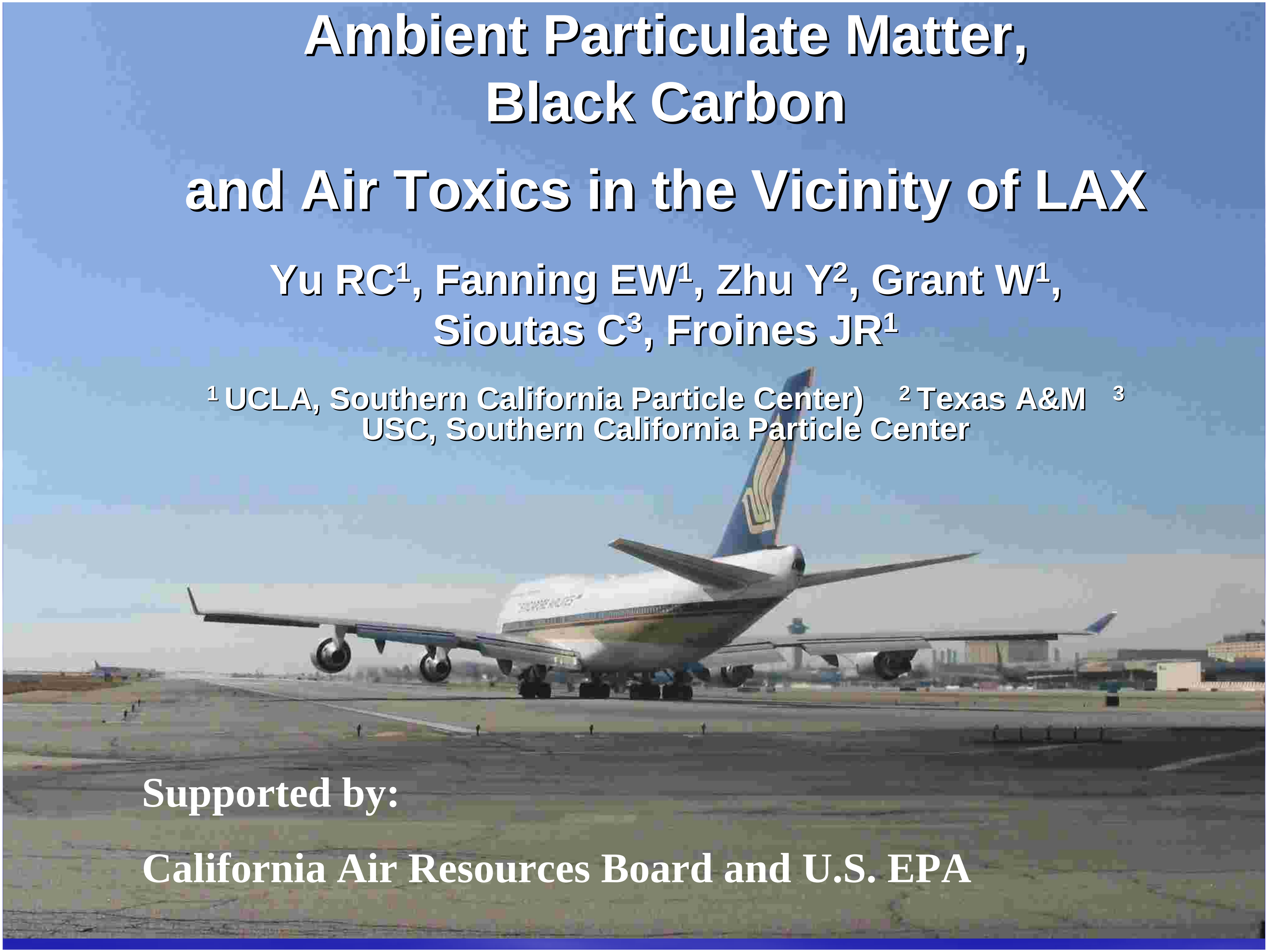
Ambient Particulate Matter, Black Carbon and Air Toxics in the Vicinity of LAX

Yu RC[1], Fanning EW[1], Zhu Y[2], Grant W[1], Sioutas C[3], Froines JR[1]

[1] UCLA, Southern California Particle Center) [2] Texas A&M [3] USC, Southern California Particle Center



Supported by:

California Air Resources Board and U.S. EPA

Background: Health effects associated with PM exposure

- **CNS and autonomic nervous system**
- **Development: Low birth weight/preterm birth**
- **Increase in asthma and other respiratory disease in children**
- **Decrease in lung development and function in children**
- **Cardiovascular disease including atherosclerosis in adults**
- **Cancer**
- ***All Airborne PM is potentially toxic; ultrafine particles have distinct toxicological properties***

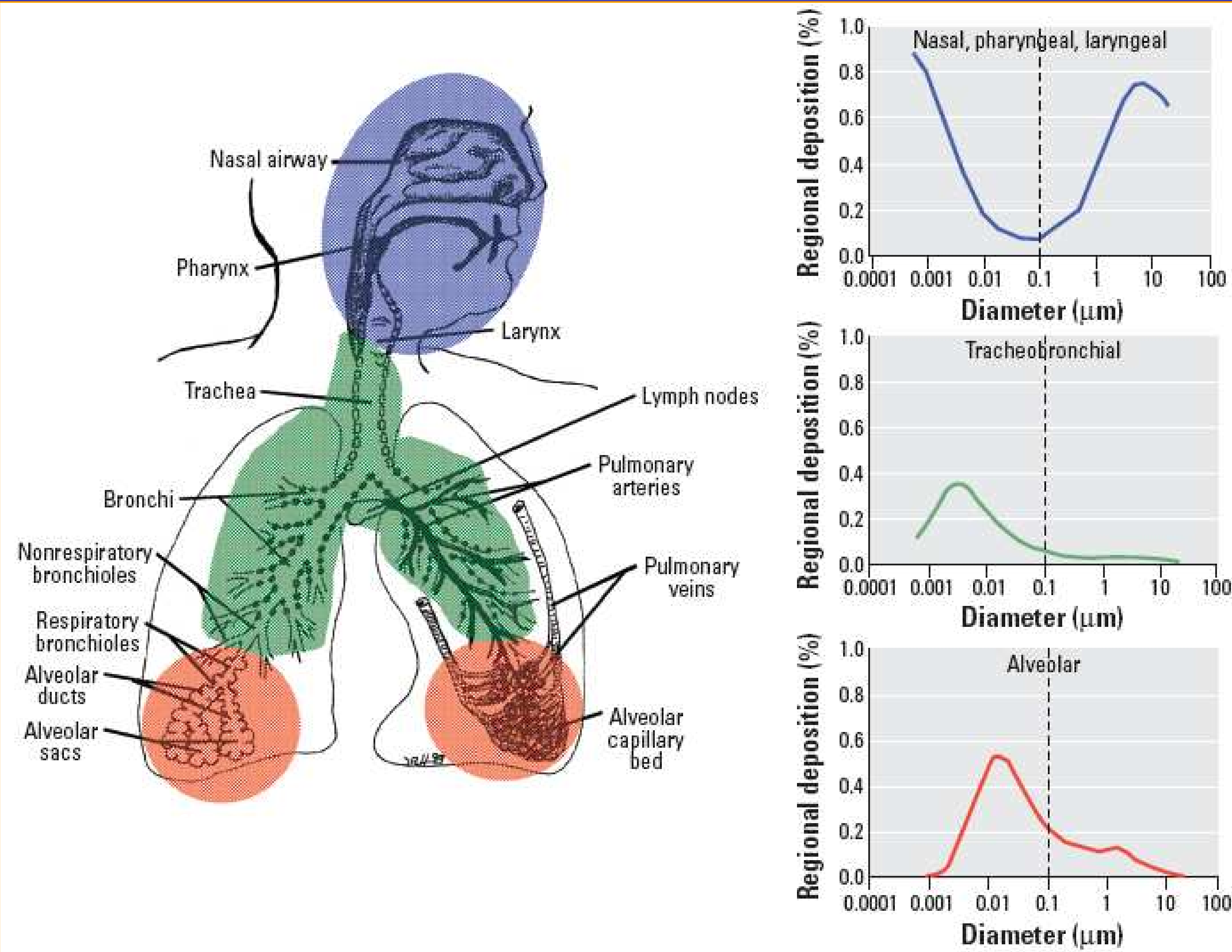
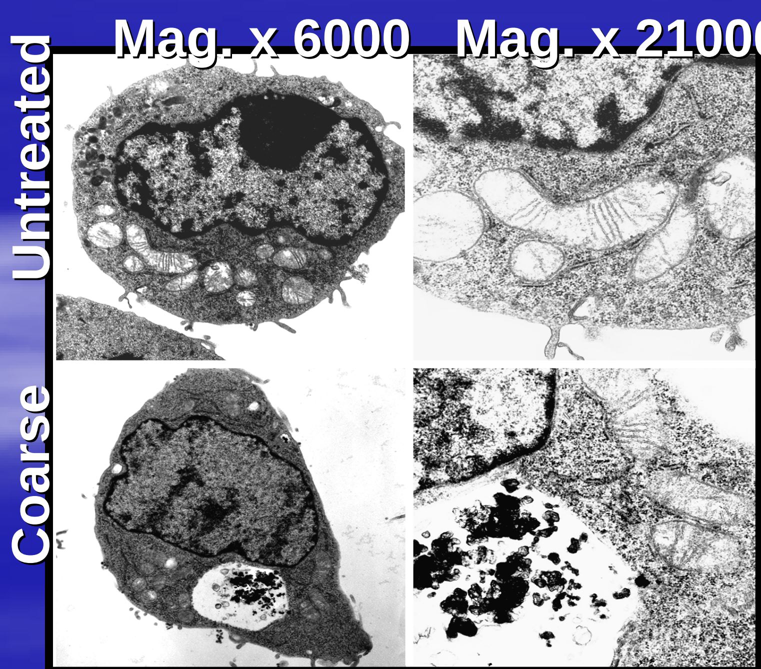

