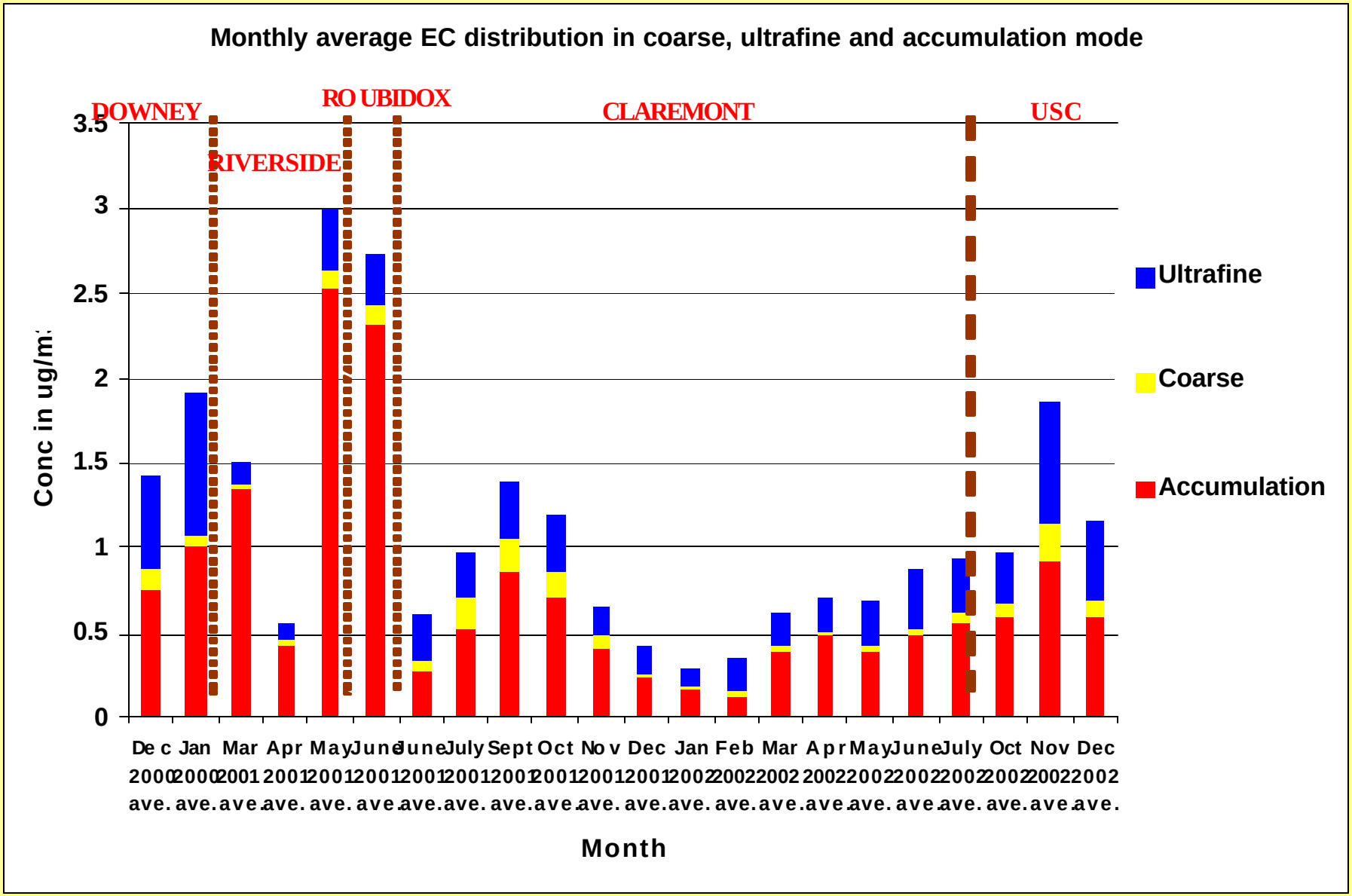
Sardar et al., Atmos. Environ, 2003



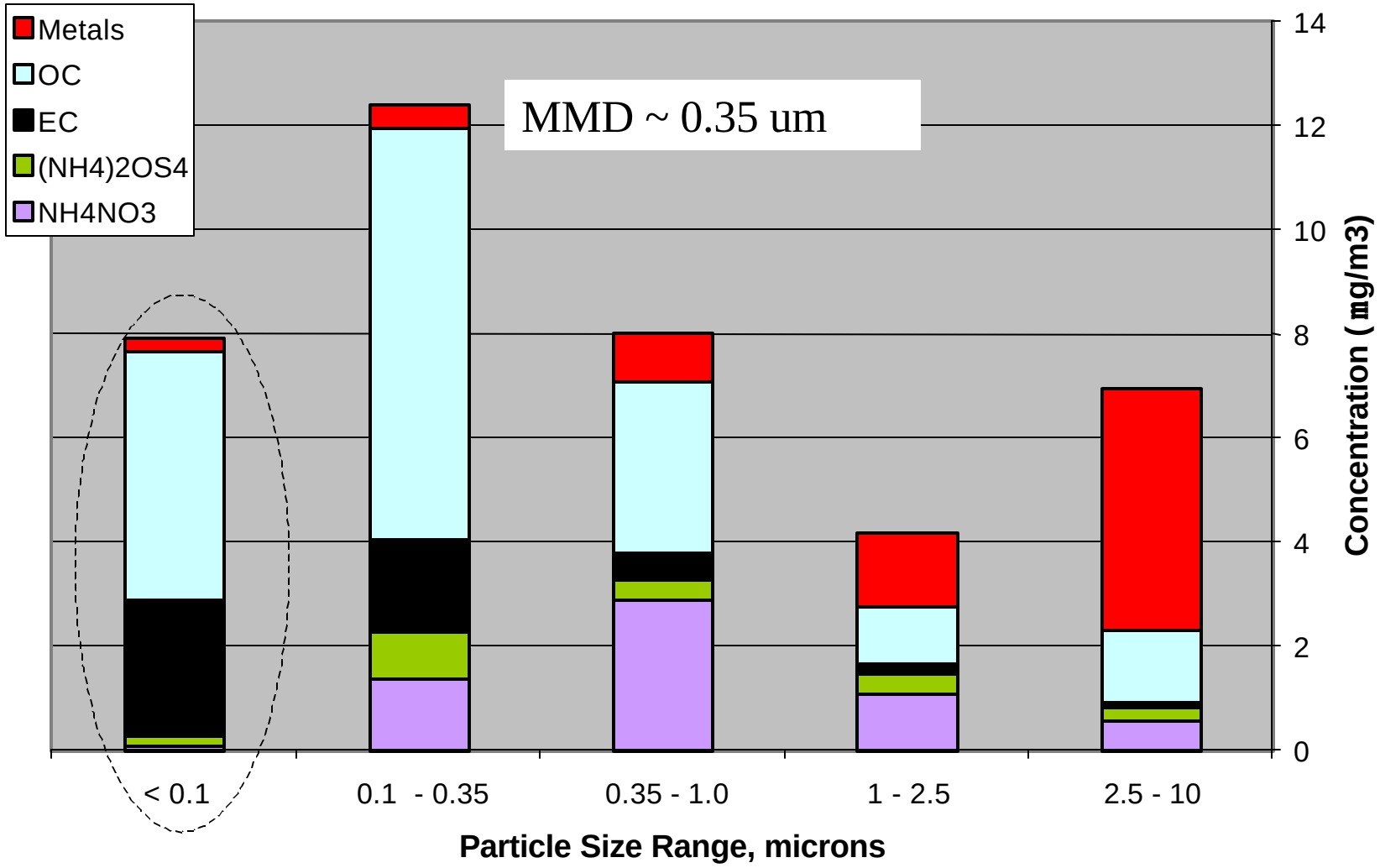
Sardar et al., Atmos. Environ, 2003



Sardar et al., Atmos. Environ, 2003

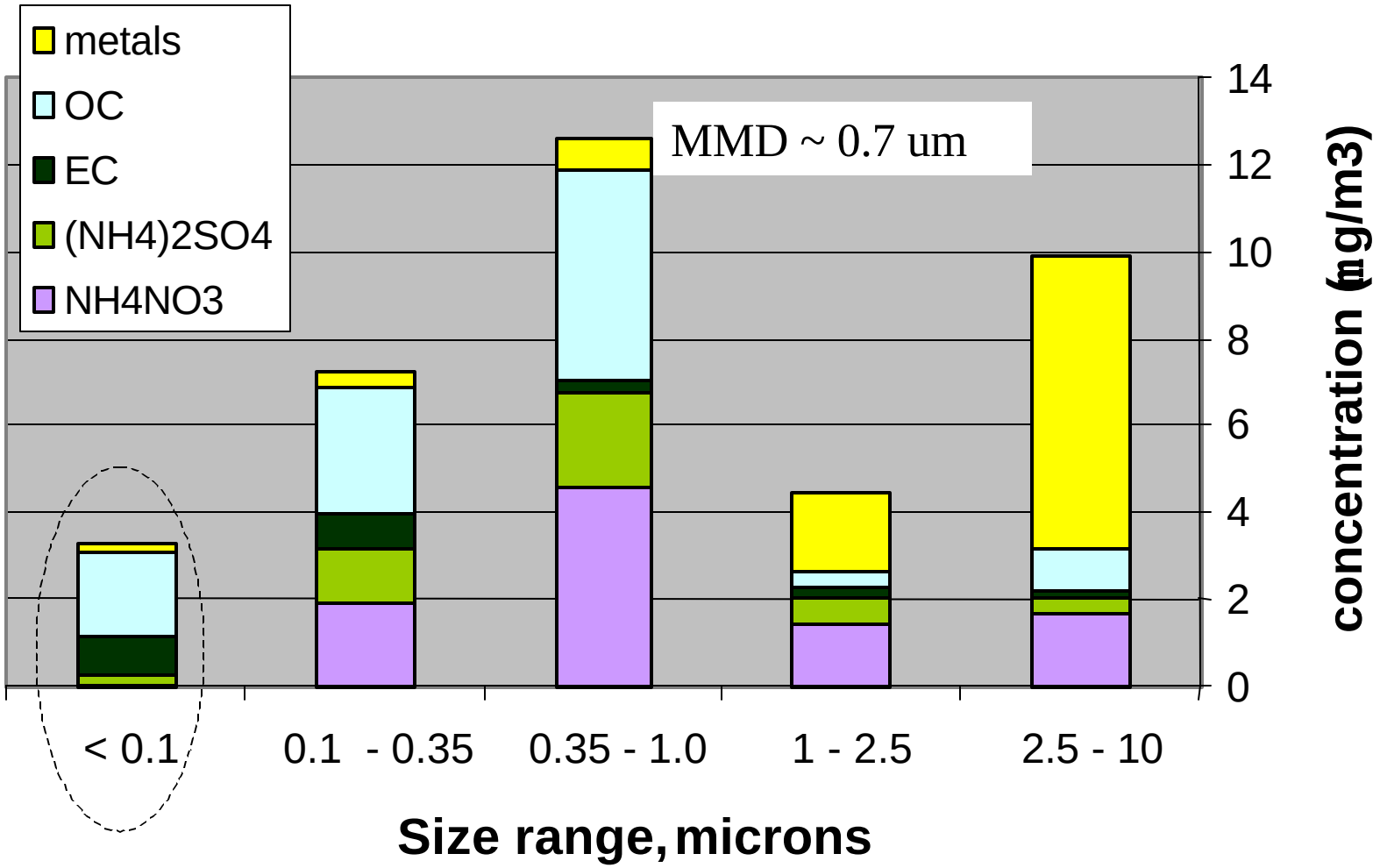


24-h Average PM10 Mass and Chemical Composition in Downey



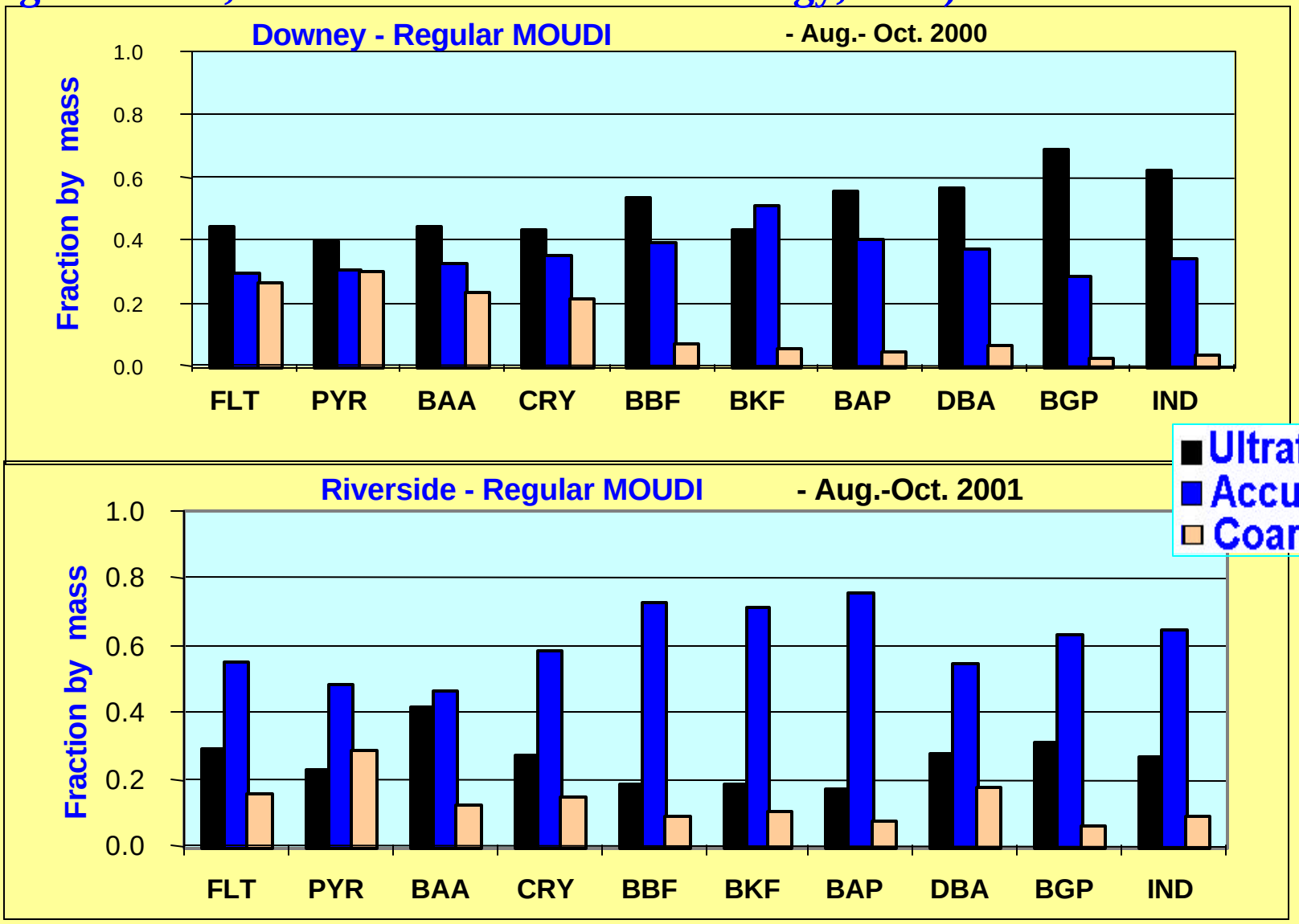
Singh et al *Atmospheric Environment*, 36(10): 1675-168, 2002

24-h Average PM10 Mass and Chemical Composition in Riverside

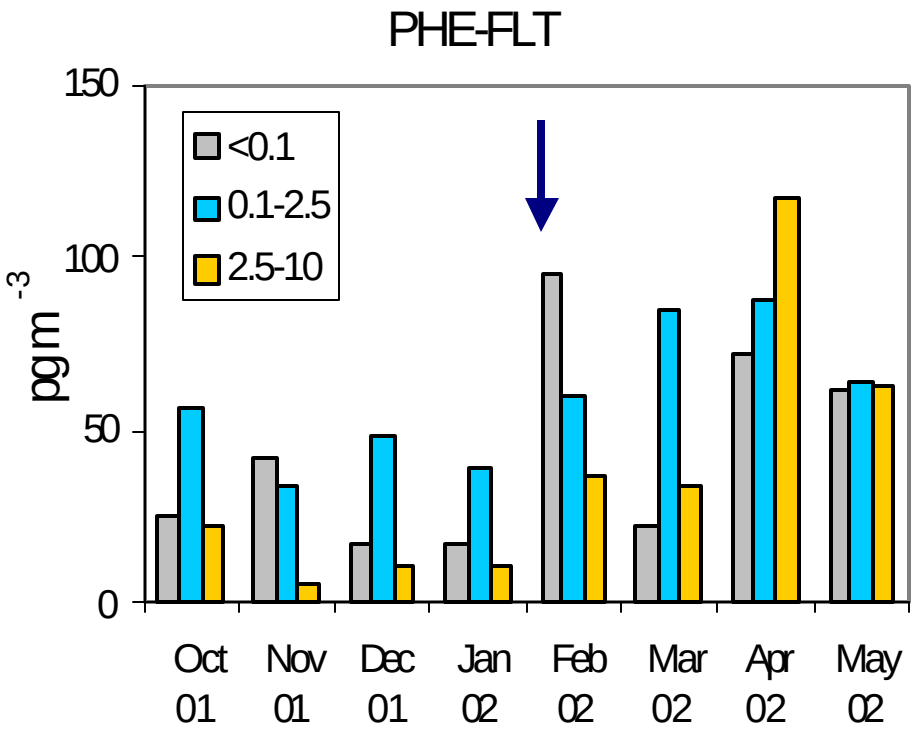


Effect of transport on PAH size distribution

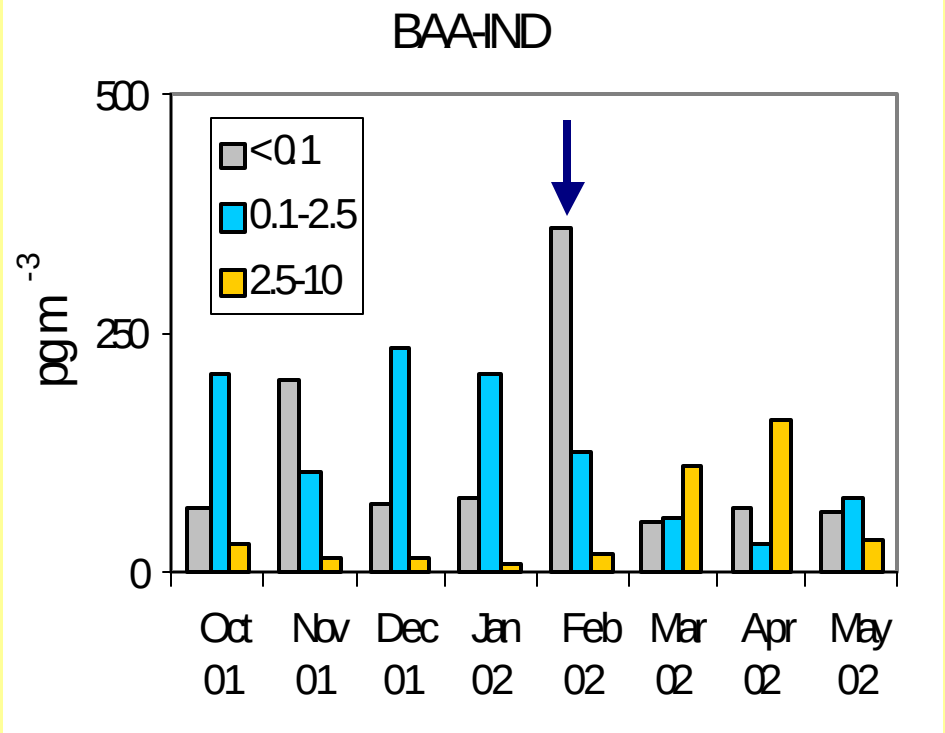
(Eiguren et al., Aerosol Science and Technology, 2003)



