AGENDA : 2A

Atmospheric Monitoring of Ultrafine Particles

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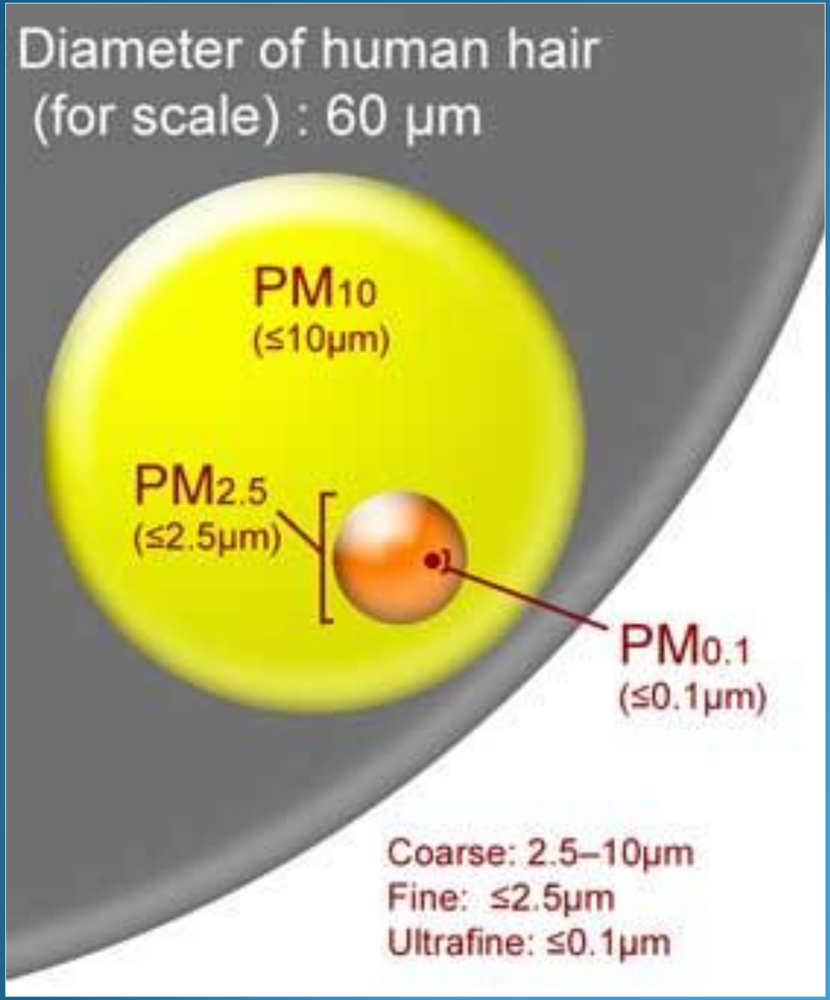
South Coast Air Quality Management District

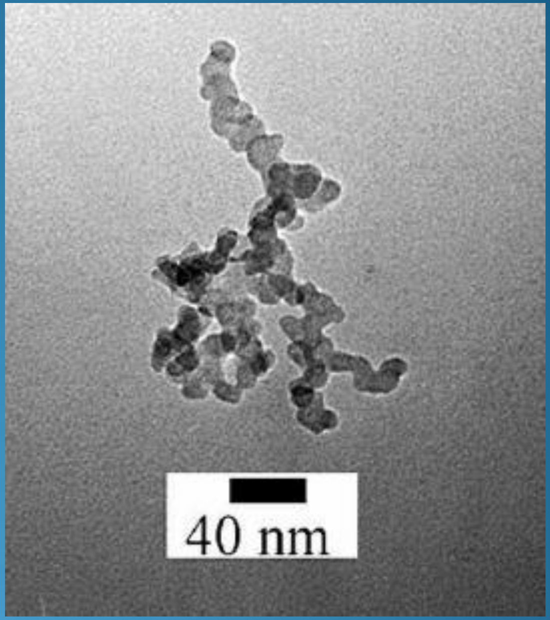
Bay Area AQMD Advisory Council Meeting: Ultrafine Particles
February 8,2012

Ultrafine Monitoring Outline

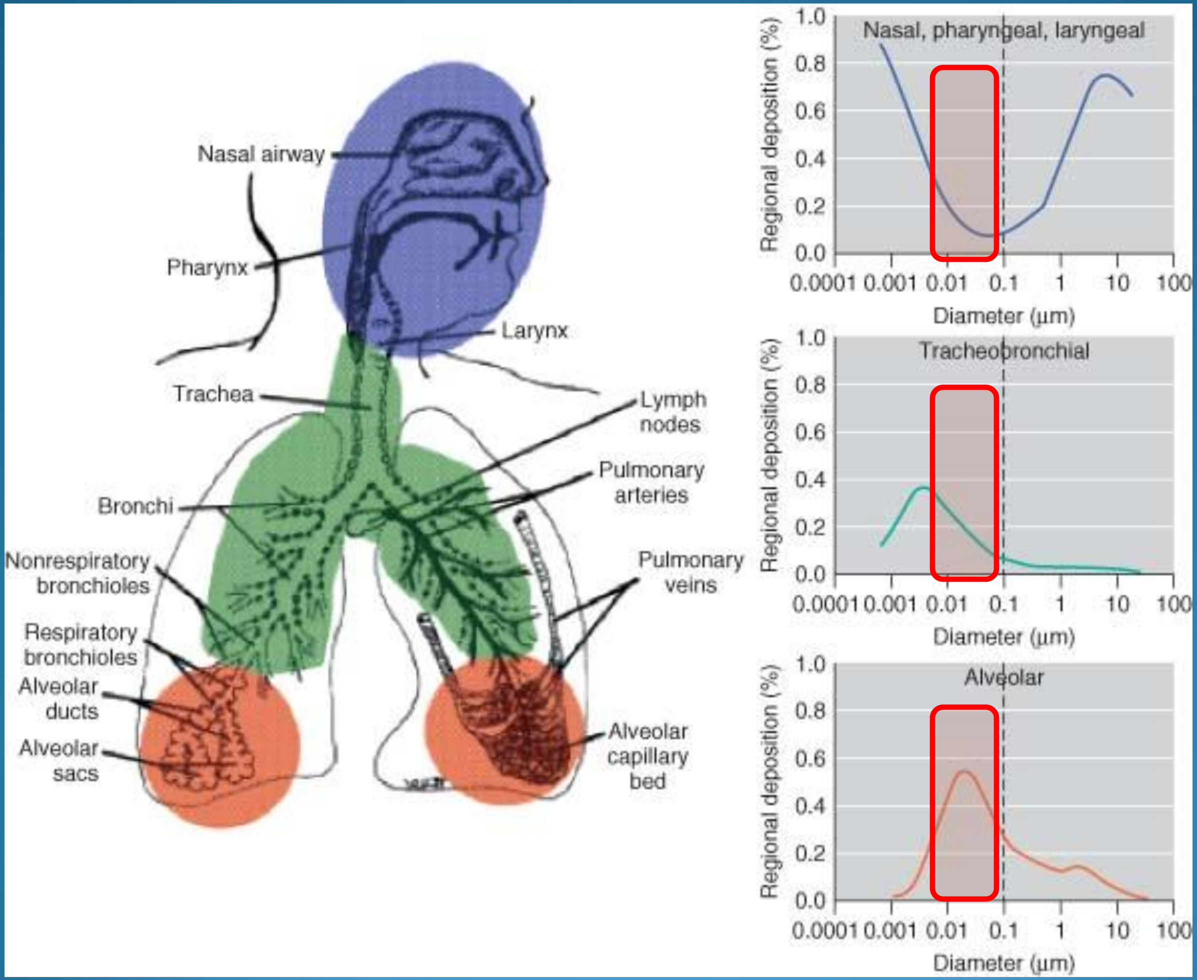
- Why should we monitor Ultrafines?
- What should we be measuring?
- How should we monitor for Ultrafines?
- Where do Ultrafines come from?
- Where should we monitor for Ultrafines?
- What do we find when we monitor?
- What should we do about it?

Ultrafine Particles





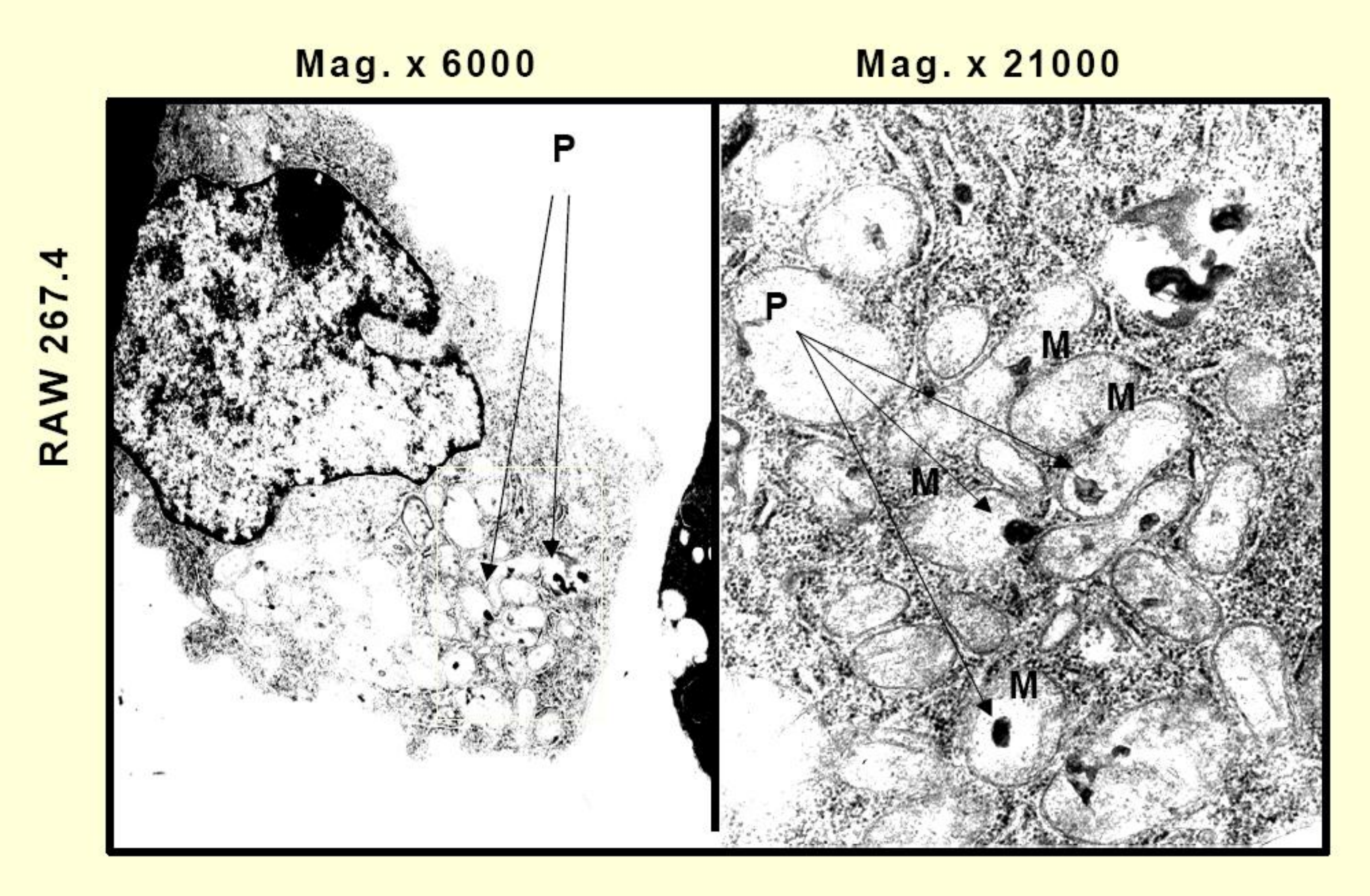
Ultrafine Particle Health Impacts



Ultrafine Particle Health Impacts

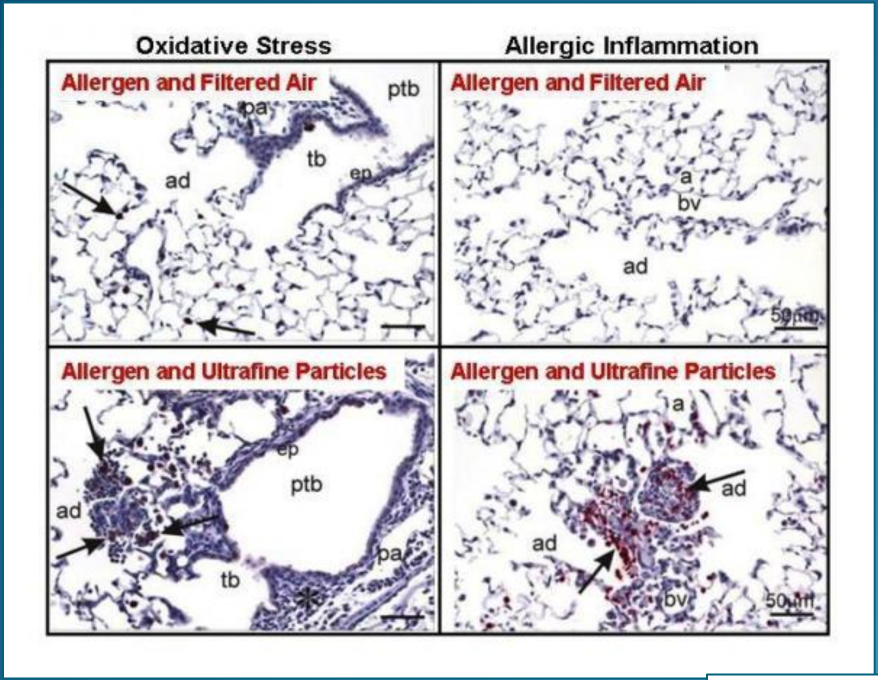
- Ultrafine particulate material is more toxic than PM2.5 material
- Ultrafine particles can cross cell membranes and can move into the circulatory system, brain, and other organs
- Ultrafine particles have been shown to cause adverse health effects related to stroke, systemic inflammation, vascular effects on diabetics, airway development, and asthma exacerbation
- Suspected as one of the causative pollutants in near-traffic epidemiology studies