Nasal airway
Pharynx
Larynx
Trachea
Lymph nodes
Pulmonary
arteries
Bronchi
Nonrespiratory
bronchioles
Pulmonary
veins
Respiratory
bronchioles
Alveolar
ducts
Alveolar
sacs
Alveolar
capillary
bed
Nasal, pharyngeal, laryngeal
Tracheobronchial
Alveolar
Regional deposition (%)
Diameter (µm)
1.0
0.8
0.6
0.4
0.2
0.0
0.0001
0.001
0.01
0.1
1
10
100

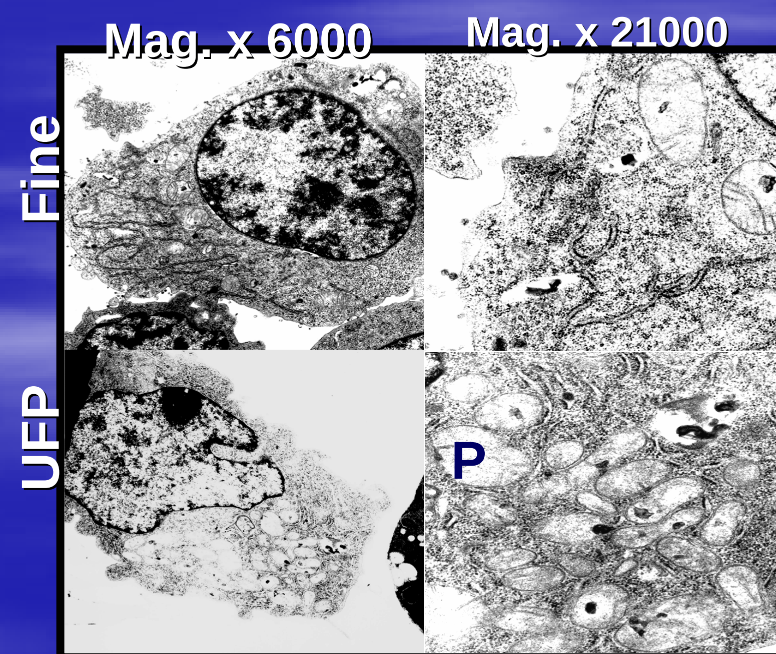
Table 1. Particle number and particle surface area for 10 μg/m^3 airborne particles (5).

Particle diameter (μm)	Particles/ml of air	Particle surface area ($μm^2$/ml of air)
2	2	30
0.5	153	120
0.02	2,390,000	3000

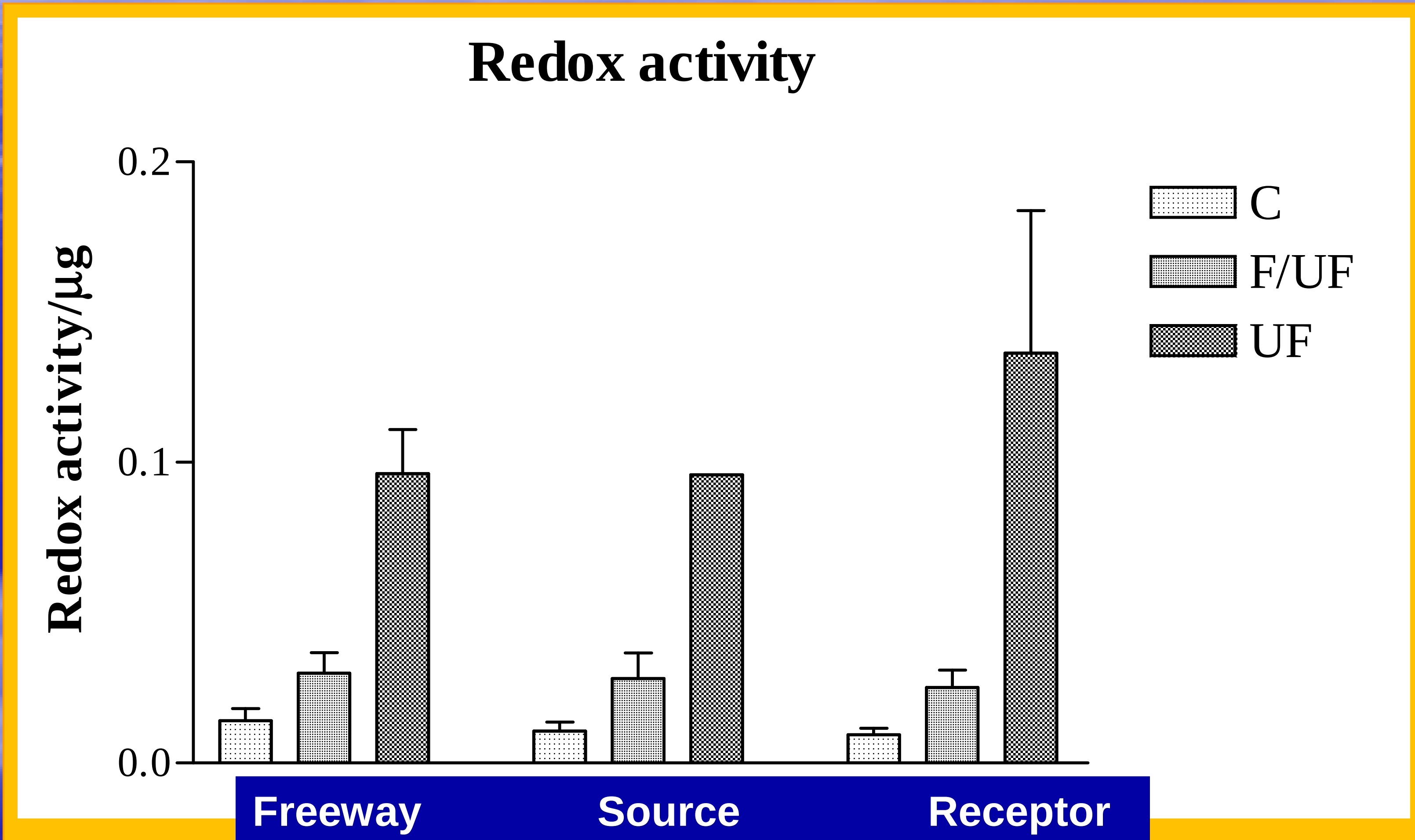
Ultrafine Particles Enter Cells

- Inhaled ultrafine particles can cross into the luminal side of airways in all major lung tissue compartments and are found in capillaries
- UFP can enter cells: within cells UFP can affect intracellular proteins, organelles, and DNA which may greatly enhance their toxic potential.
- Mitochondria are an Important Subcellular Target of PM and a Source of ROS Generation