Higher Volatility PAH



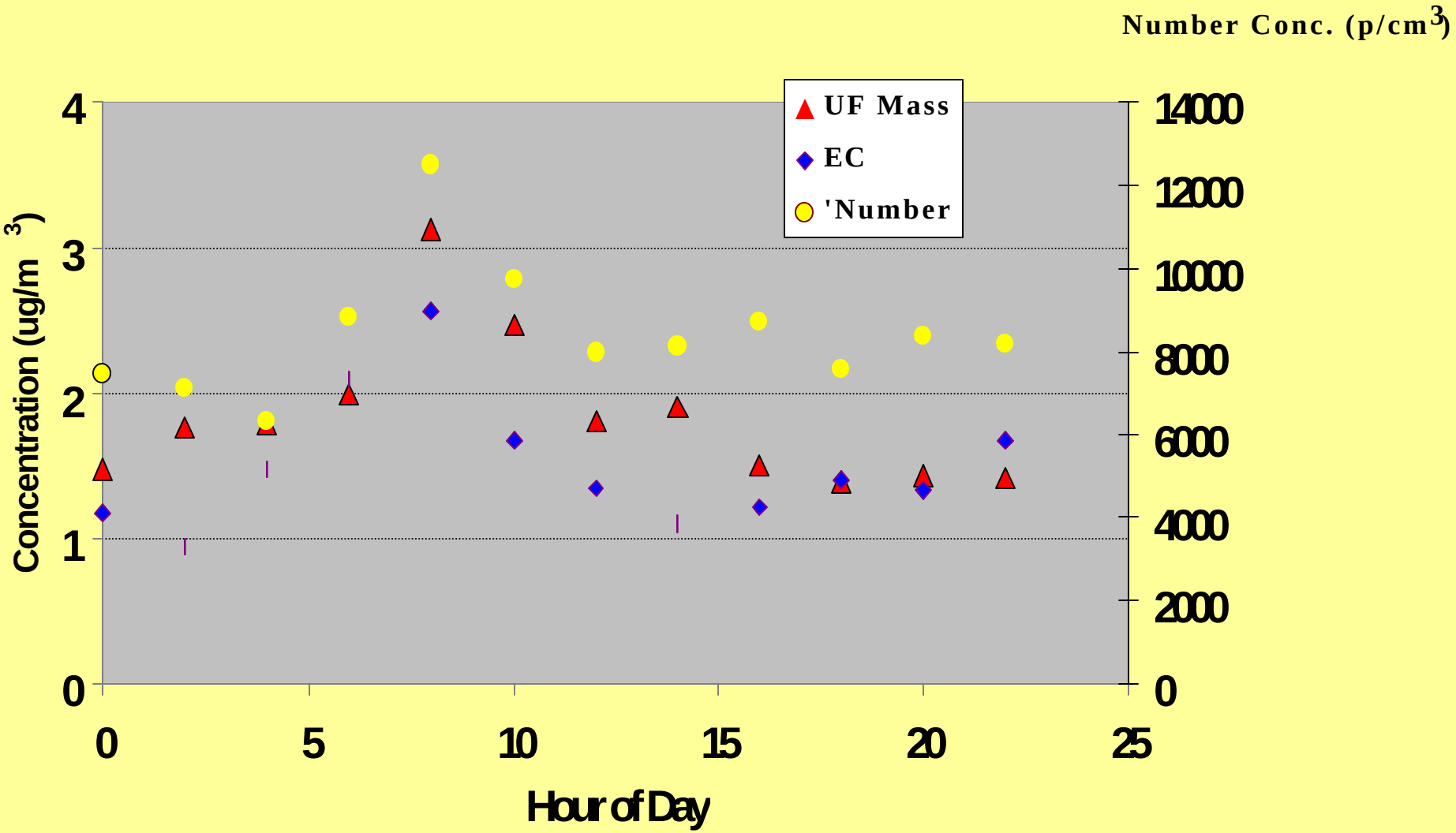
Lower Volatility PAH

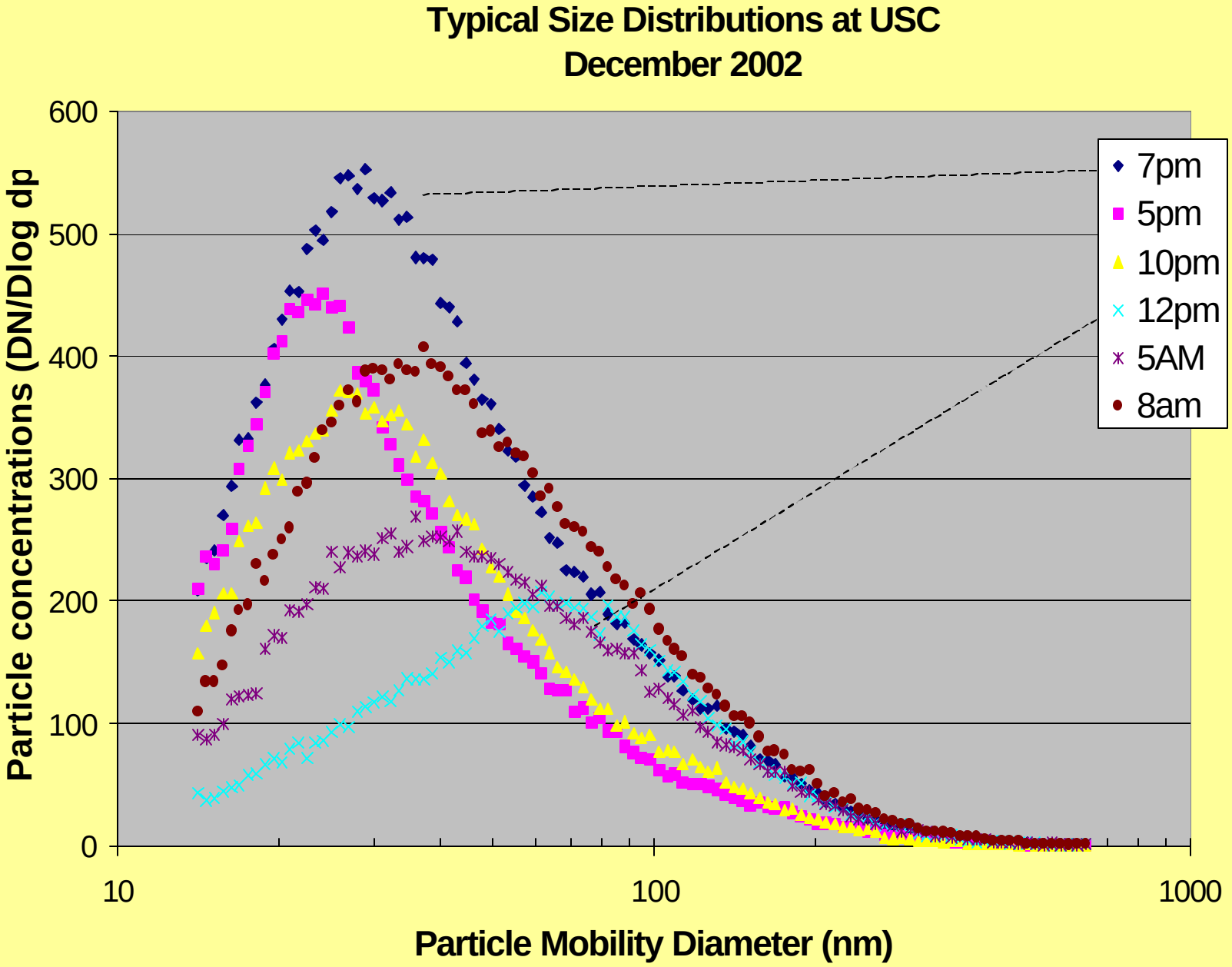


Total mass concentrations of PAH from October, 2001 to May, 2002 in Claremont, CA. Data obtained from monthly composites (Miguel et al., 2003).

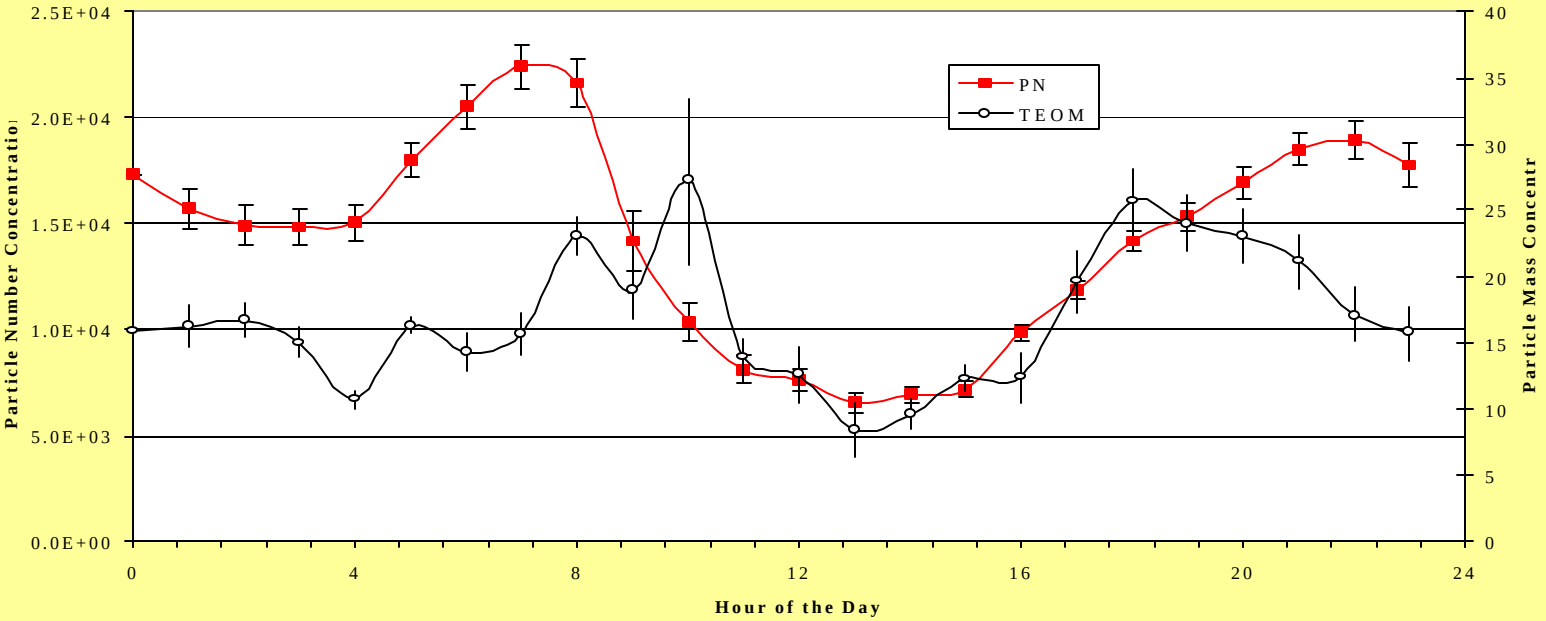
- coarse PAH increase with Temperature
- most PAH in accumulation mode except February 2002 (Santa Ana conditions)
- PM2.5 concentrations of PHE-FLT increase from winter > summer
- PM2.5 concentrations of BAA-IND decrease from winter > summer

Average EC, UF Mass and Total PM Number at USC
Nov. 2002 - February 2003

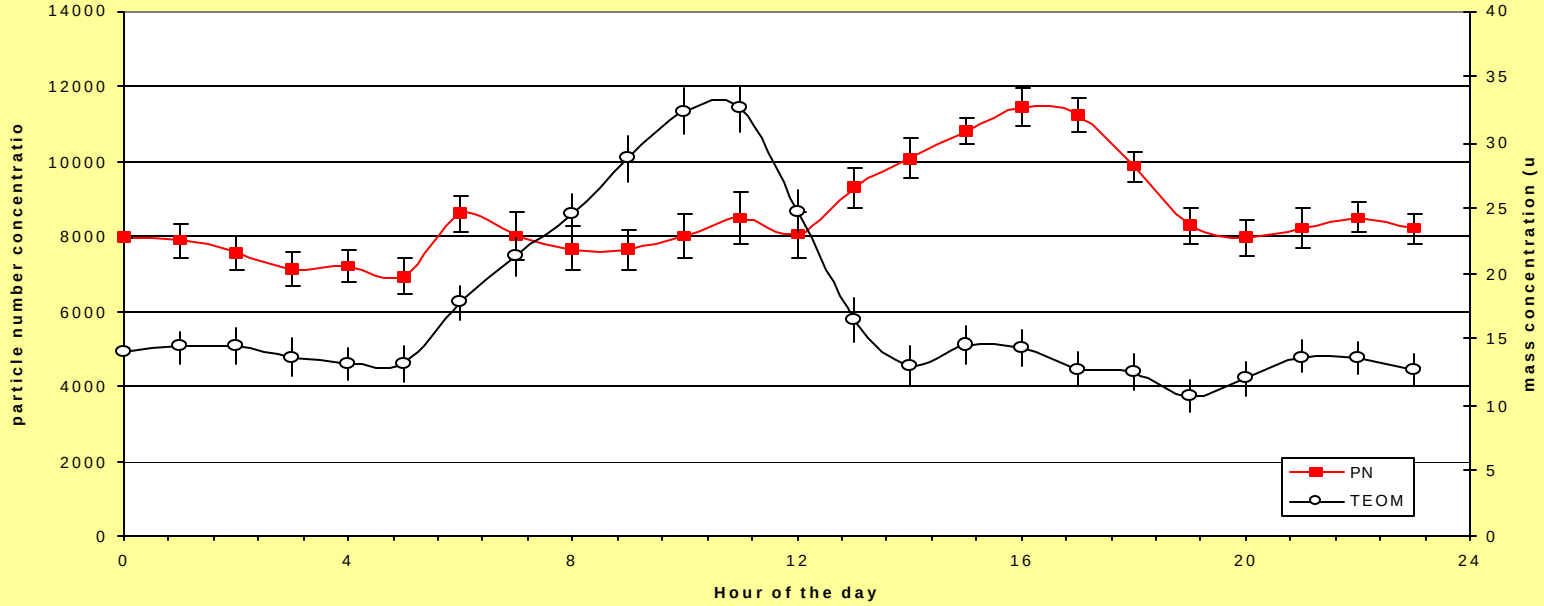



Typical Size Distributions at USC
December 2002
Particle concentrations (DN/Dlog dp
600
500
400
300
200
100
0
10
100
1000
Particle Mobility Diameter (nm)
7pm
5pm
10pm
12pm
5AM
8am

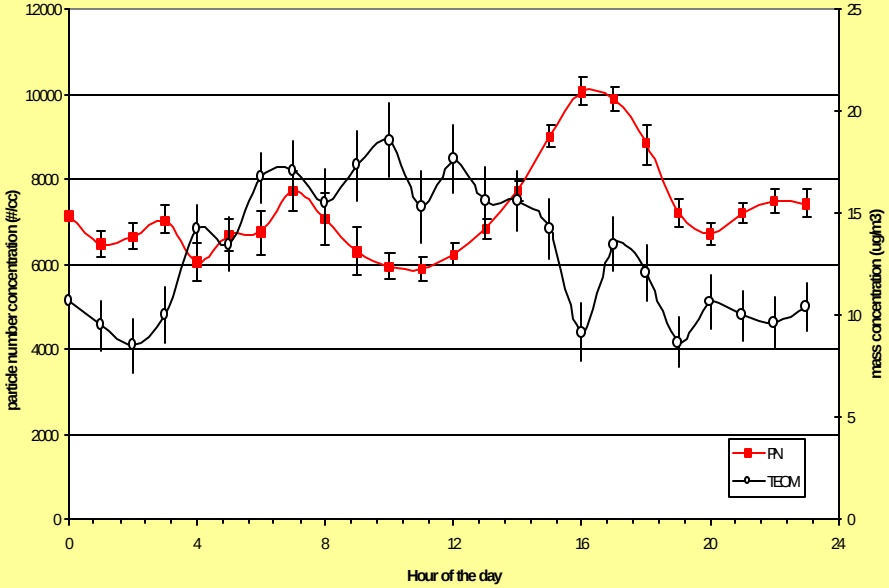
Hourly averaged PM2.5 and PN Concentrations at UCR- **January 2002**



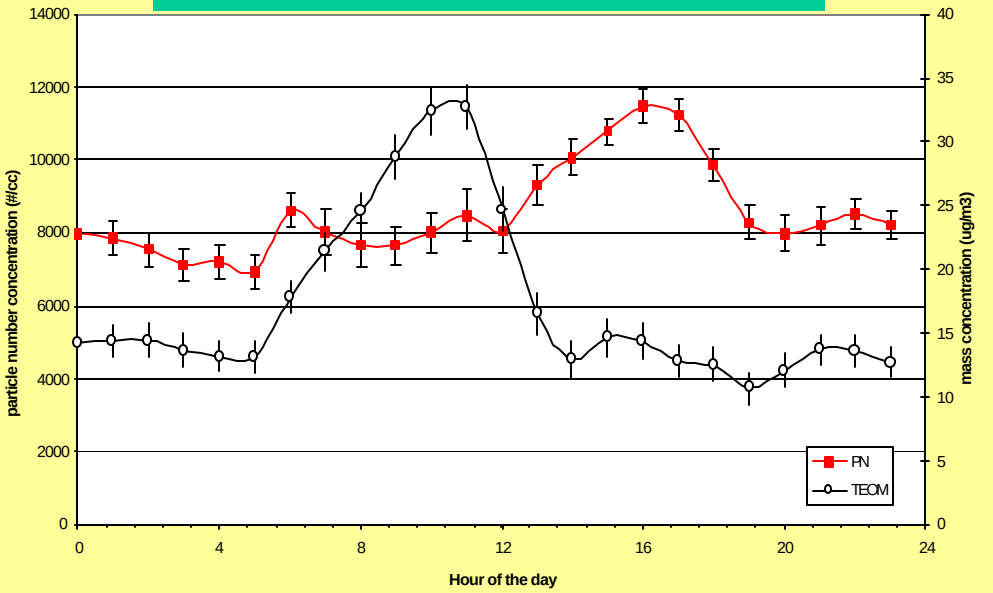
Hourly averaged PM2.5 and PN Concentrations at UCR- **July 2002**



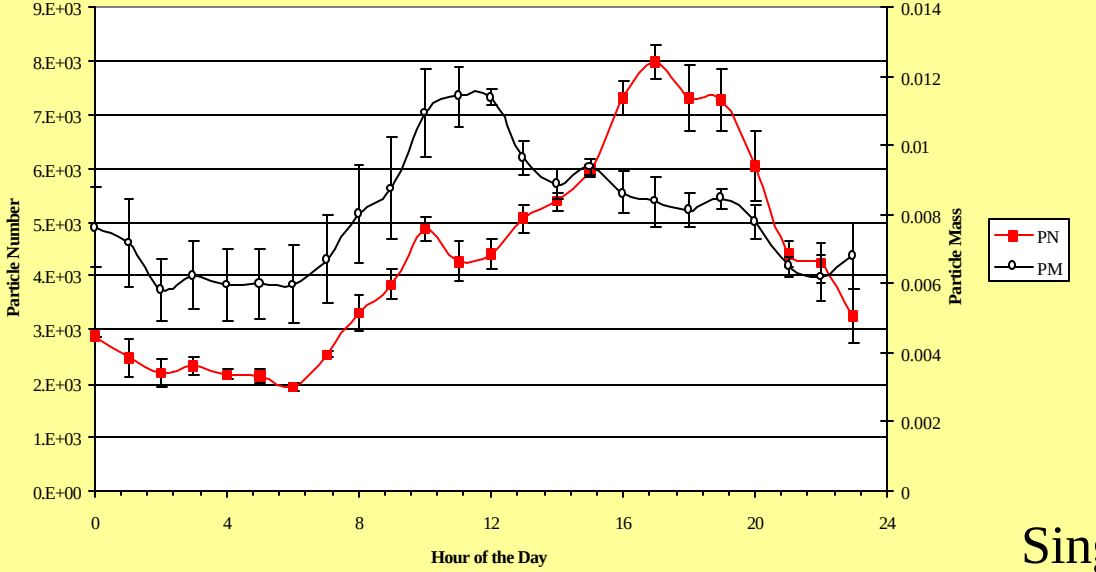
Claremont



Riverside



Glendora



Regional Nature of Ultrafine PM due to Secondary Formation

3 Receptor Sites

July 2002

Singh et al., Atmos. Environ, 2003

Advection of UFP from source to **receptor** sites is important in **warmer** period (Fine et al., 2002, AS&T)

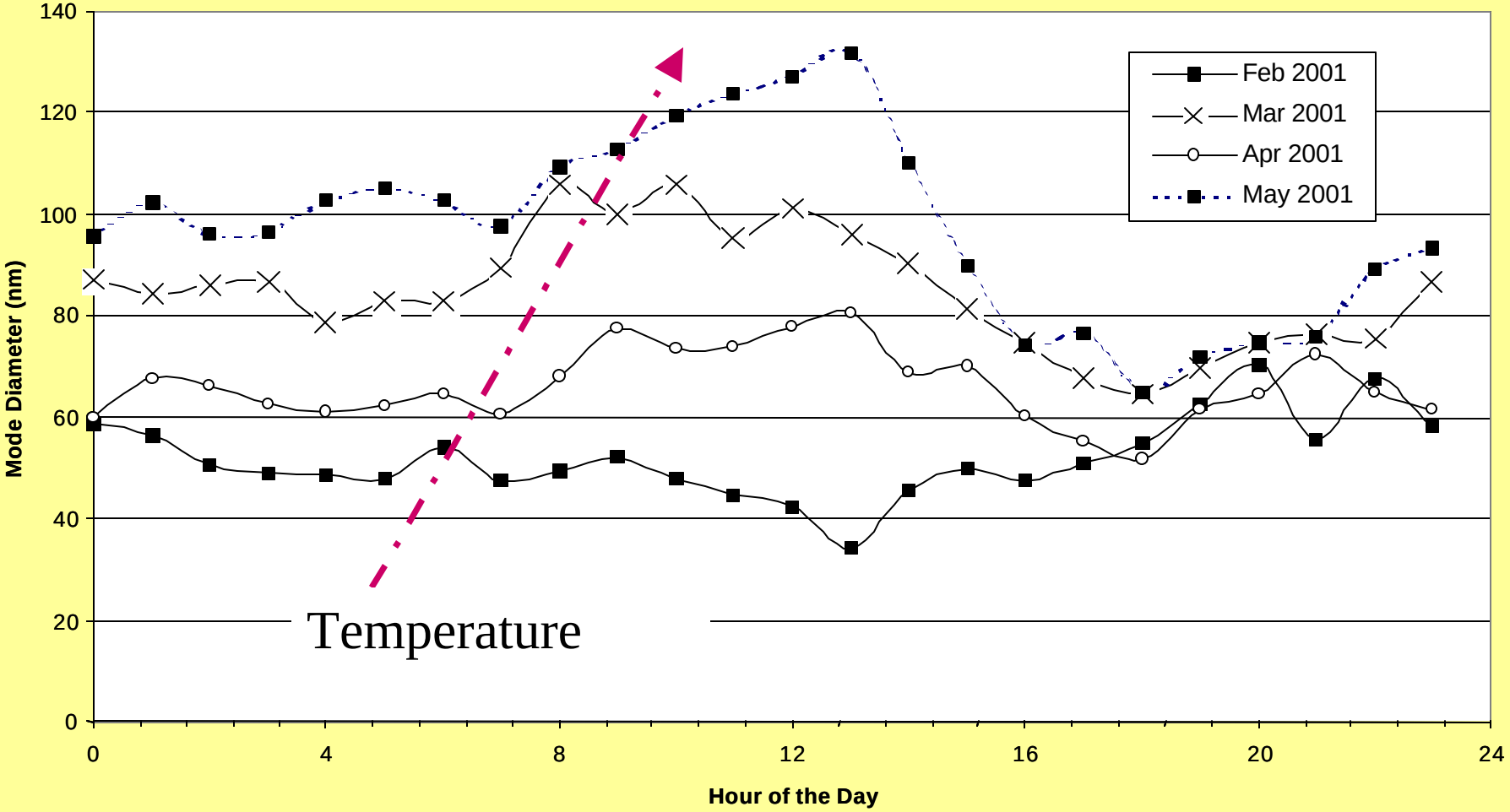


Figure 4. Monthly averaged mode diameter in Riverside, California

Effect of photochemistry on ultrafine PM production

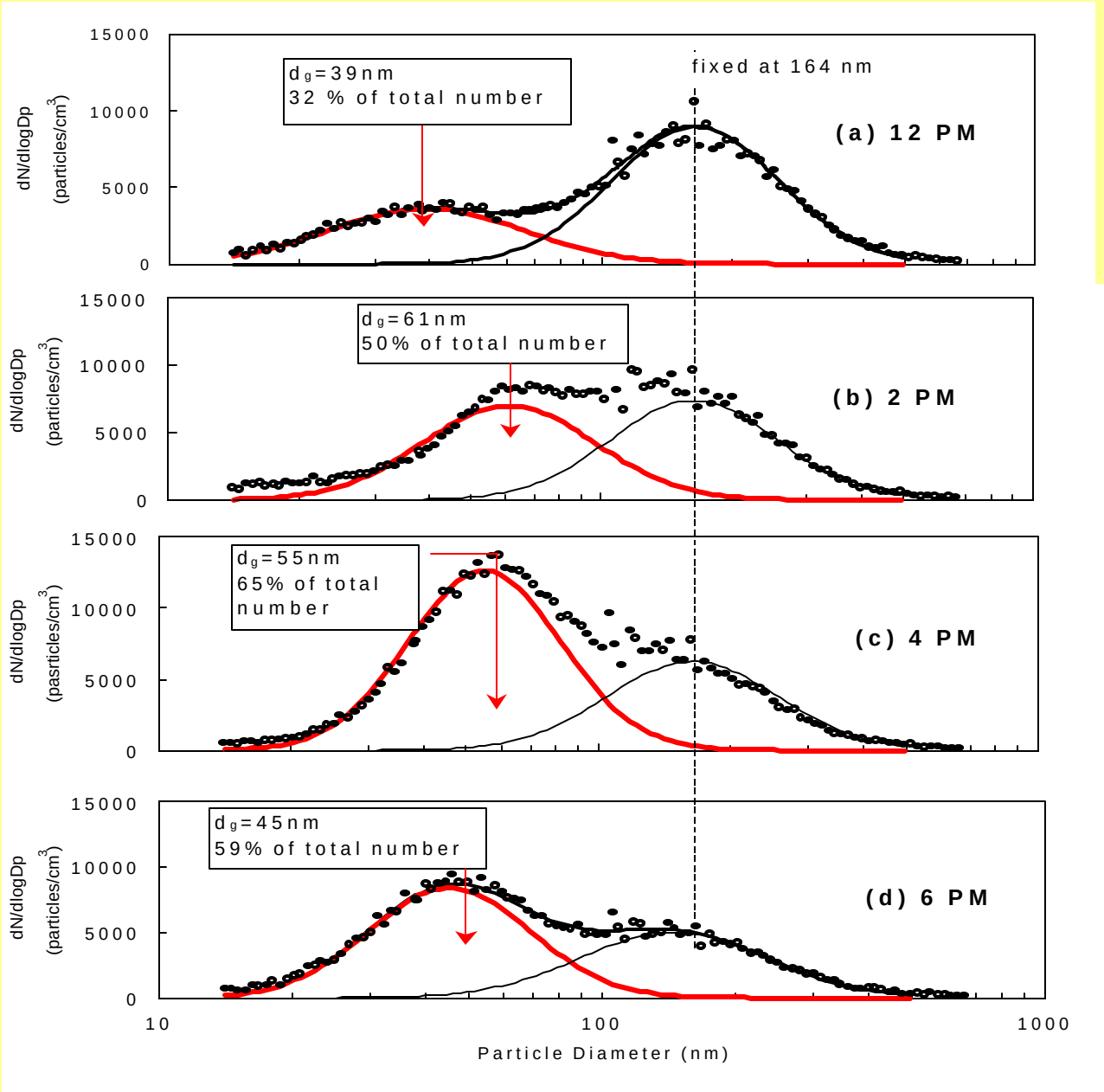


Figure 12. Simulated sub-modes of particles in the afternoon: Riverside, 5/16/2001.