Ultrafine Particle Health Impacts



Li et al., 2003

Ultrafine Particle Health Impacts

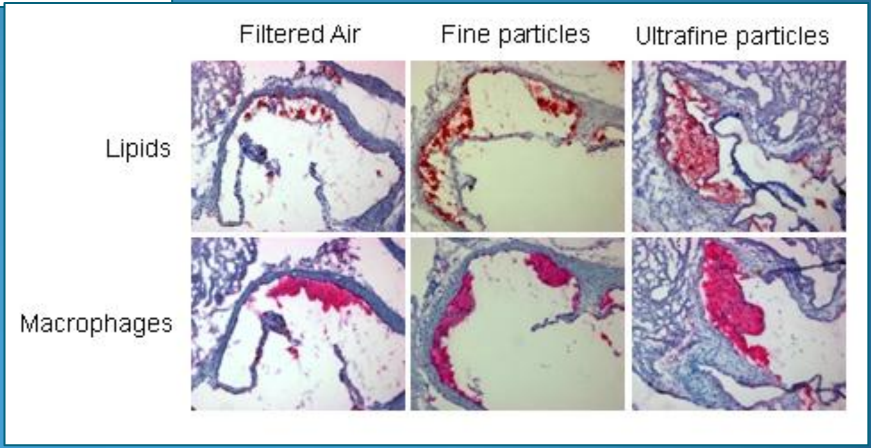


Promotes oxidative stress and allergic Inflammation in the lung

Li et al., 2008

Promotion of atherosclerosis

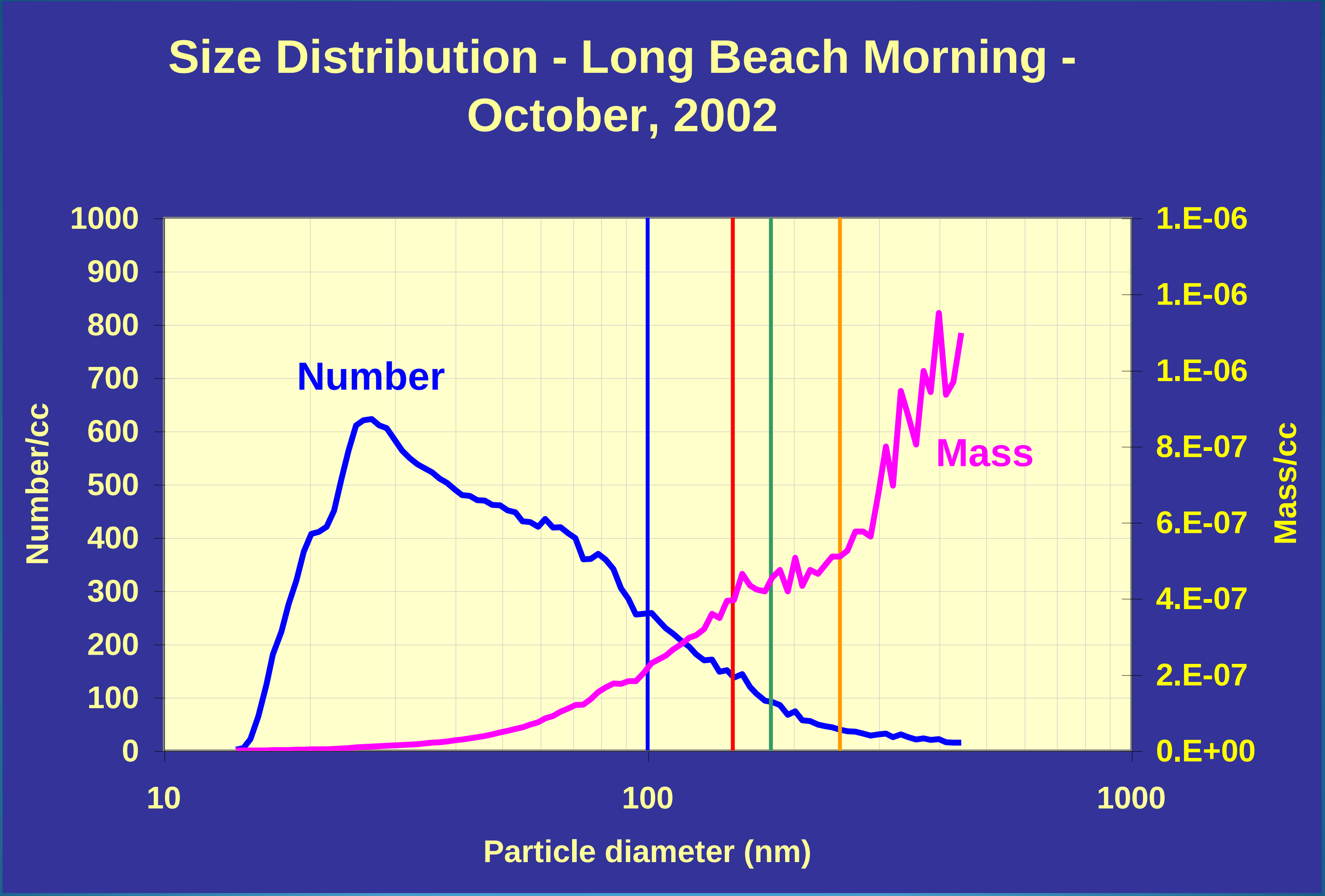
Araujo et al., 2008



What Characteristics of Ultrafines Should We Measure?

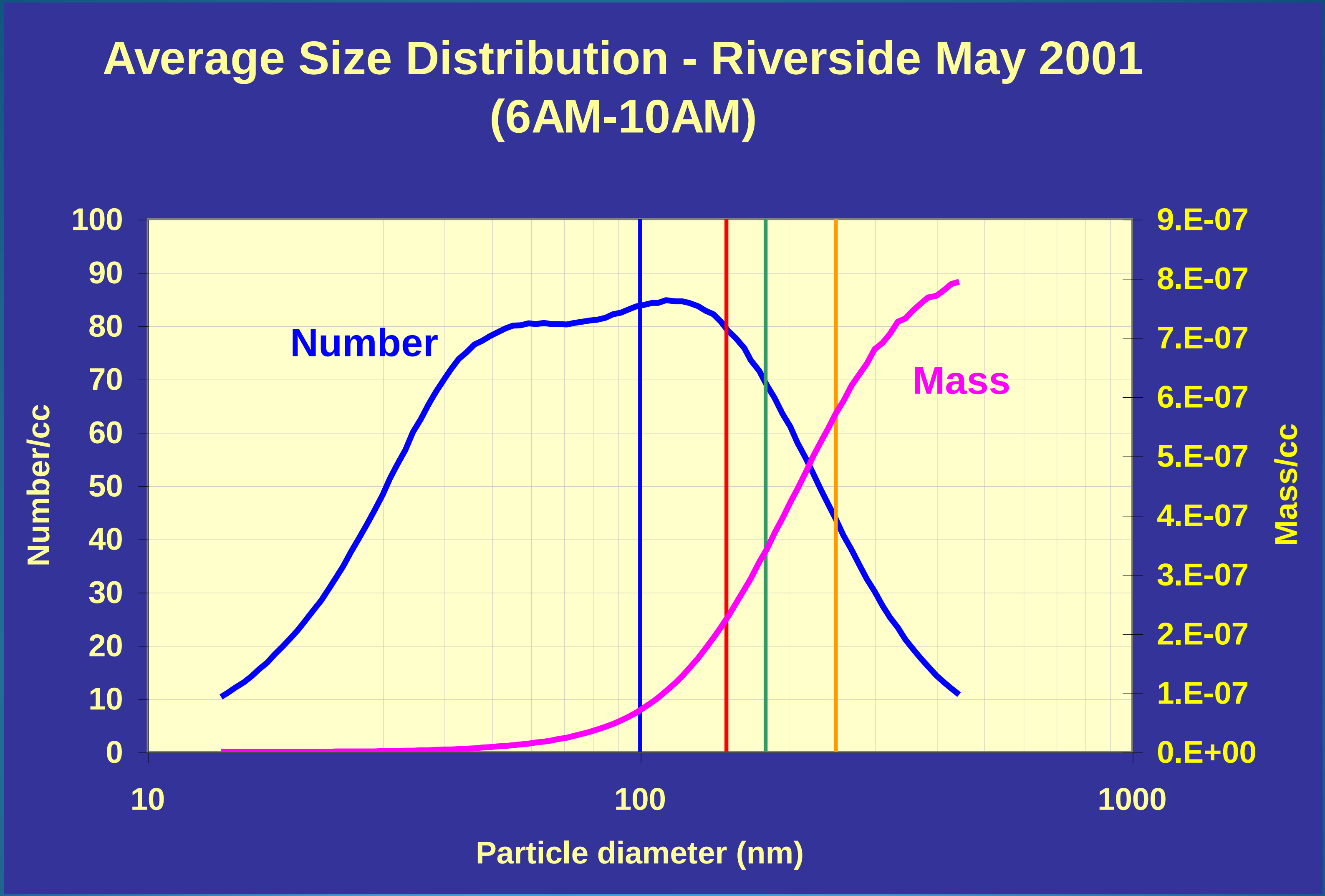
- Mass?
  - PM mass measurements similar to PM10 or PM2.5 methods
    - Time-integrated filter-based methods
    - Continuous methods (TEOM, BAM)
  - Size-selective inlet to remove larger particles
    - Ultrafine size-cut leads to higher pressure drops across inlet device
      - Still feasible down to 150-180 nm
        - Demonstrated for 150 nm inlet on BAM (Chakrabarti et al., AS&T 38(S1), 2004)
      - What is the upper size cut?
        - 50 nm, 100 nm, 150 nm, 180 nm, 250 nm

Size Cut (Source Aerosol)



100 nm 150 nm 180 nm 250 nm

Size Cut (Aged Aerosol)



100 nm 150 nm 180 nm 250 nm

Size Cut

For the previous size distributions and upper size cuts, **80% of the measured particle mass** would be found in the following size ranges, thus biasing measurements towards the upper end of the measured ranges

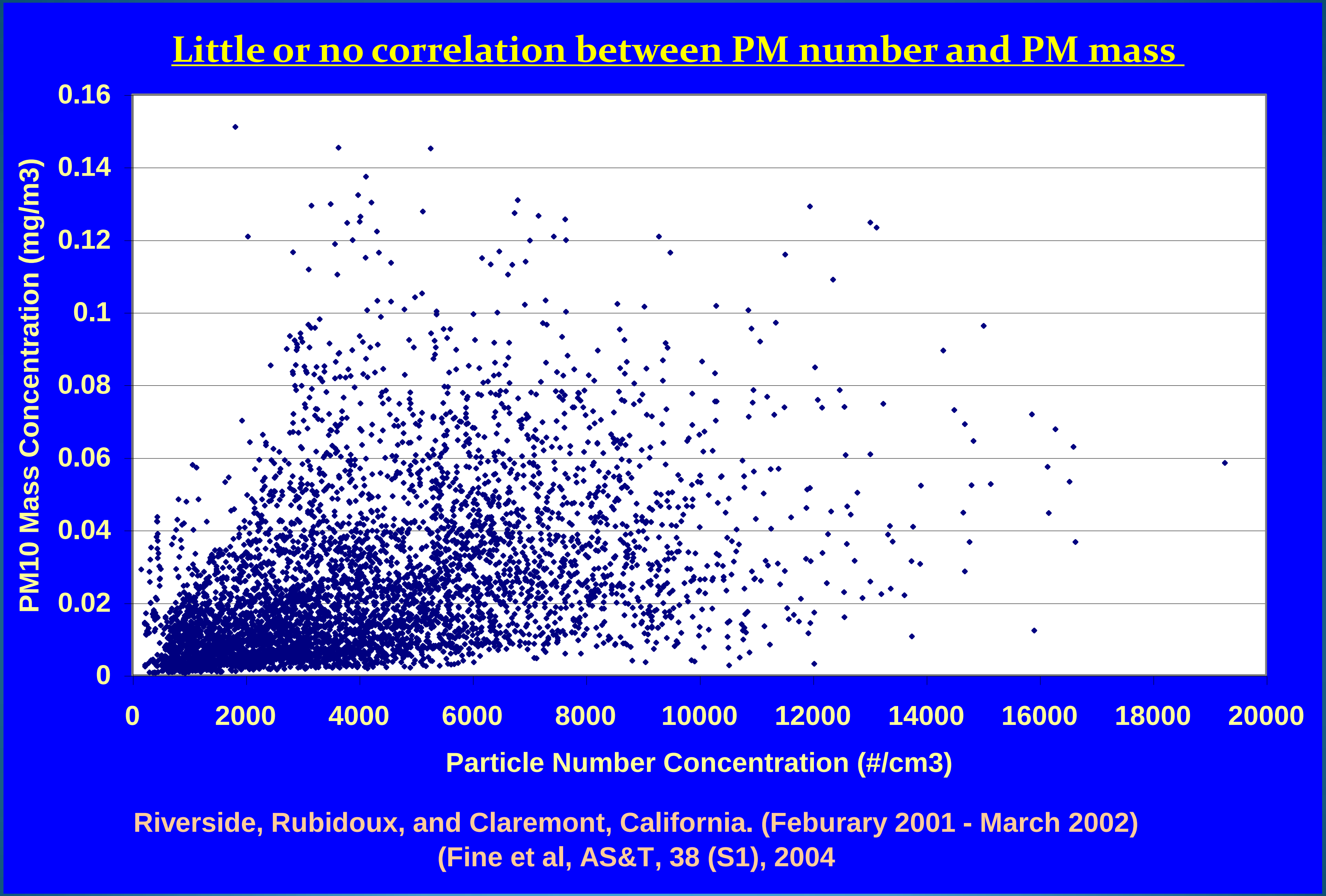
Riverside

Upper Size Cut	80% of Mass Is Within
100 nm	61-100 nm
150 nm	94-150 nm
180 nm	109-180 nm
250 nm	141-250 nm

Long Beach

Upper Size Cut	80% of Mass Is Within
100 nm	55-100 nm
150 nm	73-150 nm
180 nm	82-180 nm
250 nm	98-250 nm

Number vs. Mass



What Characteristics of Ultrafines Do We Measure?