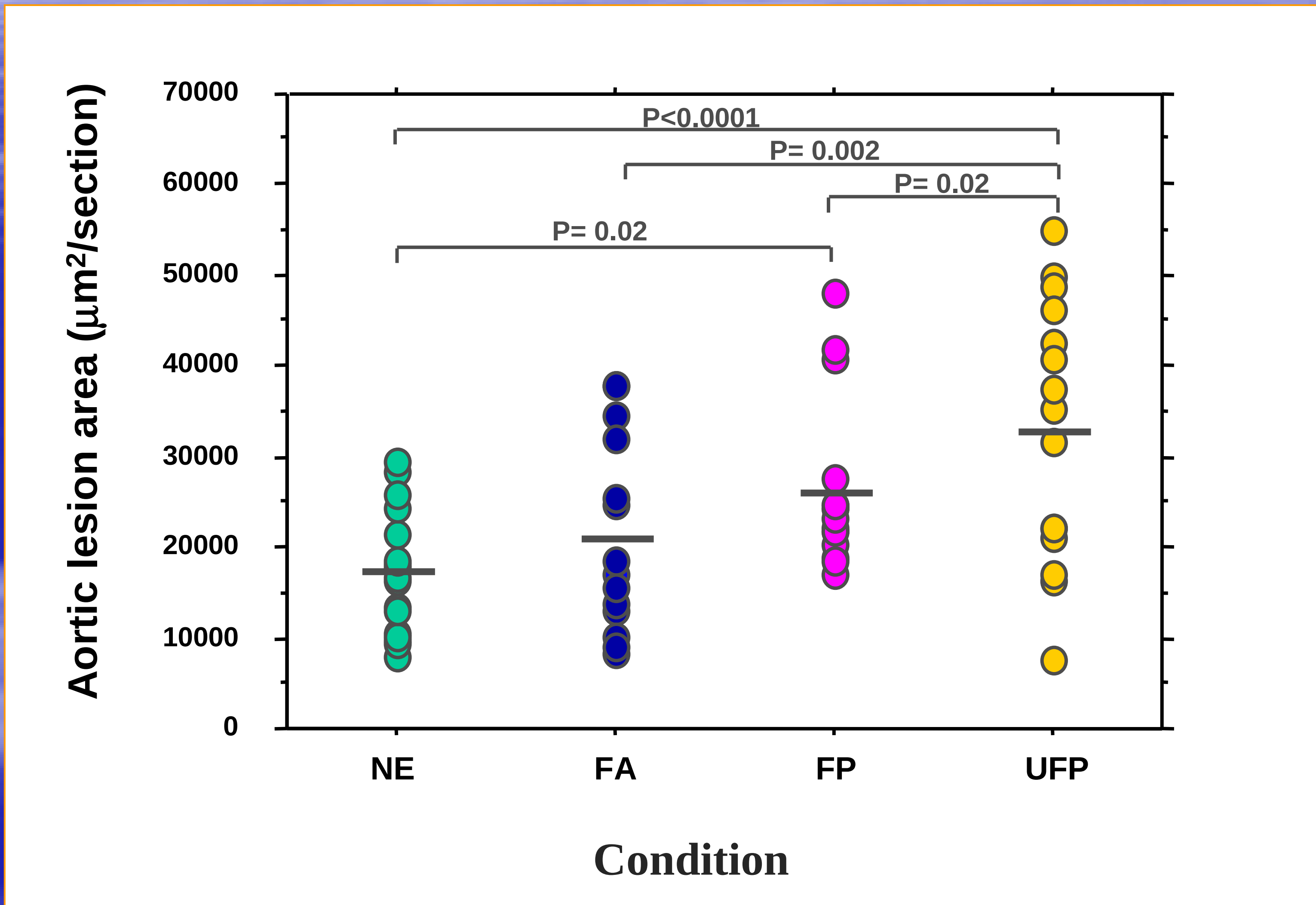




Redox activity of ambient PM: effect of location and size fraction



Aortic atherosclerotic lesions



Particle Size and Composition: Relation to Toxicity

Table 5
Contrasting features of coarse, fine, and ultrafine particles[a]

Parameters	Particle mode		
	Coarse (PM_{10})	Fine ($PM_{2.5}$)	Ultrafine
Size	2.5–10 μm	2.5–0.15 μm	<0.15 μm
Organic carbon content	+	++	+++
Elemental carbon content	+	++	+++
Metals as % of total elements	+++	++	+
PAH content	+	+	+++
Redox activity (DTT assay)	+	++	+++
HO-1 induction	+	++	+++
GSH depletion	+	+++	+++
Mitochondrial damage	None	Some	Extensive

[a] [85].

(sampled at source site)

From: Li, N., Hao, M., Phalen, R., Hinds, W., Nel, A. (2003). "Particulate air pollutants and asthma: A paradigm for the role of oxidative stress in PM-induced adverse health effects." Clinical Immunology 109: 250-265.

Introduction

- **Aircraft are an important source of ambient particulate matter with potential for human exposure in the vicinity of airports.**
- **LAX: high aircraft traffic in a dense urban setting.**
- **Studies of ultrafine particles emitted from aircraft have been limited, yet health effects studies continue to implicate ultrafine combustion particles as relevant to public health.**
- **We conducted a small scale study to begin characterization of aircraft associated ultrafine PM at LAX, using near real-time instrumentation. The study had 3 components: at LAX, immediately downwind, and an exploratory community study.**

Blast Fence Study
Objectives

- Quantify concentrations and size distribution of aircraft-associated ultrafine PM in near-source wind-advected plumes.
- Apply real-time monitoring instruments to capture temporal behavior of aircraft emitted particles and associate them with aircraft activity patterns.
- Monitor simultaneously at a background site not affected by aircraft plumes to provide reference data.

Methods
1. Sampling locations

- Near Source site – blast fence at the east end of 25R runway of LAX, positioned to capture emissions from aircraft take-off thrust.
- Background site – a residential area northwest of LAX, free of major PM sources. Airport activity is not likely to contribute to local air pollution because of westward prevailing wind.


Marina Del Rey
Ballona Creek
Loyola Marymount University
Lincoln Blvd
Loyola Blvd
Regis Way
La Tijera Blvd
Toland Ave
W Manchester Ave
W 87th St
Westchester
Westchester Golf Course
W 88th St
Hulbert Ave
Rayford Dr
Falmouth Ave
Pershing Dr
Rindge Ave
Ocean Front Walk
Westchester Pky
Arbor Vitae St
W 93rd St
W 95th St
W 96th St
W 98th St
W Century Blvd
Avion Dr
W 102nd St
S Sepulveda Blvd
Center Way
Post Way
Isis Ave
405
105
42
Playa Del Rey
Vista Del Mar
Los Angeles Int'L Airport
Pacific Ocean
W Imperial Hwy
W Imperial Ave
E Imperial Ave
W Sycamore Ave
Hindry Ave
S La Cienega Blvd
W 77th St
W 78th St
W 76th St
W 79th St
W 80th Pl
W 83rd St
W 85th Pl
W 86th St
Emerson Ave
Kenyon Ave
Chase Ave


W 104TH St
The Blast Fence
25R Runway
Bird's eye view of the east end of
25R runway & the blast fence
© 2006 Europa Technologies
© 2006 Navteq
©2005 Google
N
W
E
S
Pointer 33°56'24.22" N 118°22'47.93" W elev 95 ft
Streaming |||||||||| 100%
Eye alt 1872 ft