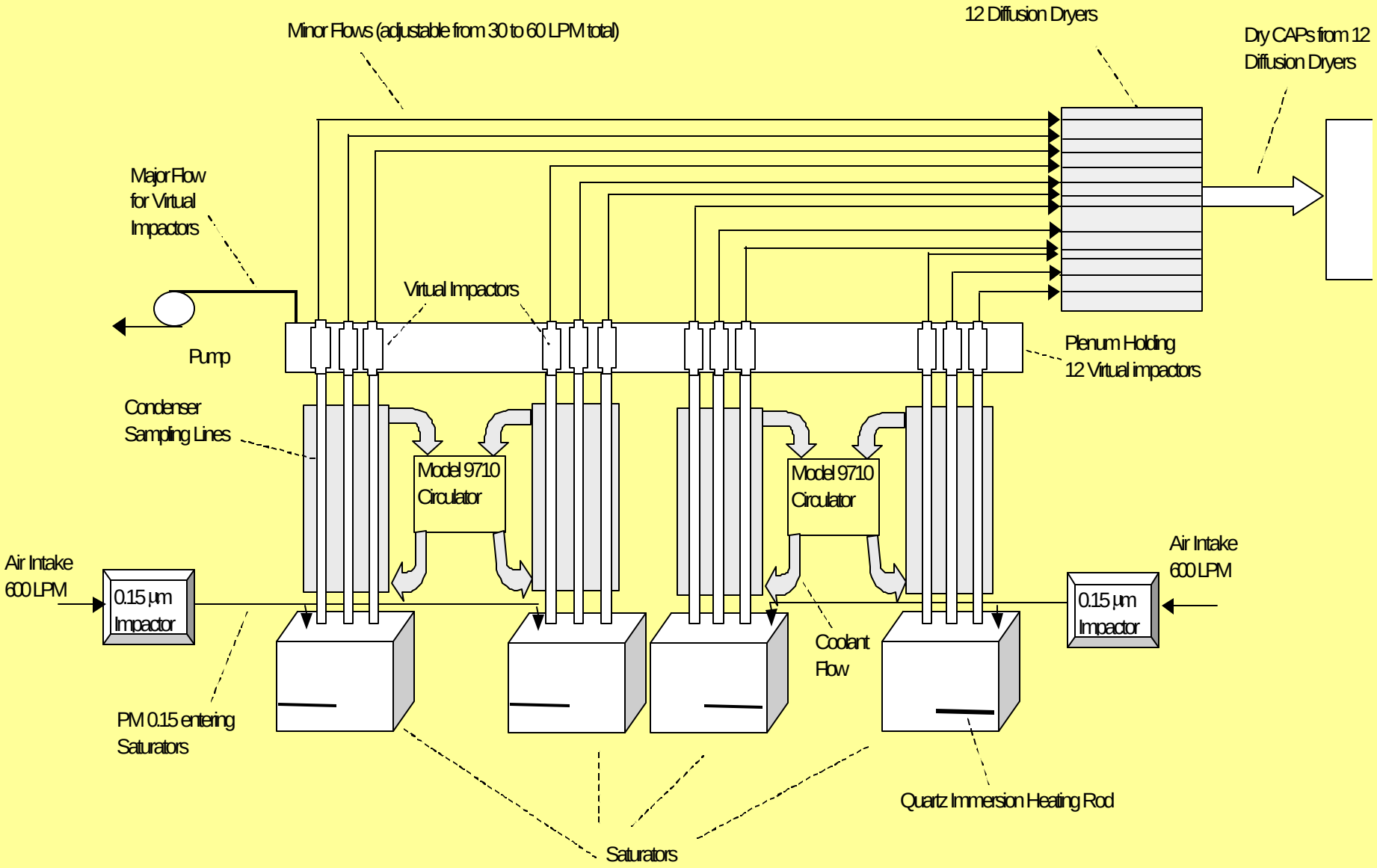


Figure 1. Schematic of the Ultrafine Particle Concentrator (UFPC) for Human Exposure

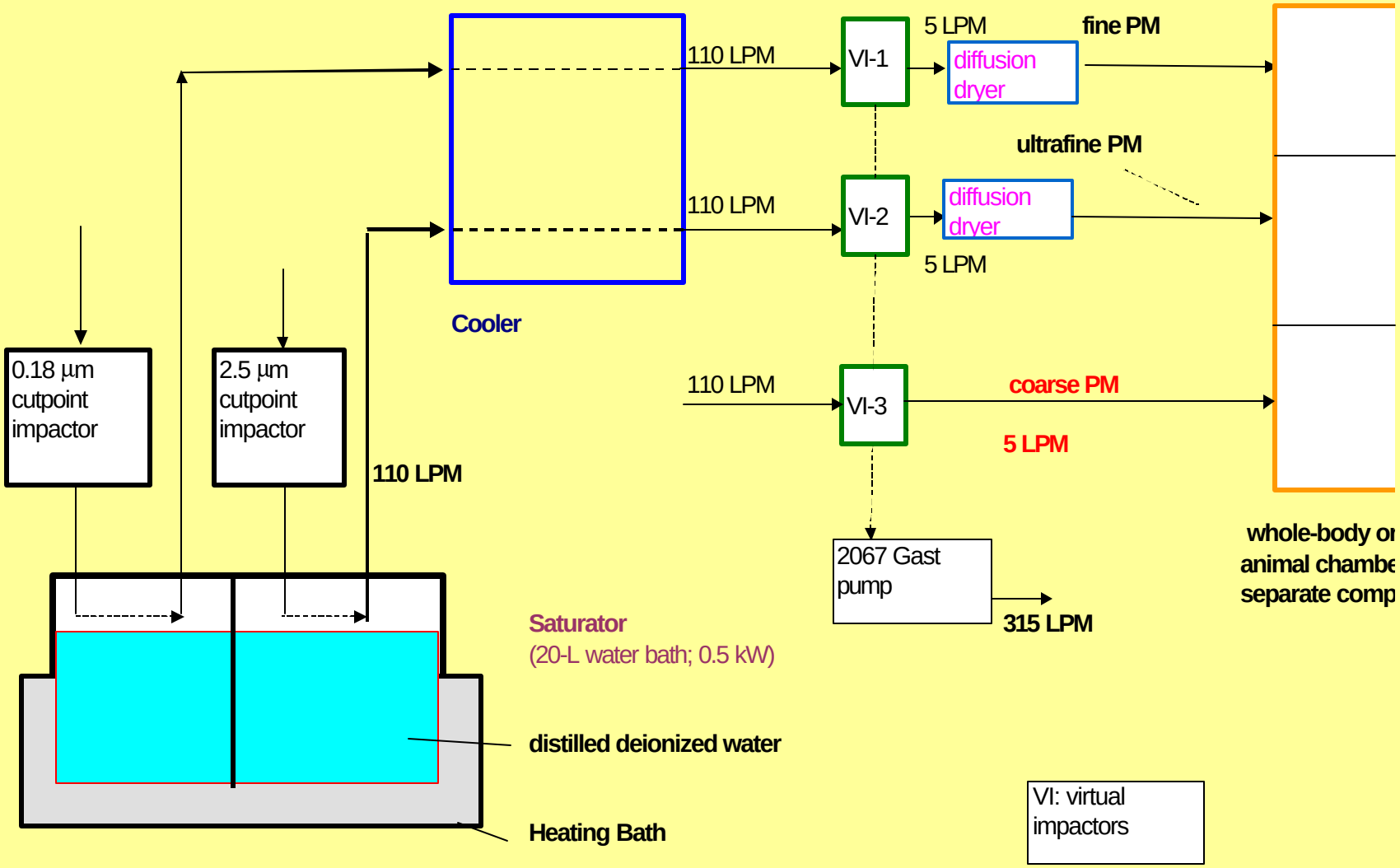
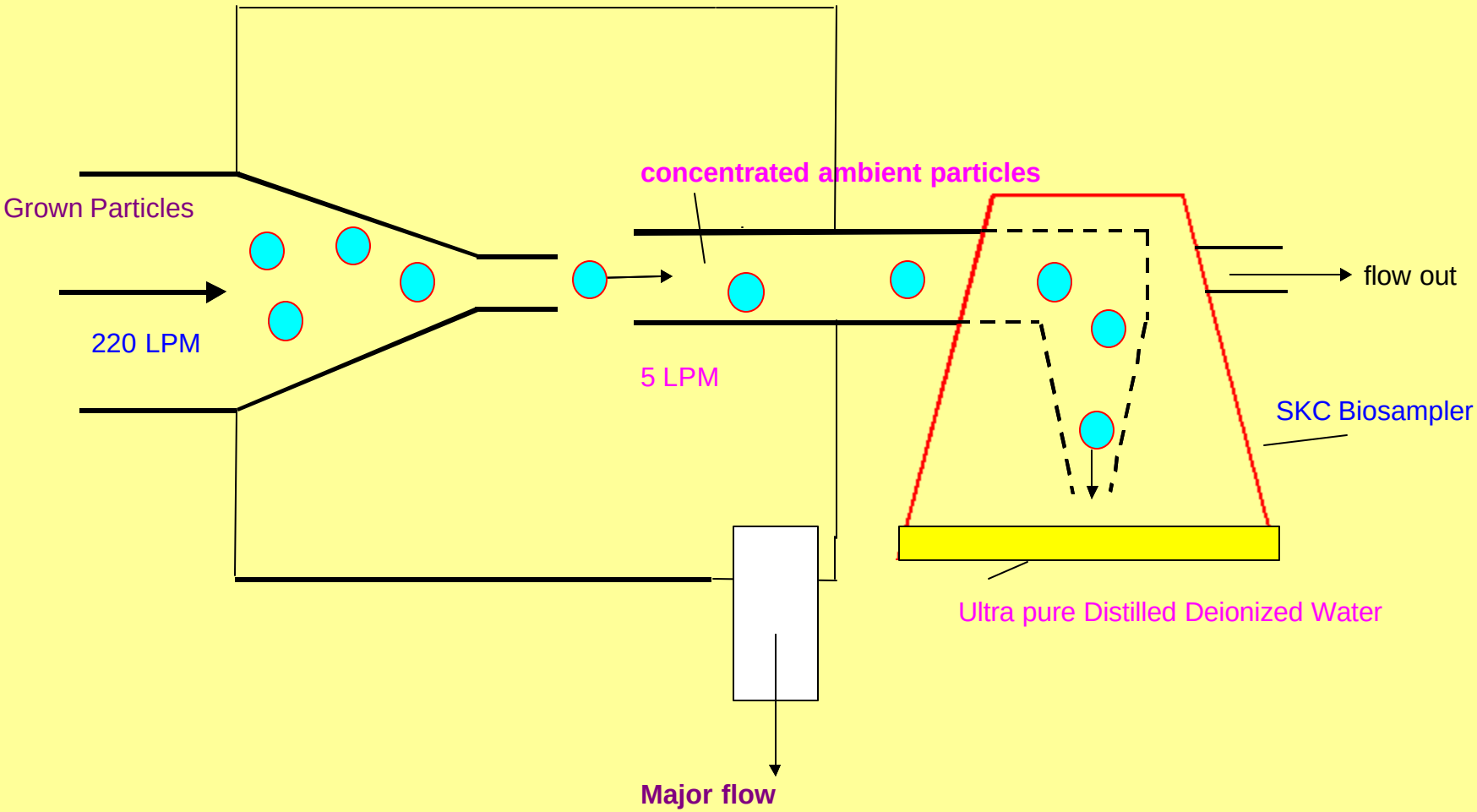


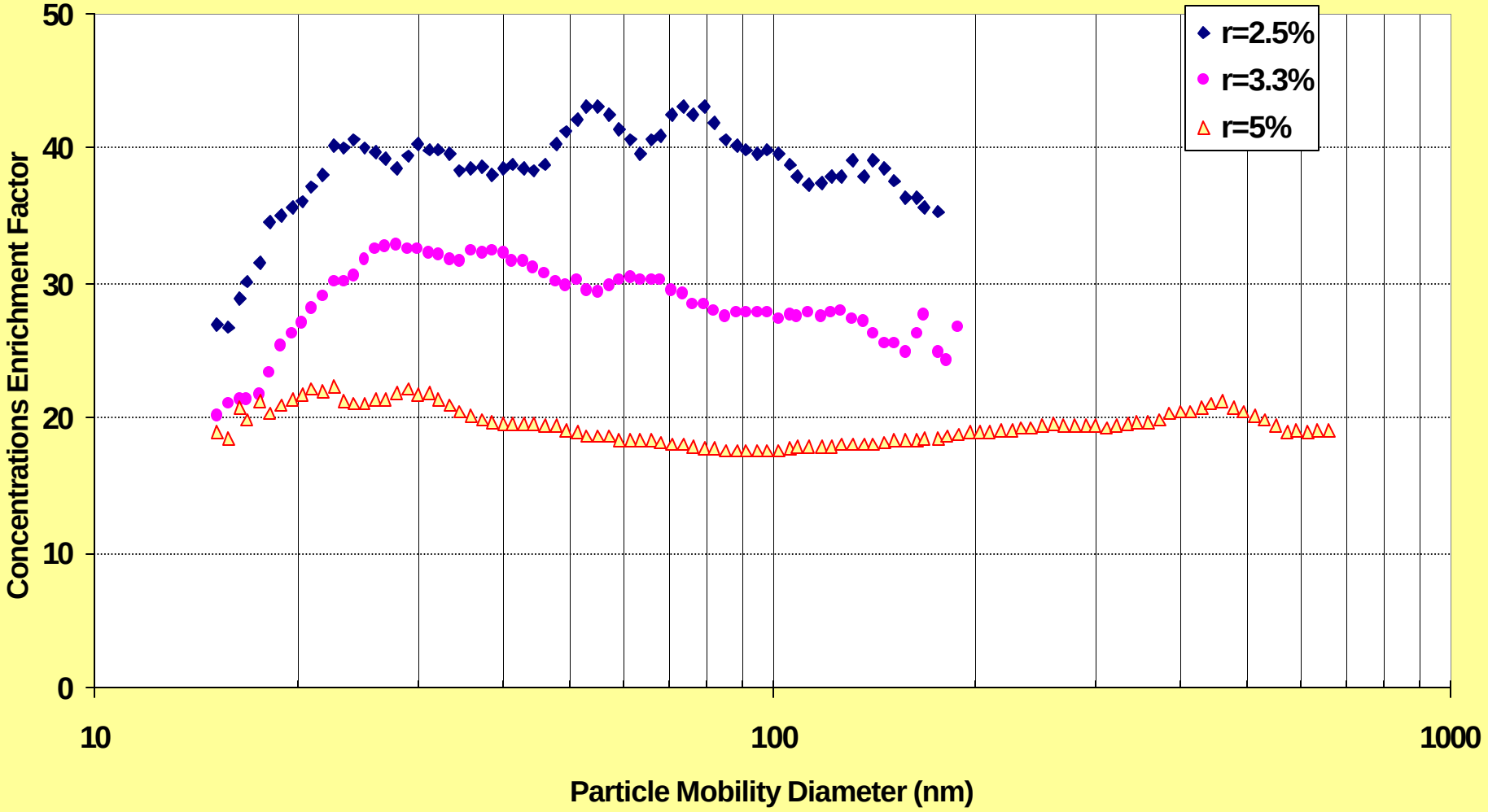
Figure 1a. Versatile Aerosol Concentration Enrichment System (VACES) for concurrent in vivo studies to coarse, fine and ultrafine PM

Kim et al., J Aerosol Sci, 2001



Particle Concentrator for Collection of Particles for in vitro tests

Concentration Enrichment as a Function of Particle Diameter for Three Minor to Total Flow Ratios (r). Intake Flow = 1200 LPM



Misra et al., AS&T, 2003

Preservation of Chemical Composition of Ambient PM After Concentration based on Single Particle Analysis (Zhao et al., AS&T, 2003)

