The Fresno Asthmatic Children's Environmental Study (FACES) Exposure Assessment

Focus on PAHs

(Polycyclic Aromatic Hydrocarbons)

Particulate Pollution in the San Joaquin Valley

Translating Science into Policy

San Joaquin Valley Air Pollution Control District
Fresno, CA
June 9, 2010

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Why the FACES study?

- Very little data on which asthmatics are susceptible to air pollutants
- Explore in detail air pollutants that have not been studied with respect to exacerbations of asthma
- No data on the relationship between the responses to short-term exposures and the long-term progression of asthma in children

The Fresno Asthmatic Children's Study: FACES

FACES is focused on the determination of the effects of chronic exposure to air pollution,

in combination with bioaerosols,

on the progression of childhood asthma

What were the study methods?

- Recruited 315 children ages 6-11
- Air quality monitoring
- Symptom and lung function monitoring
- Office visits
- Eight years of data collection (2000-2008)

Recruit Children Ages 6-11 With Asthma: Longitudinal Component

- Baseline health evaluation
  - Spirometry with bronchodilator
  - Skin testing
  - Dietary evaluation
  - Buccal cells (family)
- Six month clinic visit with spirometry
- Three-monthly telephone contact

FACES: Acute Component 14 Day Panels

- Three times/year during different seasons
- Health assessment
  - Daily diary
  - 2x daily spirometry
- Exposure assessment
  - Passive 2 week samples: O_3 , NO_2, nicotine
  - Dust: allergens, endotoxin
  - Home survey

FACES

Short Term Exposure to Pollutants

↓

Acute Exacerbation of Asthma

↓

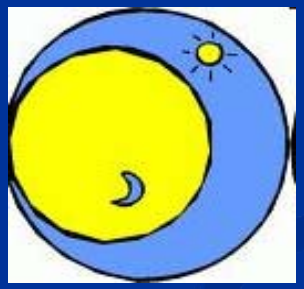
Altered Progression of Asthma

Exposure Assessment Tailored to an Epidemiology Study, FACES

- Focus is *progression* of asthma
- Relationship between *daily* exposures and acute symptoms, medication use, pulmonary function
- Relevant exposure is **daily,** but for 8 years
- 315 subjects--children with asthma

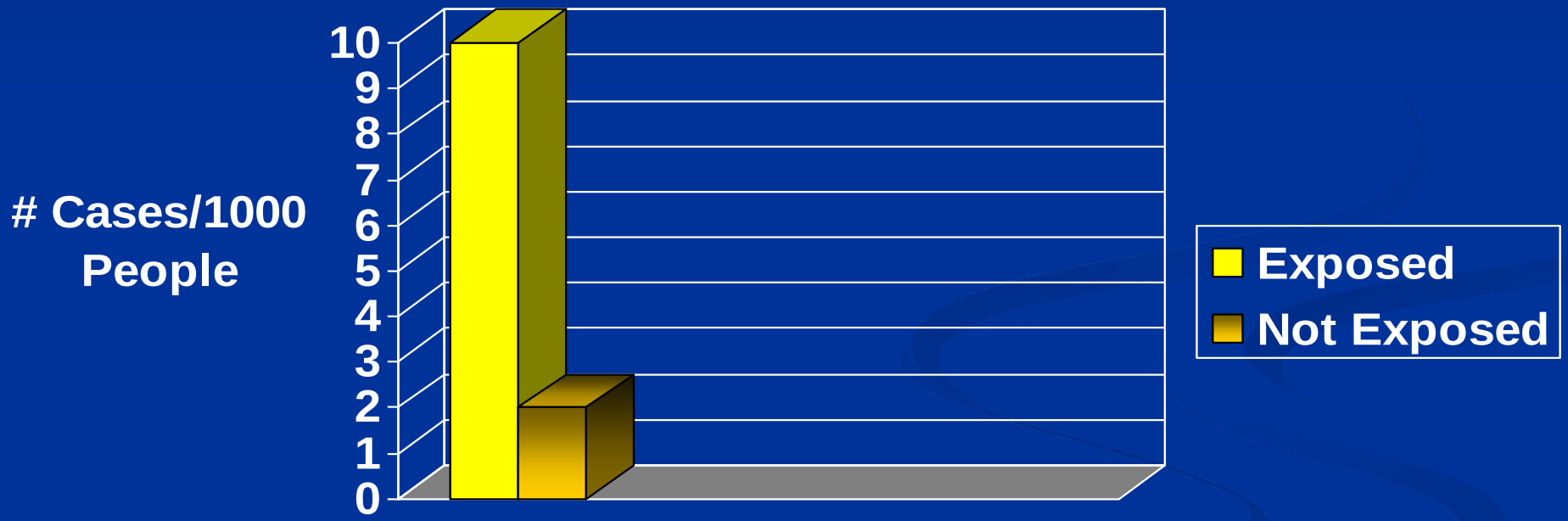
Measurements and Models to Generate Individual-Level Exposure Estimates