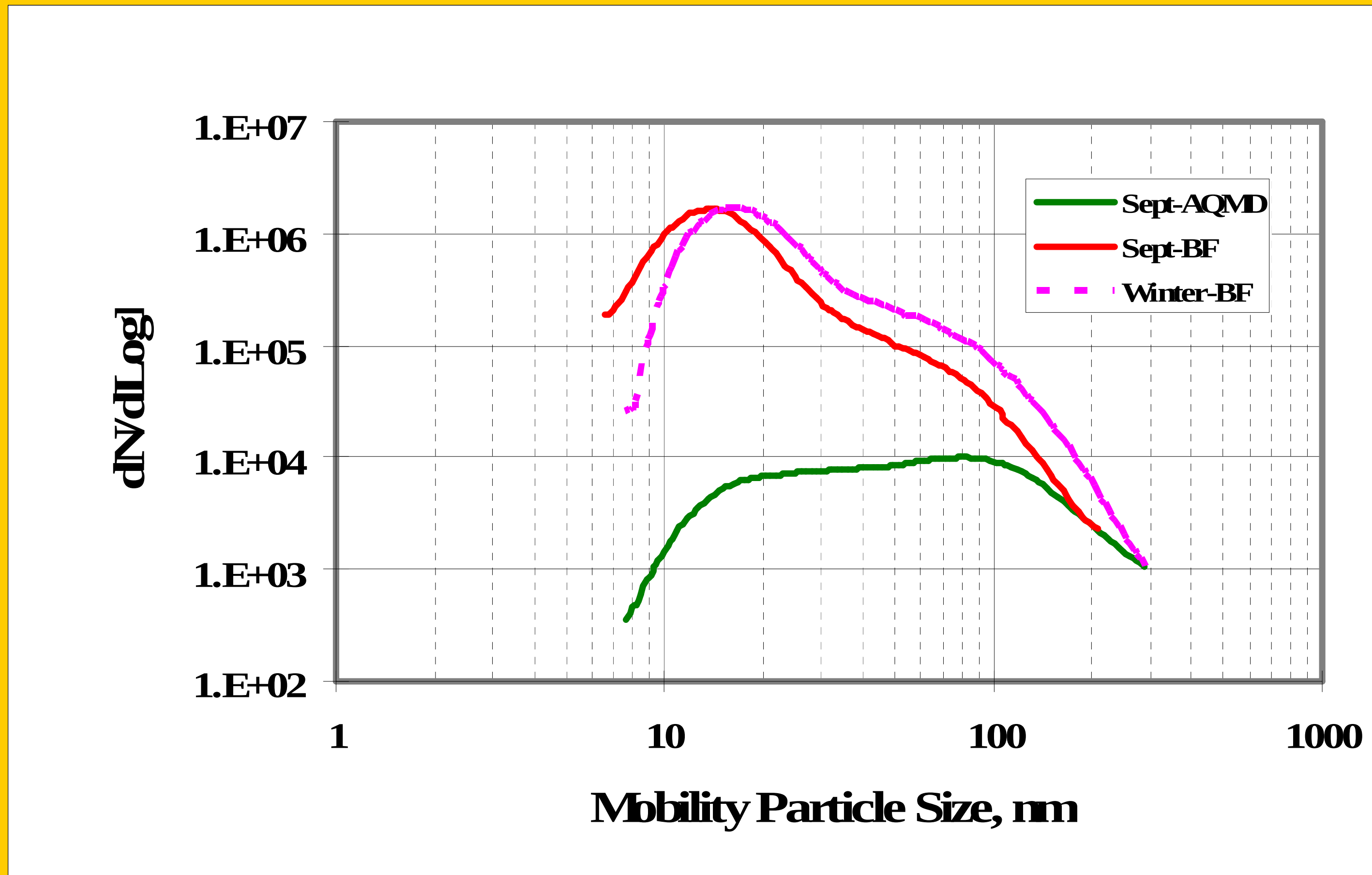
Methods
2. Instrumentation

- Ultrafine particles: Scanning Mobility Particle Sizers (SMPS 3936, TSI) + condensation particle counters (CPC 3022A, TSI) (2 min distribution scans; 1 sec size-specific scans)
- Black and Organic carbon: Aethalometer (Model AE-20, Magee Scientific, every 5 to 15 min)
- PM2.5: E-BAM mass monitors (Met One, every 30 min)
- CO, CO_2: Q-Trak (TSI, every 1 sec or 1 min)
- Air toxics (by time-integrated devices):
  - Polycyclic Aromatic Hydrocarbons (PAH) (Tisch sampler, 24 hrs)
  - Butadiene, Benzene and Acrolein: Canisters (24 hrs)
  - Formaldehyde: Cartridges (24 hrs)

Methods 3. Sampling Plan

- Two sets of instruments for simultaneous monitoring at the near source and background sites (Q-Trak at LAX blast fence only).
- Sampling: 5 to 8 days in September 2005 and late February/March, 2006
- Departure and take-off log data was provided by LAX


Results ….

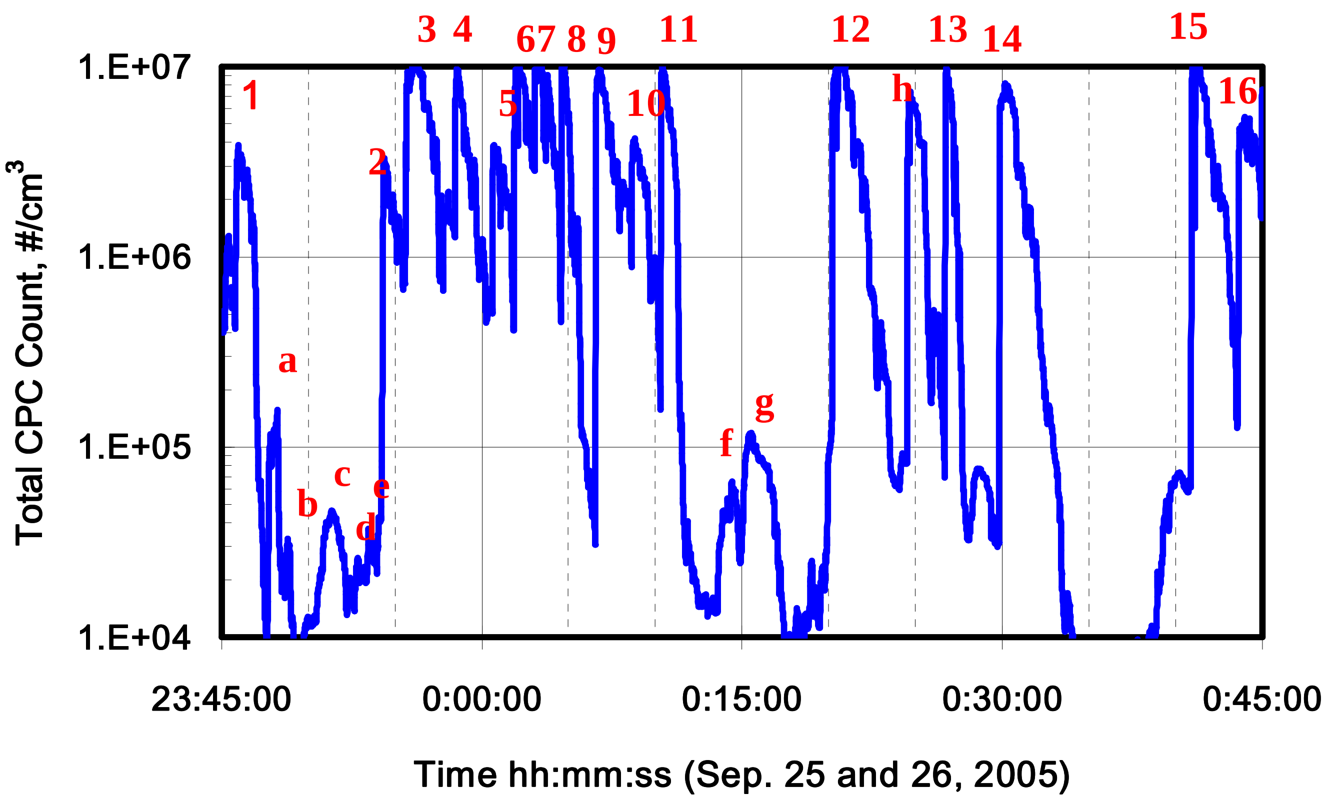


Average of aggregated SMPS scans shows a distinct UFP size distribution at the BF near-source site.