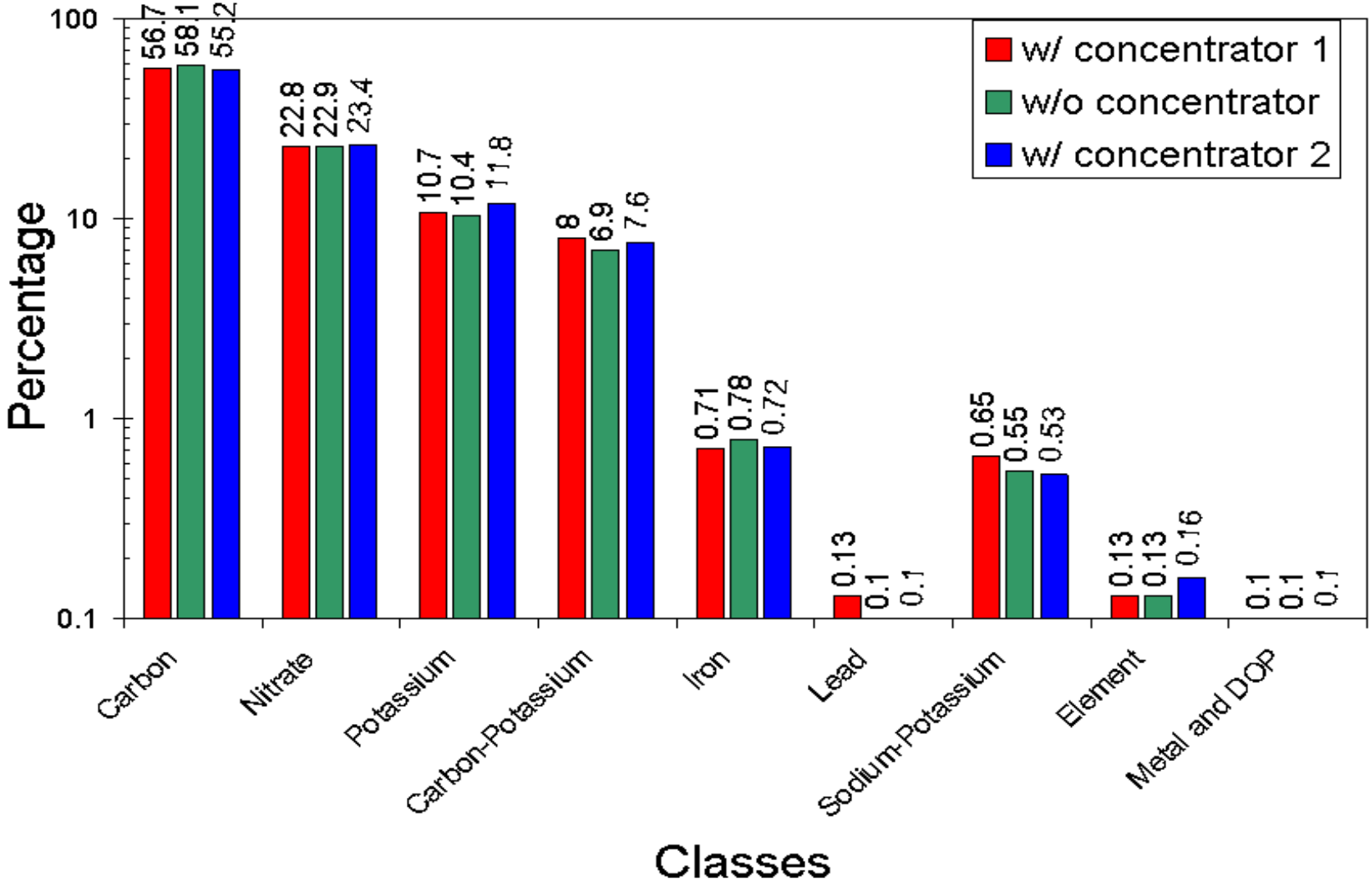
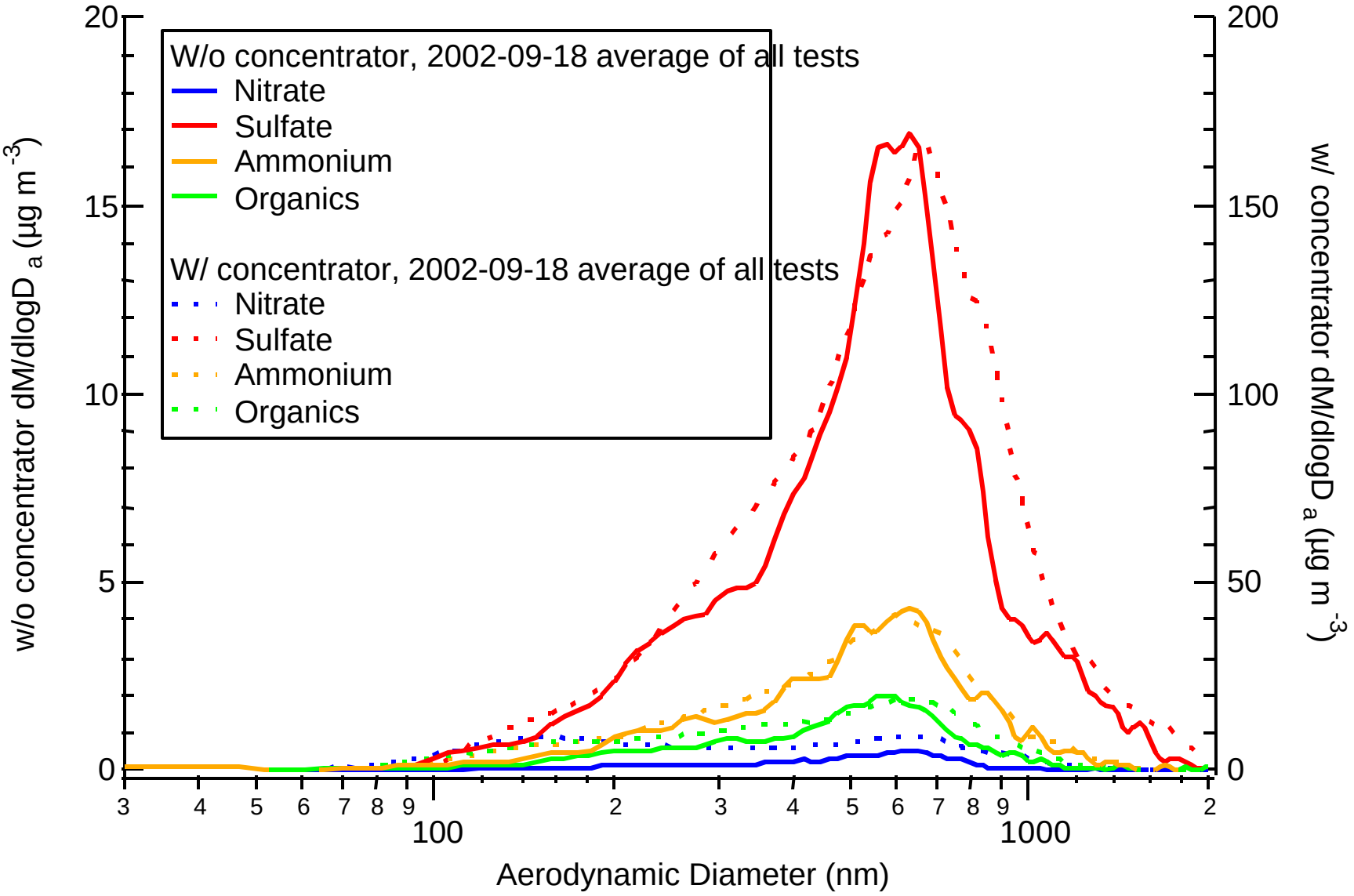
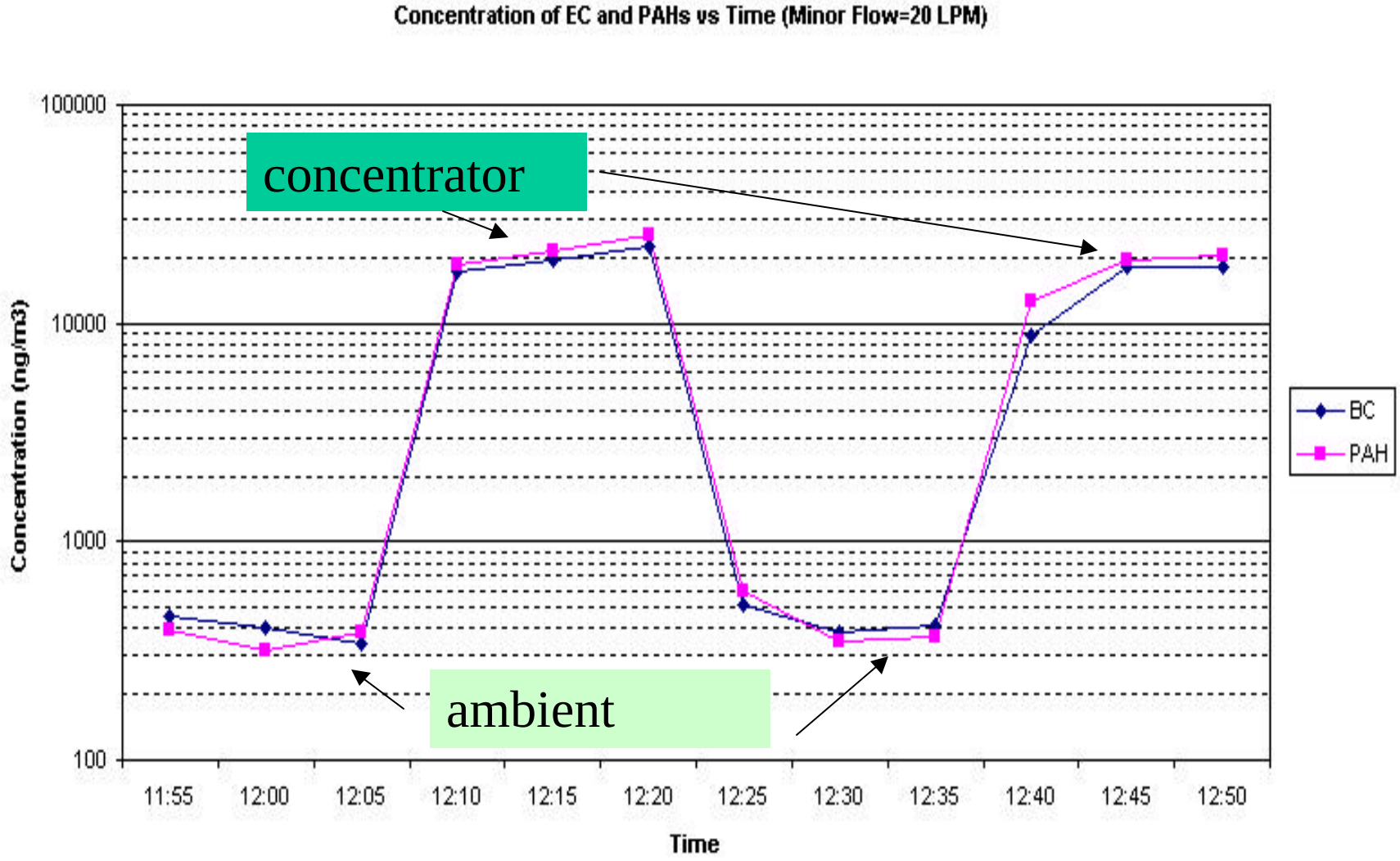


Figure 3. Stanier et al (2002) using the Aerodyne Spectrometer





Misra et al., AS&T, 2003

Max. Concentration Enrichment of 50 in a single-stage virtual impactor

Use of the F+UF Concentrators to Increase the Signal of Other Instruments :

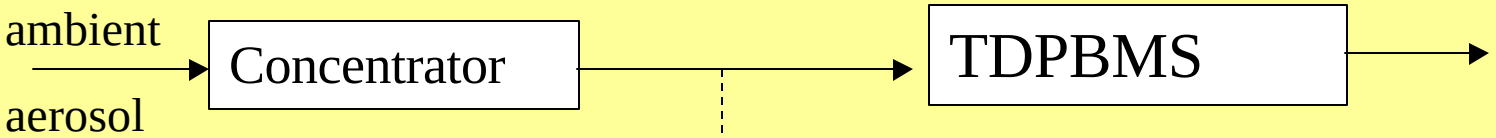
- NanoMOUDI (Geller et al., AS&T, 2002)

- Pittsburgh Supersite Nucleation Experiments (Steiner et al., 2002)

- Wexler Rapid Single-Particle Mass Spectrometer (RSMS-3)

- P. Zieman (UCR) Thermal Desorption Mass Spectrometer

Thermal Desorption Mass Spectrometer tests with Concentrators



Concentr.
Factor x 50

Goals :

- rapid organic speciation analysis of PM in accumulation and ultrafine modes

- identification of source tracers

- in source (USC) and receptor (UC Riverside) sites

- during winter and summer periods

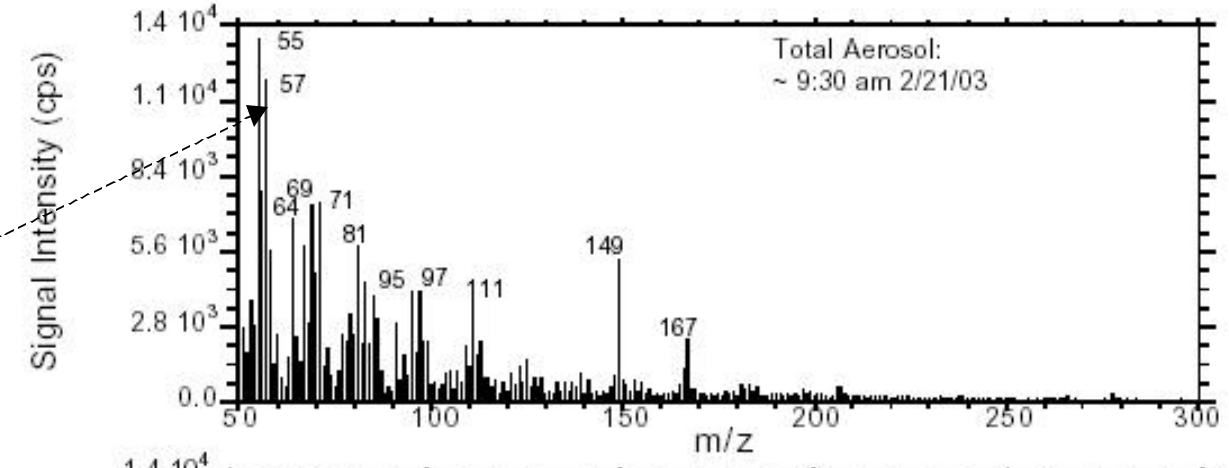
UCR samples in February 2003

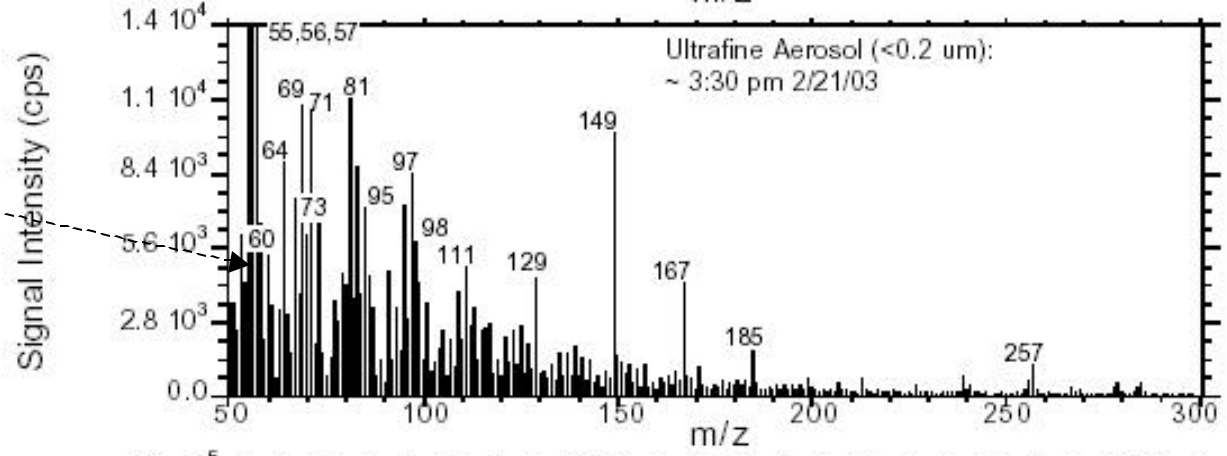
m/z: 55, 57, 69, 71, 95,97

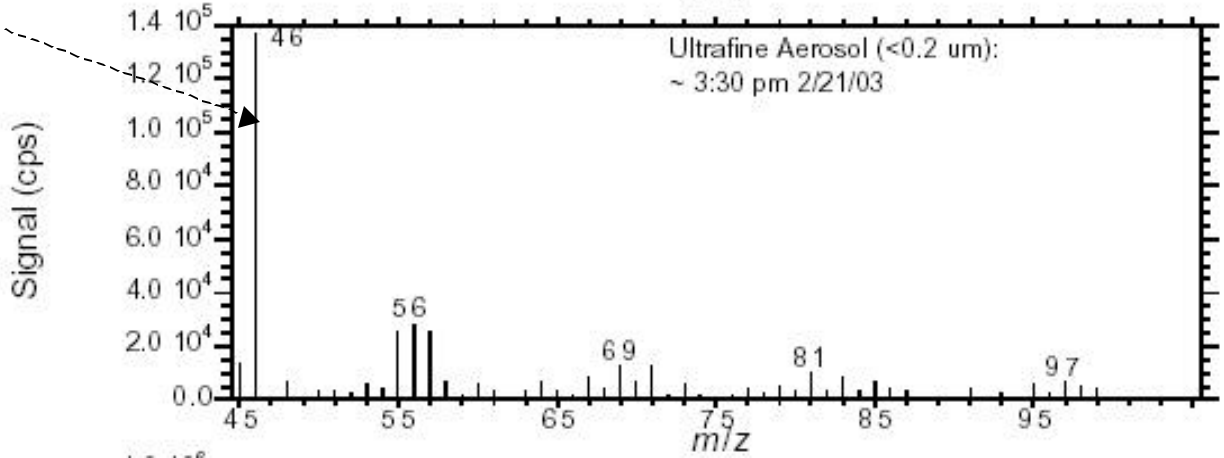
Hydrocarbons

m/z: 60, 73:
organic acids

m/z 30, 46:
ammonium nitrate

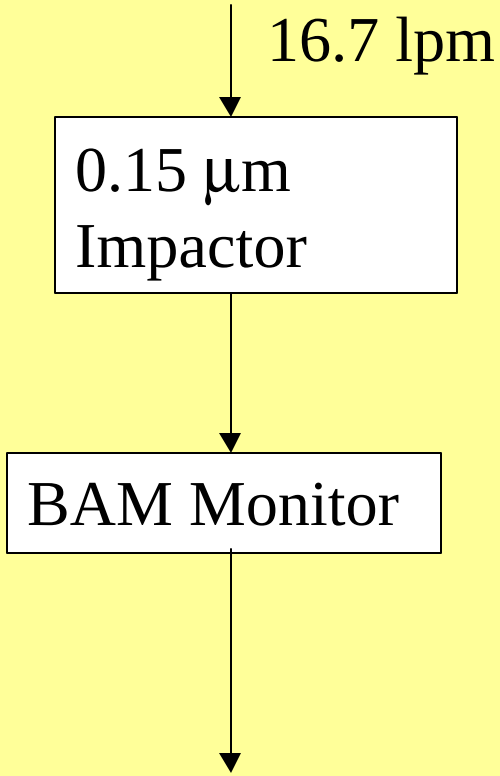






Near Continuous Ultrafine Mass Concentration Monitor

(Chakrabarti et al., *Aerosol Science and Technology*, 2002



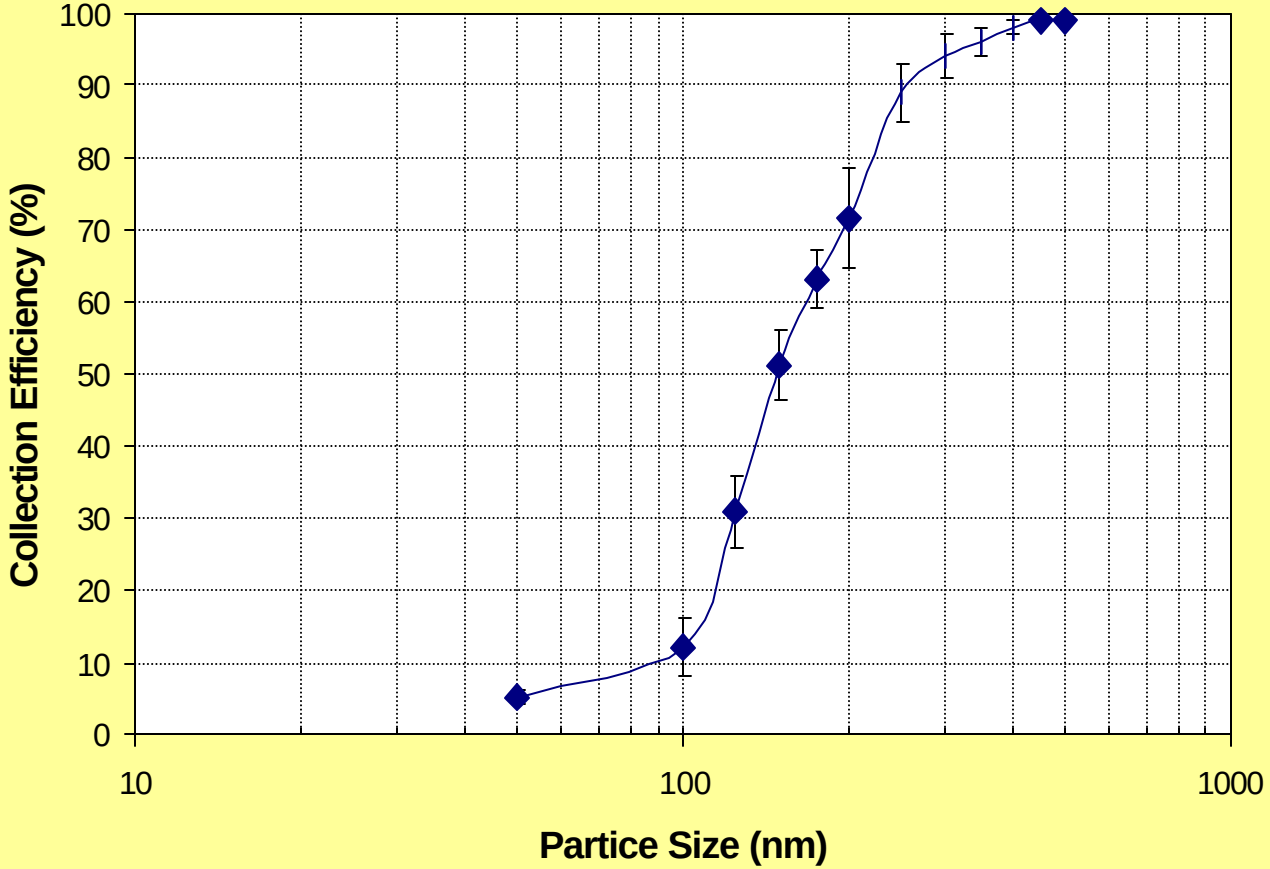
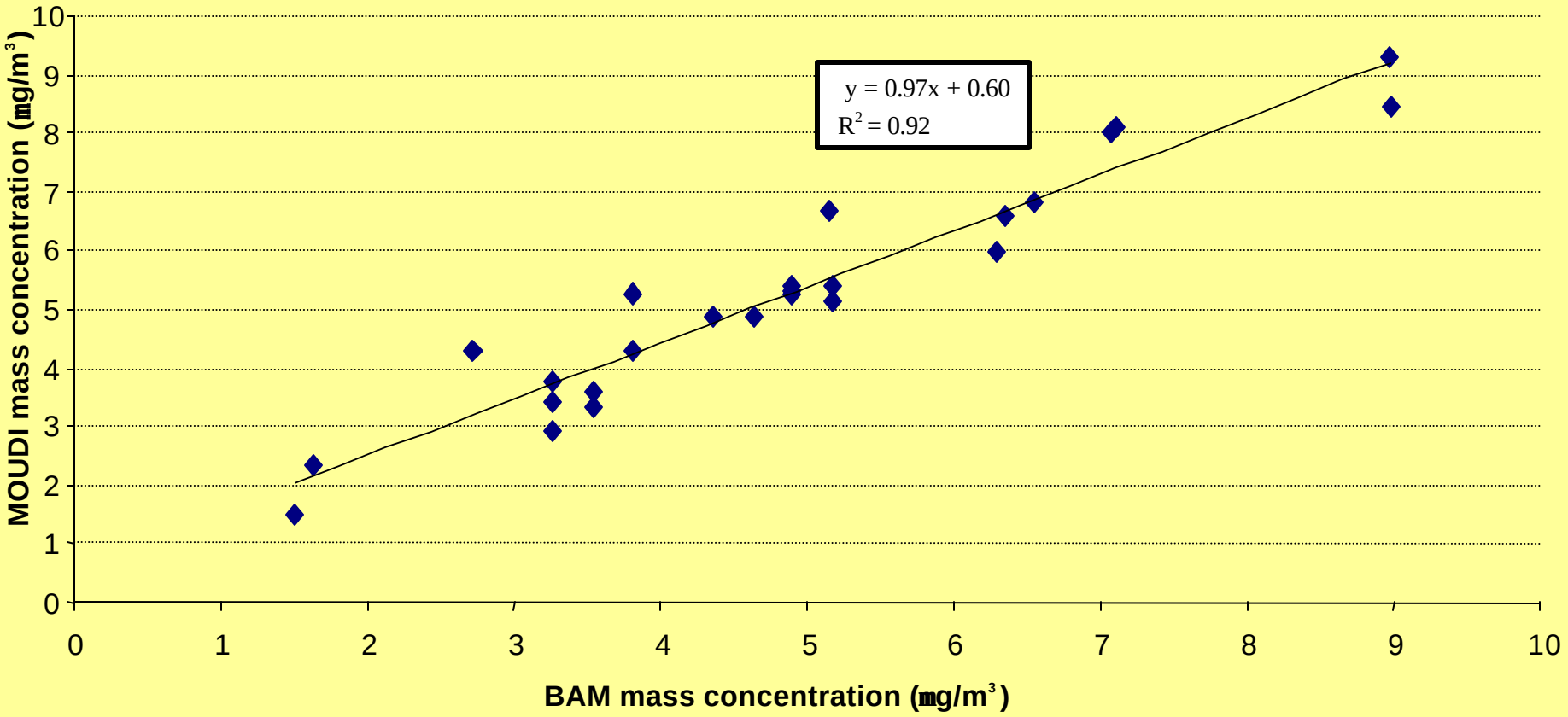
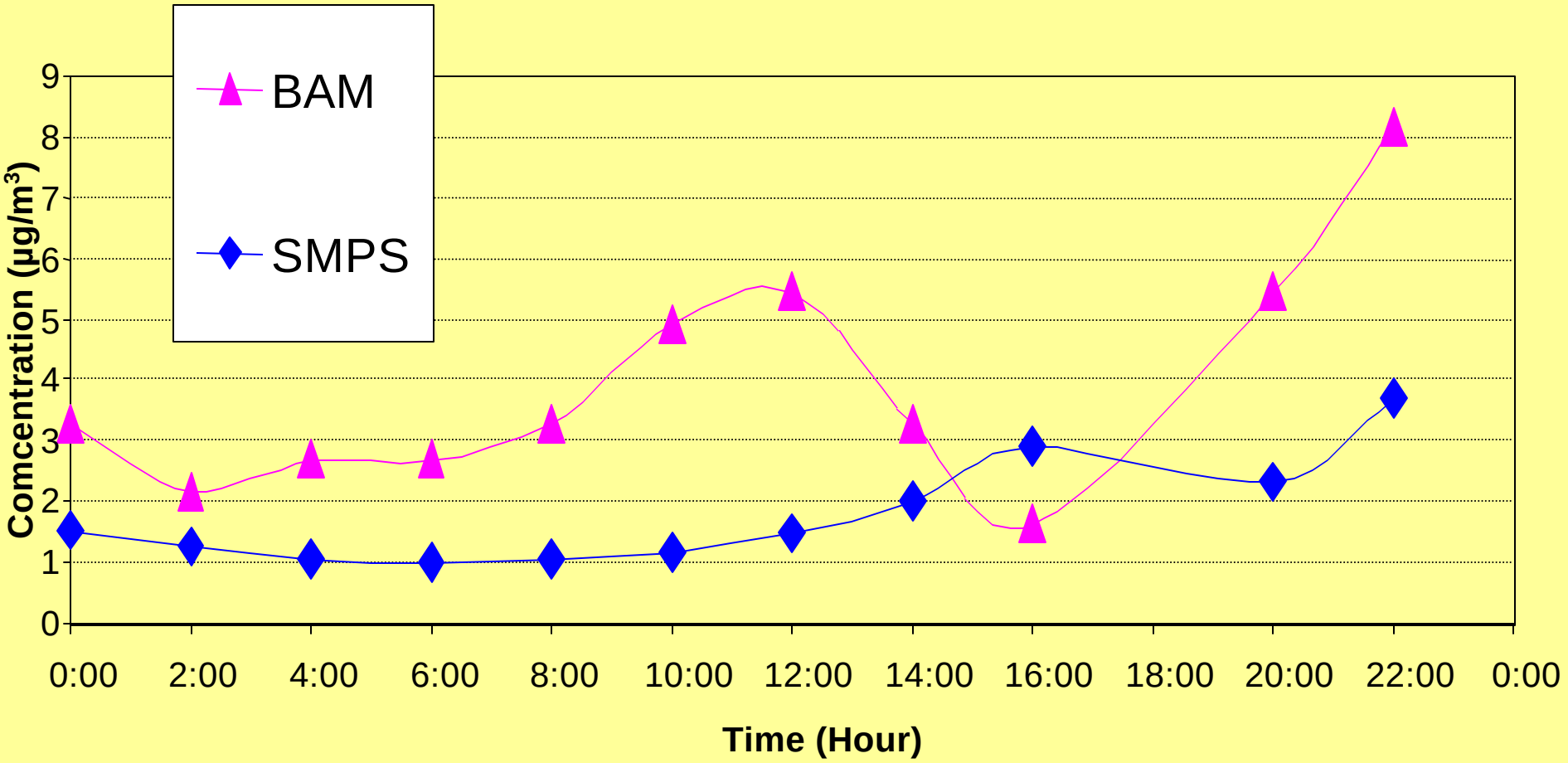