Each child 

Every Day 

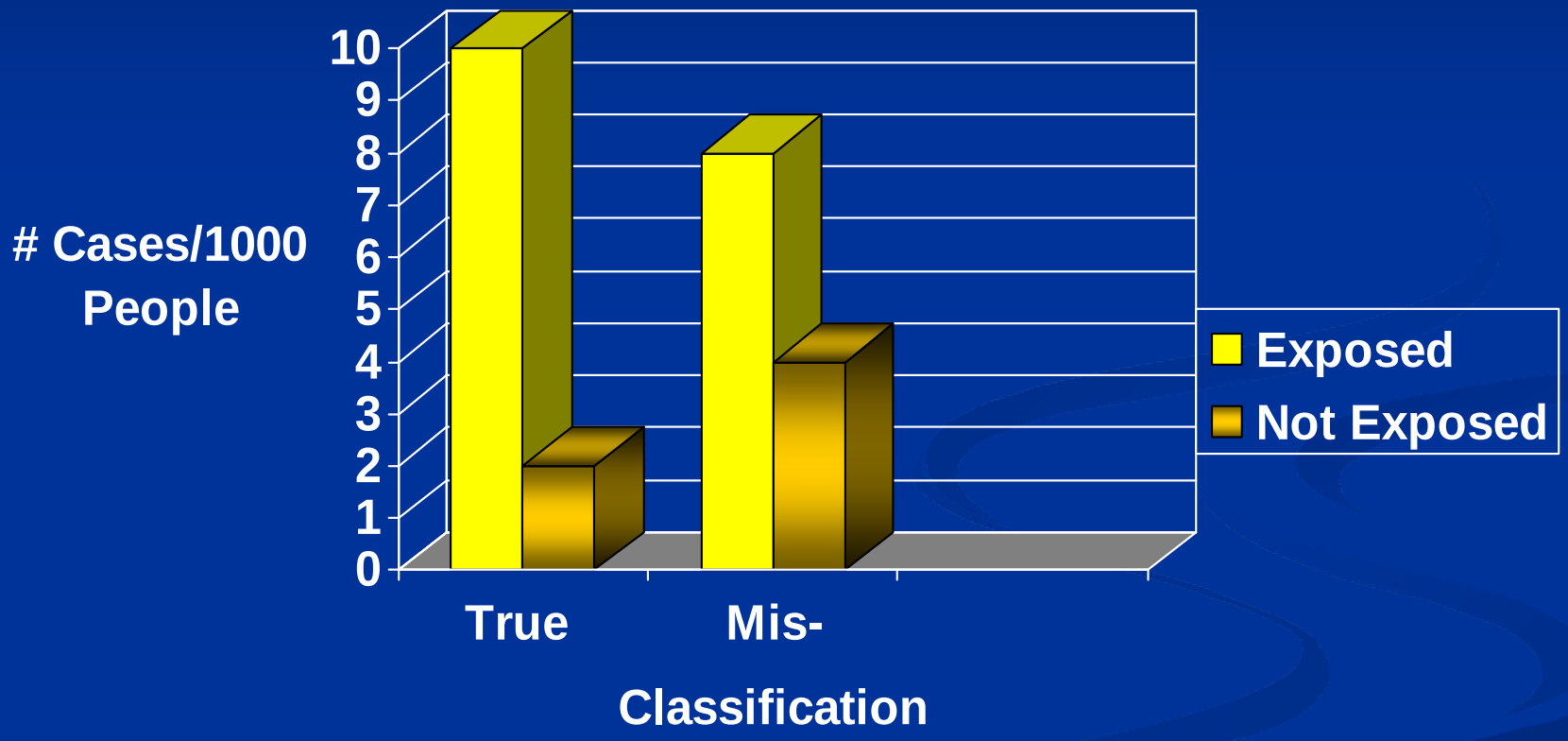
8 Years 

Effect of Exposure Misclassification on Estimates of Relative Risk



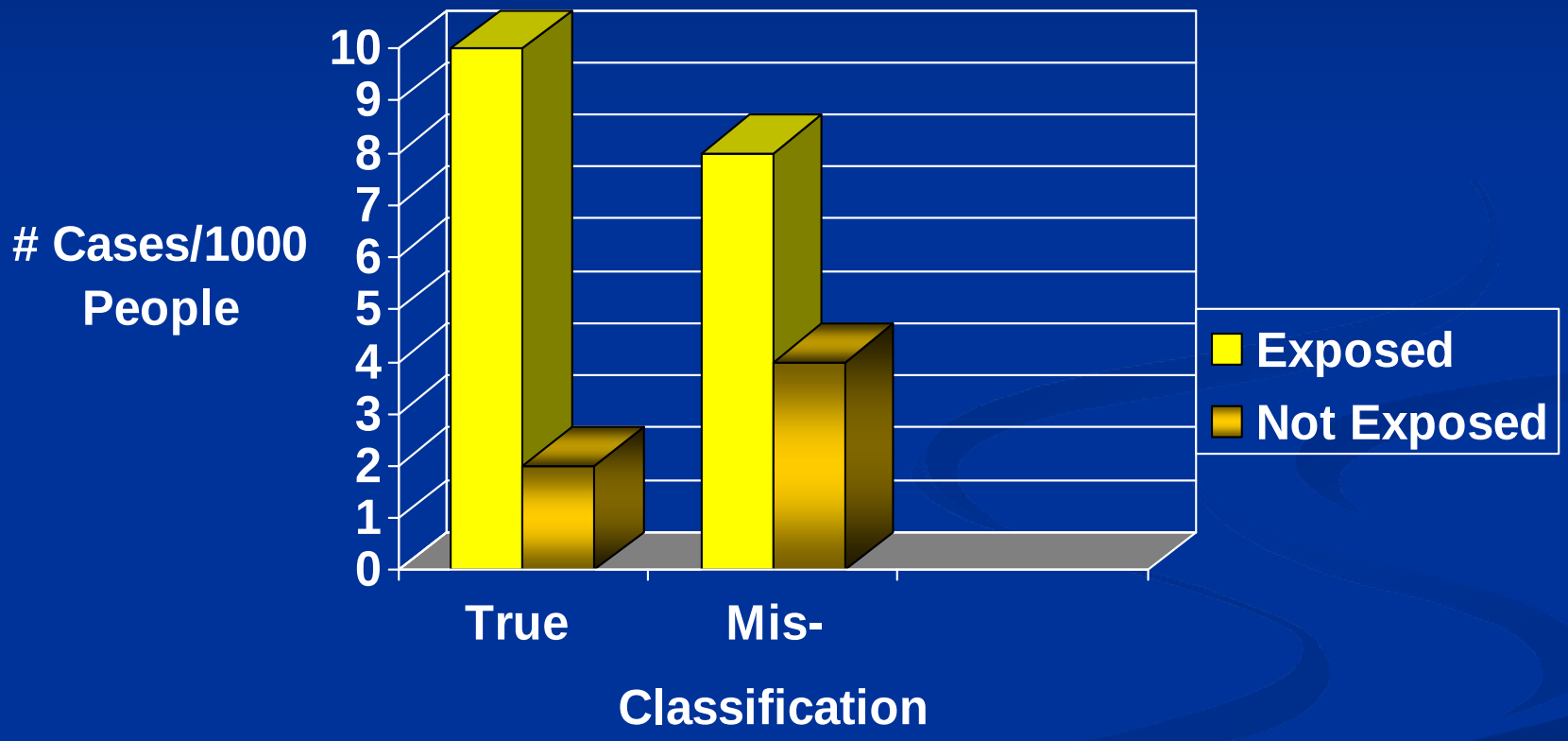
Relative Risk: $\frac{\frac{10}{1000}}{\frac{2}{1000}} = 5$

Effect of Exposure Misclassification on Estimates of Relative Risk



Relative Risk: $\frac{\frac{10}{1000}}{\frac{2}{1000}} = 5$

Effect of Exposure Misclassification on Estimates of Relative Risk

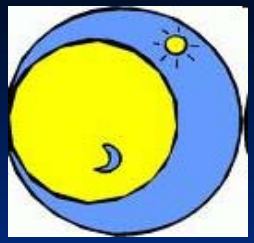


Relative Risk: $\frac{\frac{10}{1000}}{\frac{2}{1000}} = 5$ $\frac{\frac{8}{1000}}{\frac{4}{1000}} = 2$

EZ1 & Health Outcome

on each day

+



Each Child's Exposure

on each day

?

Relationship between Exposure and Health Outcome

Agents of Interest

- **Particles by size $PM_{2.5}$, PM_{10}, $PM_{10-2.5}$**
  - Mass
  - Organic carbon/Elemental carbon
  - Sulfate, nitrate, & ammonium ions
  - Metals, potassium

Agents of Interest

- **Gases**
  - NO, NO_2,, NO_3
  - Ozone
  - SO_2

Agents of Interest

- **Biological agents**
  - Pollen grains
  - Fungal spores
  - Endotoxin—both airborne & in house dust
  - Allergens in house dust
    - Dust mites
    - Cat dander
    - Dog dander
    - Cockroach eggs

Agents of Interest

- Second Hand Smoke
- Polycyclic Aromatic Hydrocarbons (PAHs)

Overview of Exposure Assessment

- **Temporal**- Daily Samples at EPA Supersite (aka “central site” or First Street)
- **Spatial Relationships**- Measurements and modeling
- **Exposure** based on microenvironmental concentrations and time-location-activity information from diaries and GPS

Overview of Air Sampling for FACES

Hourly and daily collection of target agents

Panel Studies
(all homes, ~ 7- 8 times each)

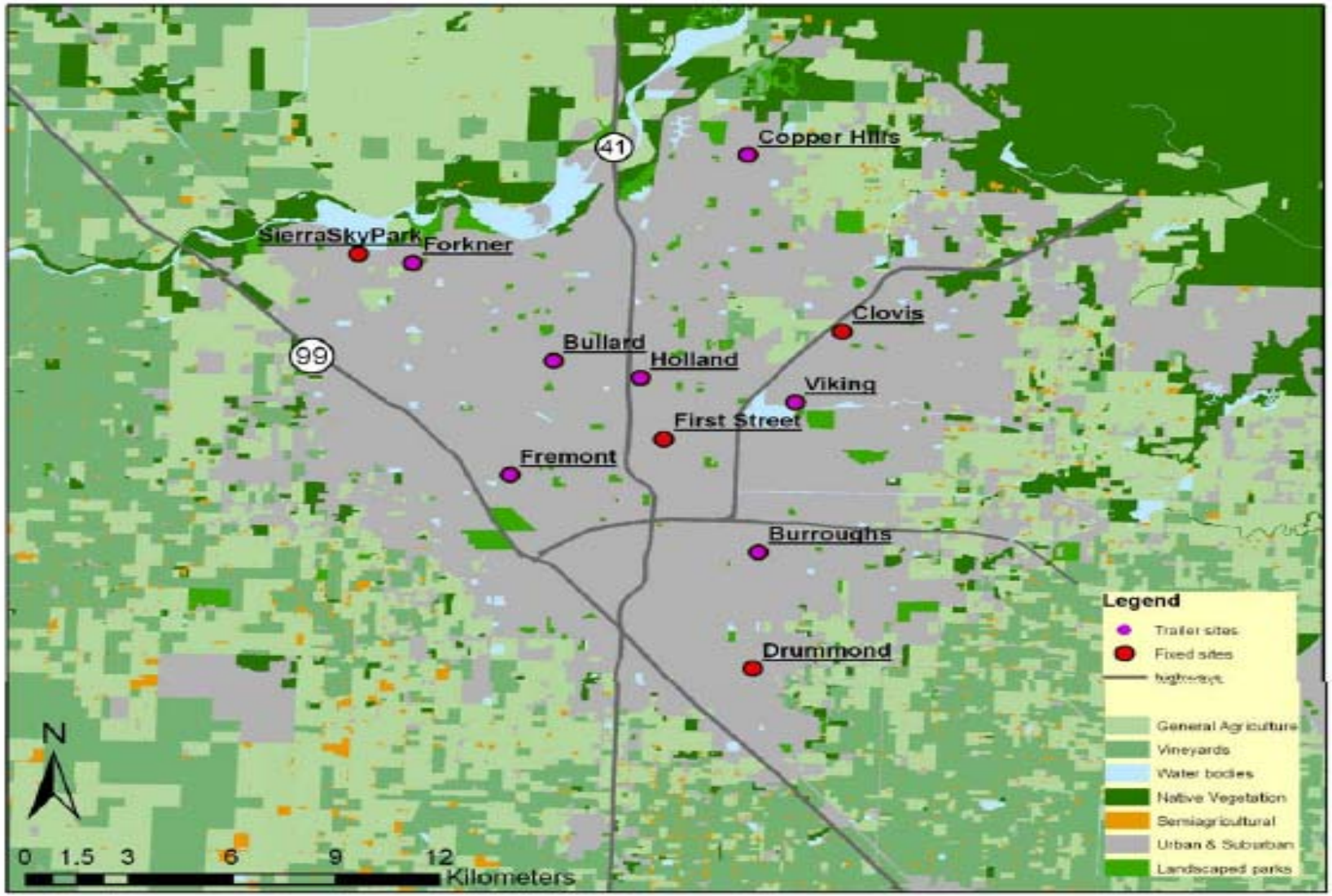
- Two week integrated sample for NO_2, O_3, nicotine
- Dust from floors and bed-- allergens & endotoxin
- Home survey

Homes

Home Intensive Study
(At 83 homes, 36 twice,)

- Continuous PM for 2 weeks
- 24 hr samples
- Indoors and outdoors at each home on 5 days during 2 week panels