AQMD = background, BF = blast fence at the east end of LAX runway 25R

UFP Number Concentration is Associated with Runway Activity

Figure 2-5: Time Profile of Total CPC Counts and Identification of Aircraft at Runways 25R and 25L



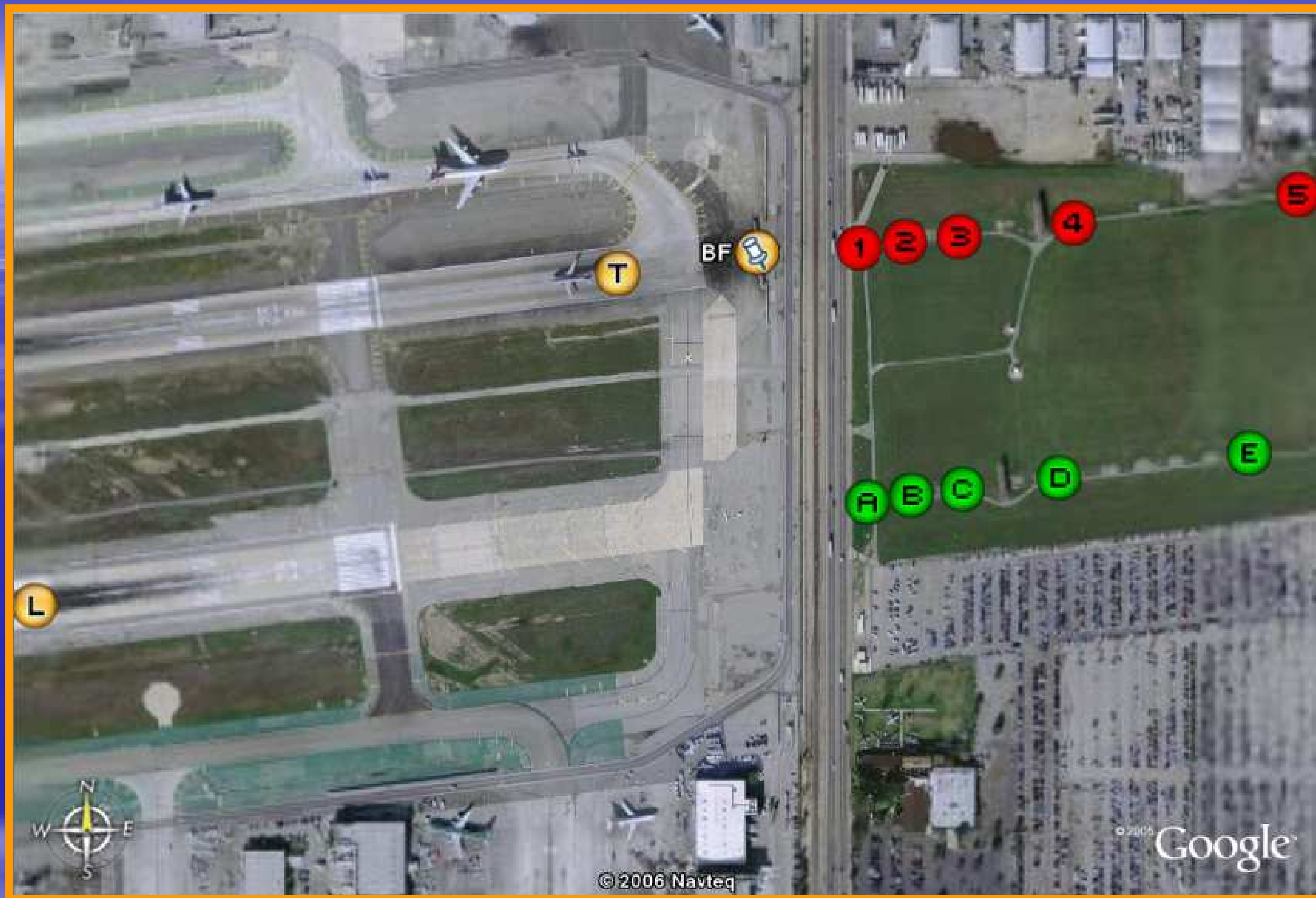
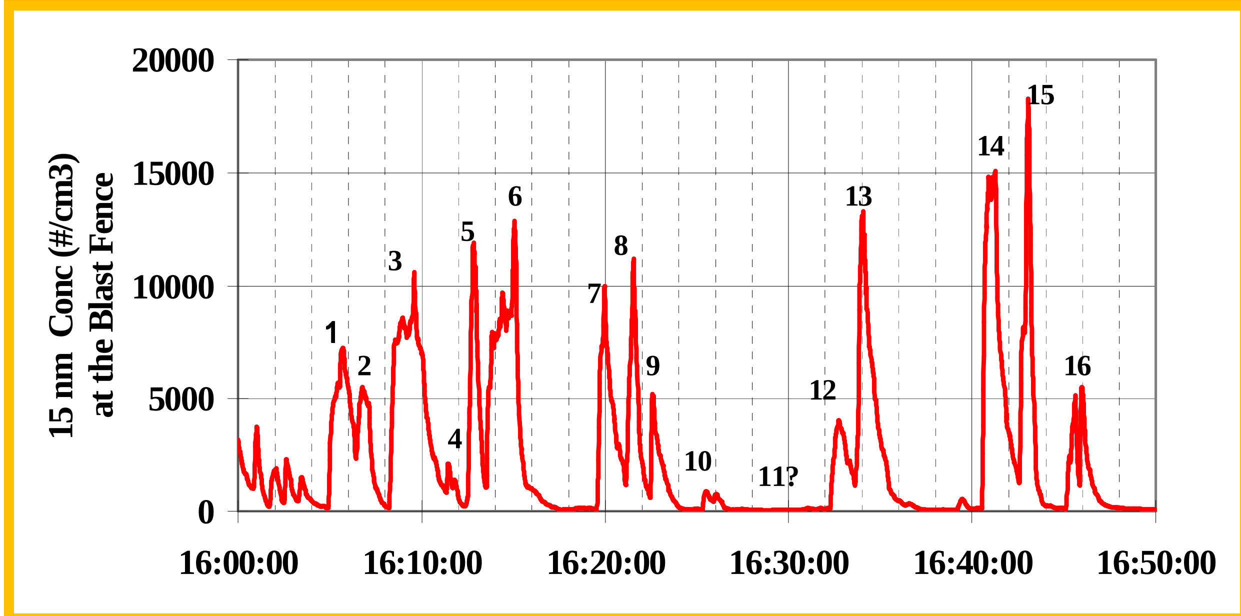
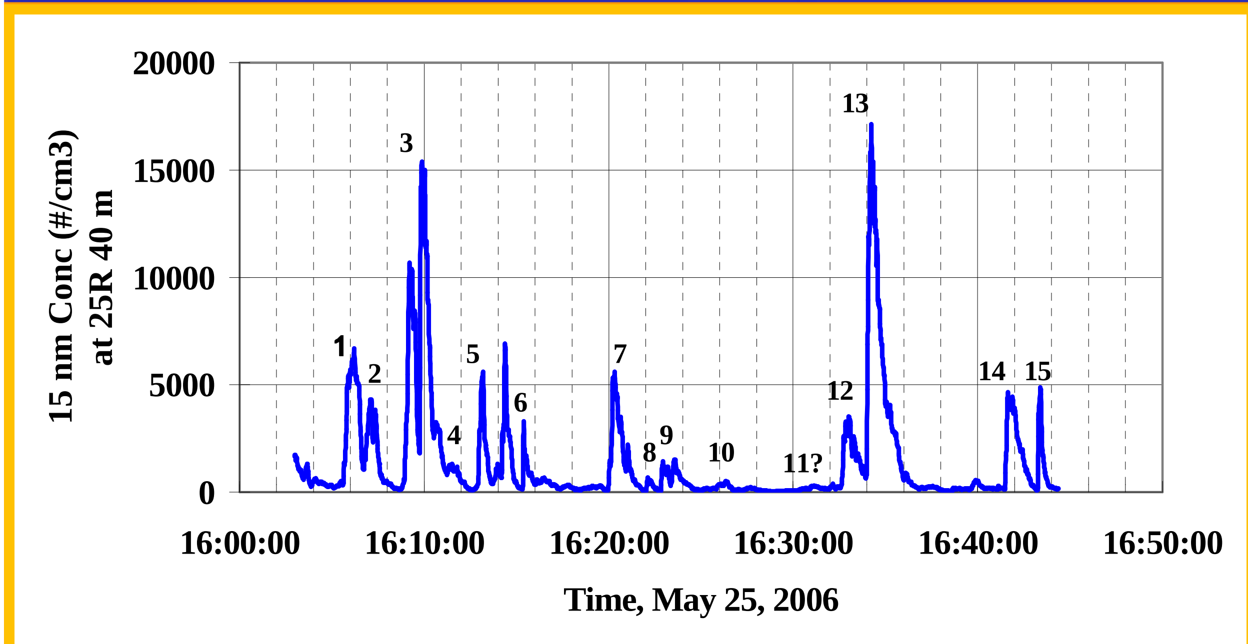