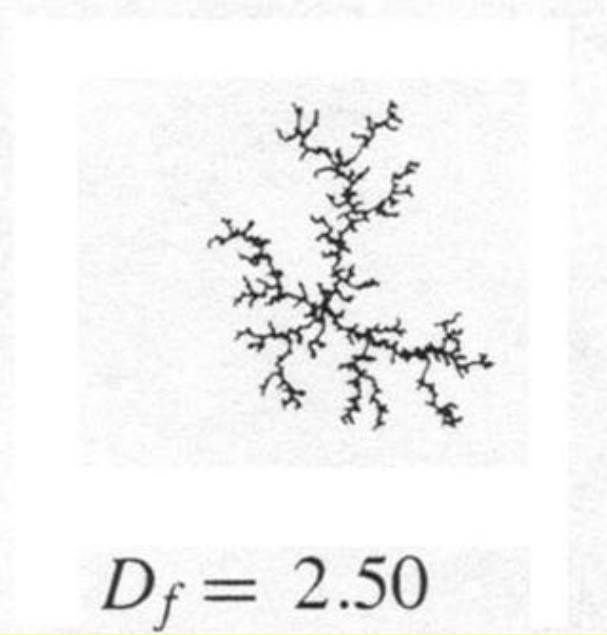
Figure 2. BAM vs. MOUDI Ultrafine PM concentration

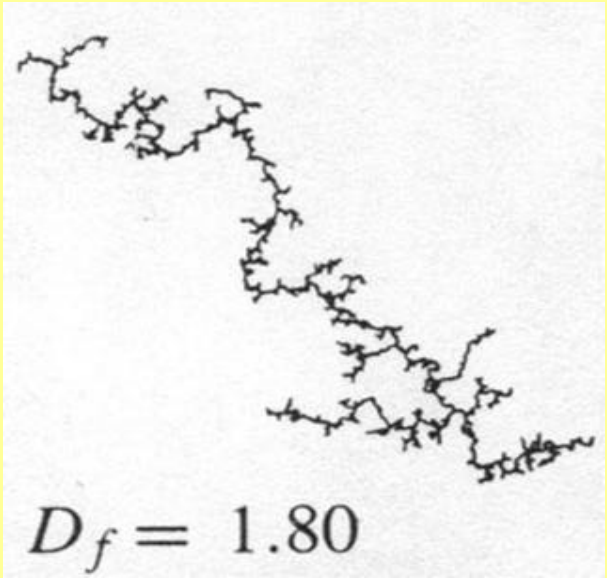


The SMPS cannot measure ultrafine PM **mass** concentrations.
Events of July 4, 2002 (fractal-like PM produced by combustion)

Figure 4c. BAM and SMPS Ultrafine Mass Concentrations on July 4, 2002

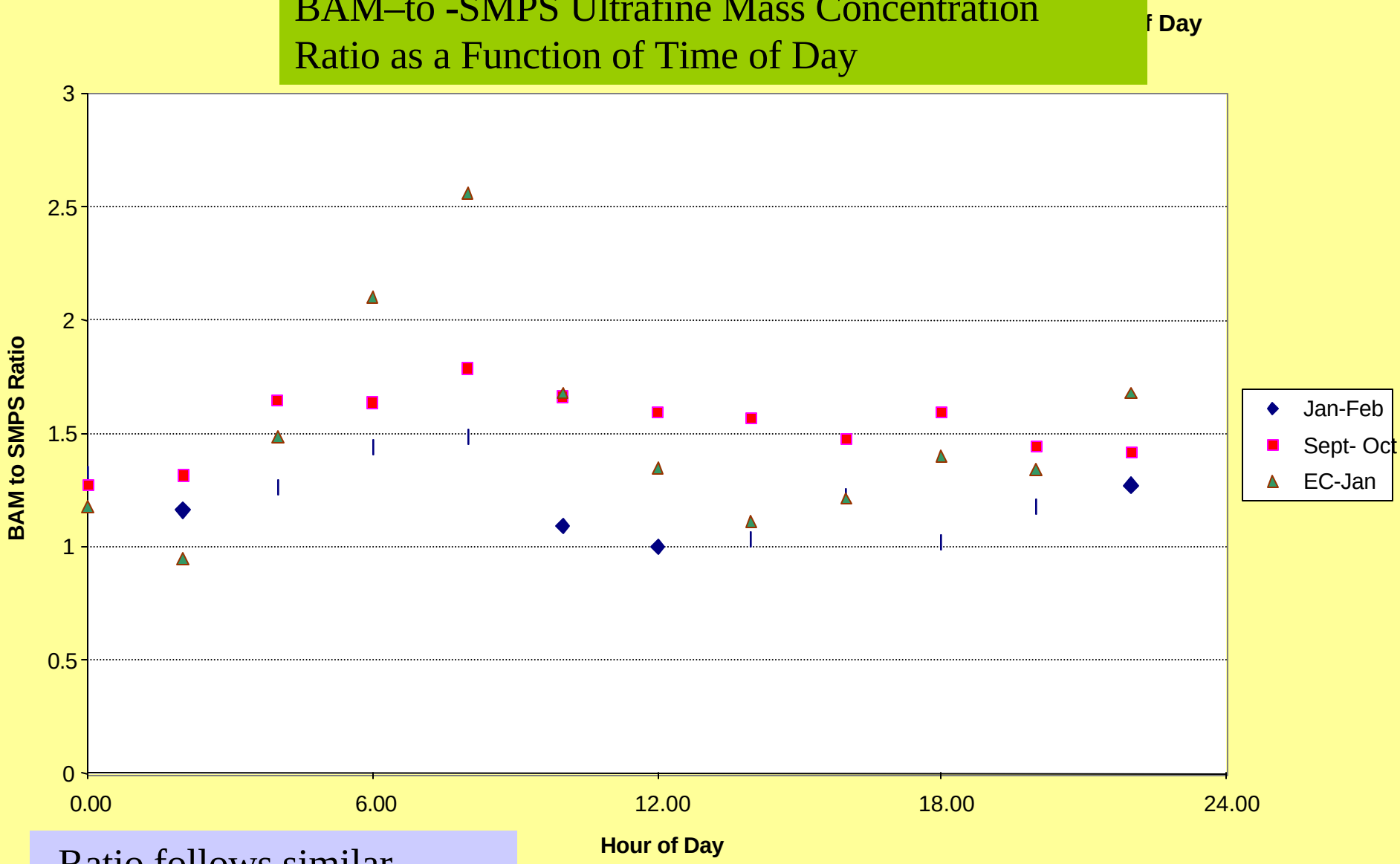






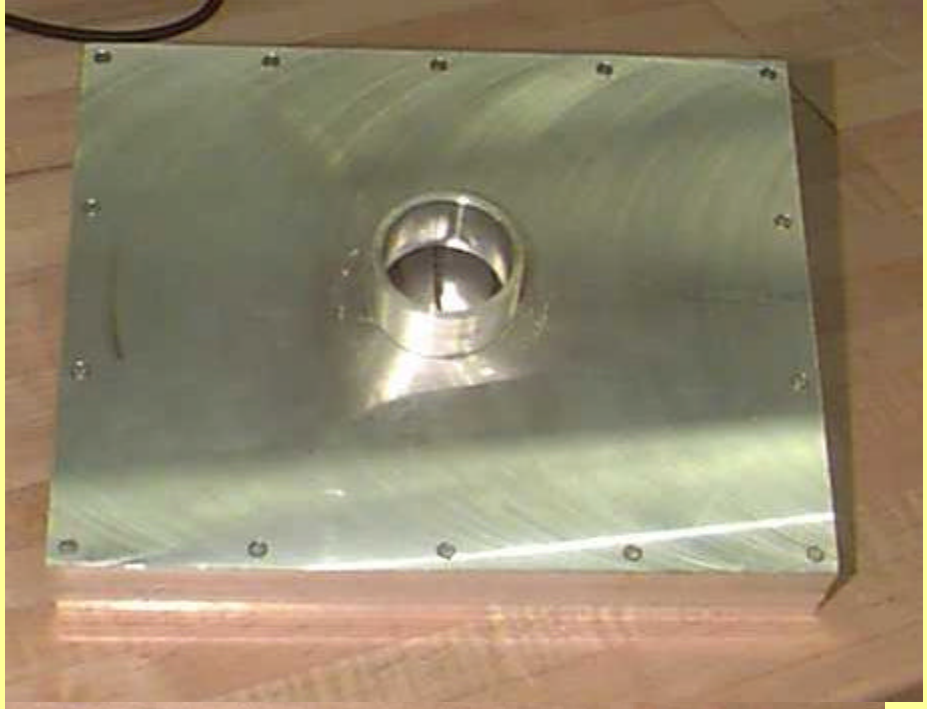
Fractal-like combustion particles have a high surface area, hence electrical mobility, but a low density

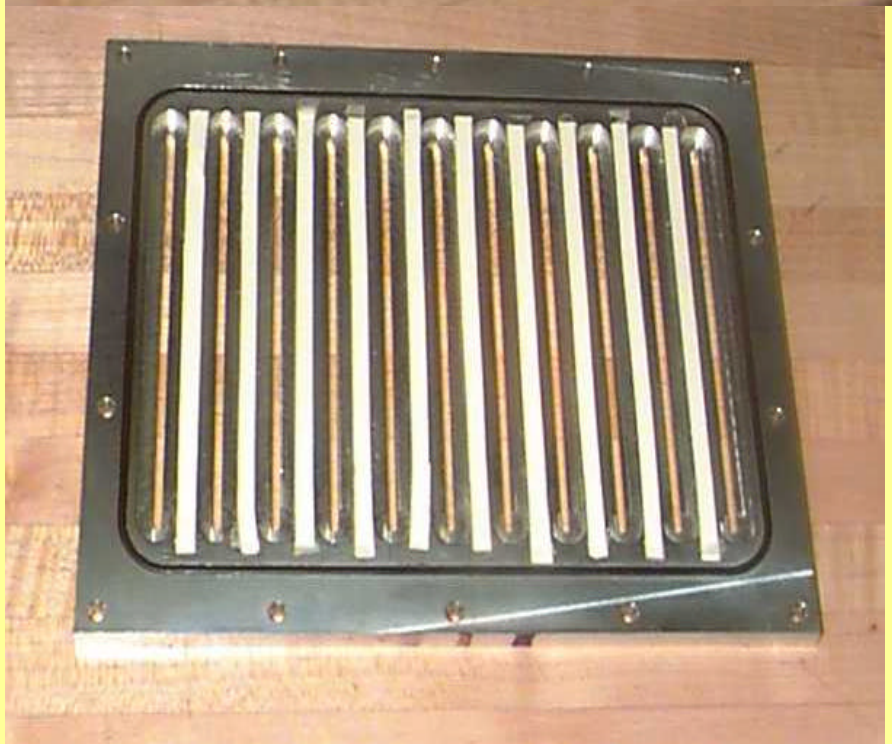
BAM–to -SMPS Ultrafine Mass Concentration Ratio as a Function of Time of Day



-Ratio follows similar diurnal trend with EC

-Evidence for increased fractal content?

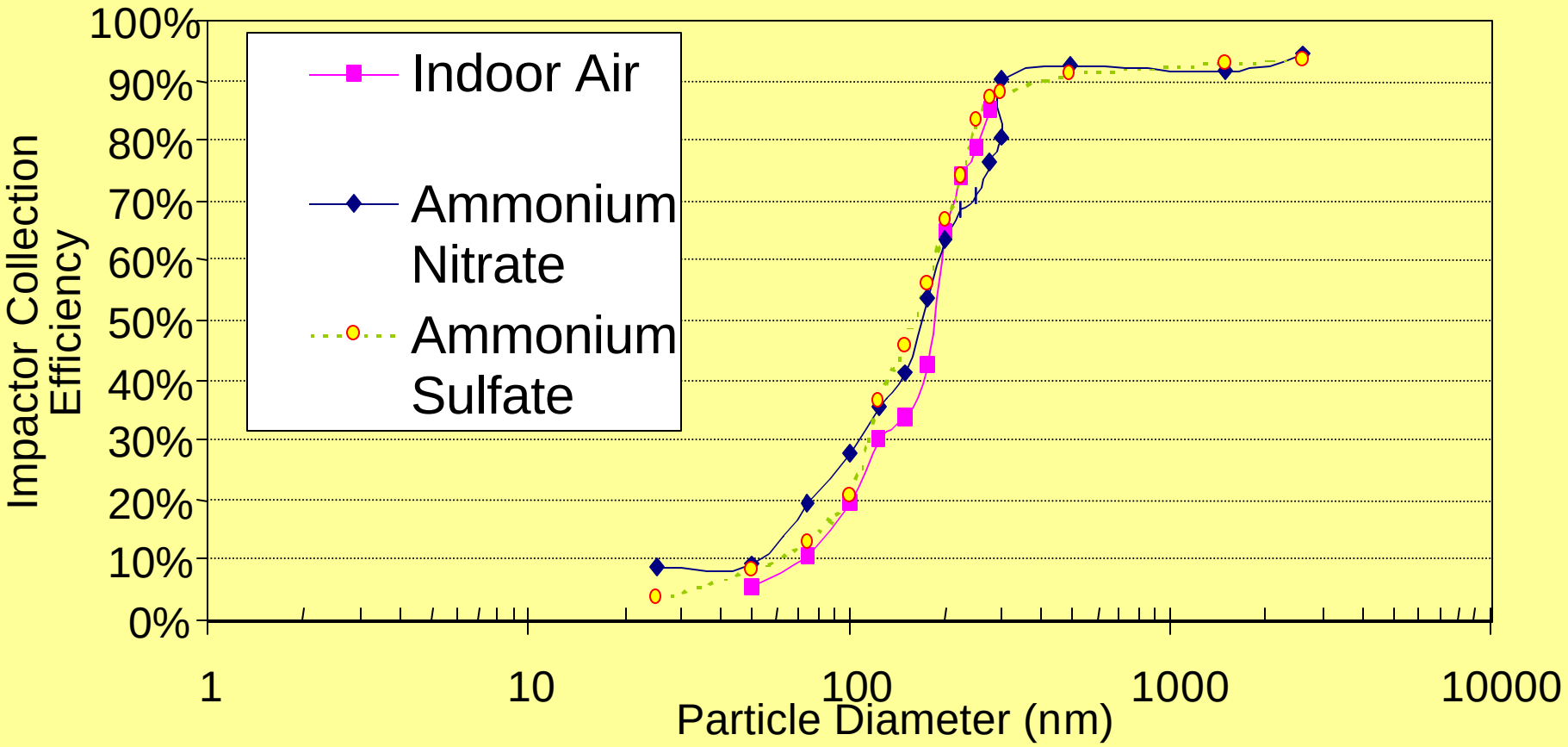




High-Volume, Very Low Pressure Drop Impactor for Separation of Coarse-Fine-Ultrafine PM

Misra et al *Journal of Aerosol Science*, 33(5): 735-752, 2002

Figure 4. Evaluation of the USC High Volume Low Cutpoint Impactor with an Uncoated Quartz Substrate and Different Types of Test Aerosols



Use of Source Tracers in Exposure and Toxicology Research

Using individual organic compounds as tracers of primary emissions sources, how do source contributions vary from:

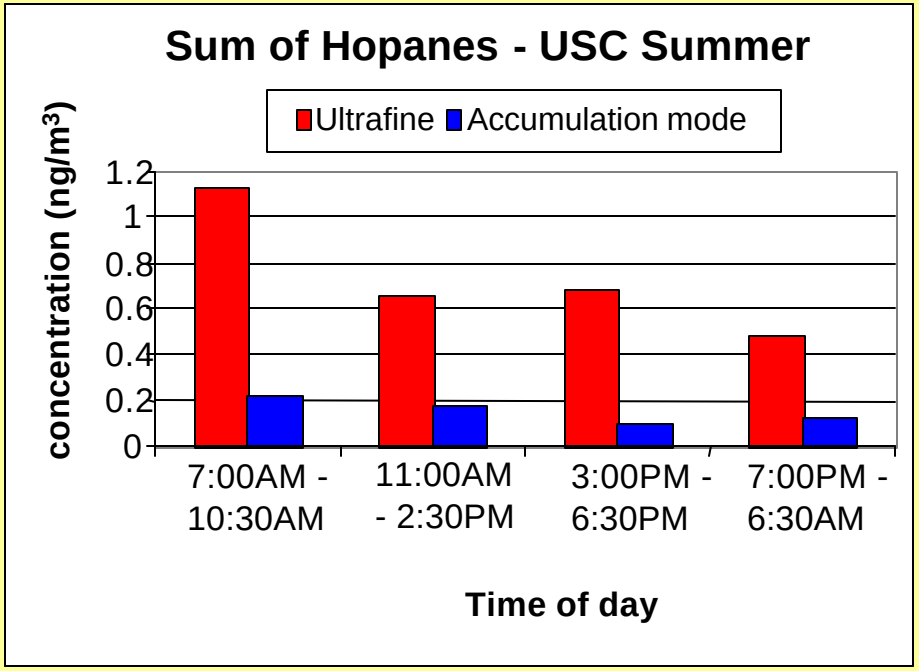
- site to site,
- over the course of the day
- between size fractions?

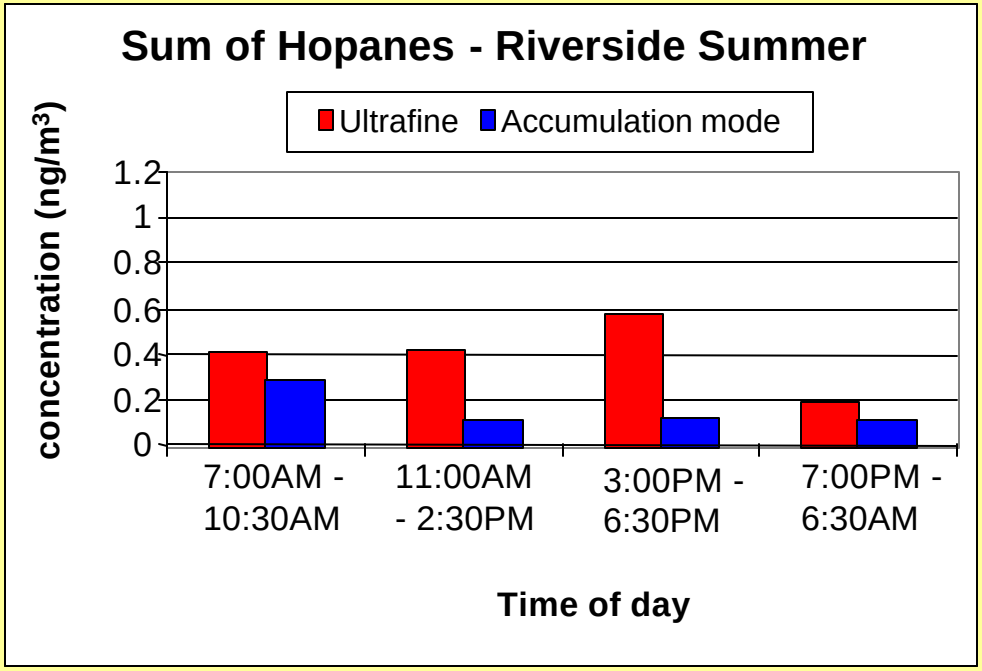
Size Distribution and Concentrations of :

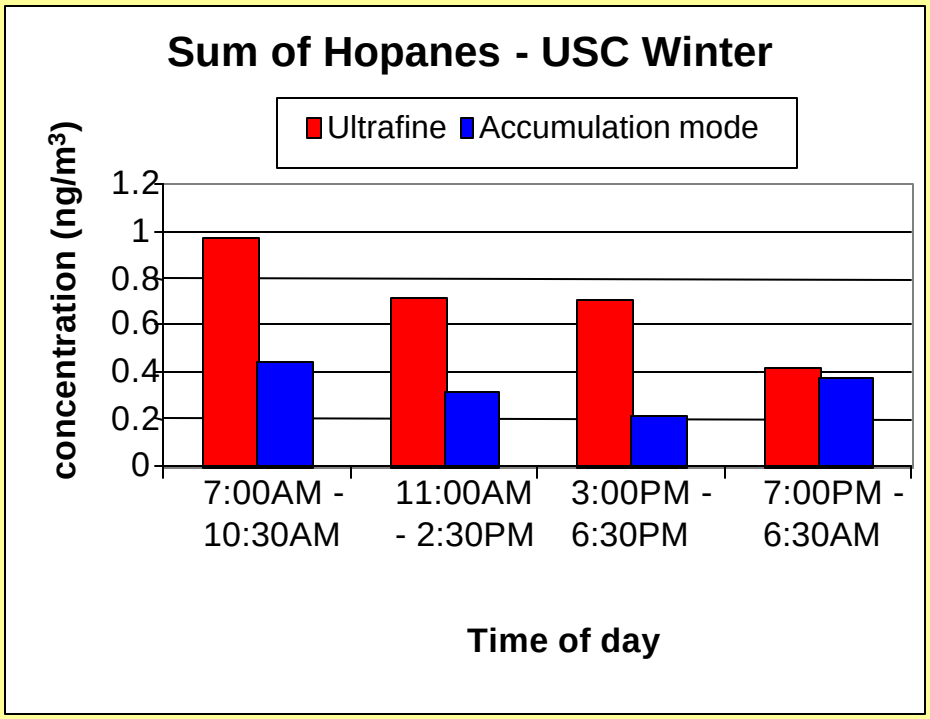
- hopanes (vehicles)
- cholesterol (cooking)
- levoglucosan (wood smoke)
- 1,2 benzenedicarboxylic acid (photochemistry)