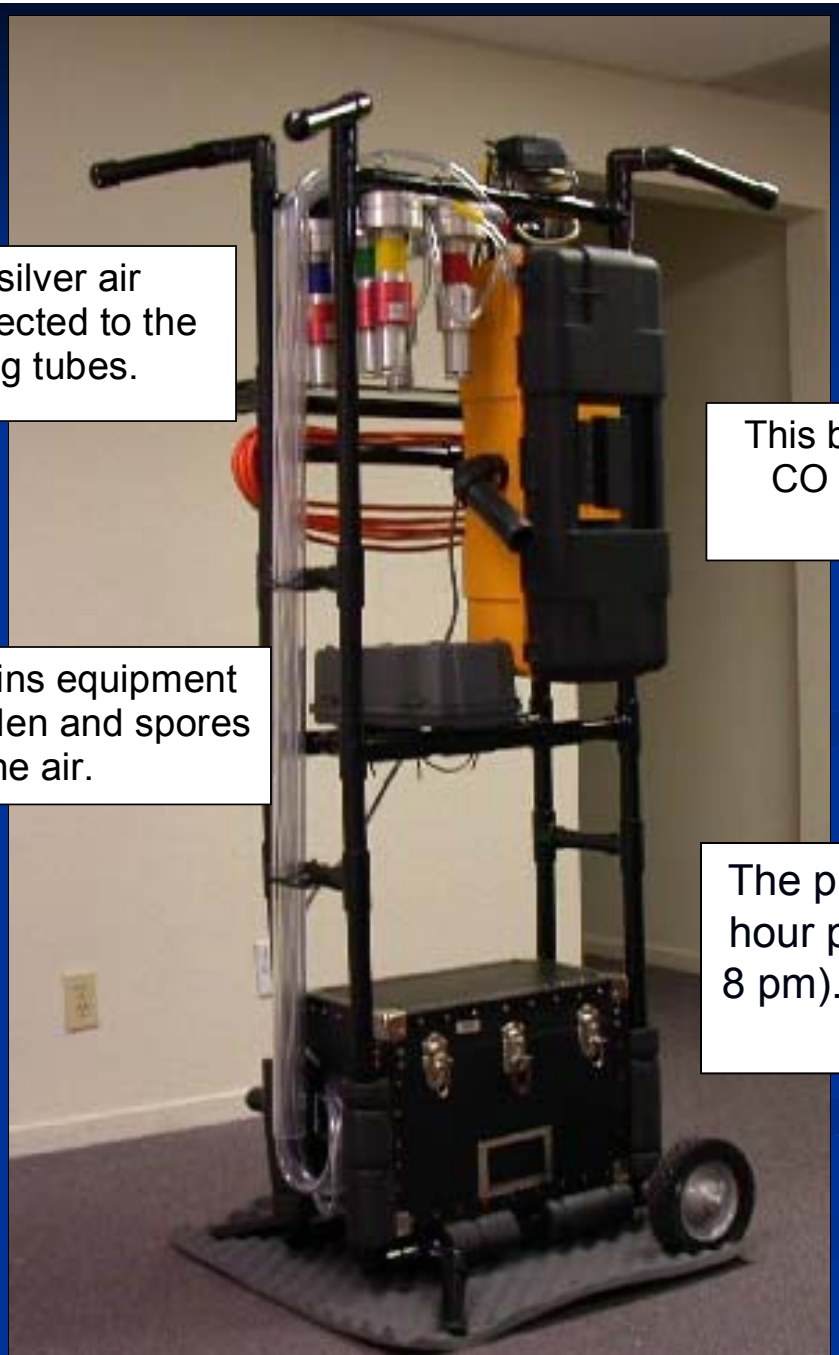
Location of Schools Studied, CARB Sampling Sites & the US EPA Supersite



Home Intensive Component

- Conducted during panel study, February 6, 2002 - February 8 2006
- Subset of panel homes, 4 - 5 per panel
- 24 hour sampling, 8 pm - 8 pm
- 5 days in two week period
- Indoors and outdoors
- 113 sets of home intensive samples collected (83 homes) sampled

Microenvironmental Exposure Monitoring System



There are 5 silver air samplers, connected to the pump by long tubes.

This box contains nephelometer, CO monitor, and Temperature sensor

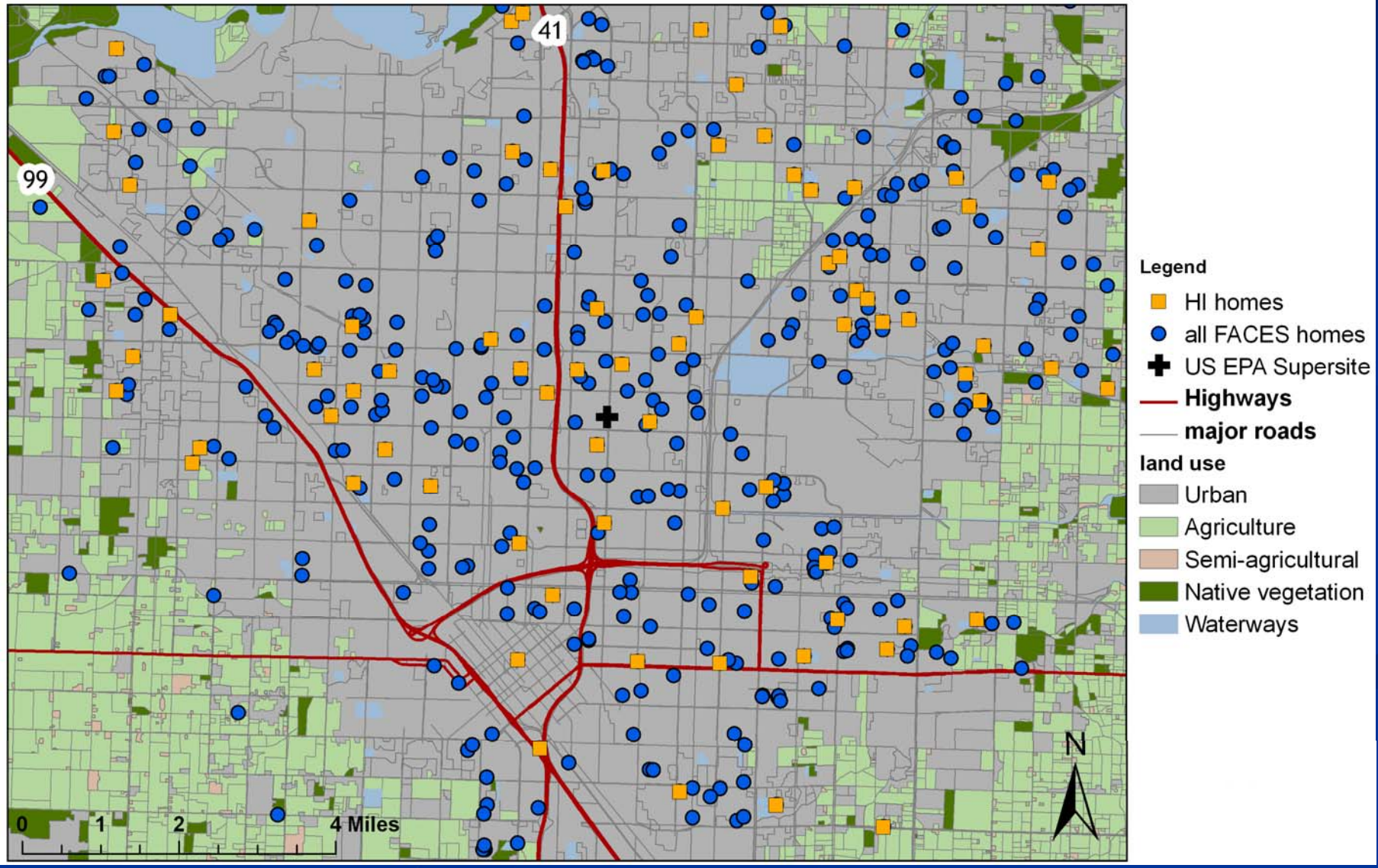
This box contains equipment that collects pollen and spores from the air.

The pump in this box runs for five 24–hour periods over two weeks (8 pm to 8 pm). It is controlled automatically by a timer.


Berkeley
University of California


Berkeley
University of California
CRAFTSMAN

FACES Participants



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Homes

Home Intensive Study
(At 83 homes, 30 twice,)

- Continuous PM for 2 weeks
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Exposure Assessment for FACES

← Outdoor Samples → Indoor Samples

Central Site	Schools	Homes	Homes	Homes
US EPA Supersite	Trailers	Home Intensive	Home Intensive	Panels
Hourly and Daily	Hourly and Daily	24 hour.	24 hour	2 weeks & grab
Daily 11/00 - 10/08	Daily 14 months 5/02-8/03	5 days in 2 weeks 2/02 – 2/03 80 homes	5 days in 2 weeks 2/02 – 2/03 80 homes	All homes at least 1 / season

Exposure Model

- *Daily* data from the Central Site
- *Spatial* relationships between the Central Site concentrations and those measured at specific homes, in specific neighborhoods, or types of neighborhoods
- *Indoor/outdoor* relationships for types of homes
- *Home specific* data for indoor sources of selected agents
- *Time-location-activity* data for participants

FACES Continuous Measurements

Parameter	← Outdoors →			Indoors
	Central Site	Schools	Homes	Homes
$PM_{2.5}$ & PM_{10} Mass (BAM)	1-hr	1-hr	-	-
$PM_{2.5}$ & PM_{10} Mass (TEOM)	1-hr	-	-	-
Black Carbon (1-λ,7-λ Aeth)	1-hr	1-hr*	-	-
$PM_{2.5}$ EC & OC (R&P)	1-hr	1-hr*	-	-
Total particle-bound PAH (EcoChem)	1-hr	1-hr	-	-
$PM_{2.5}$ NO_3 & SO_4 (R&P)	1-hr	1-hr*	-	-
Particle Number (TSI CPC)	1-hr	1-hr	-	-
Particle Size (SMPS)	1-hr	-	-	-
Light Scattering (Radiance Res.)	1-hr	1-hr	1-hr	1-hr
Ozone	1-hr	1-hr	-	-
NO/NO_2	1-hr	1-hr	-	-
CO	1-hr	1-hr	-	-
SO_2	1-hr	1-hr	-	-

* Two mobile trailers monitor at schools – OC/EC and SO4 not measured on both trailers

FACES Integrated Measurements

Parameter	Outdoors			Indoors
	Central Site	Schools	Homes	Homes
$PM_{2.5}$ & PM_{10} Mass	24-hr/1 in 6	-	24-hr/5 in 14*	24-hr/5 in 14
$PM_{2.5}$ NO_3 & SO_4	24-hr/1 in 6	-	24-hr/2 in 14*	24-hr/2 in 14
$PM_{2.5}$ OC & EC	24-hr/1 in 6	-	24-hr/2 in 14*	24-hr/2 in 14
Speciated PAHs (16)	24-hr/2 in 14*	24-hr/2 in 14*	24-hr/2 in 14*	24-hr/2 in 14
PM_{10} Metals	24-hr Daily	24-hr Daily	24-hr/2 in 14*	24-hr/2 in 14
PM_{10} Endotoxins	24-hr Daily	24-hr Daily	24-hr/5 in 14*	24-hr/5 in 14
Pollen Grains	2-hr Daily	2-hr Daily	2-hr/5 in 14*	2-hr/5 in 14
Fungal Spores	2-hr Daily	2-hr Daily	2-hr/5 in 14*	2-hr/5 in 14
Dust Allergens	-	-	-	Grab
Nicotine	-	-	-	2 wk
NO_2	-	-	-	2 wk
Ozone	-	-	8-hr & 2 wk	8-hr & 2 wk

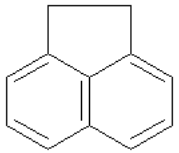
 # Integrated samples collected from 8 PM – 8 PM for use with daily symptom data
*** 1-year Home Intensive Sampling**

PAHs in Fresno

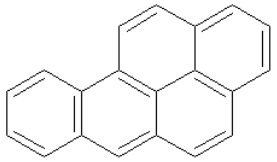
- What are PAHs ?
- What are the main sources?
- Why are we interested in PAHs?