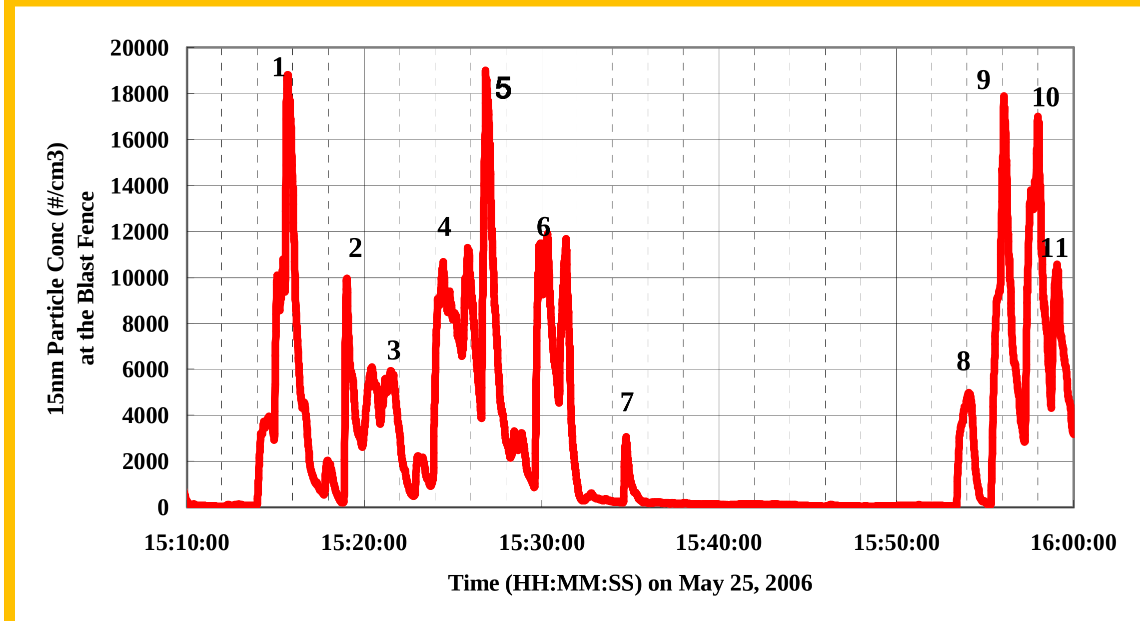
Figure 3-1: Aerial map showing Proud Bird field and dispersion study sites. L: 25L Landing Point; T: 25R Take-off Point; BF: Blast Fence, 140 m distance from Point T; Red Marked sampling sites: 1-220m, 2-250m, 3-310m, 4-410m, and 5-610m from Point T; Green Marked sampling sites: A-620m, B-660m, C-700m, D-780m, E-960m from Point L.

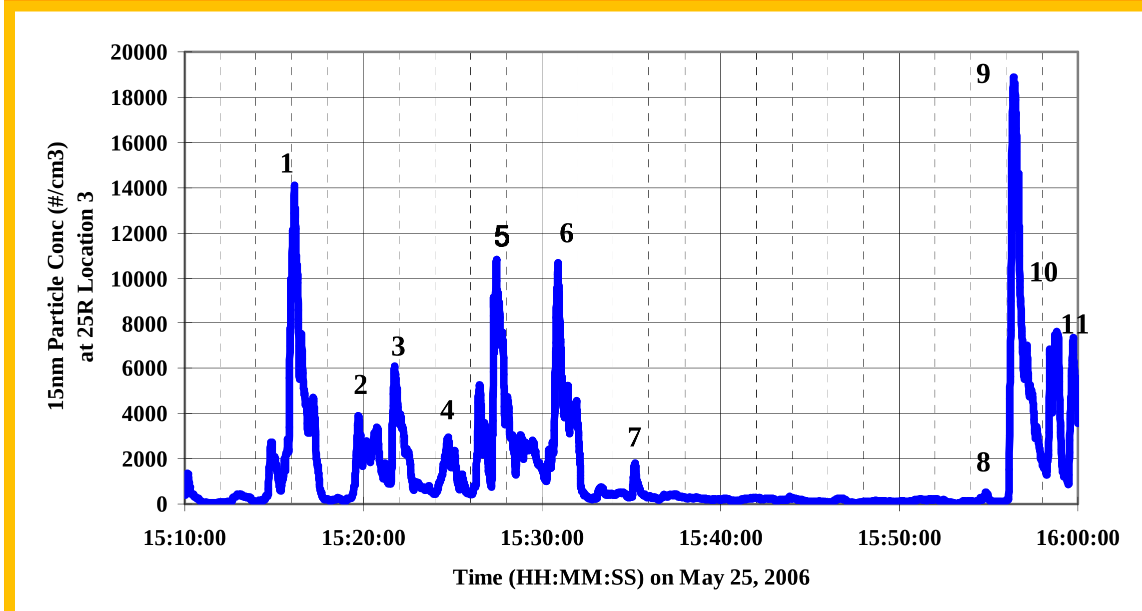




Take-off associated spikes in UFP can be detected 200m from take-off

Temporal profile of 15 nm particle concentrations at the LAX blast fence(red, upper), and a site 110 m downwind of the blast fence (blue, lower) during the same time period. Aircraft departures logged by LAX are noted with numerals.





Spikes in UFP 300m downwind follow aircraft take-offs with a short lag time

Temporal profile of 15 nm particle concentrations at the LAX blast fence (red, upper), and a site 170 m downwind of the blast fence (blue, lower), during the same time period. Aircraft departures logged by LAX are noted with numerals.

Black & Organic Carbon at LAX Blast fence and Background Site

	LAX Blast Fence	Background
Black Carbon[b] Mean ± STD (μg/m3)	13.5 ± 14.5**	0.64 ± 0.81
Organic Carbon[c] Mean ± STD (μg/m3)	11.5 ± 12.3**	0.63 ± 0.85

Black carbon (BC) and organic carbon (OC) measured on Sep 28 and 29 were excluded due to influence by the Topanga Canyon wildfires.

Measures [b]BC and [c]OC using optical absorption @ 880 nm and 370 nm, respectively.

****Statistically significant difference ($p < 0.001$).**

Summary statistics of PM 2.5 Concentrations ($\mu g/m3$) of LAX Blast Fence & the background site

Date	Background Mean ± Std ug/m^3	LAX Mean ± Std ug/m^3	p-value
9/23/2005	17.8 ± 11.6	42.1 ± 10.9	< 0.001
9/24/2005	16.8 ± 11.2	36.0 ± 17.7	< 0.001
9/25/2005	14.0 ± 7.2	39.9 ± 14.9	< 0.001
9/26/2005	13.8 ± 10.3	36.9 ± 17.8	< 0.001
9/27/2005	9.3 ± 10.2	32.7 ± 21.5	< 0.001
9/28/2005	14.8 ± 9.8	37.9 ± 12.1	< 0.001
9/29/2005	13.3 ± 8.4	33.9 ± 8.5	< 0.001
Overall	**14.8 ± 10.7**	**36.5 ± 16.1**	**< 0.001**

Polycyclic Aromatic Hydrocarbons LAX blast fence vs. background site

	Particle-phase PAHs, ng/m^3	Vapor-phase PAHs, ng/m^3	Vapor-phase naphthalene, ng/m^3 (% of vapor PAHs)
Background	0.7	63	56 (89%)
LAX	0.8	97	83 (86%)

Excluding PAH data collected on Sep. 28 & 29 when wildfires occurred.