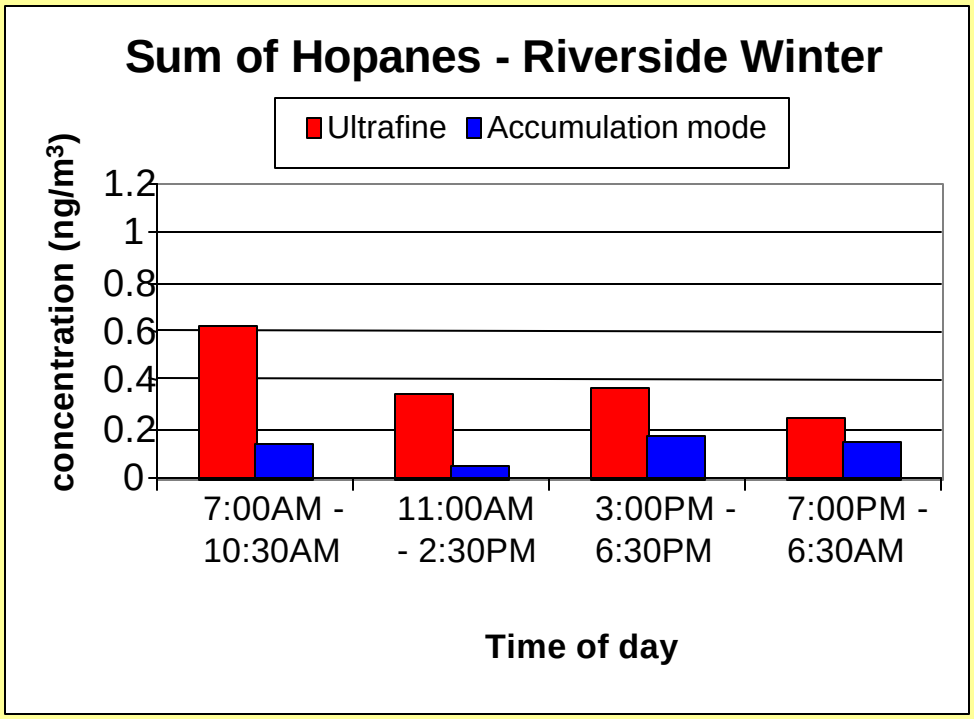
At UCR (receptor) and USC (source)

(Fine at al., Atmos. Environ., 2003)

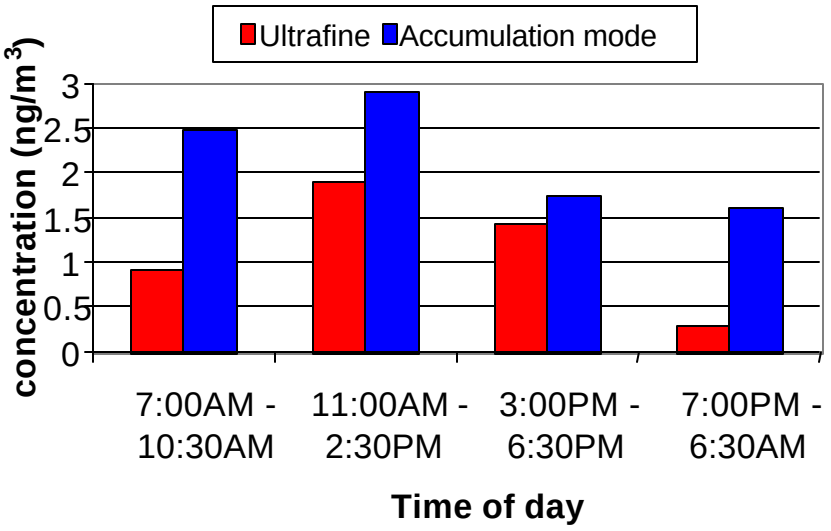

Sum of Hopanes - USC Summer
Ultrafine
Accumulation mode
concentration (ng/m³)
1.2
1
0.8
0.6
0.4
0.2
0
7:00AM - 10:30AM
11:00AM - 2:30PM
3:00PM - 6:30PM
7:00PM - 6:30AM
Time of day


Sum of Hopanes - Riverside Summer
Ultrafine
Accumulation mode
concentration (ng/m³)
1.2
1
0.8
0.6
0.4
0.2
0
7:00AM - 10:30AM
11:00AM - 2:30PM
3:00PM - 6:30PM
7:00PM - 6:30AM
Time of day

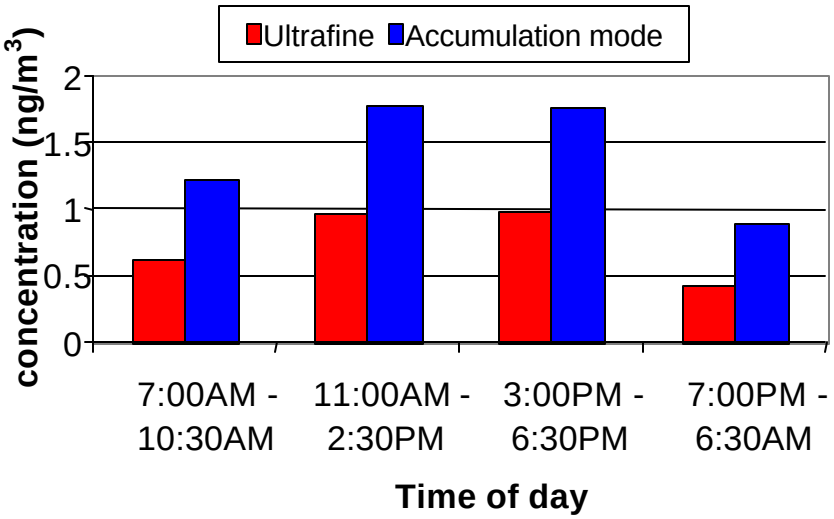

Sum of Hopanes - USC Winter
Ultrafine
Accumulation mode
concentration (ng/m³)
1.2
1
0.8
0.6
0.4
0.2
0
7:00AM - 10:30AM
11:00AM - 2:30PM
3:00PM - 6:30PM
7:00PM - 6:30AM
Time of day


Sum of Hopanes - Riverside Winter
Ultrafine
Accumulation mode
concentration (ng/m³)
1.2
1
0.8
0.6
0.4
0.2
0
7:00AM - 10:30AM
11:00AM - 2:30PM
3:00PM - 6:30PM
7:00PM - 6:30AM
Time of day

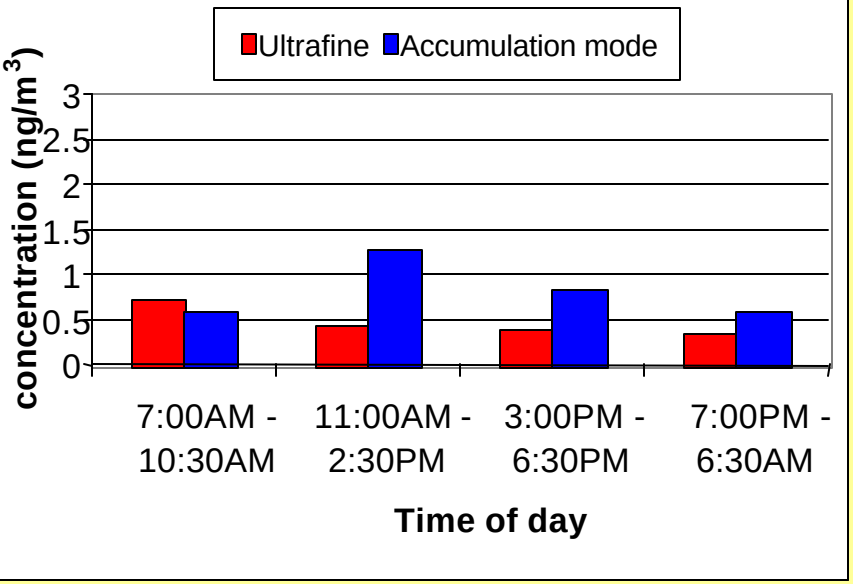
1,2 benzenedicarboxylic acid- USC Summer



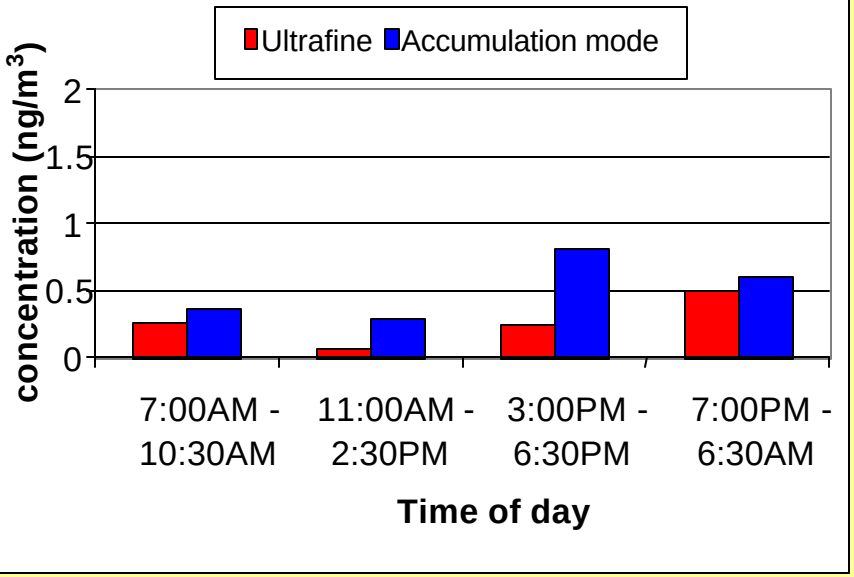
1,2 benzenedicarboxylic acid - Riverside Summer

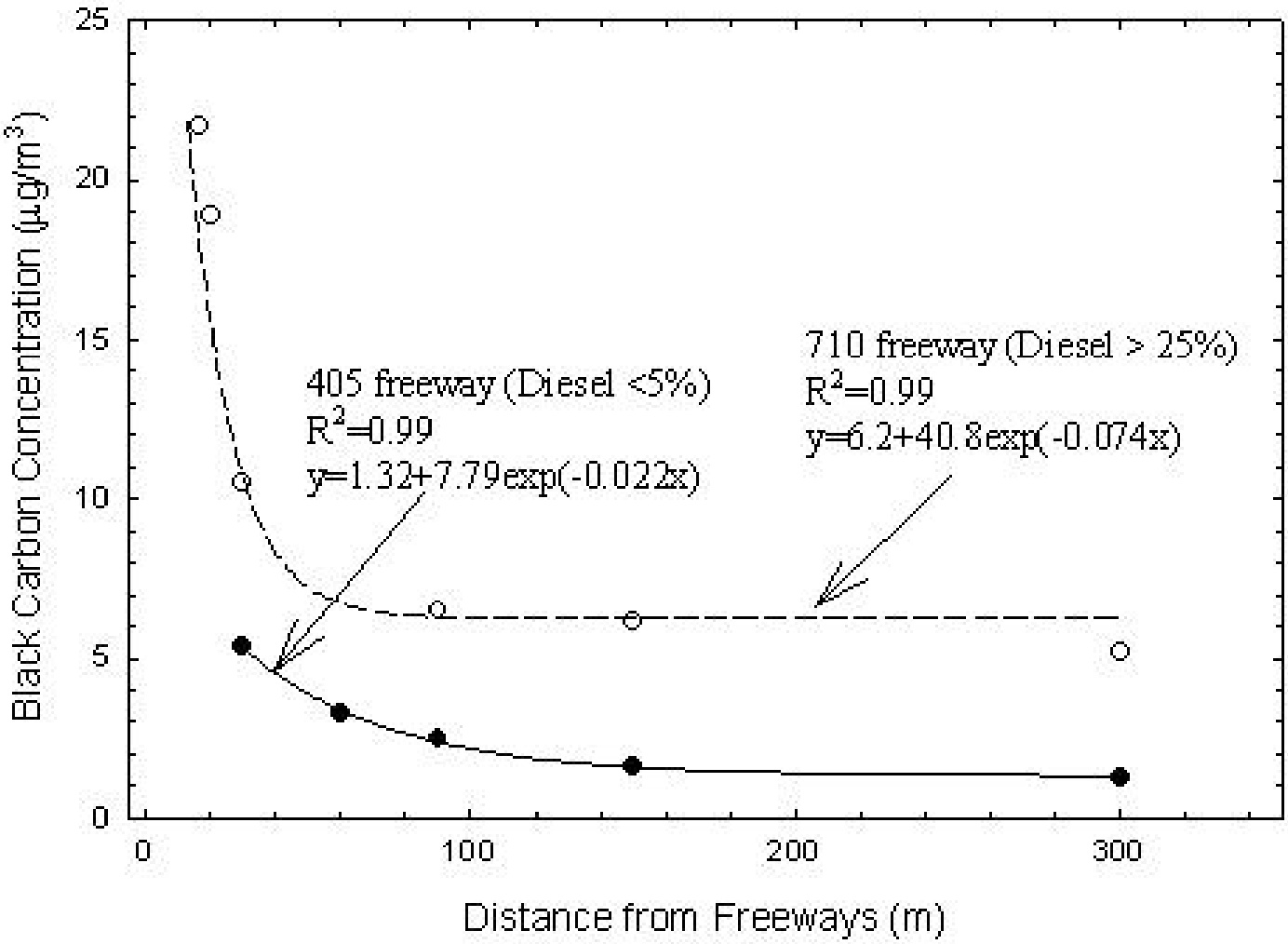


1,2 benzenedicarboxylic acid - USC Winter



1,2 benzenedicarboxylic acid - Riverside Winter





EC Diesel vs Gasoline Freeways (Zhu et al., *Atmospheric Environment*. 36, 4375-4383, 2002

(b)

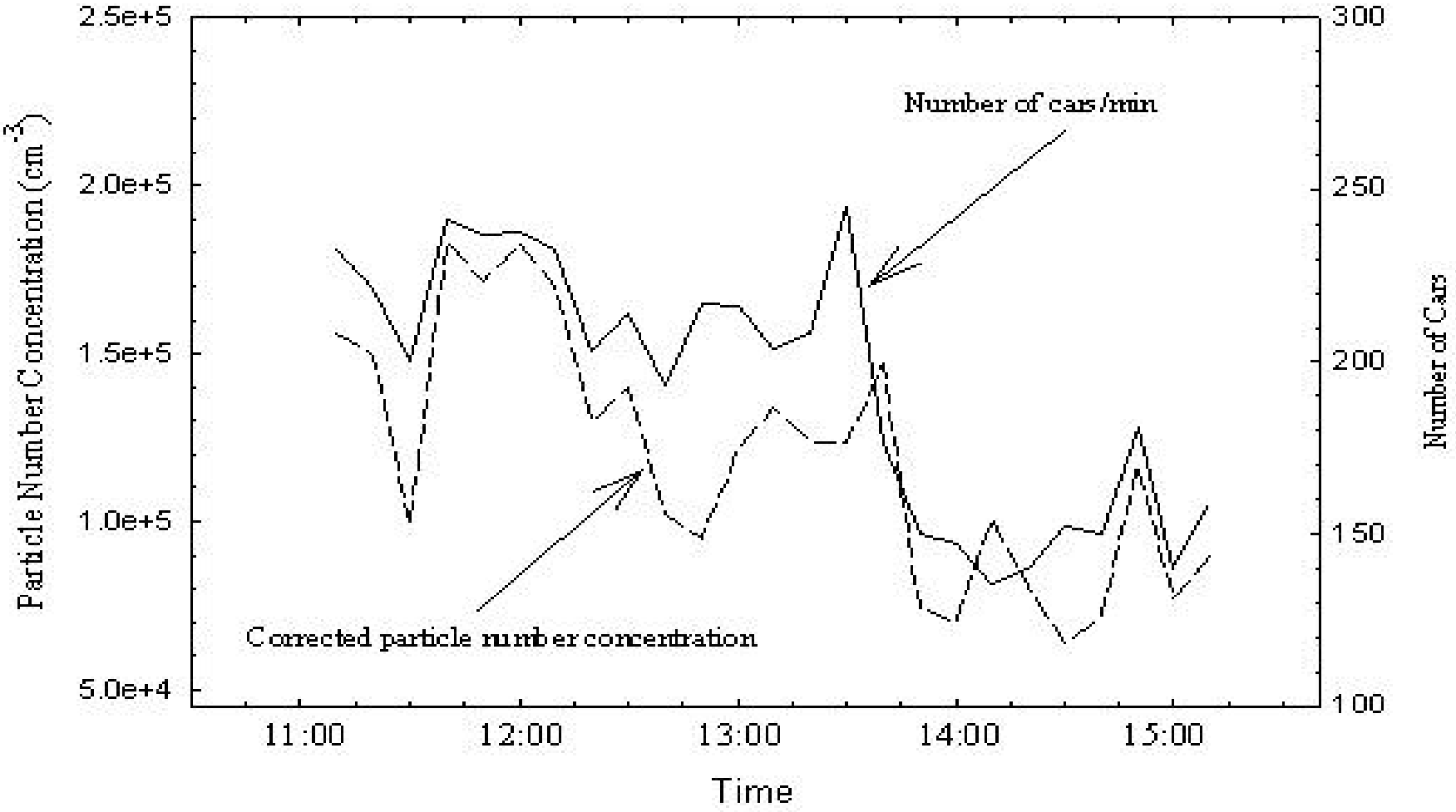
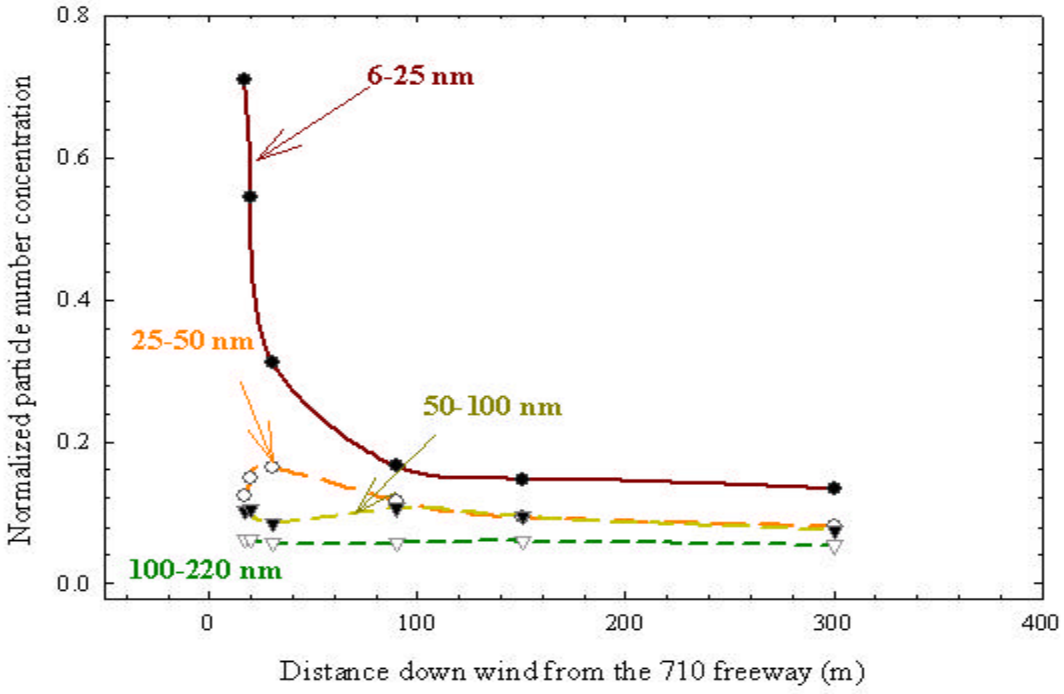


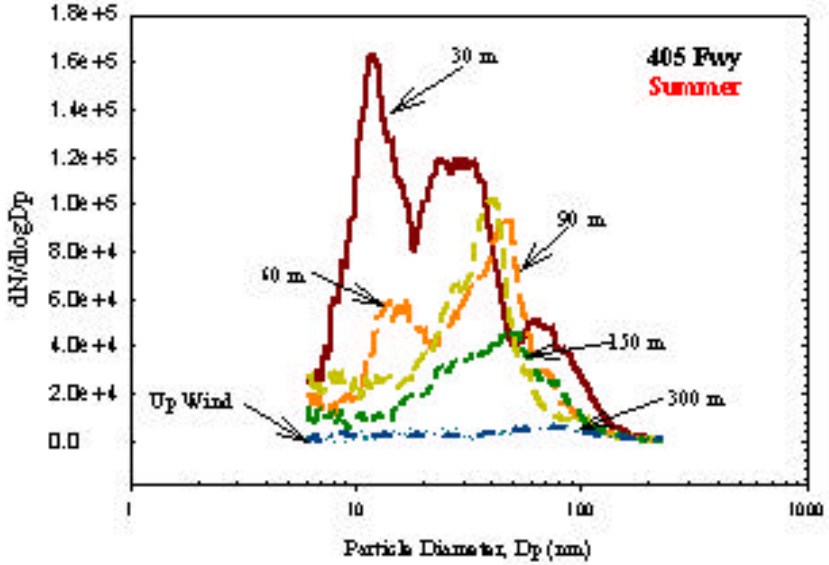
Figure 3. Correlation between traffic density and measured total particle number concentration, corrected for wind velocity at 30 m downwind from the freeway.