- Counting Particles
  - Full or Partial Size Distributions
    - Expensive, some are semi-continuous
  - Total Particle
    - Relatively easy continuous measurements with CPCs
    - Lower size cut of the type and model of CPC
    - Potential composition effects
    - Single counting vs. photometric modes
  - Non-Volatile Particles Only
    - Adapt PMP Protocol to ambient measurements
    - Thermal denuder or heater upstream
    - Possibly more consistent measurements
    - Lose the majority of particles

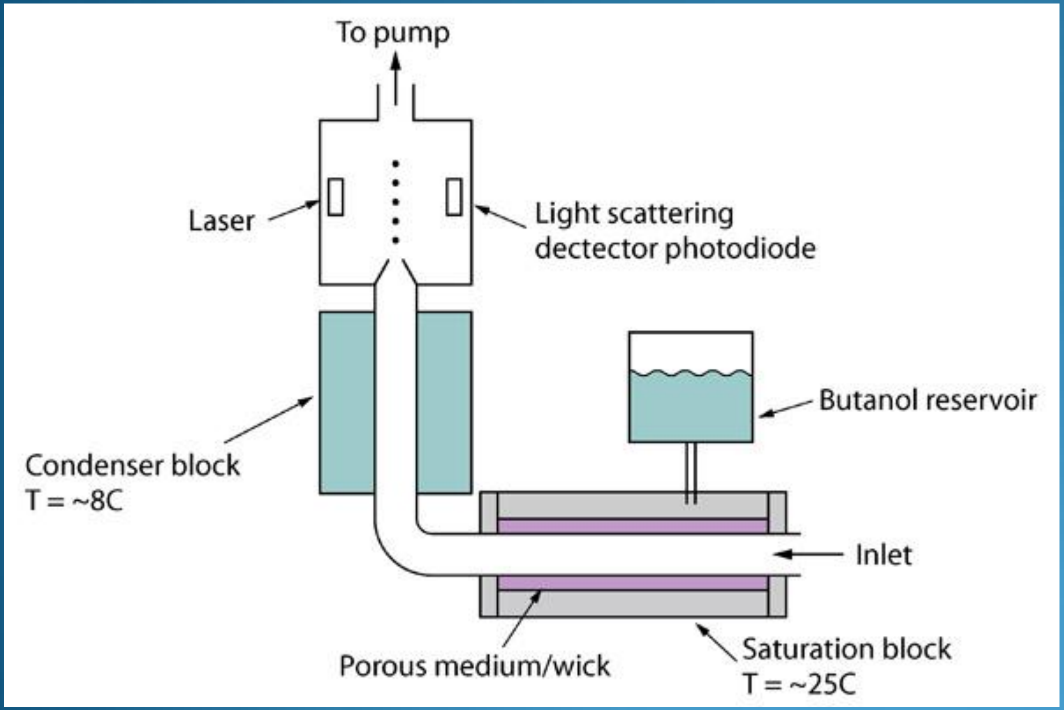
What Characteristics of Ultrafines Do We Measure?

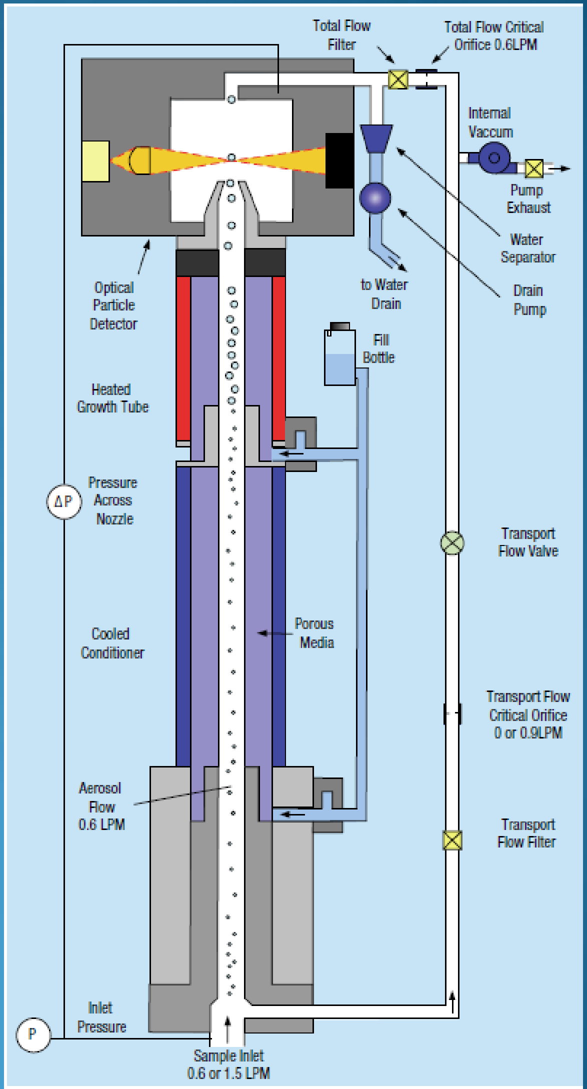
- The Ultrafine characteristics measured by any ambient monitoring program should reflect the latest health effects data
  - Volatile vs. Solid Particles
  - Mass vs. Number
  - Specific size ranges
- Evidence exists for adverse health effects for all of the above.

Instrumentation

- Condensation Particle Counters (CPCs)($12K-$30K)
  - Particle number only
- Scanning Mobility Particle Sizers (up to $70K)
  - Full size distributions
  - Number and mass (with assumptions)
  - Semi-continuous
- Fast Mobility Particle Sizer (up to $120K)
  - Solid state
  - Continuous
- Filter-based techniques with inlet ($5K-$25K)
  - Mass only, speciation, toxicology possible
  - Time-integrated or continuous

Condensation Particle Counters





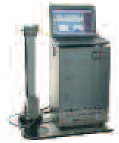
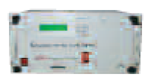
Condensation Particle Counters (1)

Table 1: CPC Specification Comparison

	8525	3007	3783	3772	3787	3775	3790	3776	3788
Specifications									
D_{50} Min. Size (nm)	20	10	7	10	5	4	20	2.5	2.5
Max. Concentration (particles/cm^3)	500,000	100,000	1,000,000	10,000	250,000	50,000 $<10^7$*	10,000	300,000	400,000
Concentration Accuracy (%)	N/A	±20	±10	±10	±10	±10 ±20*	±10	±10	±10
Response - T95 (s)	~3	<~3	<3	~3	~0.7	~4	~3	~0.8	~0.25
Sample Flow (LPM)	0.1	0.1	0.12	1.0	0.6	0.3	1.0	0.05	0.3
Total Inlet Flow	0.7	0.7	0.6/1.5	1.0	0.6/1.5	0.3/1.5	1.0	0.3/1.5	0.6/1.5
Flow Source	Internal	Internal	External	External	Internal	Internal	External	Internal	Internal
Working Fluid	Isopropanol	Isopropanol	Water	Butanol	Water	Butanol	Butanol	Butanol	Water
Weight	1.7 kg (3.8 lbs)	1.7 kg (3.8 lbs)	9.9 kg (22 lbs)	5.5 kg (12 lbs)	8.2 kg (18 lbs)	9.9 kg (22 lbs)	5.5 kg (12 lbs)	9.9 kg (22 lbs)	8.2 kg (18 lbs)
Display	Digital LCD	Digital LCD	Touch w/graph	Digital LCD	Touch w/graph	LCD w/graph	Digital LCD	LCD w/graph	Touch w/graph
Data Logging/ Storage	On-board	On-board	Flash drive	N/A	Flash drive	Memory Card	N/A	Memory Card	Flash drive
SMPS Compatibility	No	No	No	Yes	Yes	Yes	No	Yes	Yes
Price	$	$	$$	$$	$$	$$$	$$$$	$$$$	$$$$

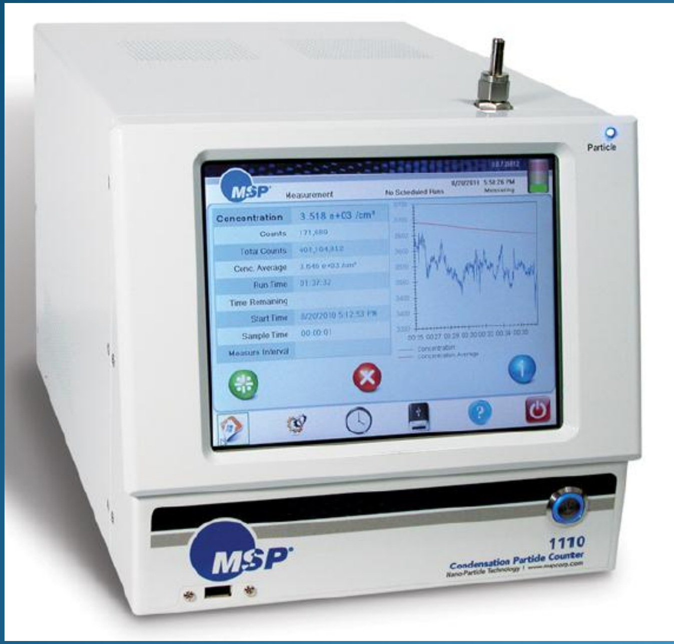
Condensation Particle Counters (2)

GRIMM CPC line-up

	Mobile	Stationary CPC Line					
							
Grimm Model	**5.403**	**5.410**	**5.412**	**5.414**	**5.416**	**5.420**	**5.430**
Short description	All-inclusive portable CPC	Counter only for external pumps	Counter only with pump	Counter and SMPS with sample pump	All-inclusive stationary CPC	All-inclusive CPC for 19" racks	PMP-CPC for automotive applications
Max Conc. [1/ccm] Single count mode	20,000	100,000	100,000	150,000 (0.3 lpm) 100,000 (0.6 lpm)	150,000	150,000	70,000
Max Conc. [1/ccm] Photometric mode	10^7	10^7	10^7	10^7	10^7	10^7	–
D50 [nm]	4.5 (1)	4.1 (1)	4.1 (1)	4.1 (1)	4.1 (1)	4.1 (1)	23 (2)
Sample Flow [lpm]	0.3	0.6	0.6	0.3 & 0.6	0.3	0.3	0.6
SMPS option	yes	–	–	yes	yes	yes	–
Battery	yes	–	–	–	–	–	–
Internal pumps	yes	–	yes	yes (sample air)	yes	yes	–
Internal tank	yes	–	–	–	–	–	–
Netbook included	–	yes	yes	yes	yes	yes	–
Port for external sensors	yes	–	–	yes	yes	yes	–
Size (h x w x d) [cm]	22 x 26 x 30	23 x 25 x 29	23 x 25 x 29	23 x 25 x 29	40 x 25 x 29	19"	23 x 25 x 29

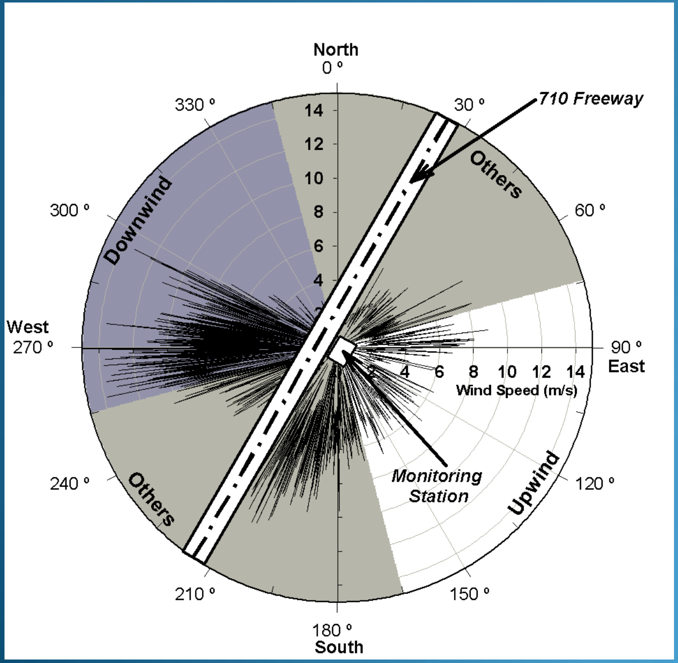
(1) Measured with Ag particles (2) Measured with soot particles