Concentrations of CO, CO2, 1,3-butadiene, benzene, acrolein and formaldehyde at LAX blast fence and the background site

Measure	Background Mean ± Std	LAX Mean ± Std	P-value
Carbon monoxide (ppm)	0.104 ± 0.22	2.66 ± 2.19	< 0.001**
Carbon dioxide (ppm)	-	355 ± 39	-
1,3-butadiene (ppb)	0.15 ± 0.08	0.36 ± 0.23	0.173
Benzene (ppb)	0.42 ± 0.29	0.52 ± 0.57	0.766
Acrolein (ppb)	1.03 ± 0.35	1.26 ± 0.08	0.373
Formaldehyde (ppb)	0.53 ± 0.22	1.70 ± 0.66	0.014*

Key Findings

1. Significantly greater amounts of ultrafine carbon-based particles, PM2.5, carbon monoxide and formaldehyde were measured at the near-source site than a nearby residential background site.
2. The average ultrafine size distribution at the take off runway was characterized by a strong mode at 14-15 nm, regardless of season.
3. The temporal variation of 15nm particle levels corresponded to aircraft activity; take-offs were associated with a sharp spike in particle number

Findings

4. Although the near source site had significantly greater PM2.5 levels than the background site, the mean PM2.5 concentration (37 $\mu g/m^3$) is below the current 24-hr PM2.5 standard (65 $\mu g/m^3$) and lower than other Los Angeles sites.
5. Formaldehyde and vapor phase PAH (primarily naphthalene) were elevated at the blast fence relative to the selected background site, but levels were not remarkable. 1,3-butadiene, benzene, and acrolein were weakly elevated.

Community Study

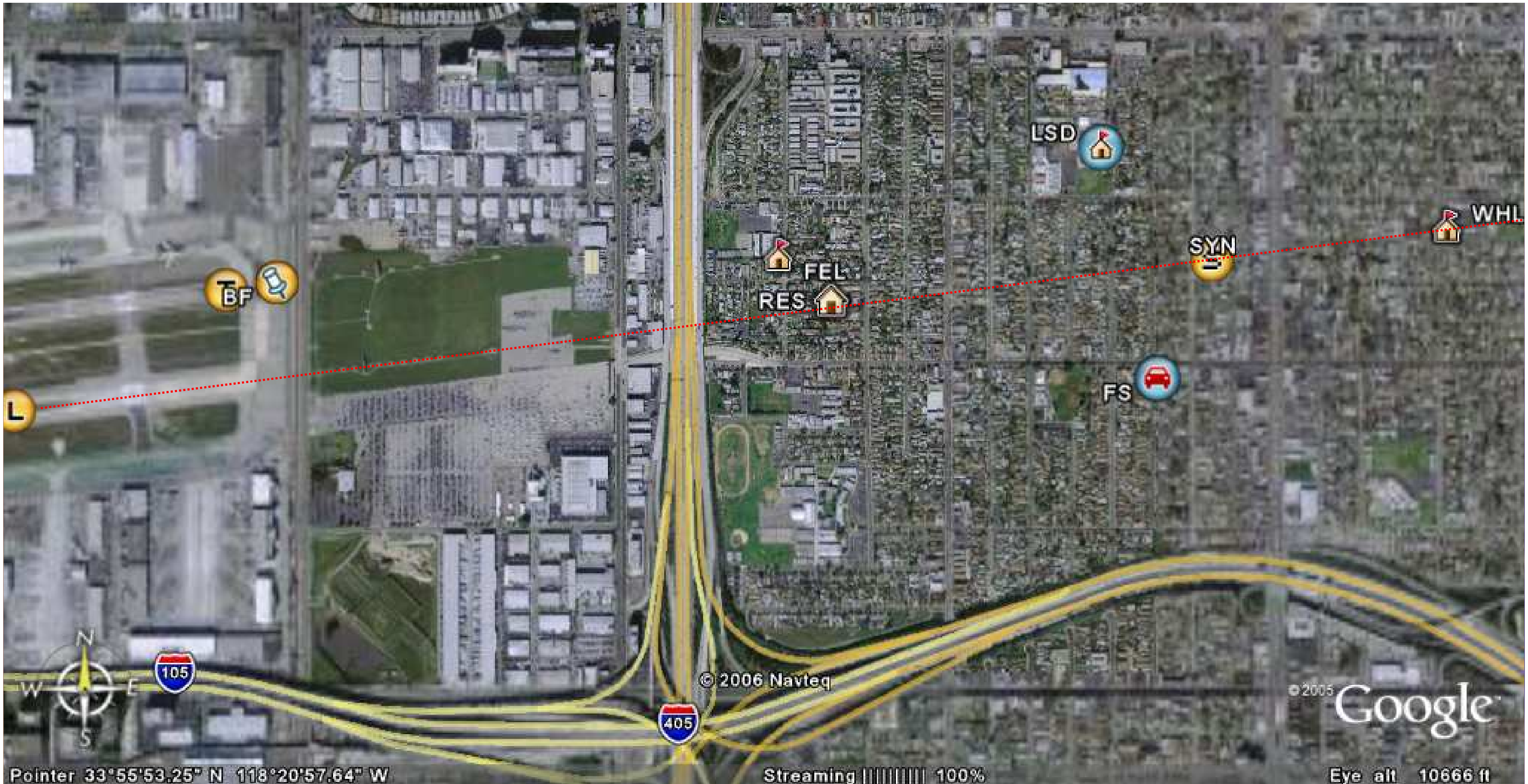
- **Target measurements:**
  UFP size distribution, temporal profile of 15 nm particles, black carbon and PM2.5 mass. Some exploratory PAH samples taken.

- **Dates**:
  * Synagogue: June 6 – 10, 2006
  * Local Resident: June 12 – 15, 2006
  * Fire station: June 15 – 19, 2006
  * Whelan School: June 20 – 23, 2006
  * Felton School: June 23 – 26, 2006
  * Lennox School District: June 26 – 30, 2006

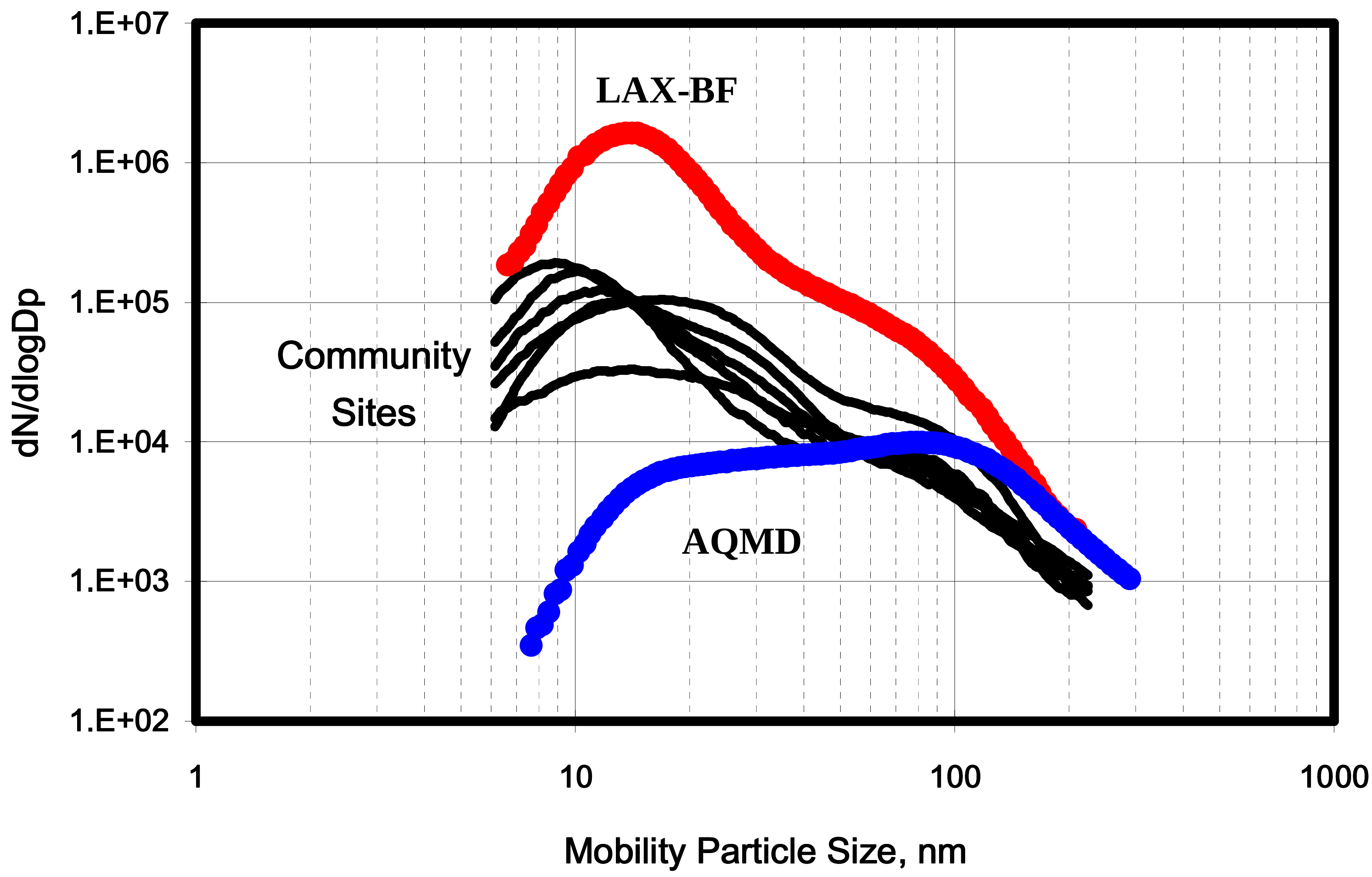
- Data analysis limited to winds from 200 to 290 degrees