Gas, by Edward Hopper 1940

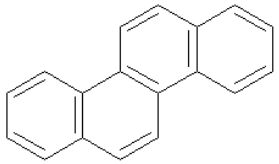
Structure of PAHs



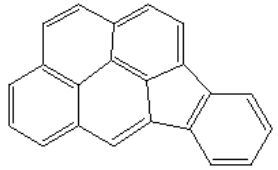
Acenaphthene



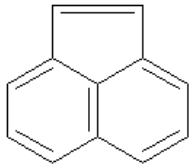
Benzo[a]pyrene



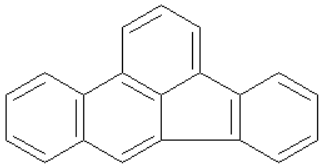
Chrysene



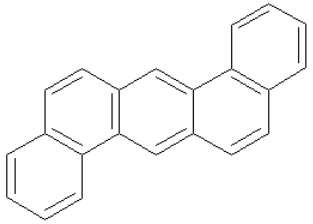
Indeno[1,2,3-cd]pyrene



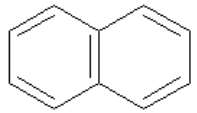
Acenaphthylene



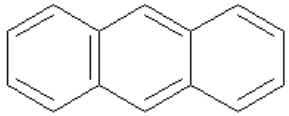
Benzo[b]fluoranthene



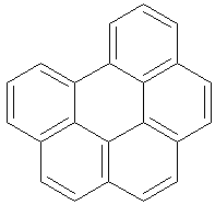
Dibenz[a,h]anthracene



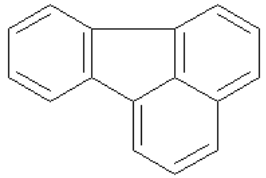
Naphthalene



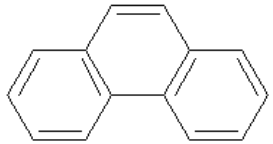
Anthracene



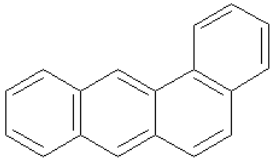
Benzo[ghi]perylene



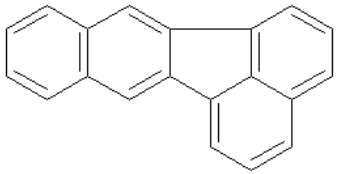
Fluoranthene



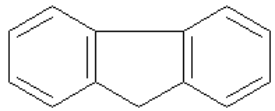
Phenathrene



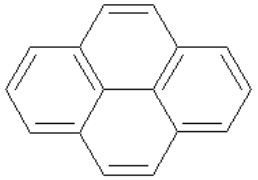
Benz[a]anthracene



Benzo[k]fluoranthene



Fluorene



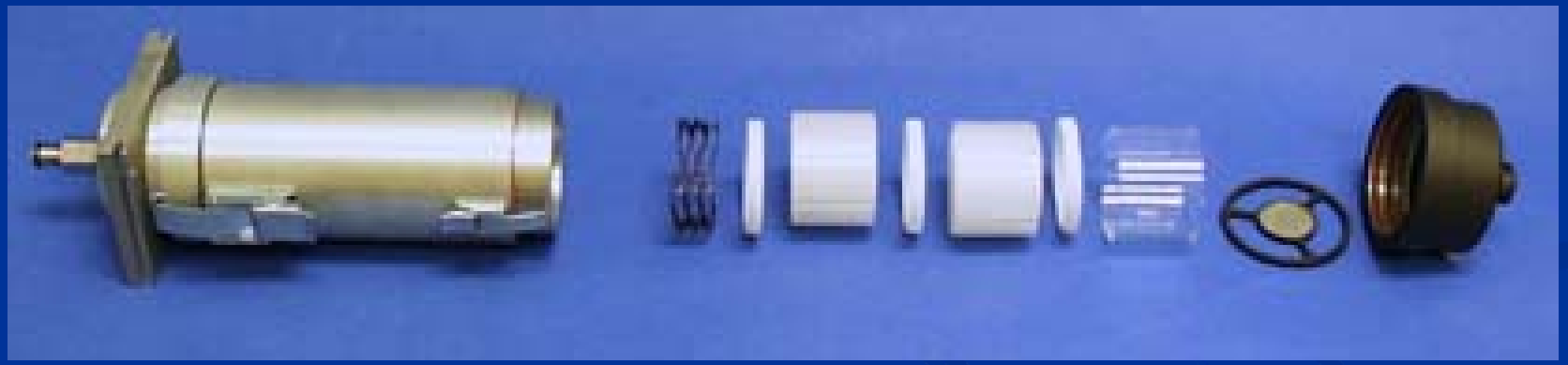
Pyrene

Characteristics of Airborne PAHs

- Most PAHs are neighborhood-level air pollutants, large number of samples needed.

- PAHs are sampled using active samplers
  - filters only (homes)
  - filters + denuders (Supersite and schools)
  - Continuous sampler (Supersite and schools)

Chemcombs



Exposure Assessment for FACES

CARB: EcoChem PAS2000

USEPA: Chemcomb (denuders + filters)