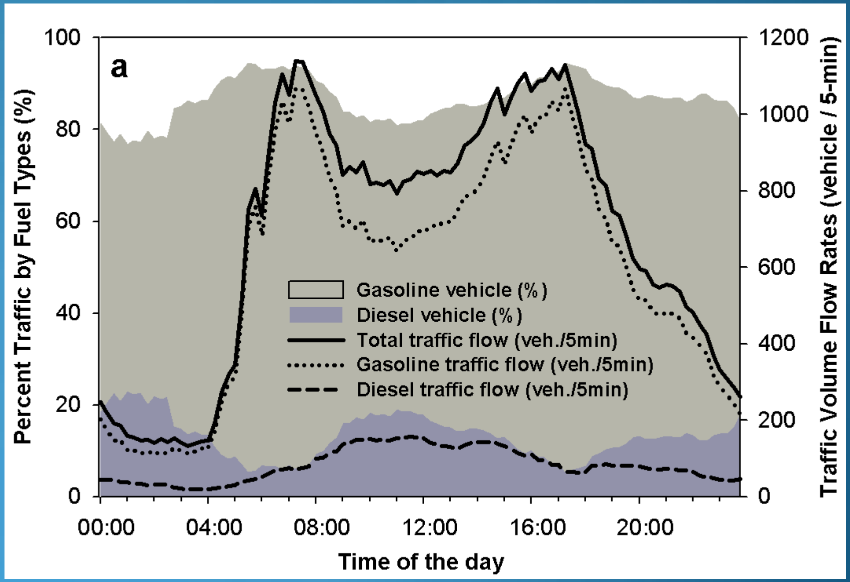
Condensation Particle Counters (3)



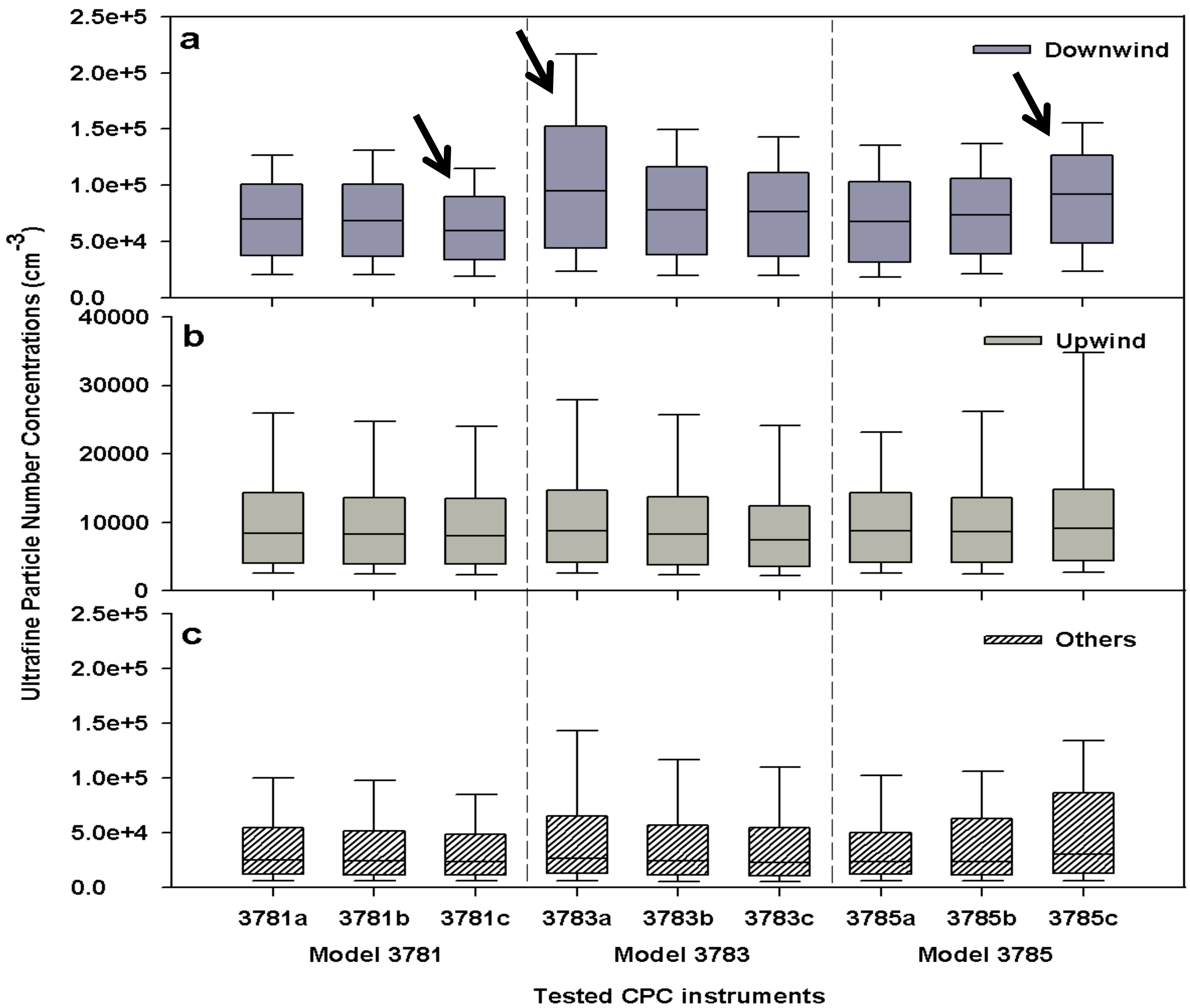
CPC COMPARISON

Specifications	Model 3781	Model 3783	Model 3785
Detectable Particle Diameter Range	6 nm to 3 µm	7 nm to 3 µm	5 nm to 3 µm
Maximum Detectable Particle Concentration (cm^{-3})	5×10^5	1×10^6	1×10^7
Particle Counting Errors	± 10 % at 5×10^5 cm^{-3}	± 10 % at 1×10^6 cm^{-3}	± 10 % at 2×10^4 cm^{-3}
Aerosol Flow Rates (L/min)	0.12 ± 0.012	0.12 ± 0.012	1.0 ± 0.1
Inlet Flow Rates (L/min)	0.6 ± 0.12	3 ± 0.3	1.035