Community Study Sites

Site	Distance from I-405 (m)	Position relative to typical landing path	Estimated aircraft altitude (m)
Felton School	200	120 m north	97
Local Resident	337	Directly beneath	104
Synagogue	1325	Directly beneath	156
Whelan School	1810	Directly beneath	182
Fire Station	1170	300 m south	150
Lennox School District	1030	300 m north	140



Location of six community sites. Red dotted line: aircraft landing path with a gliding angle = 3°. L: 25L Landing Point; T: 25R Take-off Point; BF: Blast Fence; FEL: Felton School; RES: a Buford local resident; SYN: a synagogue; WHL: Whelan School; FS: Fire Station; LSD: Lennox School District.



Aggregated UFP Size Distributions from 6 Community Sites in Relation to LAX-BF and background AQMD site.

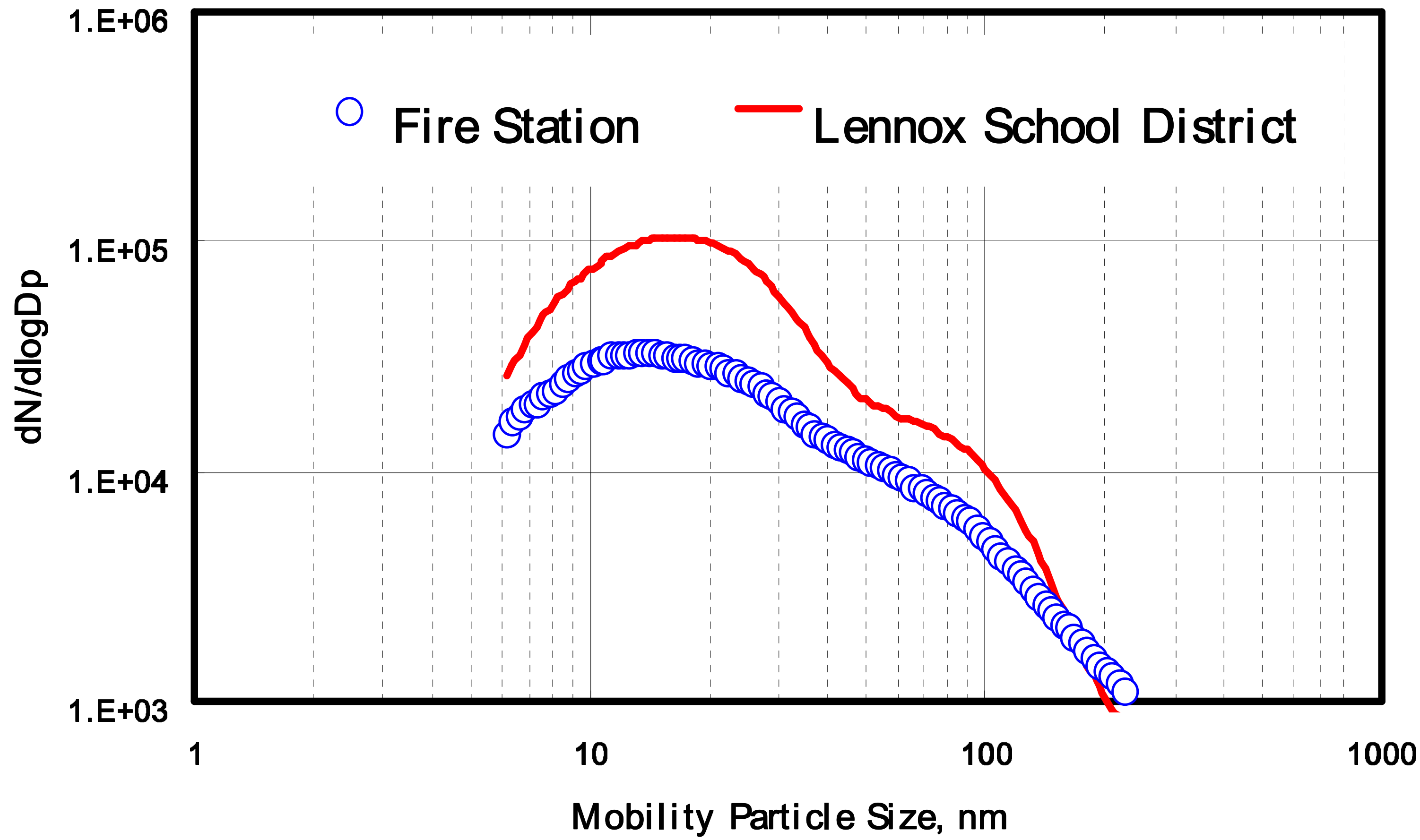


Figure 4-5: Particle size distribution of fire station and Lennox School District sites. These two locations are situated approx. 300 m S and N of the direct landing path, respectively.

$PM_{2.5}$ mass, black carbon mass, and PMN_{10-100}[a] concentration at six community sites, LAX blast fence, and background reference site

Location	$PM_{2.5}$[b] Mean (N) ± SD µg/m^3	Black Carbon Mean (N) ± SD µg/m^3	PMN_{10-100} Mean (N) ± SD x 1,000 particles/cm^3
LAX Blast Fence	36.5 (1,497) ± 16.1	13.9 (1416) ± 13.9	532 (70) ± 292
Community	15.6 (467) ± 12.0	1.3 (5,487) ± 1.2	38 (108) ± 25
Felton School	18.7 (63) ± 12.6	1.2 (765) ± 0.7	40 (5) ± 8
Local Resident	8.2 (62) ± 11.6	1.0 (832) ± 0.6	39 (15) ± 9
Synagogue	11.5 (85) ± 8.3	1.0 (786) ± 0.6	43 (17) ± 27
Whelan School	22.7 (71) ± 11.6	1.1 (1,100) ± 0.6	44 (22) ± 22
Fire Station	17.3 (94) ± 9.9	1.3 (987) ± 1.1	20 (31) ± 12
Lennox SD	15.1 (92) ± 13.0	1.9 (1,017) ± 2.1	54 (18) ± 35
Background Site (AQMD)	14.3 (133) ± 10.4	0.9 (1,713) ± 1.2	7 (77) ± 10

[a]PMN_{10-100} is the number concentration of particles size from 10-100 nm computed from SMPS scan data.
[b]PM2.5 data from Summer 2005 and 2006 were combined for BF and AQMD sites.
BF and AQMD locations were not monitored simultaneous with the community study

Follow-up Research Needs

- Toxicology Assays of aircraft emitted UFP; compare over different engines and power (idle vs. TO vs. approach)
- Compare UFP emissions factors for aircraft at LAX to other combustion and road traffic sources
- Expanded community study:
  - Temporal profiles of other UFP size cuts (we looked at 15nm)
  - Detailed assessment of overhead landing aircraft activity for better interpretation of temporal profiles of UFP
  - Compare community UFP under varying wind conditions to assess contribution of advected take-off plumes
  - Simultaneous monitoring at multiple sites to better characterize spatial variability.
  - SMPS scans in Proud Bird Field to characterize particle fate during dispersion
  - Consider midnight sampling to reduce impact of other sources