USEPA/NUATRP: Filters

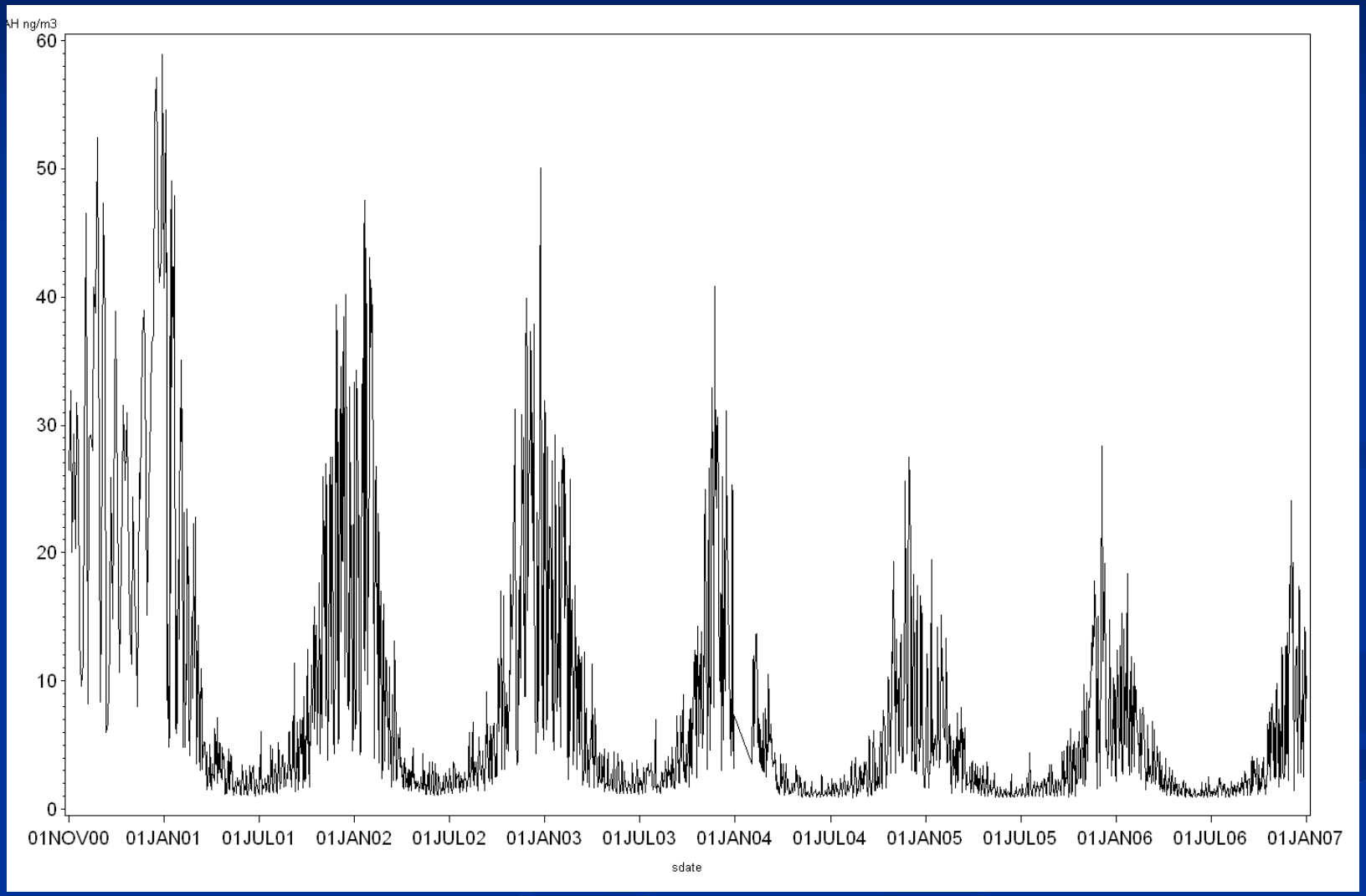
PAHs

Outdoor Samples ⟵ ⟶ **Indoor Samples**

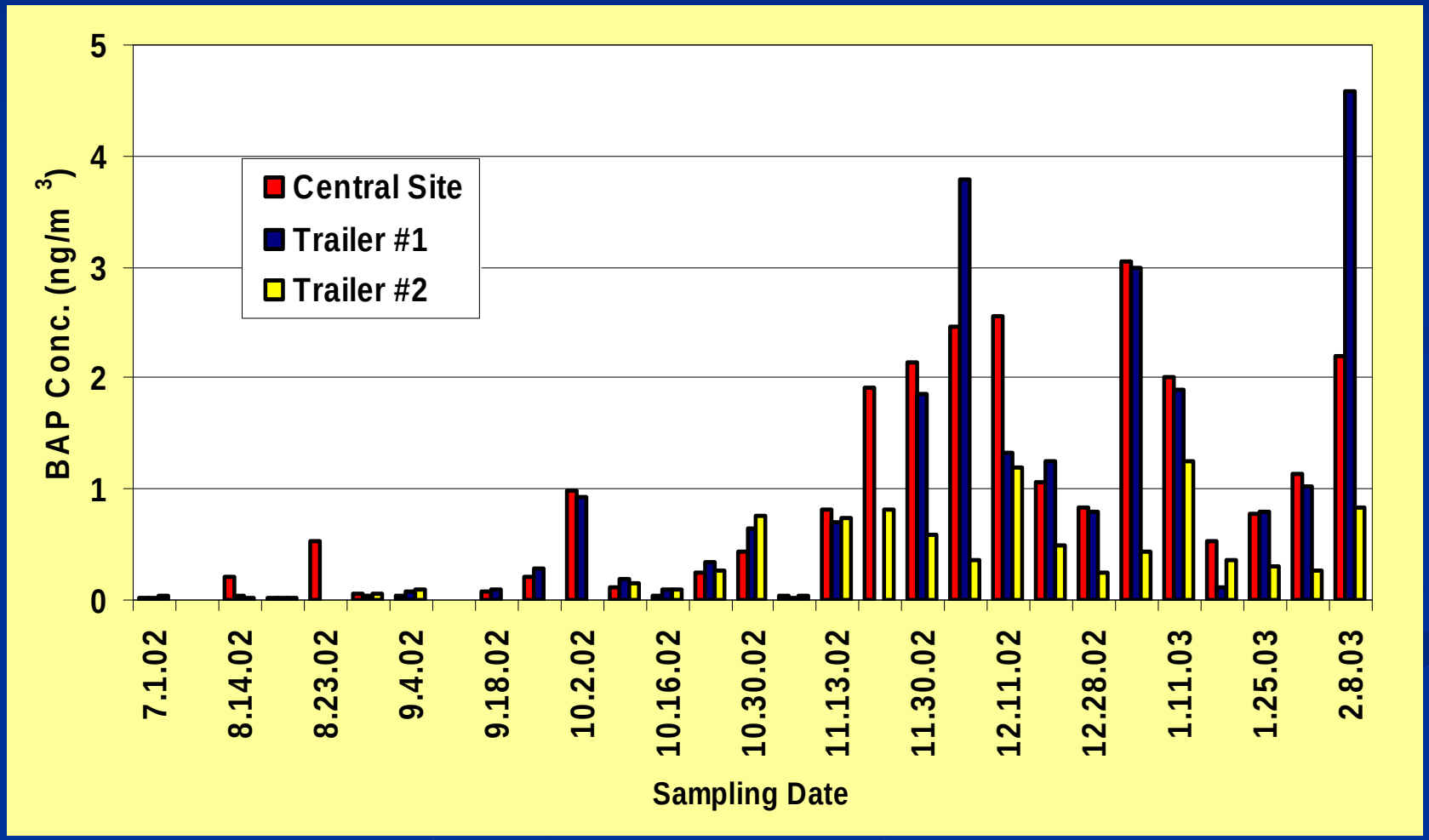
Central Site	Schools	Homes	Homes	Homes
US EPA Supersite 11/00 - 10/08	**Trailers** 14 mo 6/02-8/03	**Home Intensive** 2/02 – 2/03	**Home Intensive** 2/02 – 2/03	**Panels**
Hourly and Daily	Hourly and Daily	24 hour.	24 hour	2 weeks & grab
(PAHs 5 days in 2 weeks) 7/02 – 2/03	(PAHs 5 days in 2 weeks) 7/02 – 2/03	5 days in 2 weeks 80 homes	5 days in 2 weeks 80 homes	All 300 homes at least 1 / season

Temporal Variability Particle-Phase PAHs

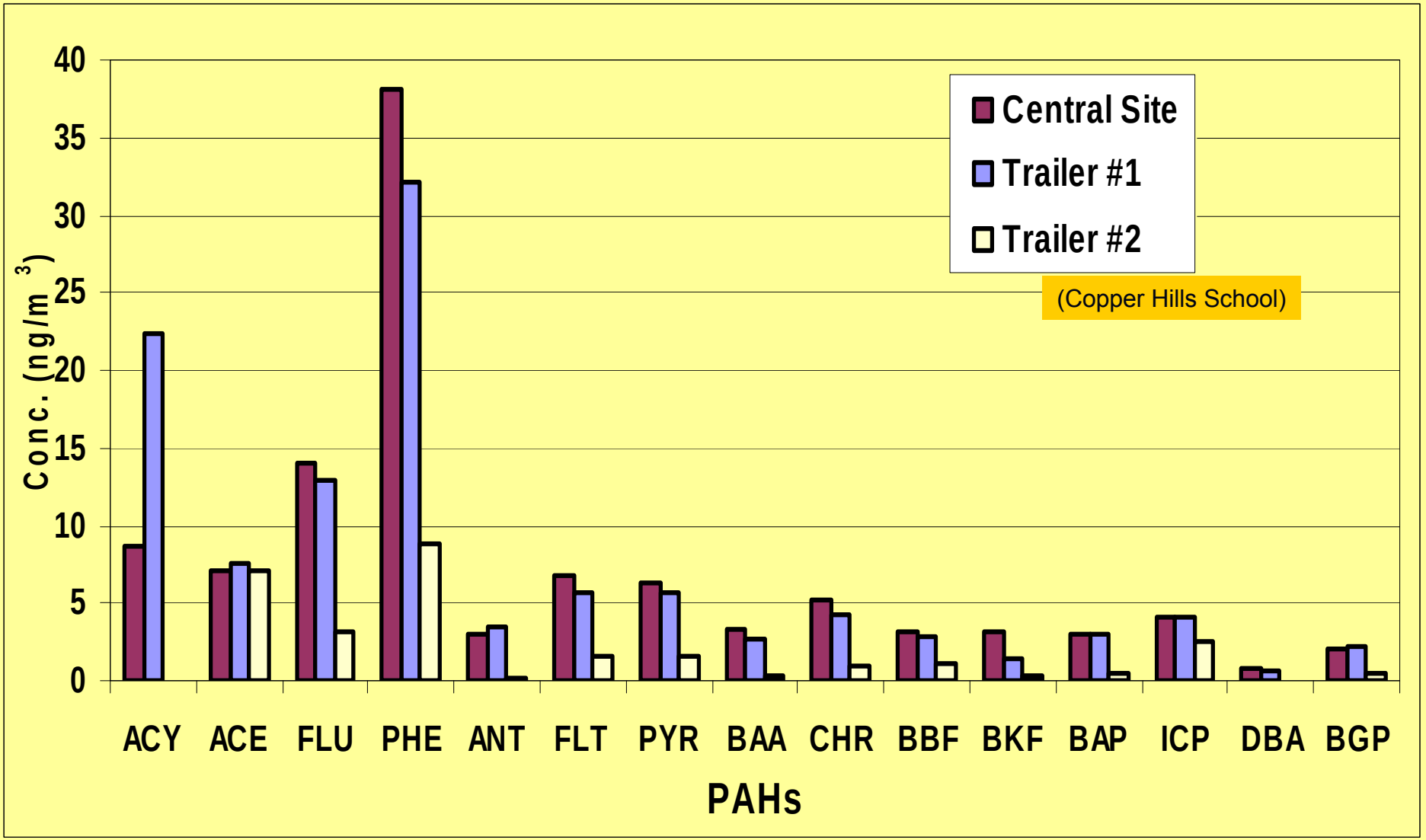
Fresno, Oct 31, 2000 – February 28, 2007



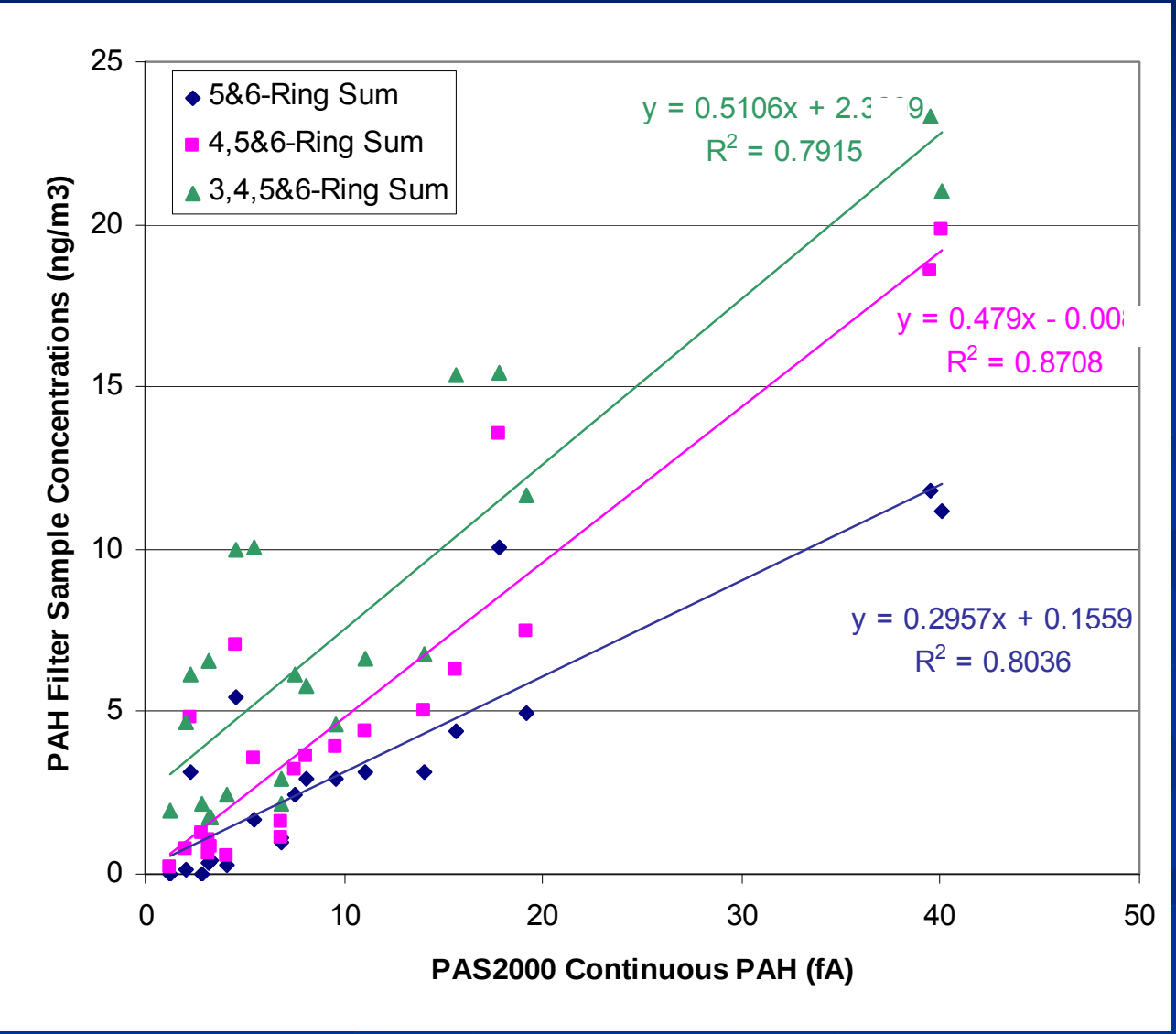
Benzo (a) Pyrene Concentration
July 2002 to February 2003