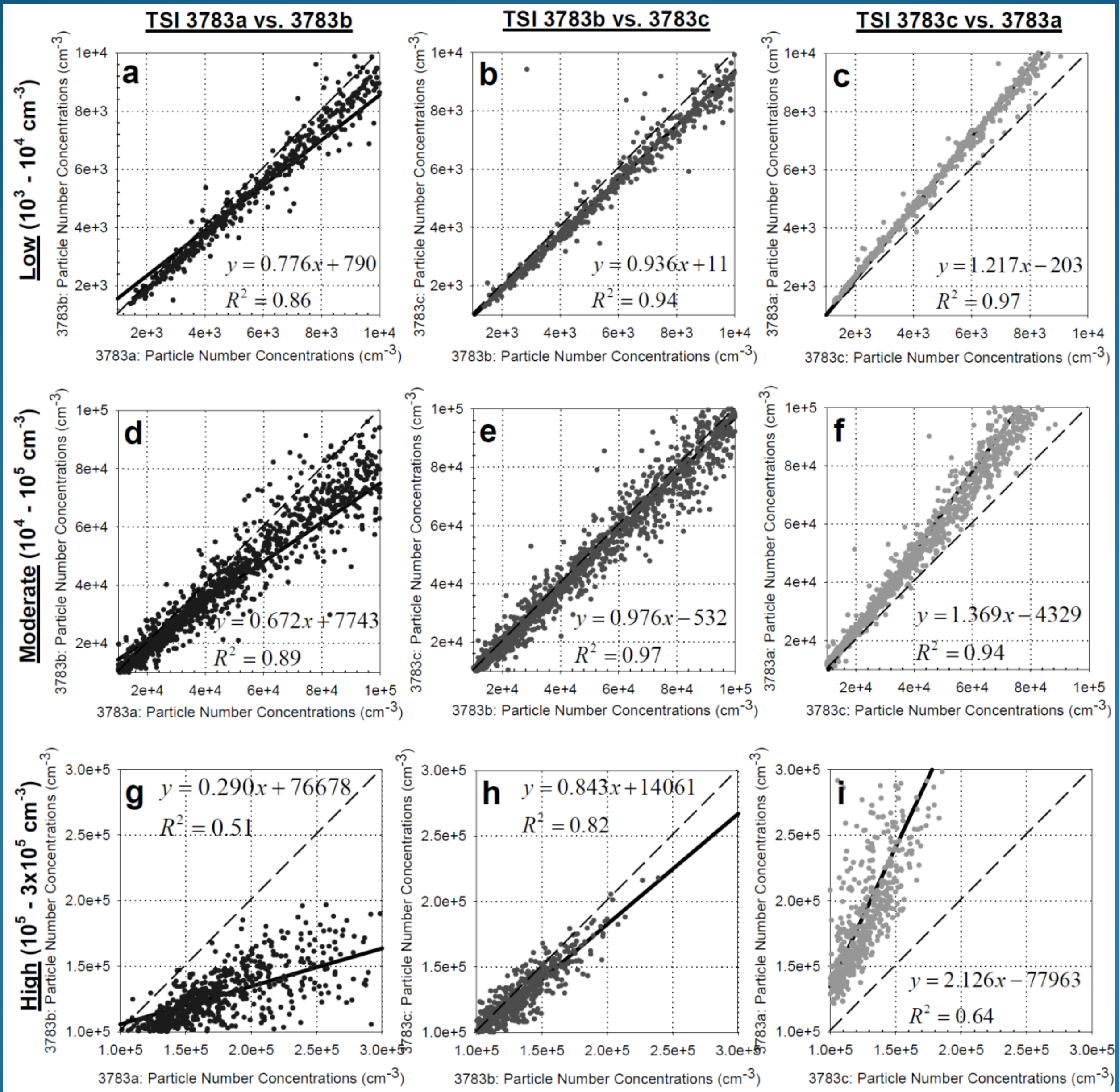




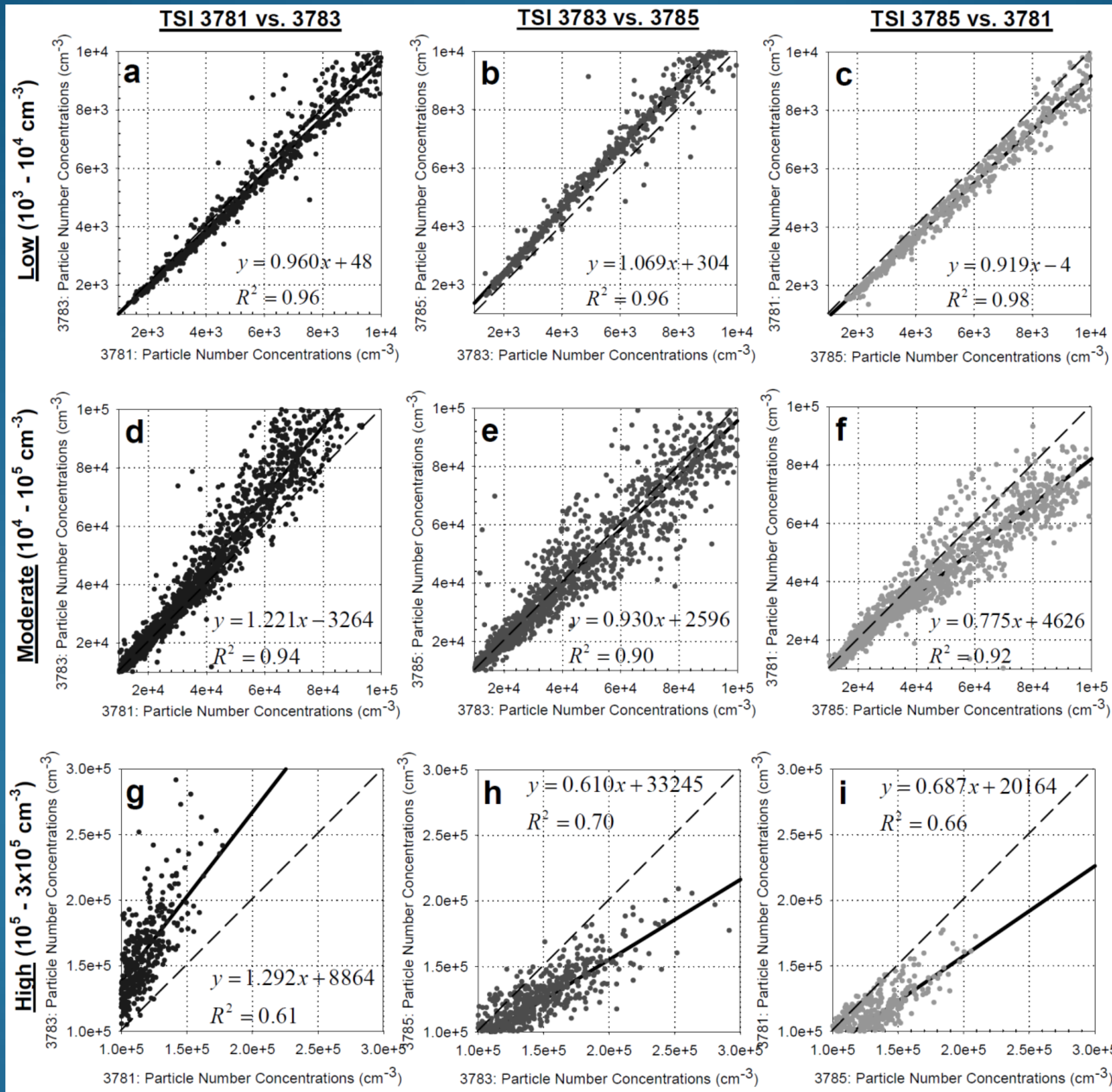
CPC COMPARISON



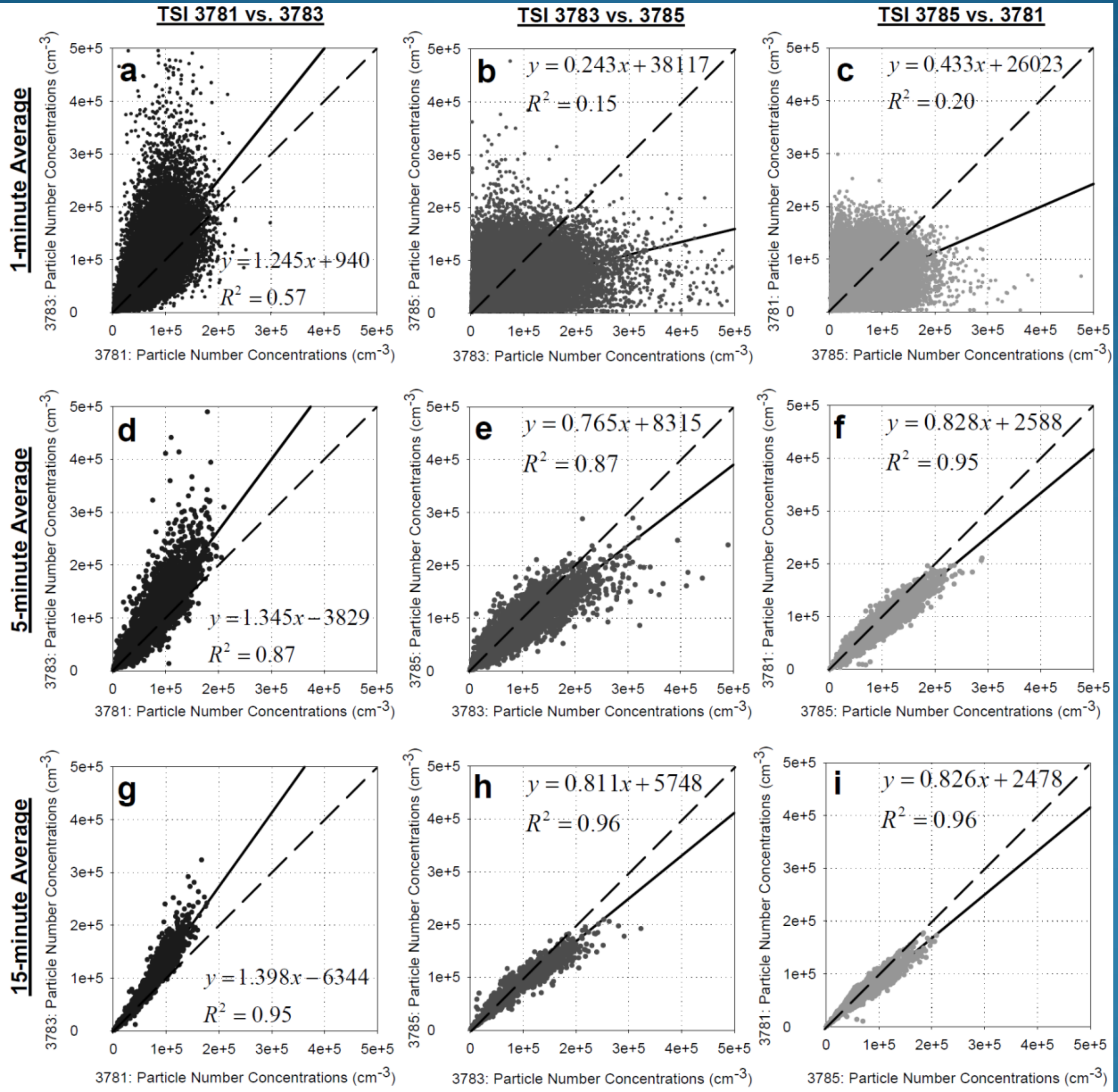
CPC COMPARISON - Precision



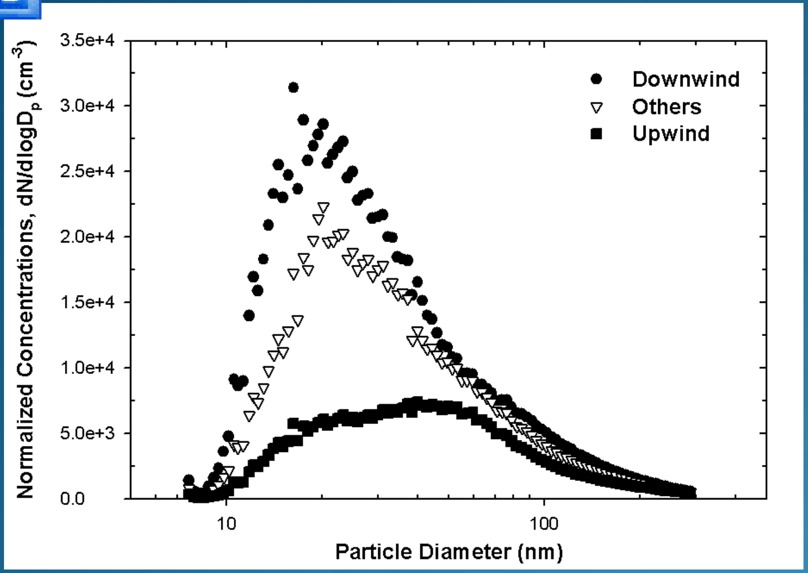
CPC COMPARISON - Accuracy

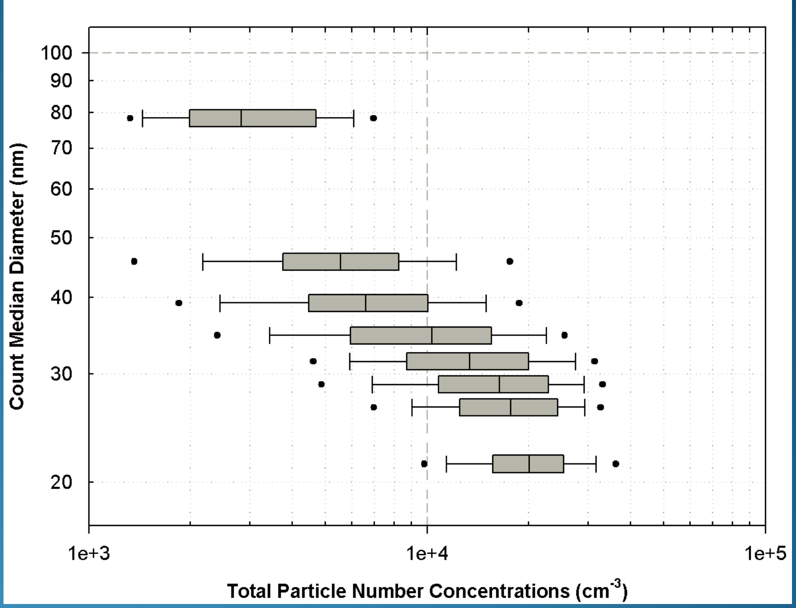


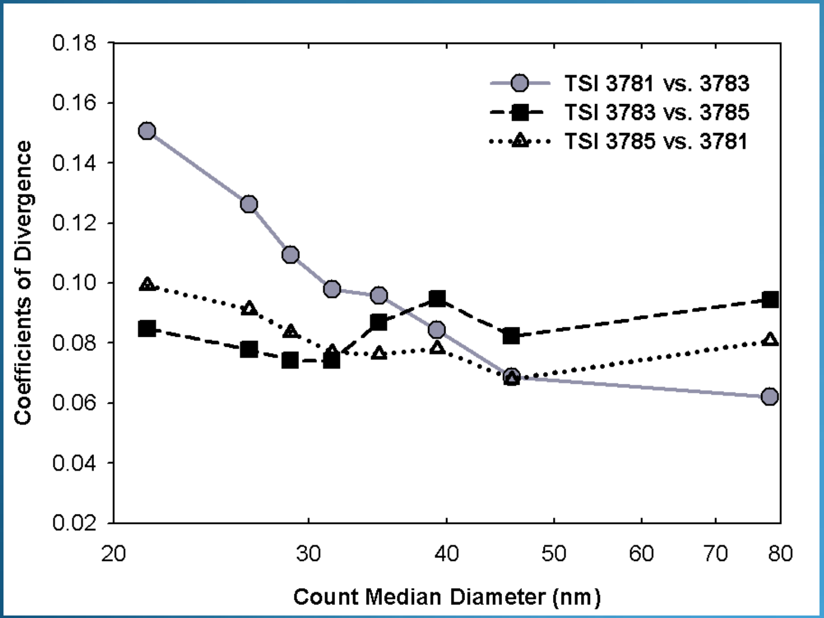
CPC COMPARISON – Averaging Time

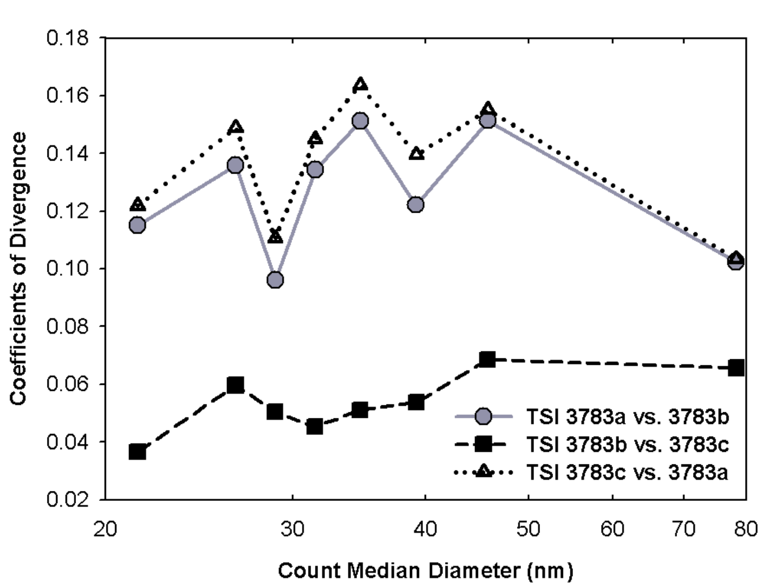


CPC COMPARISON – Particle Size







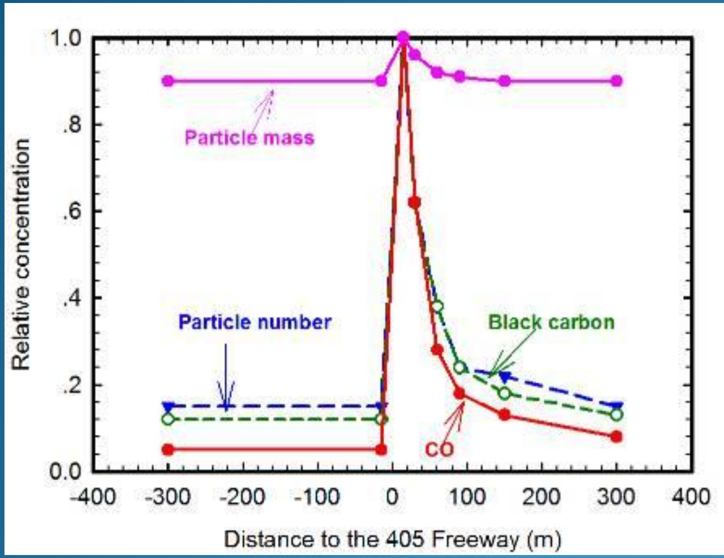


Size Distribution Measurements ($$$$)