Freeway 710

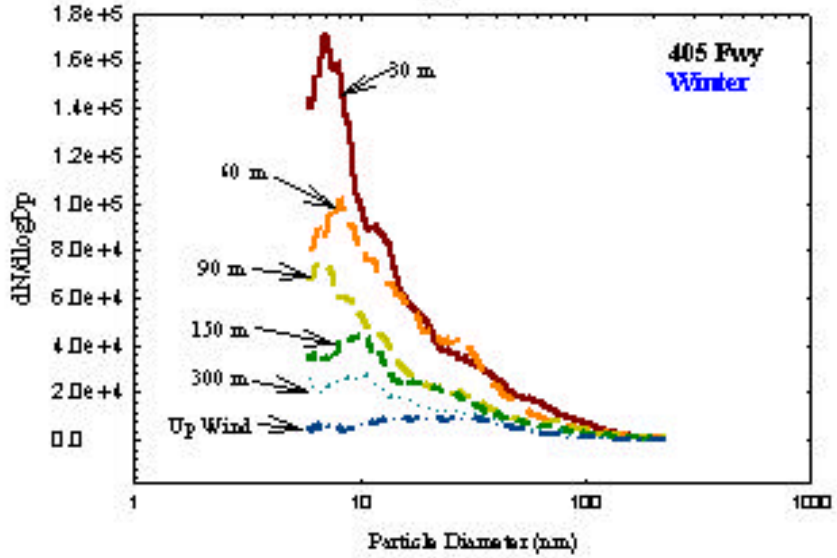
RESULTS AND DISCUSSION

- **Number Concentration for Different Size Ranges Vs. Increasing Distance from Freeway 710.**




405 Fwy
Summer
30 m
60 m
90 m
150 m
300 m
Up Wind
dN/dlogDp
1.8e+5
1.6e+5
1.4e+5
1.2e+5
1.0e+5
8.0e+4
6.0e+4
4.0e+4
2.0e+4
0.0
1
10
100
1000
Particle Diameter, Dp (nm)

(a)


405 Fwy
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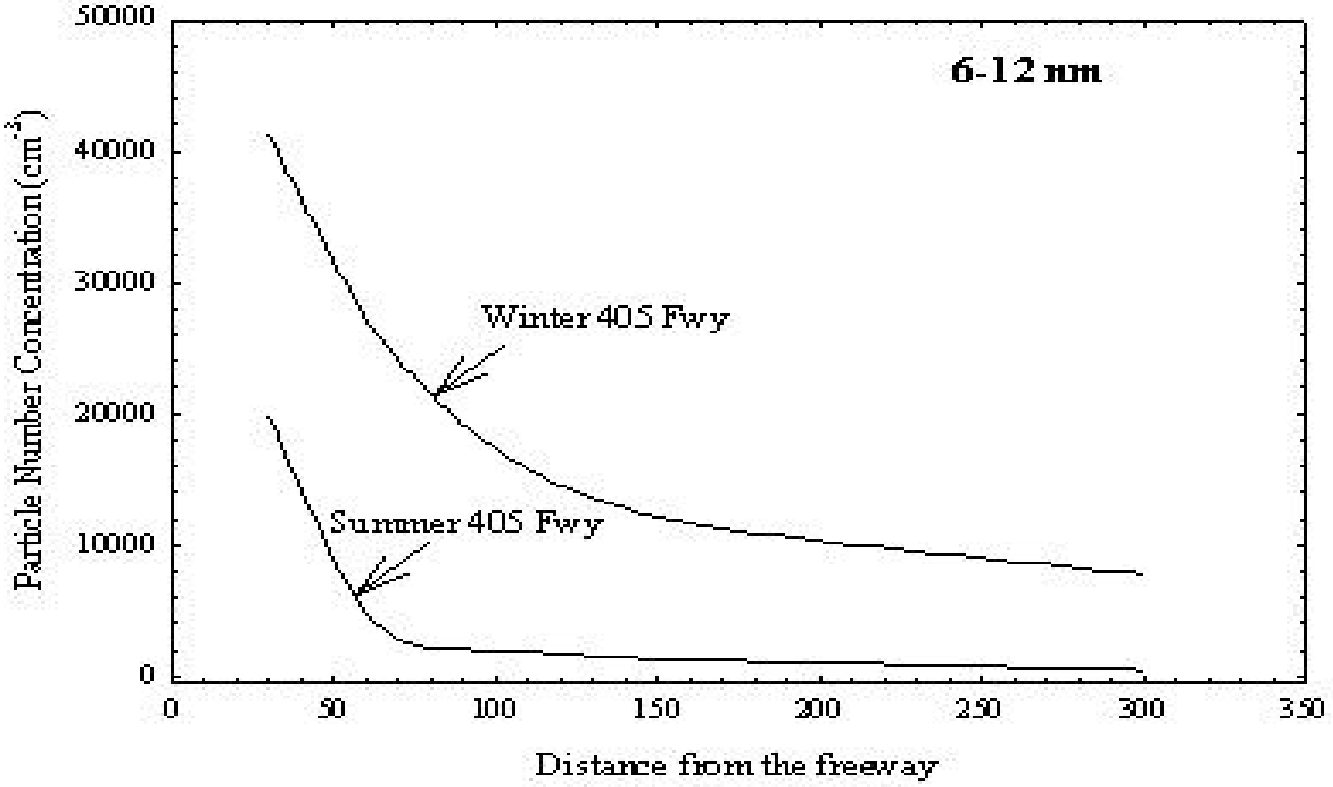
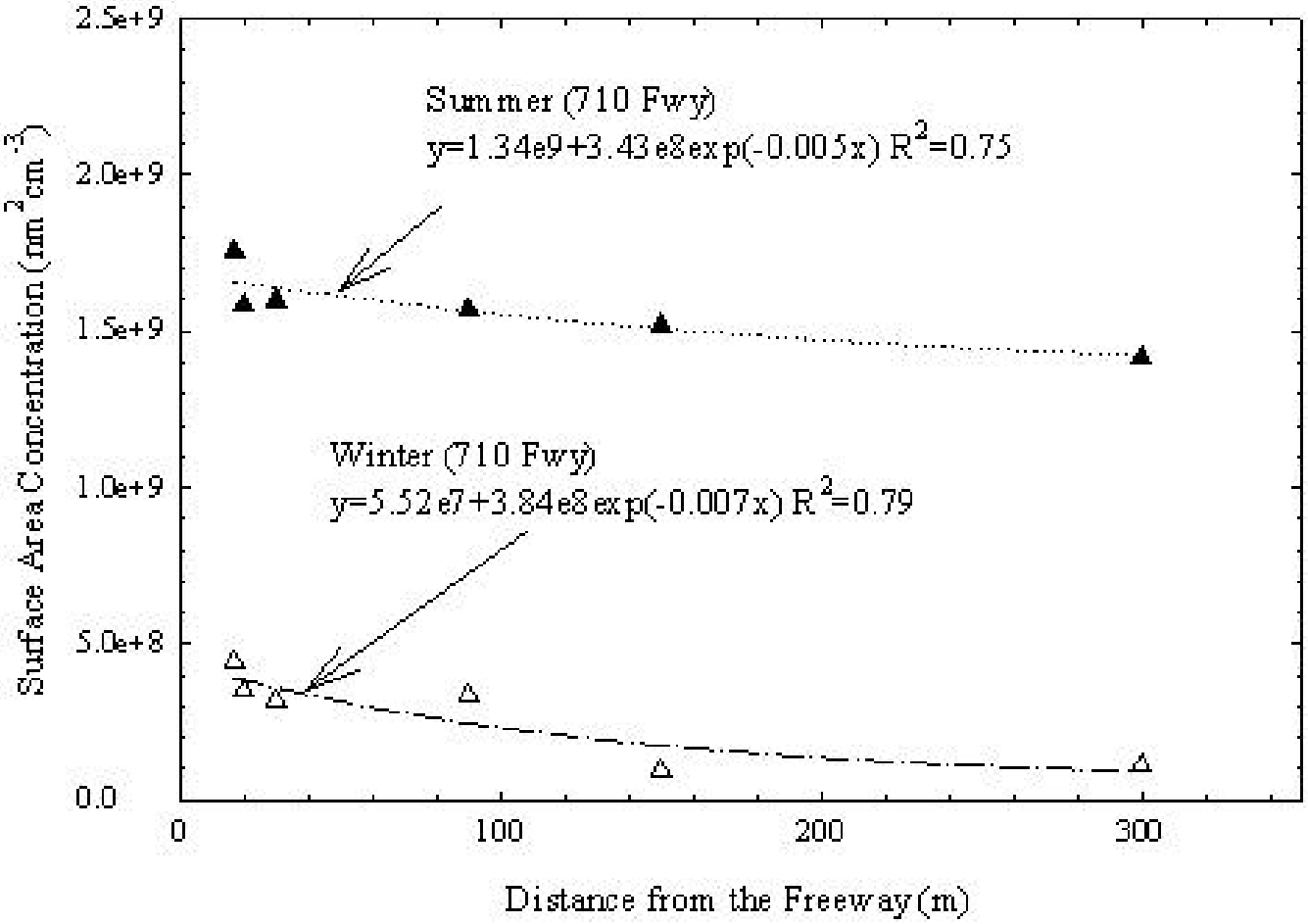
1.0e+5
8.0e+4
6.0e+4
4.0e+4
2.0e+4
0.0
1
10
100
1000
Particle Diameter (nm)

(b)



(a)

Figure 4. Comparison of decay of particle number concentrations in summer and winter in the size range of (a) 6-12 nm, (b) 12-25 nm, (c) 25-50 nm, (d) 50-100 nm, and (e) 100-200 nm near the 405 freeway.



Increase of Particle Surface Area in Summer

Monitoring Particulate Matter in Community Air (Collaboration Between CARB and SCPCS)

CARB Staff:

Dane Westerdahl, Scott Fruin, Ken Bowers, and Steve Mara

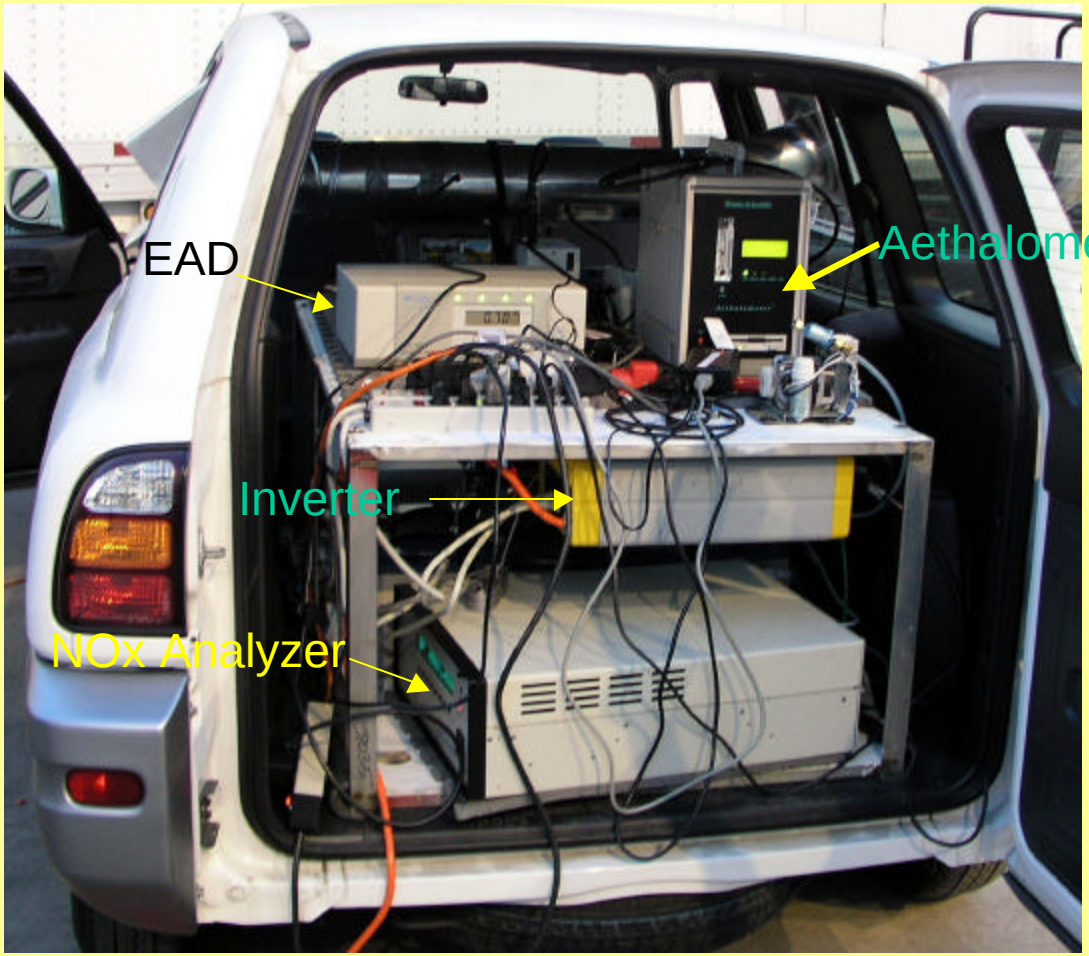
Overarching Concepts

- People do not live at monitoring sites
- Fixed site monitors don't capture complexity of urban air pollution
- Fixed site monitoring does not measure many pollutants of concern

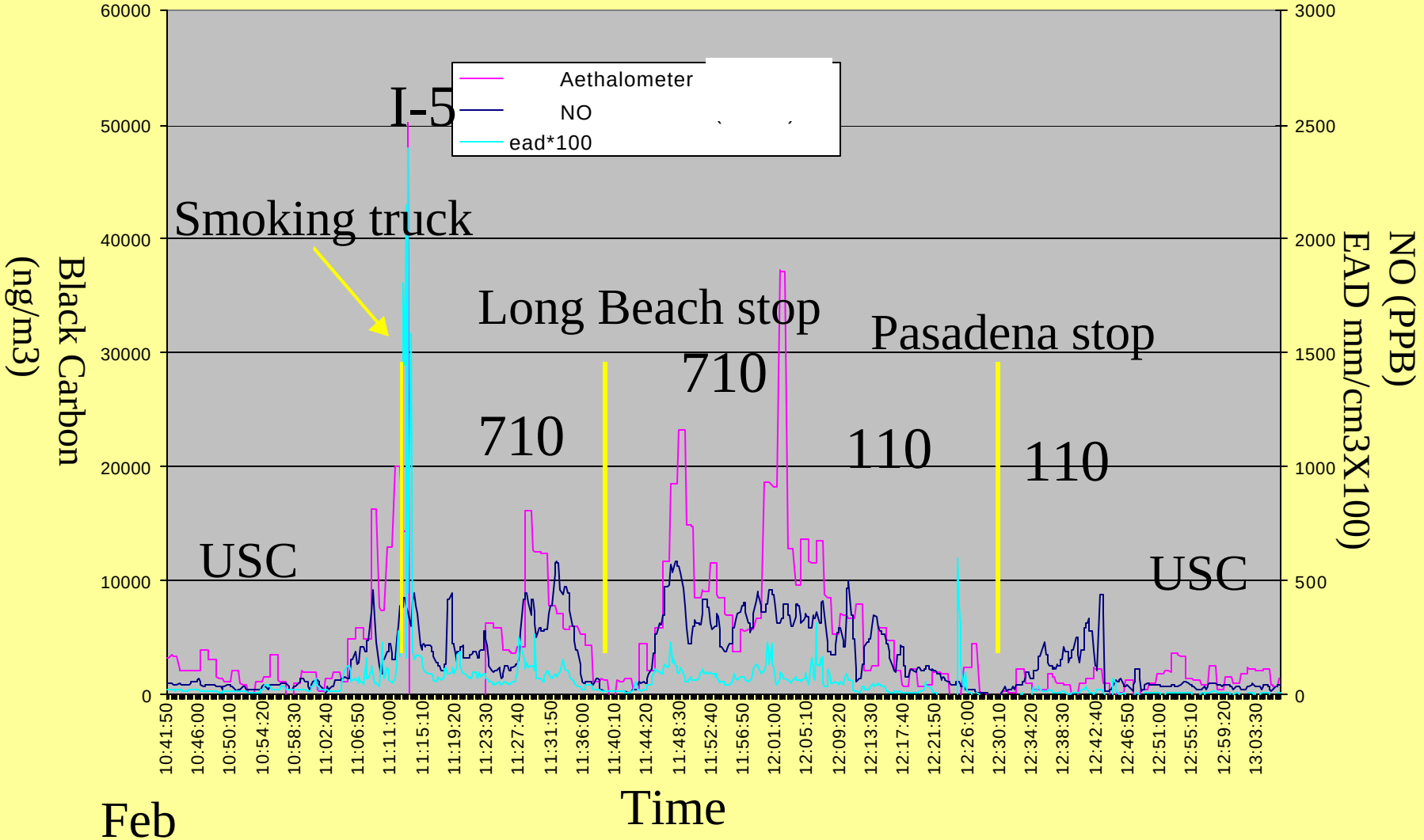
Objectives of Pilot Level Studies

- Evaluate new methods to determine community exposures to fine and ultrafine PM and gases
- Compare observations with fixed site monitors
- Design future investigations

Mobile Monitoring Project
Electric RAV4 Instrumentation

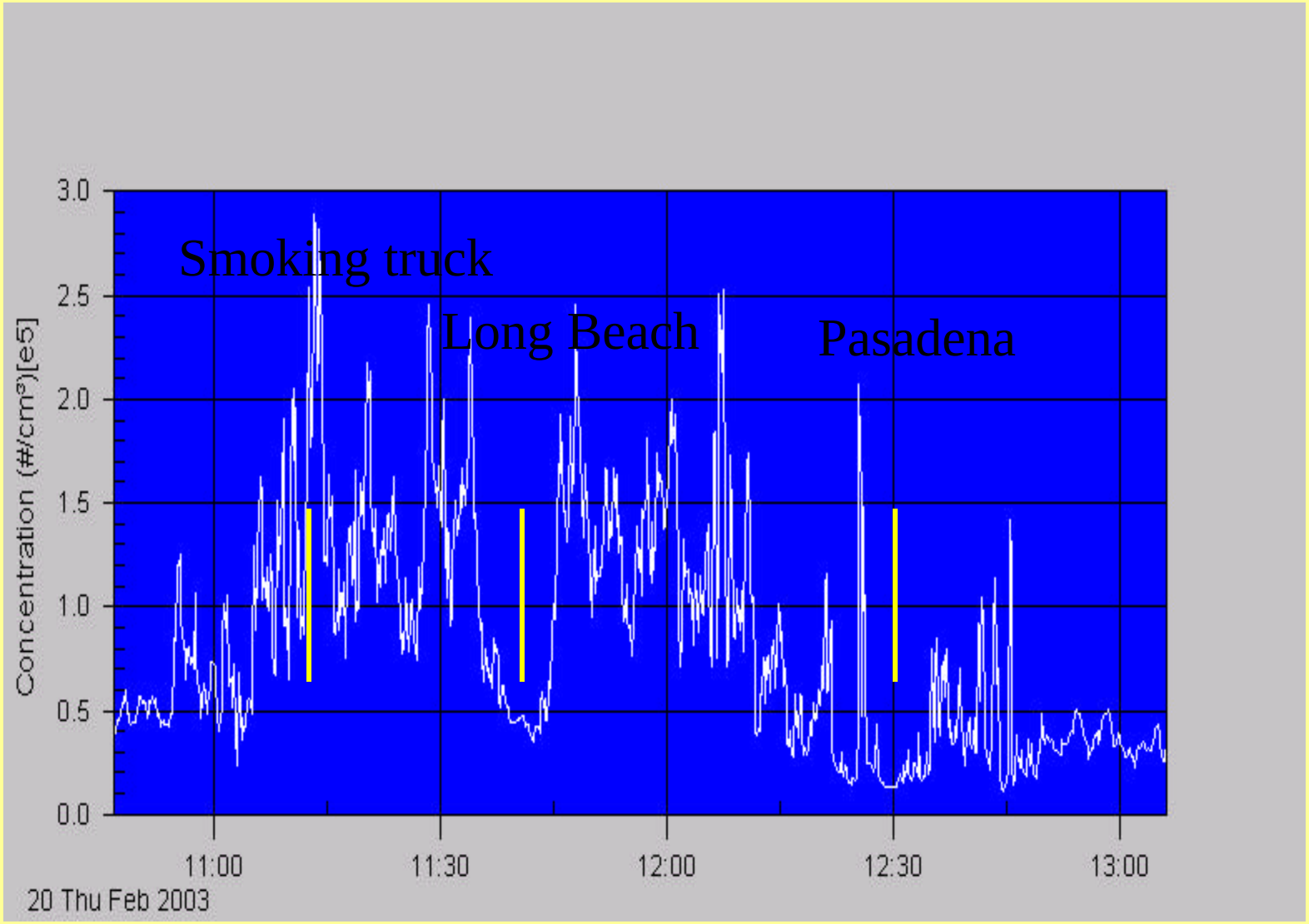


Freeway Monitoring
Aethalometer, NO, and EAD



Feb 20

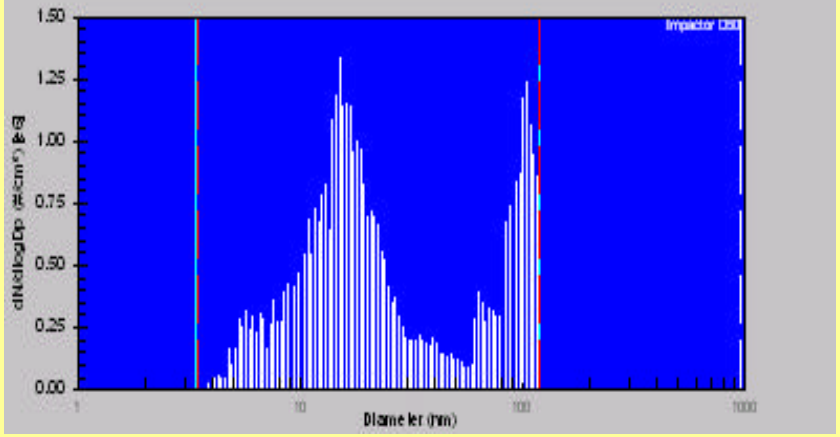
Freeway Monitoring
Portable CPC 3007



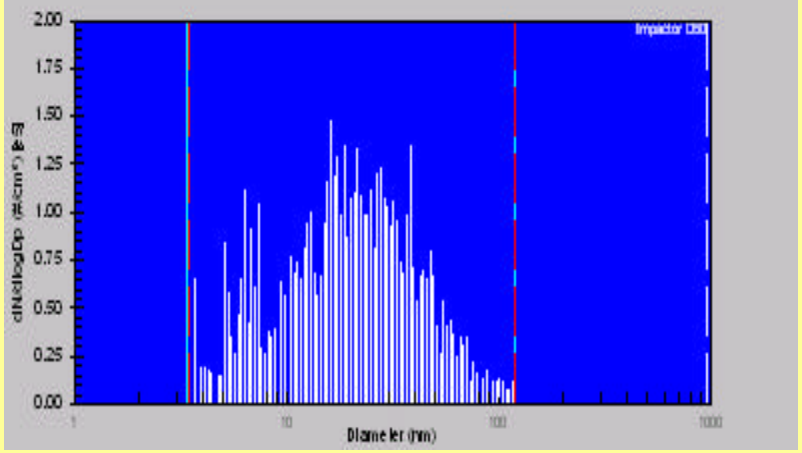
Freeway and City Monitoring
SMPS with Nano DMA