PAHs in Fresno on January 1, 2003

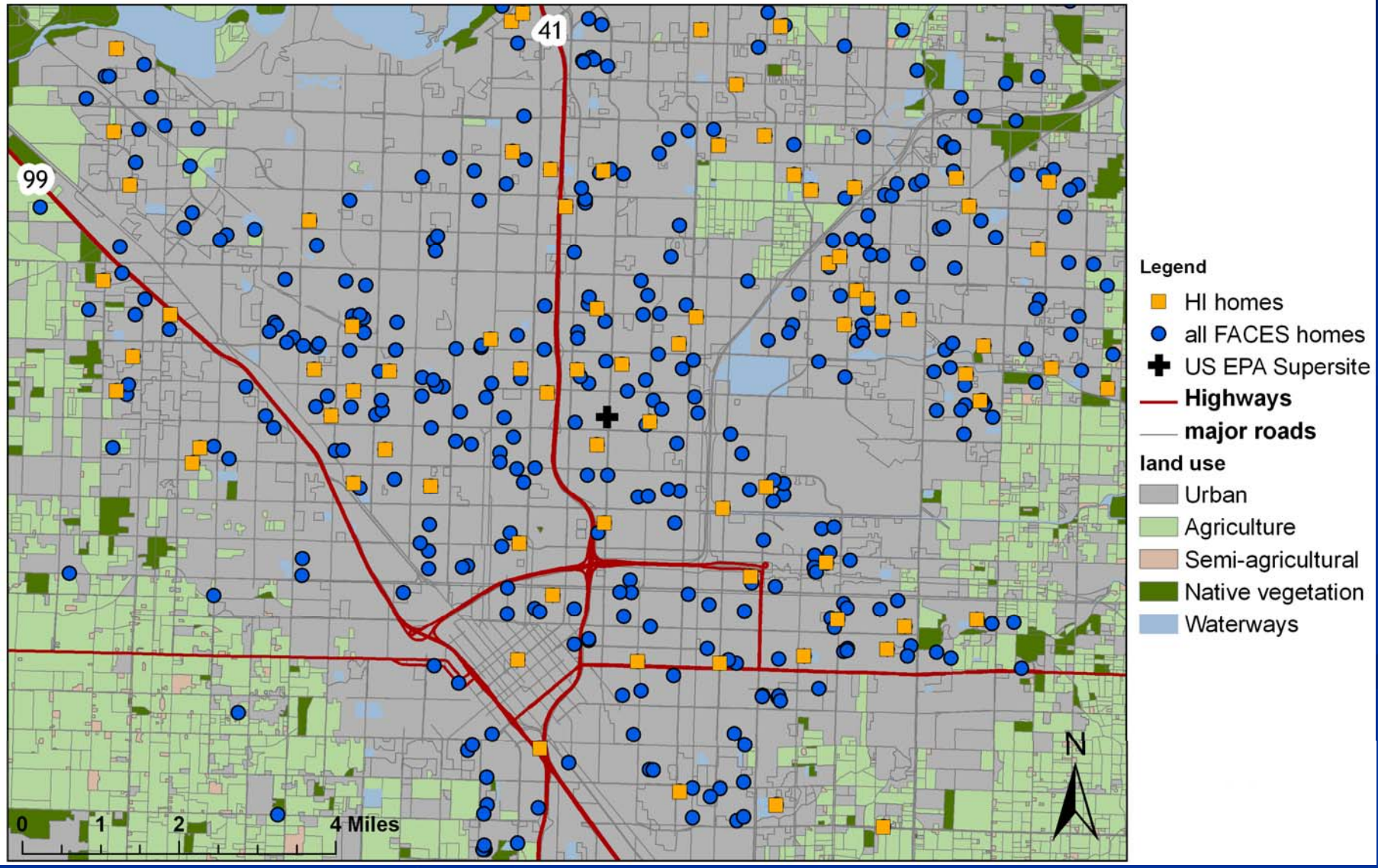


PAH: Filters Versus PAS2000



Fresno Super Site

FACES Participants

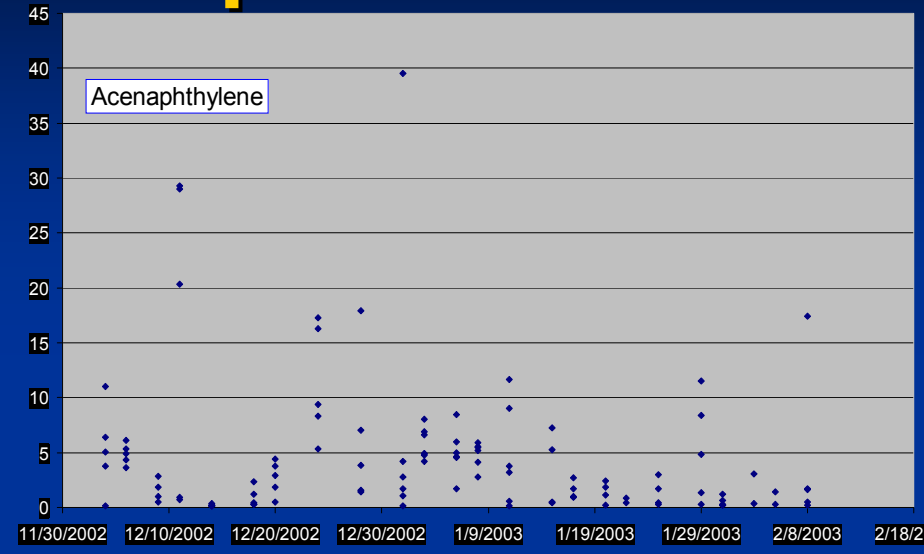


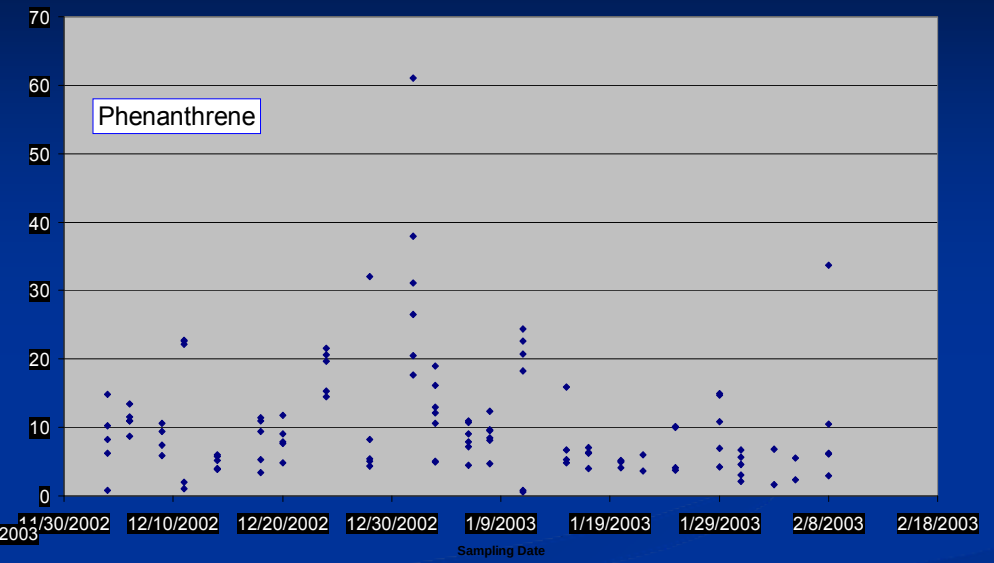
Spatial Data

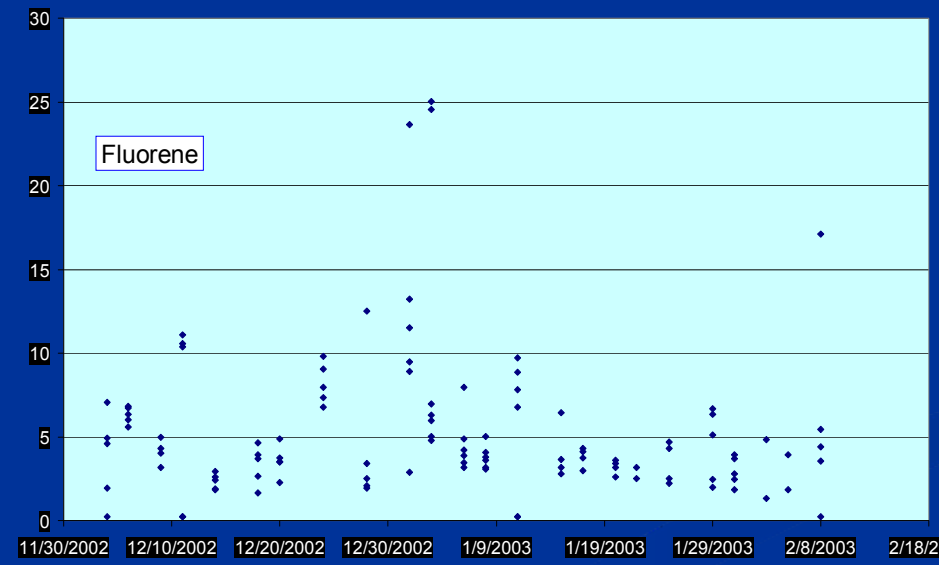
- Locations sampled on a given day
  - Supersite
  - Two schools
  - Home Intensive—up to 5 homes (matched indoors)
- Timing
  - Continuous, daily data (PAS 2000)
    - Central Site, 2000 – ongoing
    - Schools July 2002 – August 2003
  - Integrated 24 hour samples
    - Supersite July 2002 – Auust 2003
    - Schools May 2002 – August 2003
    - Homes February 2002 - February 2003