AQMD

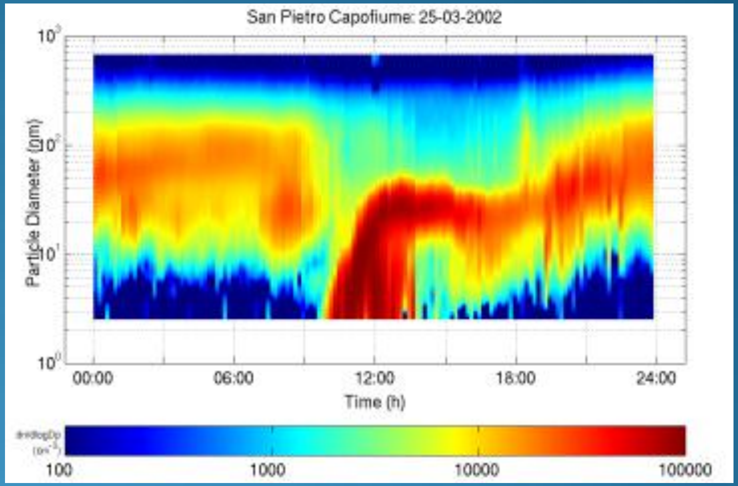
Sources of Ultrafine Particles

Combustion Sources



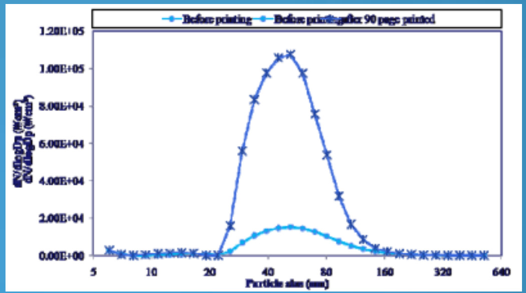
Zhu, JAWMA, 2002

Atmospheric Nucleation



Laaksonen, Univ. of Kuopio

Other Non-Combustion Sources



Balasubramanian, National University of Singapore

Monitoring Locations

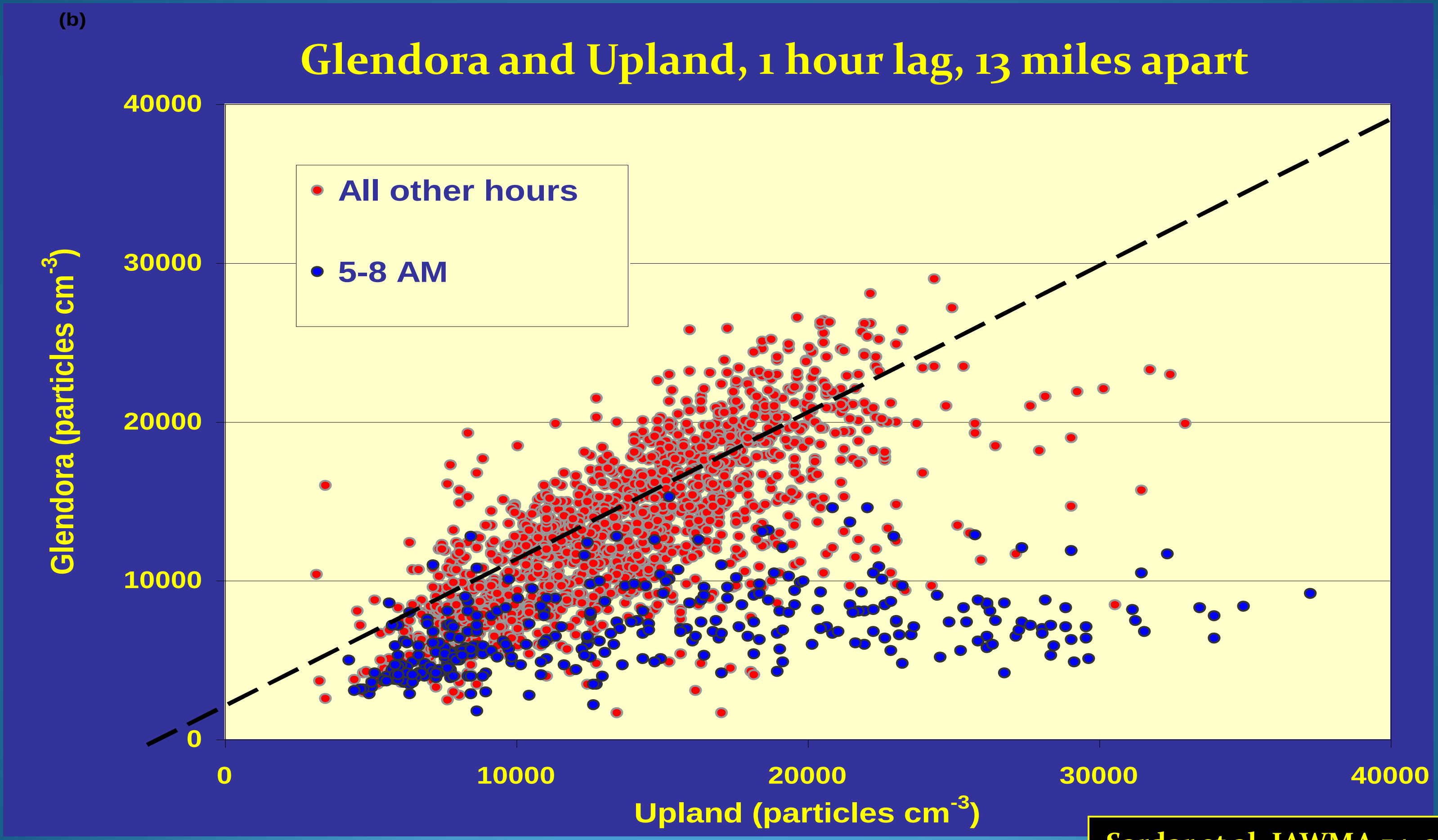
Choosing monitoring locations always depends on the objective

- Source characterization
  - Very near the source – upwind/downwind
  - At the tailpipe/stack
- Atmospheric behavior and fate
  - Multiple locations downwind from source
- Human Exposure
  - Where human exposures are highest
  - Differential exposures for health studies
- Potential regulatory monitoring for ambient standards
  - Representative locations
  - Proper scale

Typical Ultrafine Concentrations

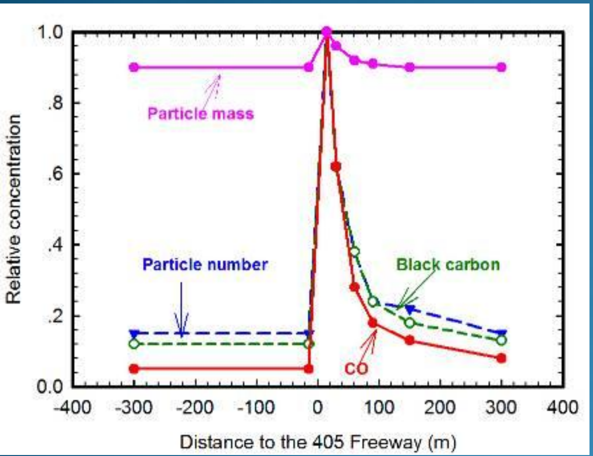
- Clean backgound: 500 – 2,000 p/cc
- Typical urban air: 5000 – 30,000 p/cc
- Freeway: 50,000 – 200,000 p/cc
- Jet exhaust: up to 6,000,000 p/cc