Feb. 20

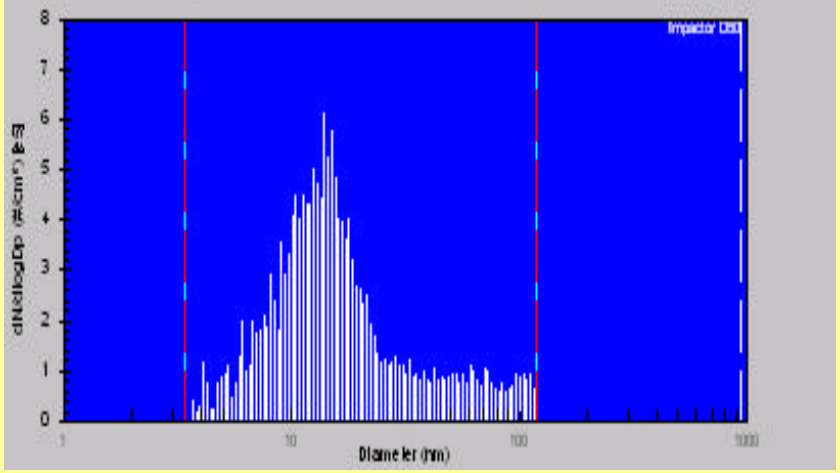
11:13 Smoking truck on 10



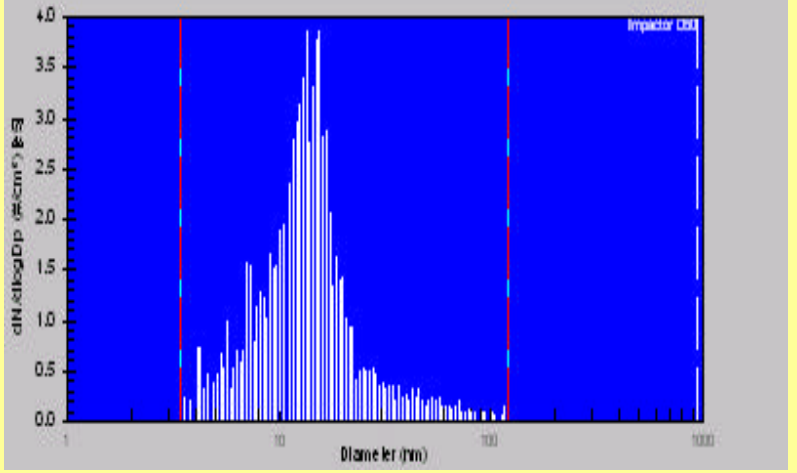
11:40 Long Beach Stop (urban)



12:02 710 Freeway (diesel)



12:36 Pasadena 110 (gasoline only)

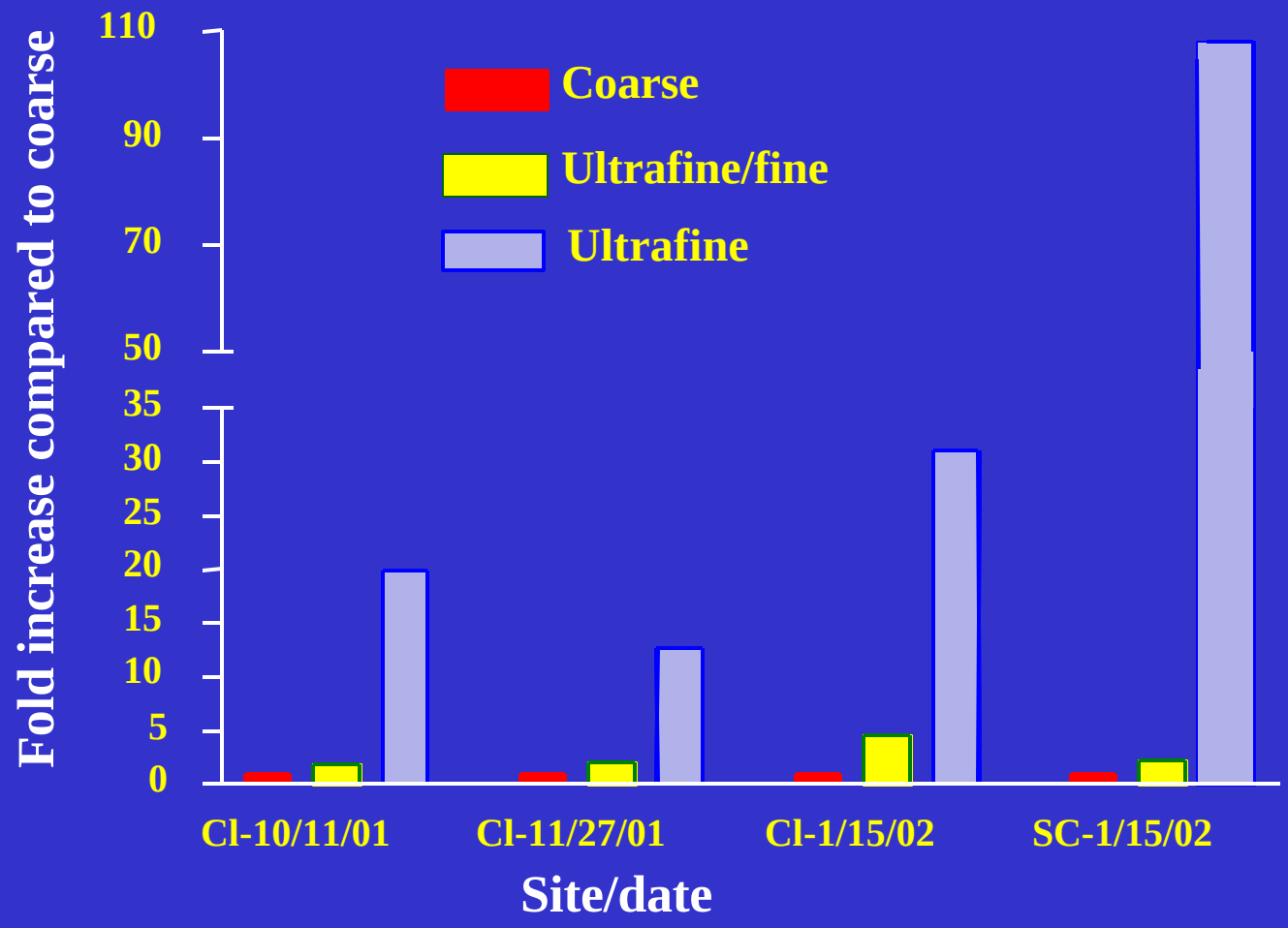


Oxidative stress hypothesis

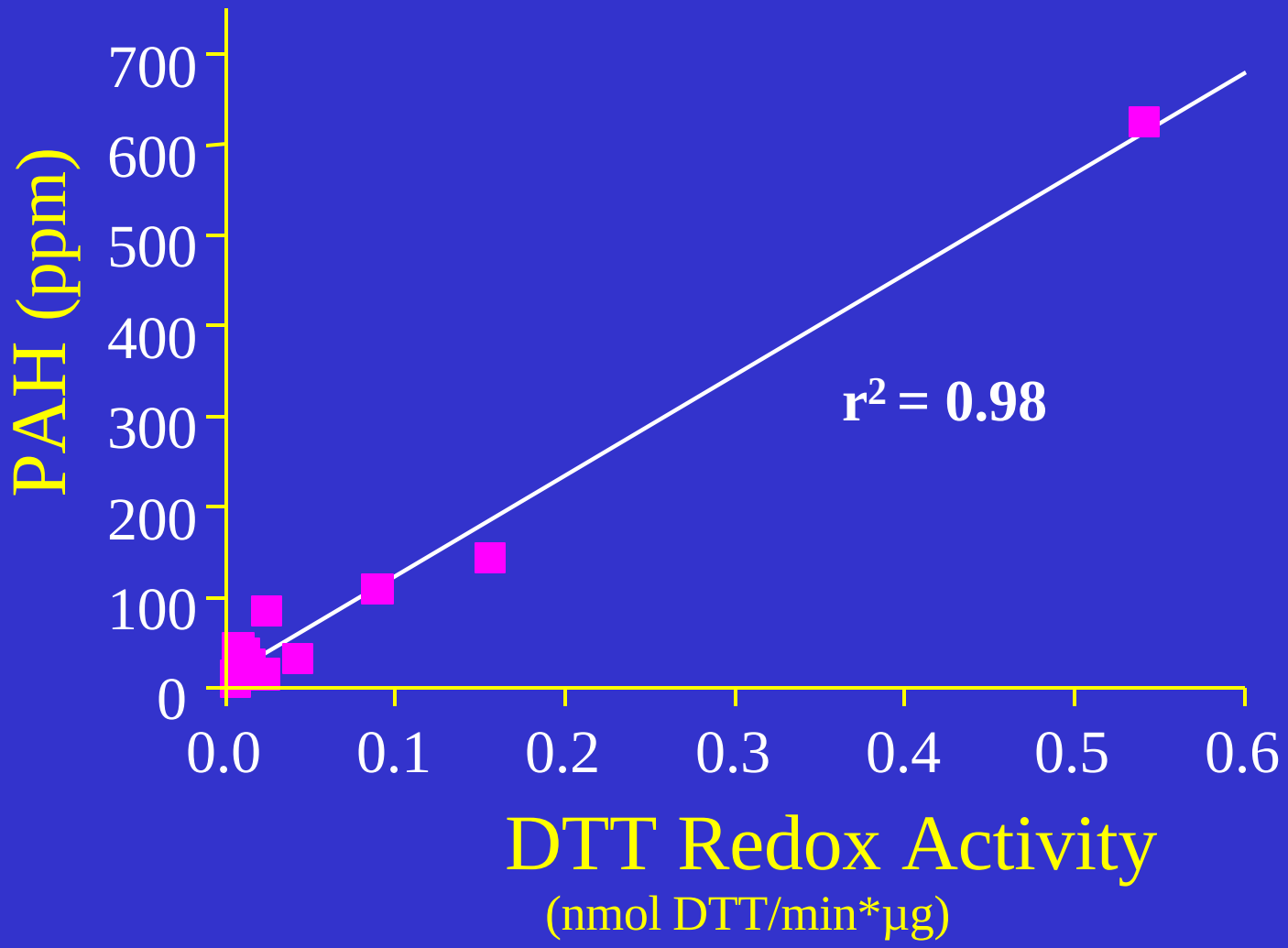
- Part of our SCPCS investigations focused on identifying PM components that induce pulmonary inflammation through the generation of oxidative stress

- We collected coarse (2.5-10 μm), fine (< 2.5 μm) and ultrafine (UFP) particles (< 0.15 μm) and examined their toxicity.
- UFP were most potent towards inducing cellular heme oxygenase 1 (HO-1) expression as an oxidative stress marker.
- This effect is directly correlated to the high organic carbon and polycyclic aromatic hydrocarbon (PAH) content of UFP.
- The PAH content of concentrated PM samples is a good surrogate for redox cycling chemicals, as demonstrated by electron transfer from dithiothreitol (DTT).

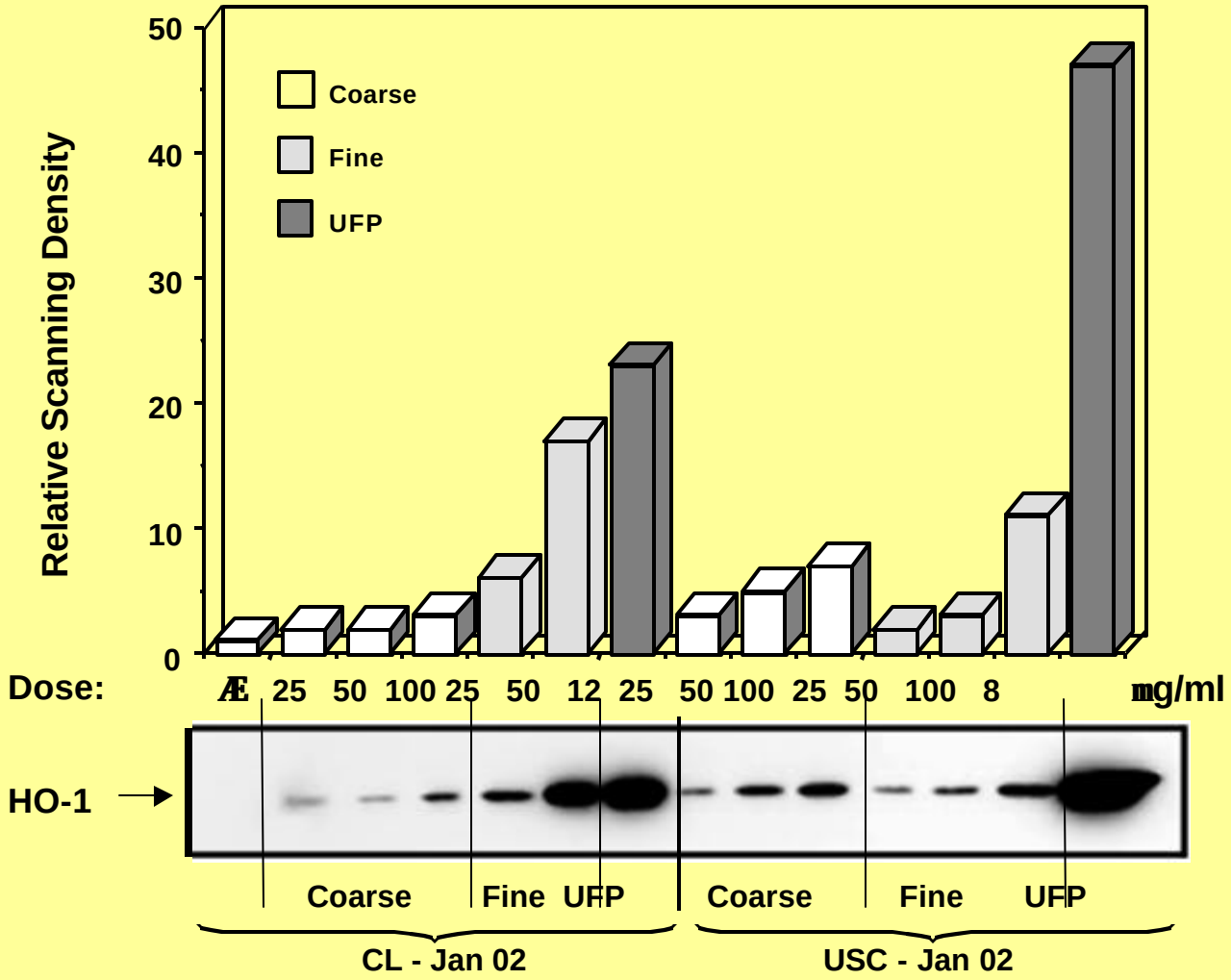
Redox Activity vs Fraction (Li et al., EHP, 2002)



Redox Activity vs Total PAH levels (Li et al., EHP, 2002)



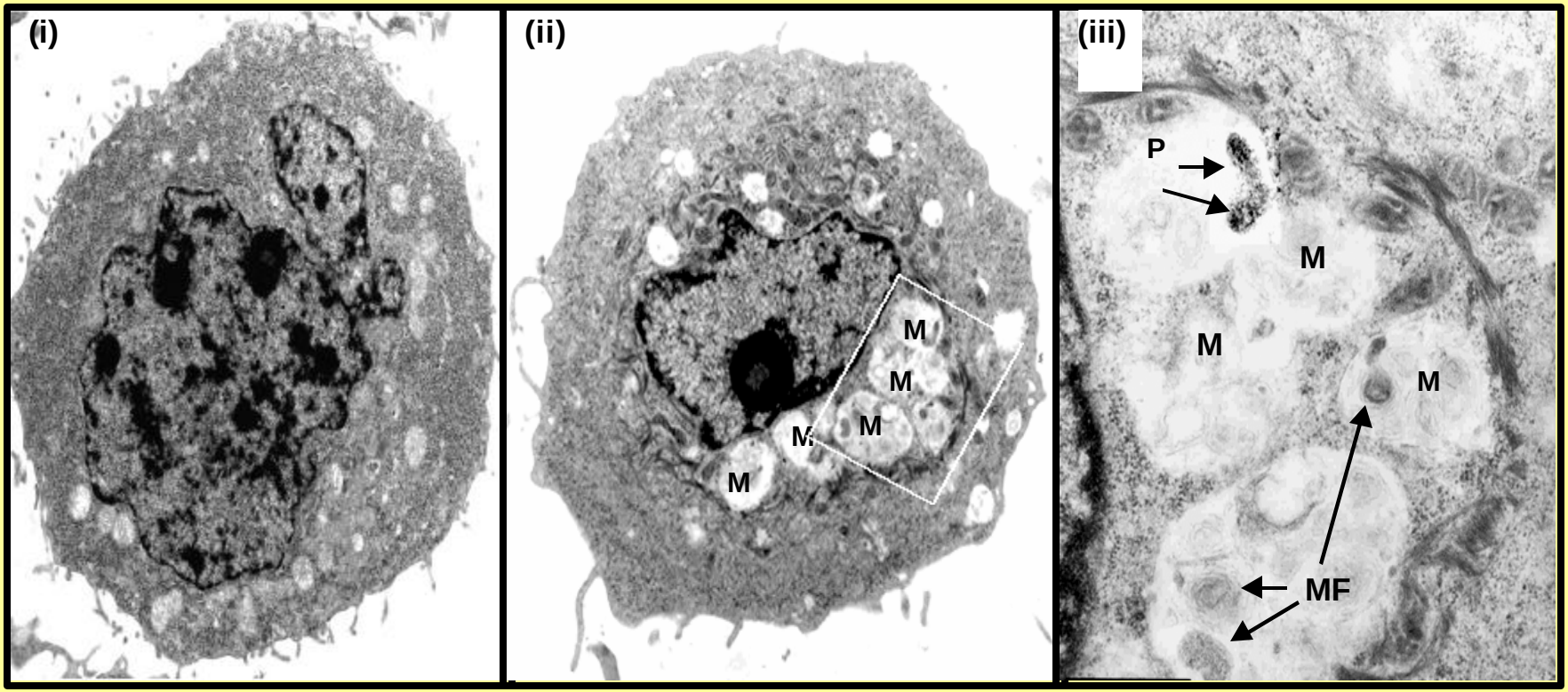
UFP Induce Much Higher Oxidative Stress (Li et al., Env. Health Perspect., 2002)



•**UFP localize in mitochondria where they induce major structural damage.**

•**This contributes to oxidative stress.**

Untreated Mag. x 8500 **UFP Mag. x 8500** **UFP Mag. x 85000**



BEAS-2B

Issues Related to the Diurnal, Spatial and Seasonal Characteristics of Individual Exposure to PM

Observations from our studies in LA which are (hopefully) applicable to other urban areas

$$PM_{pers} = PM_{amb} + PM_{non\ amb}$$

Important Attributes of Ambient PM in Determining Where-When People Are Exposed

- **Local (PM from specific sources)**
- **Regional (secondary PM; PM advected from source to receptor areas)**
- **Volatile vs. Non – Volatile**
  - **the concentrations of volatile PM of outdoor origin decrease substantially in indoor environments, especially in wintertime**

- **Particle Decrease from freeway or busy road is a delicate balance between 2 mechanisms:**
  - **dilution (affecting PM, CO and NOx)**
  - **condensation-nucleation (affecting PM only)**
- **Summer:**
  - **Dilution and mixing more pronounced in summertime**
  - **Concentrations decrease more rapidly with distance from the road**
  - **Particles grow faster to larger sizes by turbulent coagulation**
- **Winter:**
  - **Depressed mixing height preserves size distributions**
  - **Slower decay, higher number concentrations (by a factor of 5 -10)**
  - **Higher concentrations of nuclei mode PM (3-10 nm) even at distances ~ 150 away from road**

Implication for Exposure Assessment- EPI studies

- **The concentrations of PM do not follow the same spatial, seasonal trends with CO and NOx**
- **These gases cannot be used as surrogates of PM attributable to vehicular emissions**

Effect of Season on PM Exposure from Our Studies in LA

Cooler Season (Higher RH and Lower T)

- **Increased Concentrations of PM from Vehicles and Wood Smoke**
- **Increased Spatial Variability in PM concentrations**
- **Much higher particle number concentrations**
- **High concentrations in urban areas and low concentrations in receptor sites**
- **Finer PM size – increased ultrafine fraction**

  (indoor implications for dosimetry as well as outdoor- penetration)
- **People spend less time outdoors and PM infiltration rates lower**

Warmer Season

- **Increased secondary formation of PM**
- **Increased long-range transport of PM from sources to receptors**
  - **More spatially homogenous distribution of PM**
- **Higher PM fraction in accumulation mode**
- **More time spent outdoors and (in the absence of A/C) more infiltration**

Few concluding thoughts

- **Rigorous Assessment of Contribution of PM of Ambient Origin to Personal Exposure is of Paramount Importance**

- **(Even more important) assessment of PM from specific outdoor sources and formation mechanisms to individual exposure**

- **Use of Molecular Tracers-Signatures of Specific Sources, Combined with Advances in Personal PM Monitoring to:**

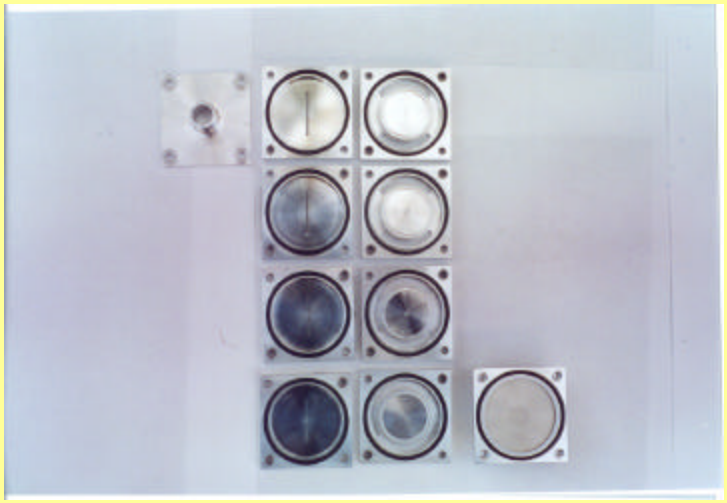
  - **Understand the degree of the source contribution to personal exposure**

  - **Its dependence on season, proximity to source, home characteristics, individual activity patterns**

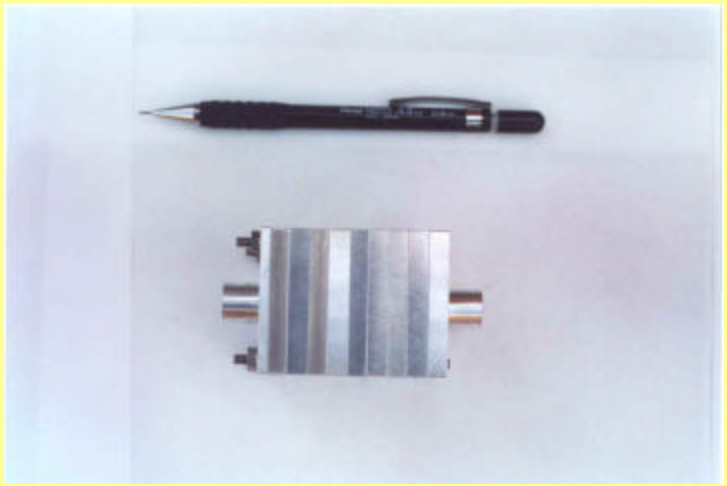
  - **(ideally) concurrent with panel studies as well as toxicological studies (CAP or other)**

  - **determine the effectiveness of reducing source emissions in protecting public health**

Figure 4: Pictures of Personal Cascade Impactor Sampler (PCIS)



Misra et al., *Journal of Aerosol Science*, 33(7), 1027-1047, 2002



USC Personal Cascade Impactor Sampler (PCIS)

- **Classifies PM in 5 ranges at a flow of 10 LPM**

  - **2.5 - 10; 1-2.5; 0.5 –1.0; 0.2 - 0.5; and ≤ 0.2 μm**

- **Used with a light, battery-operated personal pump**
-
- **Combined with outdoor measurements and tracers of specific outdoor sources (i.e., vehicular emissions, photochemistry) allows us to determine the degree to which they contribute to personal exposures**