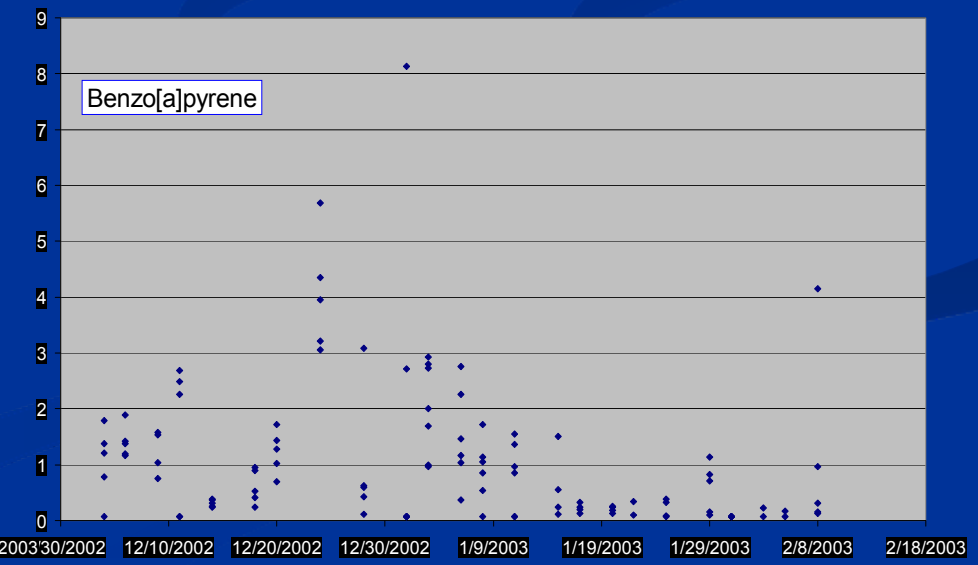
      2-5 homes at a time, 5 days/2 weeks [497 samples + QC]

Spatial Variation of PAHs in Fresno

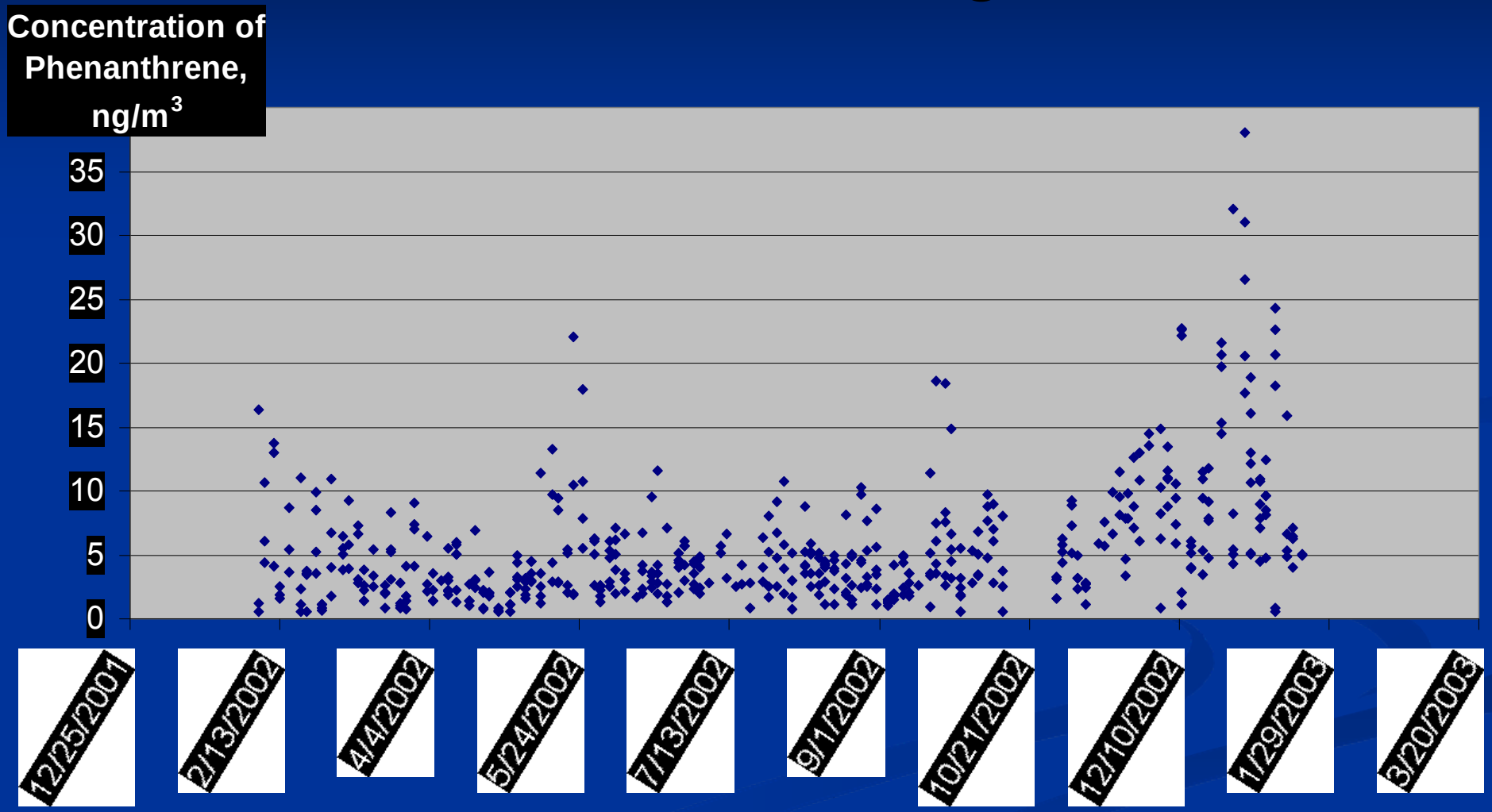








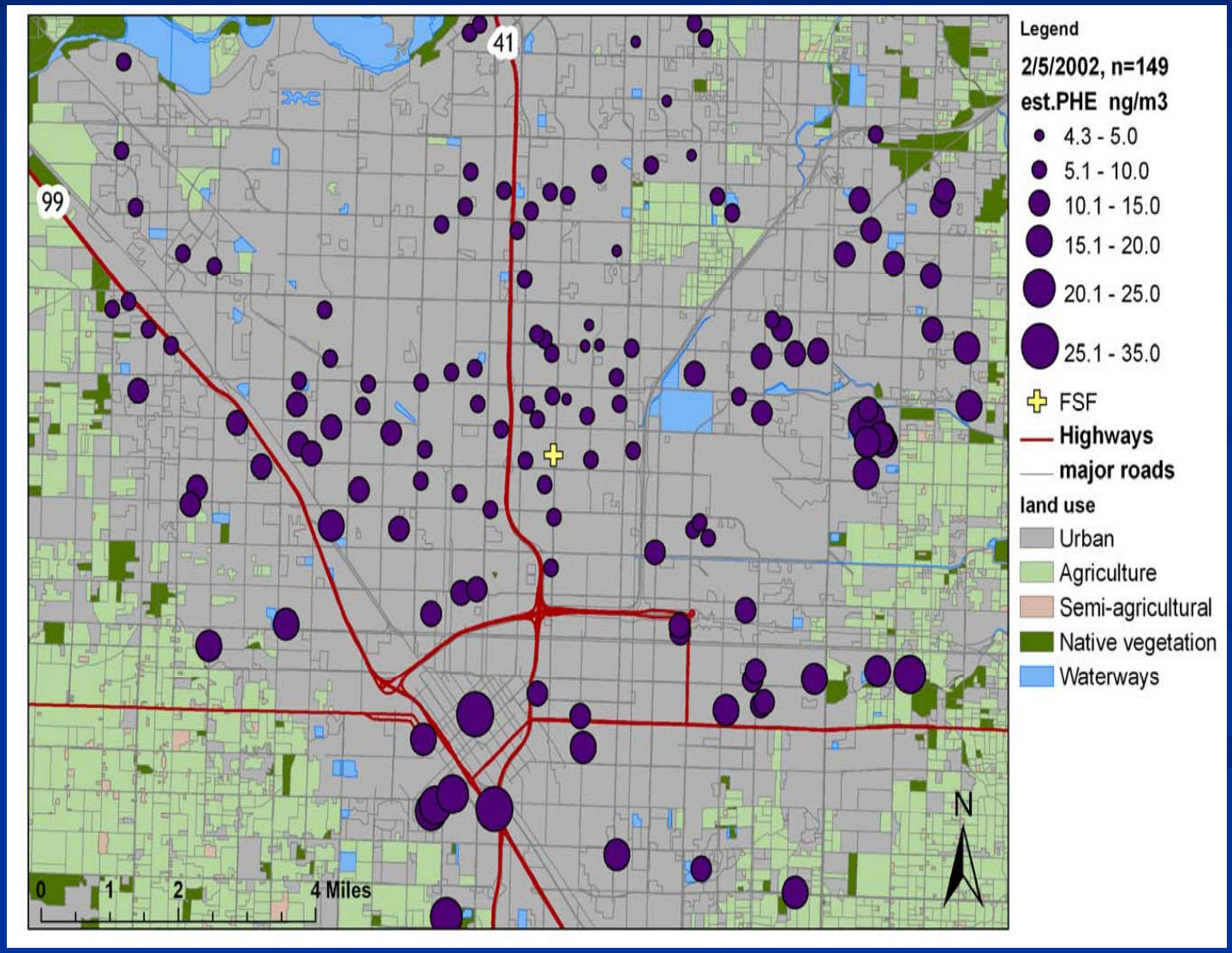
Phenanthrene Concentration Outside Fresno Homes, ng/m^3