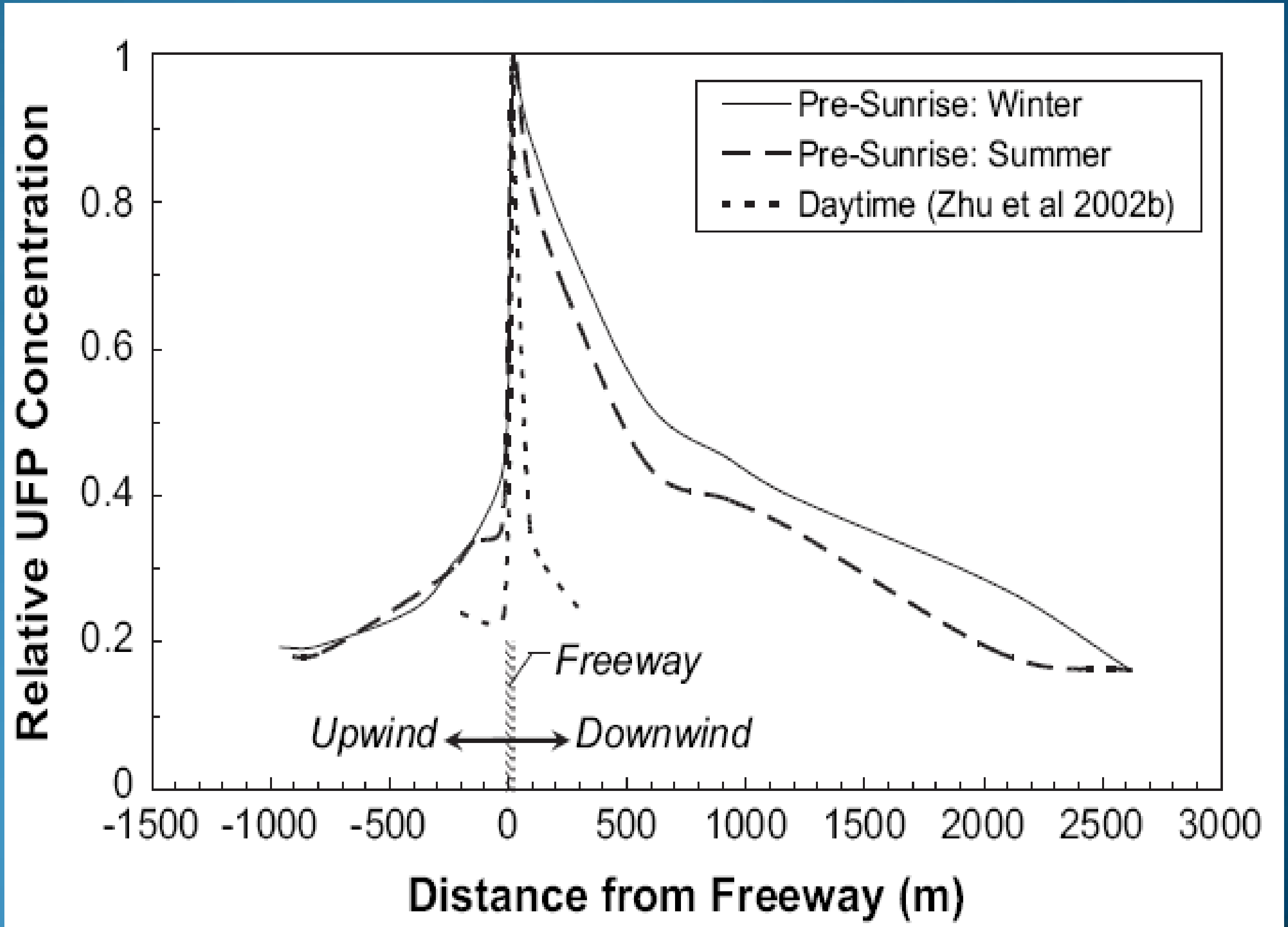
Network Sites - Spatial Scale



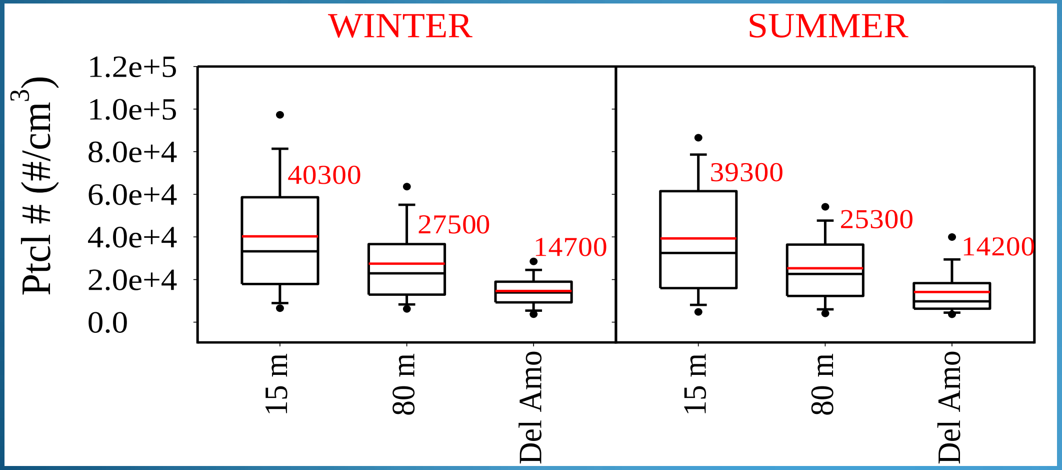
Sardar et al. JAWMA 54, 2004

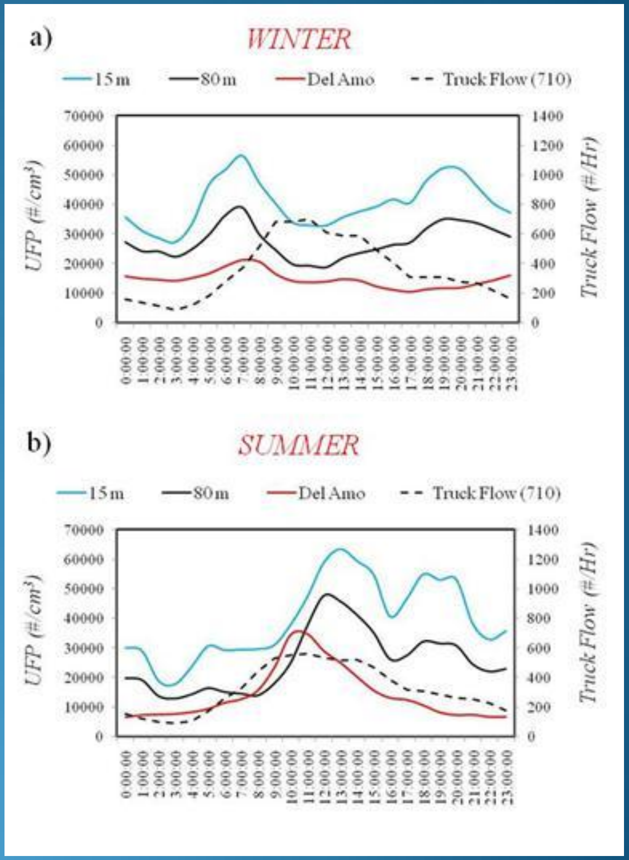
Meteorological Effects



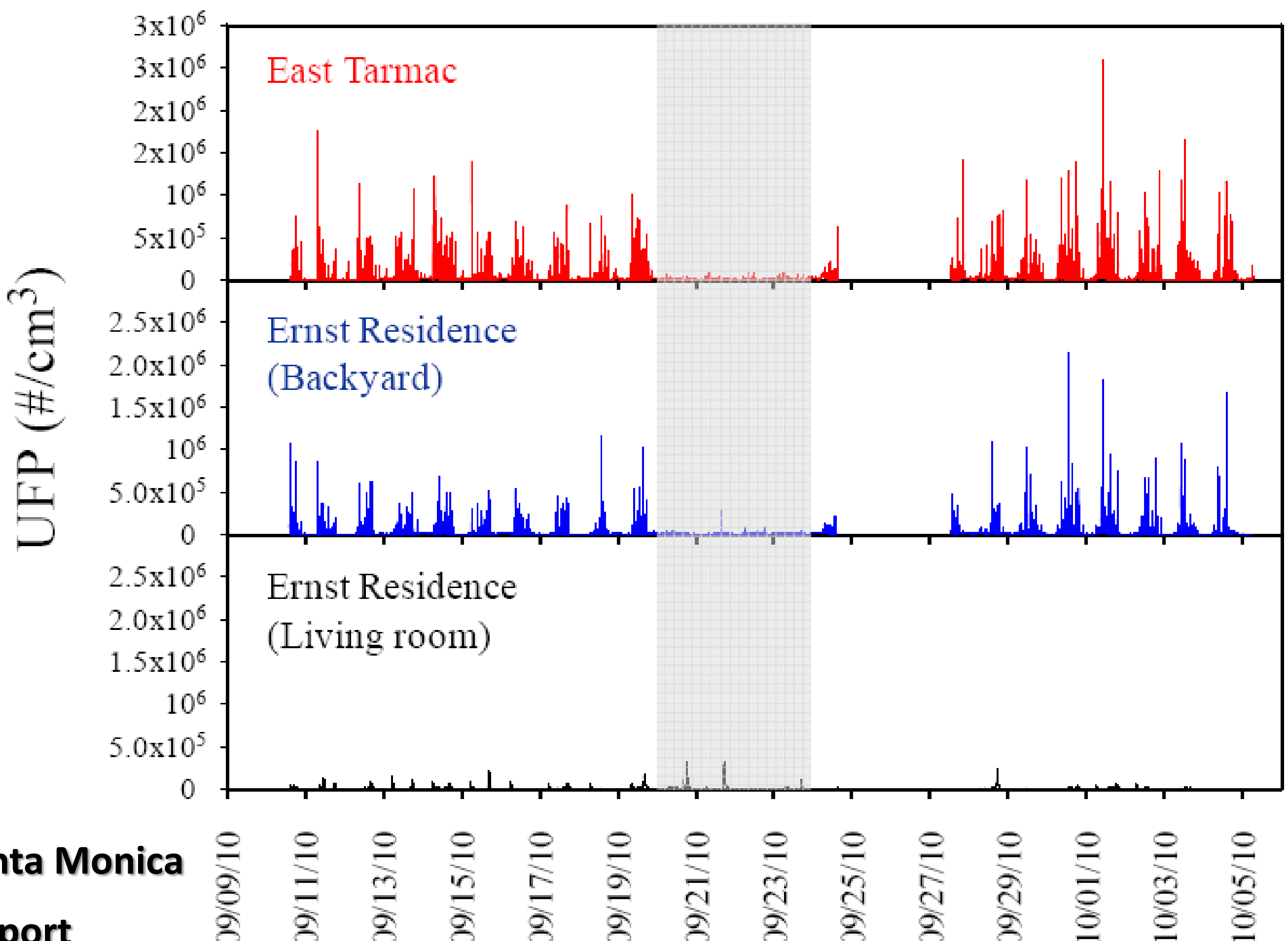


Near Freeway



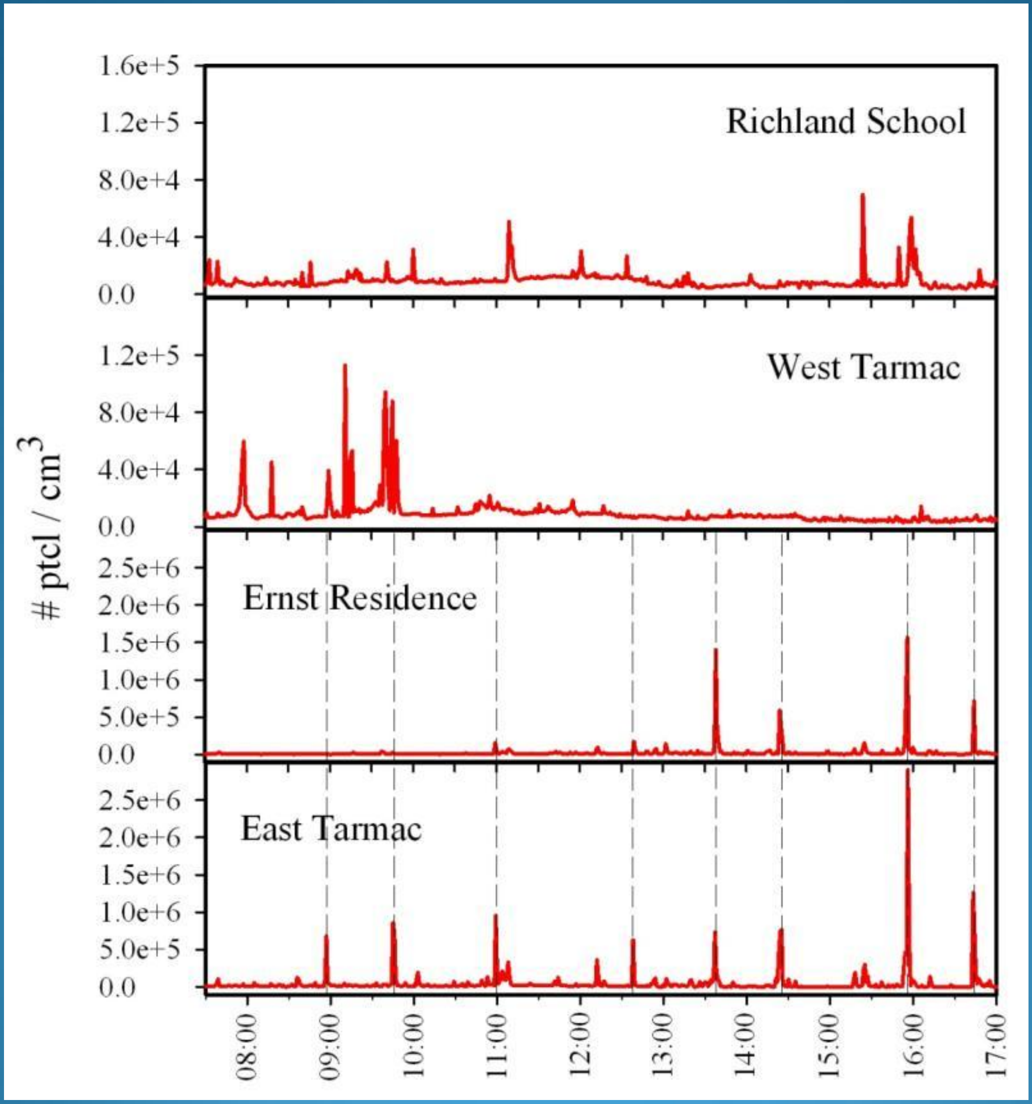


Jet Aircraft



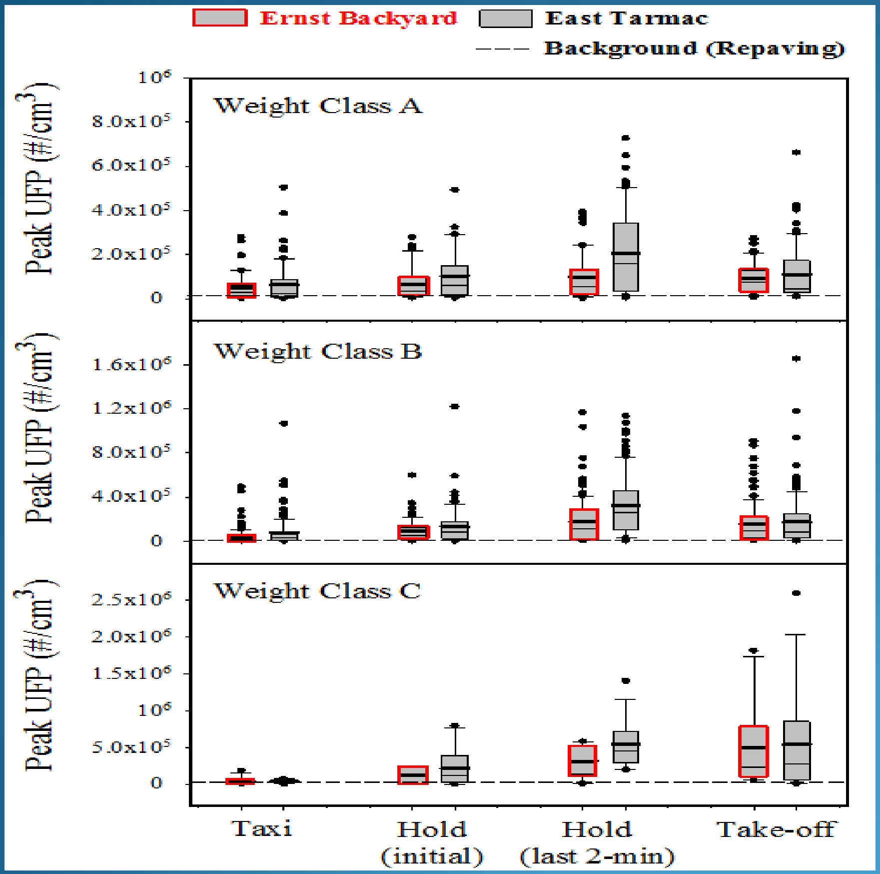
Santa Monica Airport

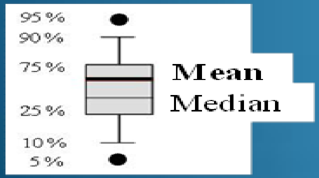
Short-term Fluctuations



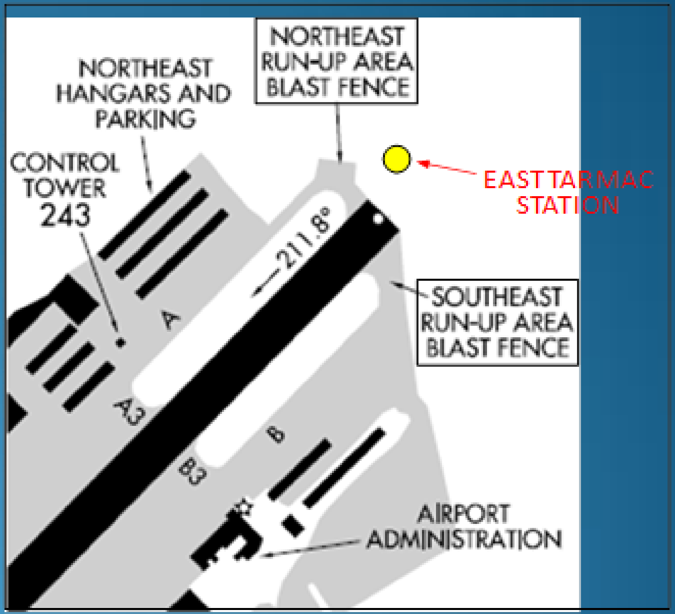
Santa Monica Airport

Dependence on Source and Activity





Weight Class A: < 12,500 lb
Weight Class B: 12,500 – 41,000 lb
Weight Class C: > 41000 lb



Santa Monica Airport

At The Tailpipe - Volatility

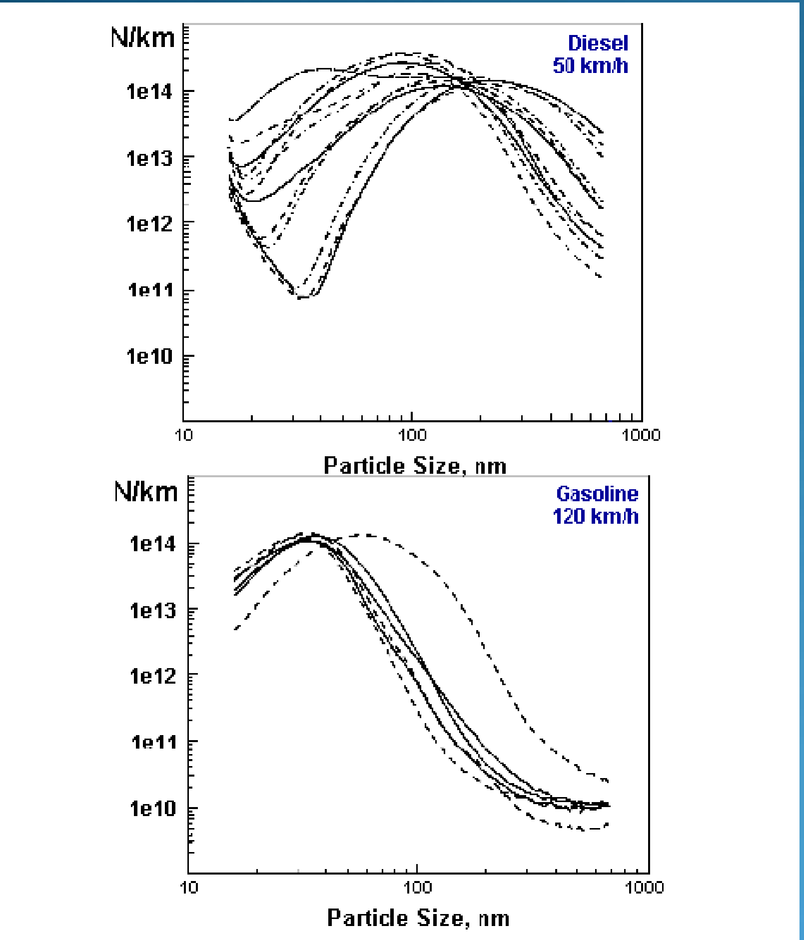
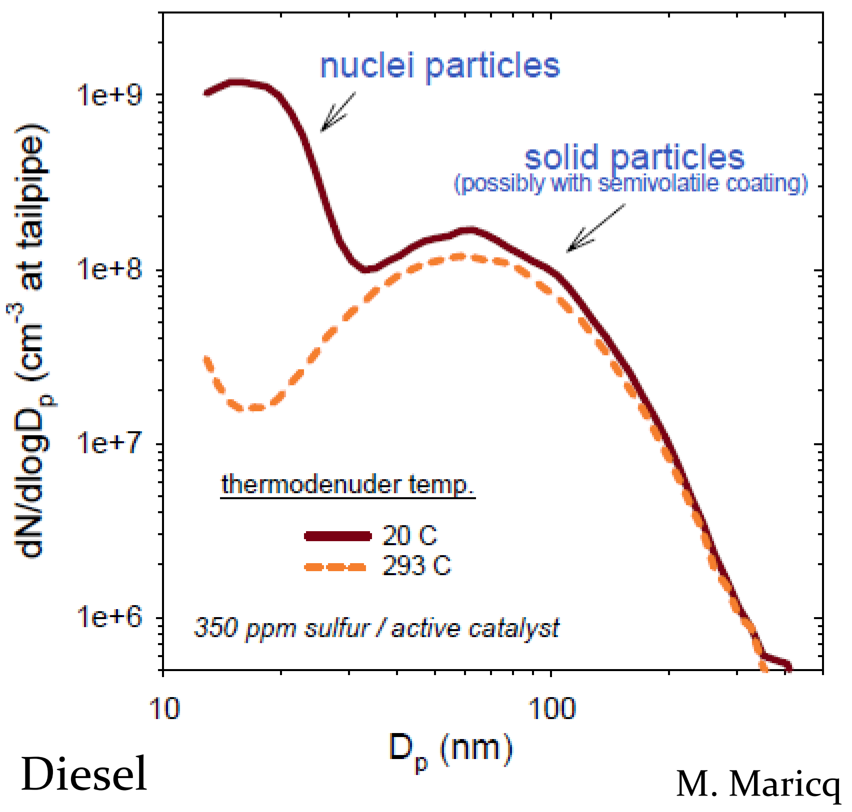


Figure 5. Particle Size Distributions from Diesel and Gasoline Cars

http://courses.washington.edu/cive494/DieselParticleSize.pdf



•European tailpipe standards (PMP) use thermal denuder and thus ignore nuclei mode

Outstanding Issues

- Measurements
  - Standardize methods - accuracy
  - Lower cost, more precise and more reliable instruments
- Studies
  - Instruments
  - Health
  - Atmospheric
- Mitigation
- Policy/Regulation
  - Ambient Standards
  - Tailpipe standards - PMP
  - Criteria Pollutant / Air Toxic

South Coast AQMD Activities

Multiple Air Toxics Exposure Studies (MATES)

MATES I: 1986

Identified benzene, 1,3 butadiene, hexavalent chromium as most important air toxics

MATES II: 1998-1999

Demonstrated diesel PM as the major toxic risk driver

MATES III: 2004-2006

Better estimates of diesel risk, micro-scale sites, identified hexavalent chromium from cement plants

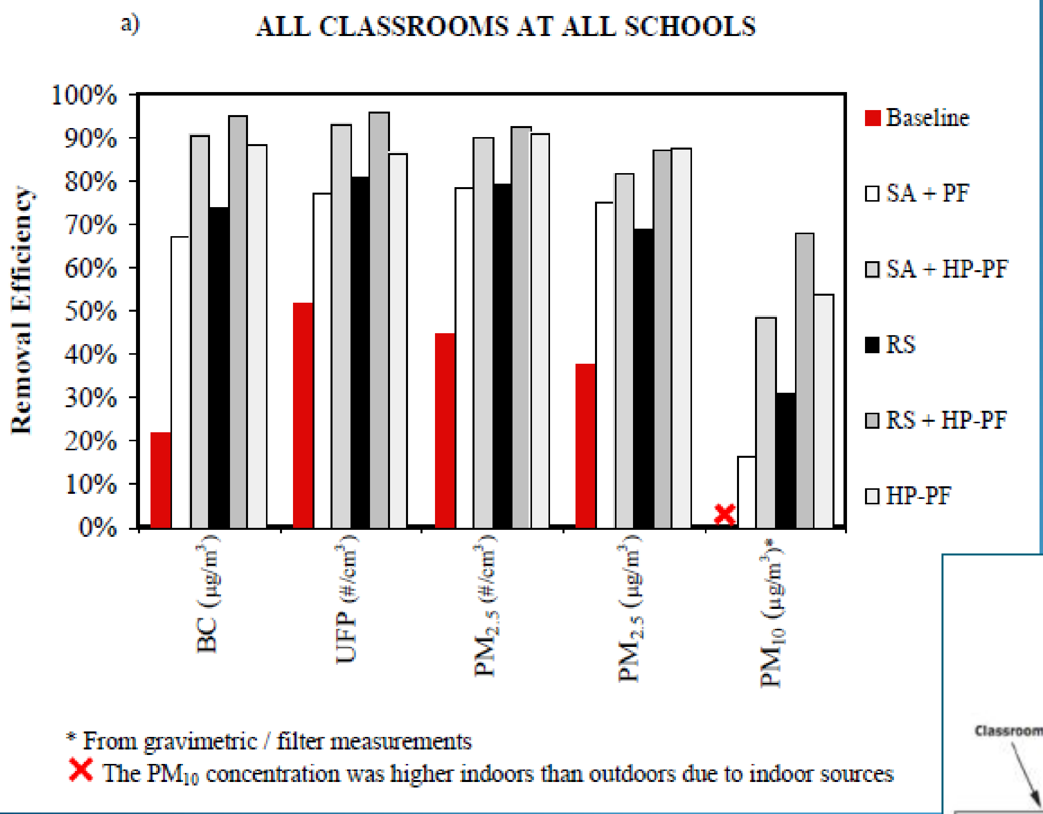
All had major impacts on air toxics policy and regulation

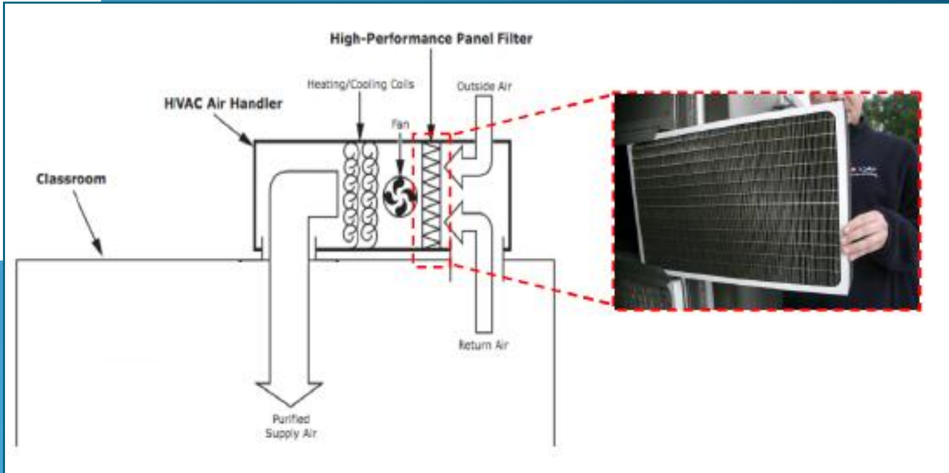
MATES IV: 2012-2013

New focus on the local impacts of mobile sources on <u>ultrafine</u> and diesel PM exposure

South Coast AQMD Activities

Mitigation – Filtration at Schools

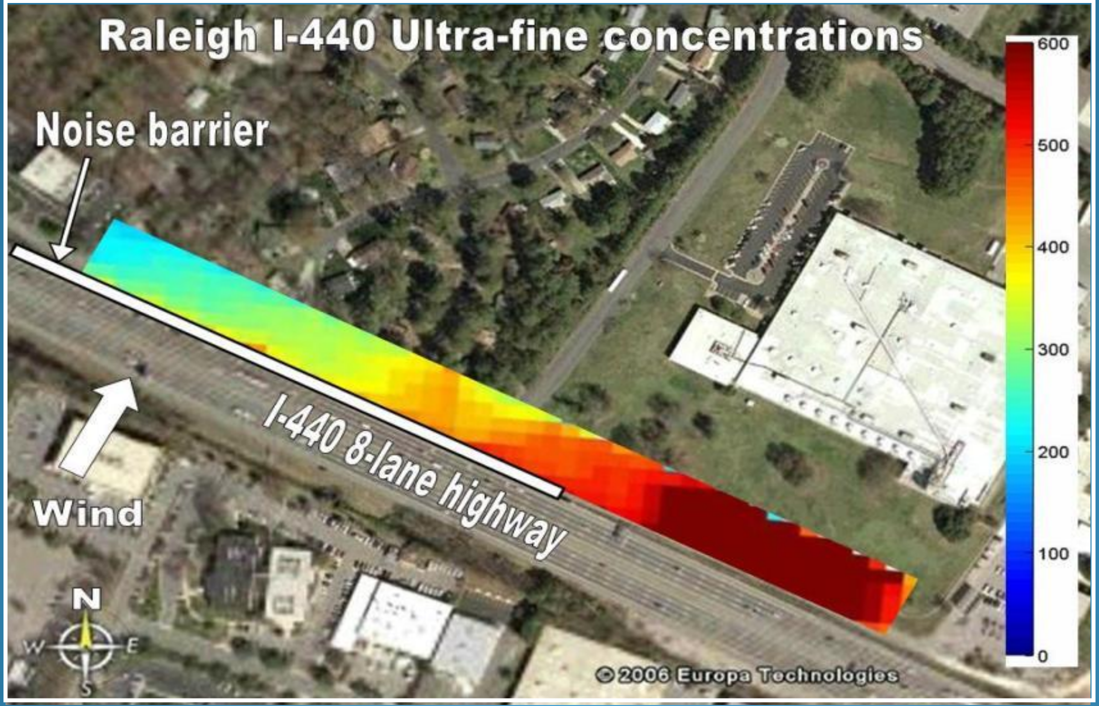




South Coast AQMD Activities

Mitigation – Near Road

- Funding three current research projects on near-freeway mitigation of pollutants
  - Trees, sound walls, elevation, active measures

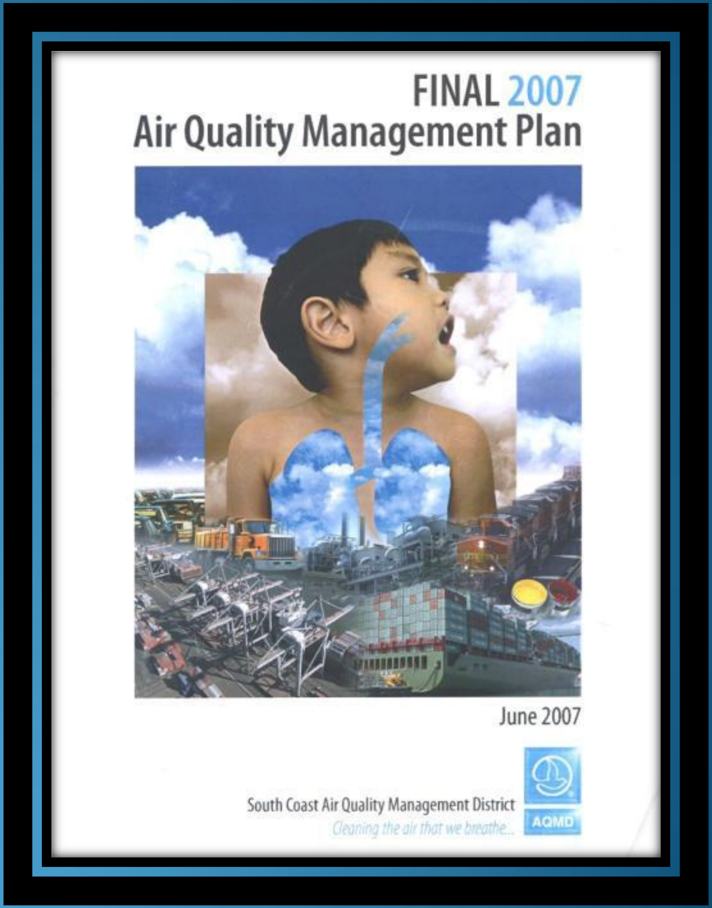


Adapted from Isakov, EPA. CRC MSAT Conference, 2008

South Coast AQMD Activities

Policy / Regulation

- 2007 Air Quality Management Plan
  - Chapter on Ultrafine Particles as an emerging issue
- 2012 Air Quality Management Plan
  - Chapter on Near Roadway Exposures and Ultrafine Particles
  - Potential Policy Recommendations



Questions?