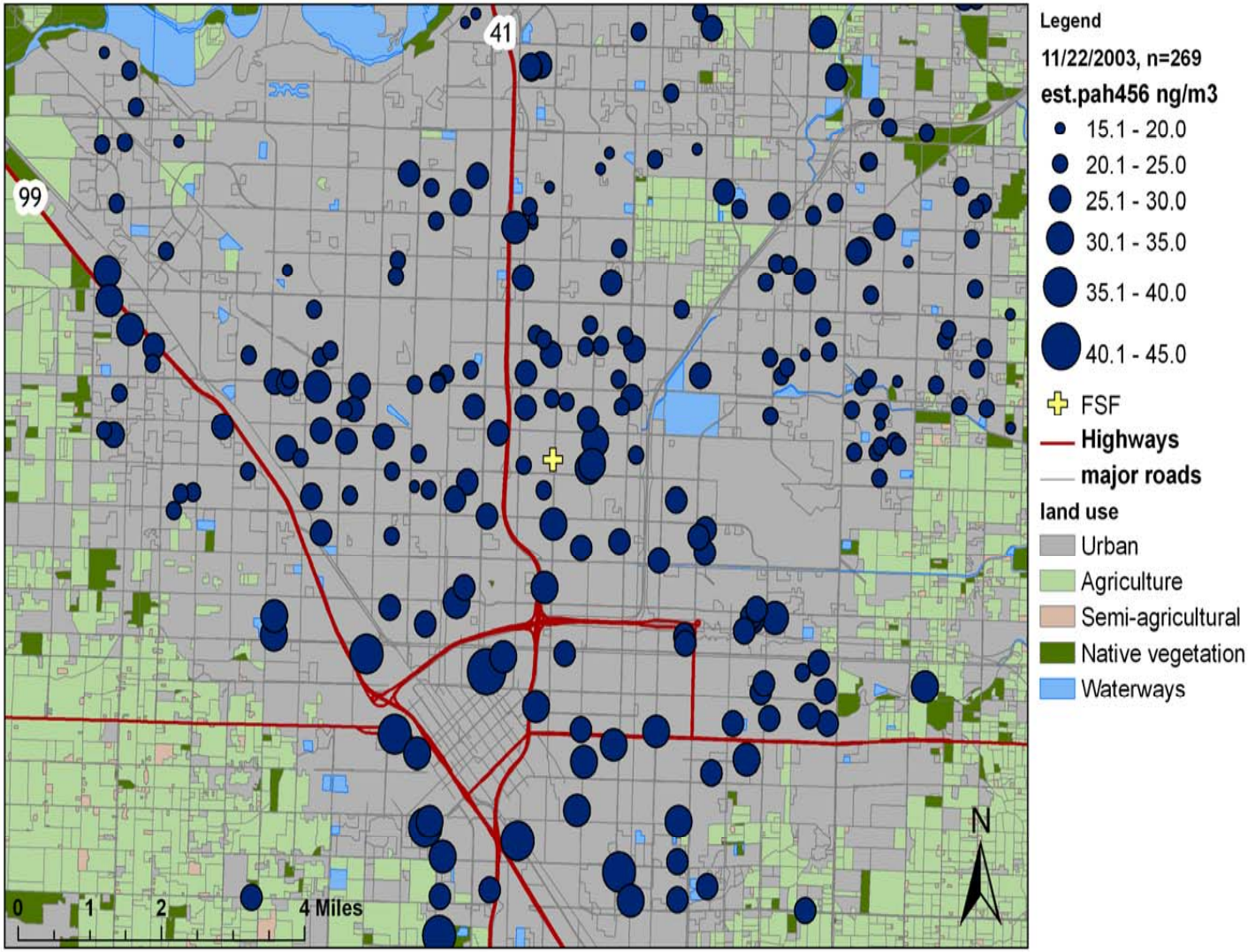
Spatial Variables Used for Filter Based PAH Model

- Traffic related variables
  - Distance to Highway 99
  - Distance to nearest Minor Collector road
  - Distance to nearest Major Arterial road
  - Length of highway within 100 meter buffer
- Land use variables
  - Total agricultural area within 500 meter buffer Total industrial area within 200 meter buffer
- Other spatial variables
  - Distance to EPA supersite
  - Direction to EPA supersite
  - Total agricultural burning within 5 miles on day of sampling

Individual Exposure Estimates for Phenanthrene on February 5, 2002



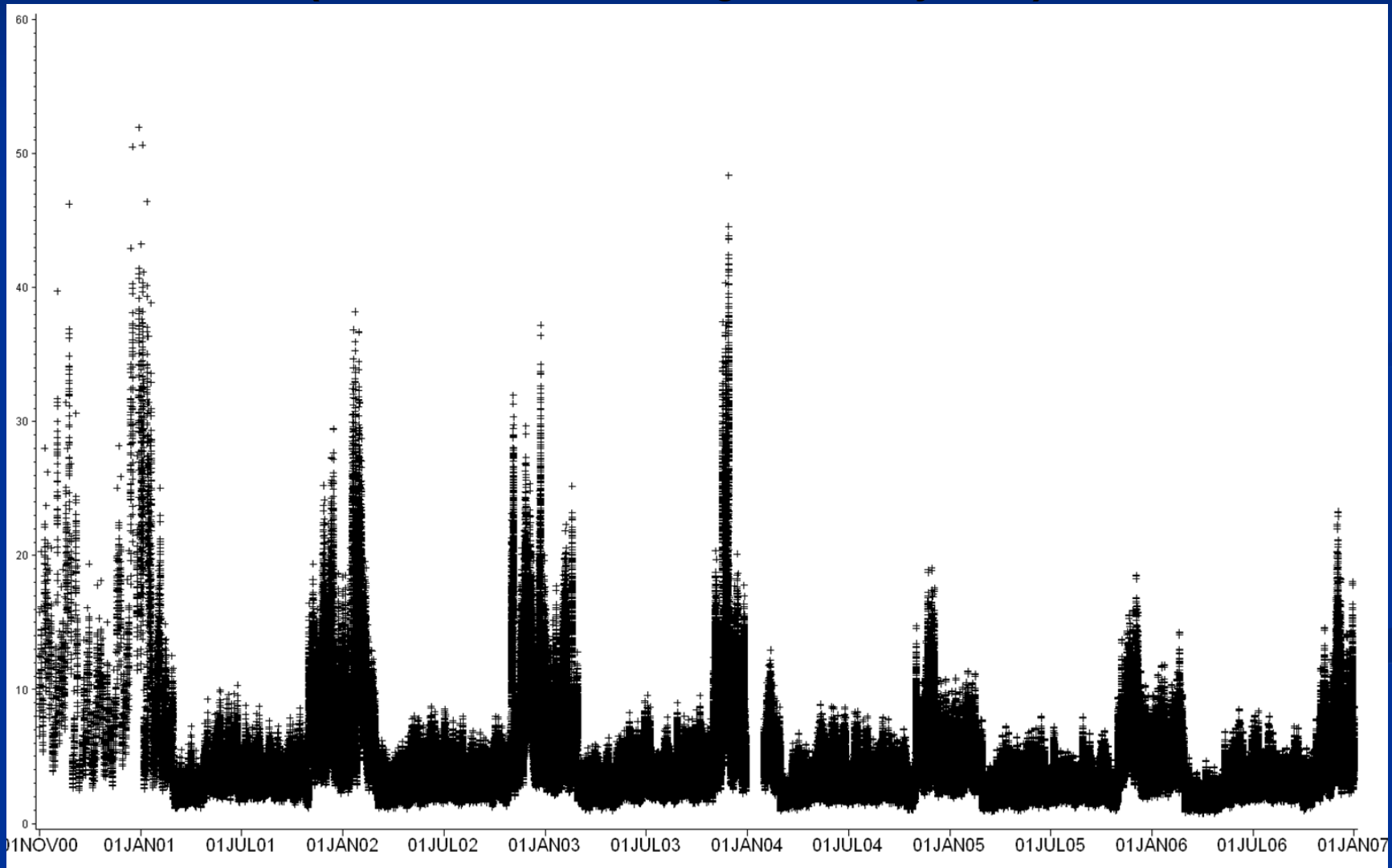
Individual Exposure Estimates for PAH456 on November 22, 2003



Temporal Distribution of Individual Exposure Estimates for PAH456

for all FACES participants on all days

(November 2000 through February 2007)



Conclusions from Modeling

- Longitudinal analysis, especially mixed modeling, is advantageous for modeling daily individual exposure estimates using temporally- and spatially-rich datasets.
- PAH456 & PHE concentrations and ratios fluctuate significantly within a metropolitan region. The use of a single central monitor value would simplify the variability in the daily individual exposure estimates.
- PAH456 & PHE concentrations in greater Fresno, CA are dependant on the PAH concentrations at a central monitor (US EPA Supersite), meteorological conditions, and source proximity.

Summary—Goals

- Exposure assessment for FACES aims to evaluate exposure for each child on each day over 8 years
- Both temporal and spatial variability important
- Temporal variability captured with monitoring at USEPA Supersite/ARB

Conclusions—Spatial Variability

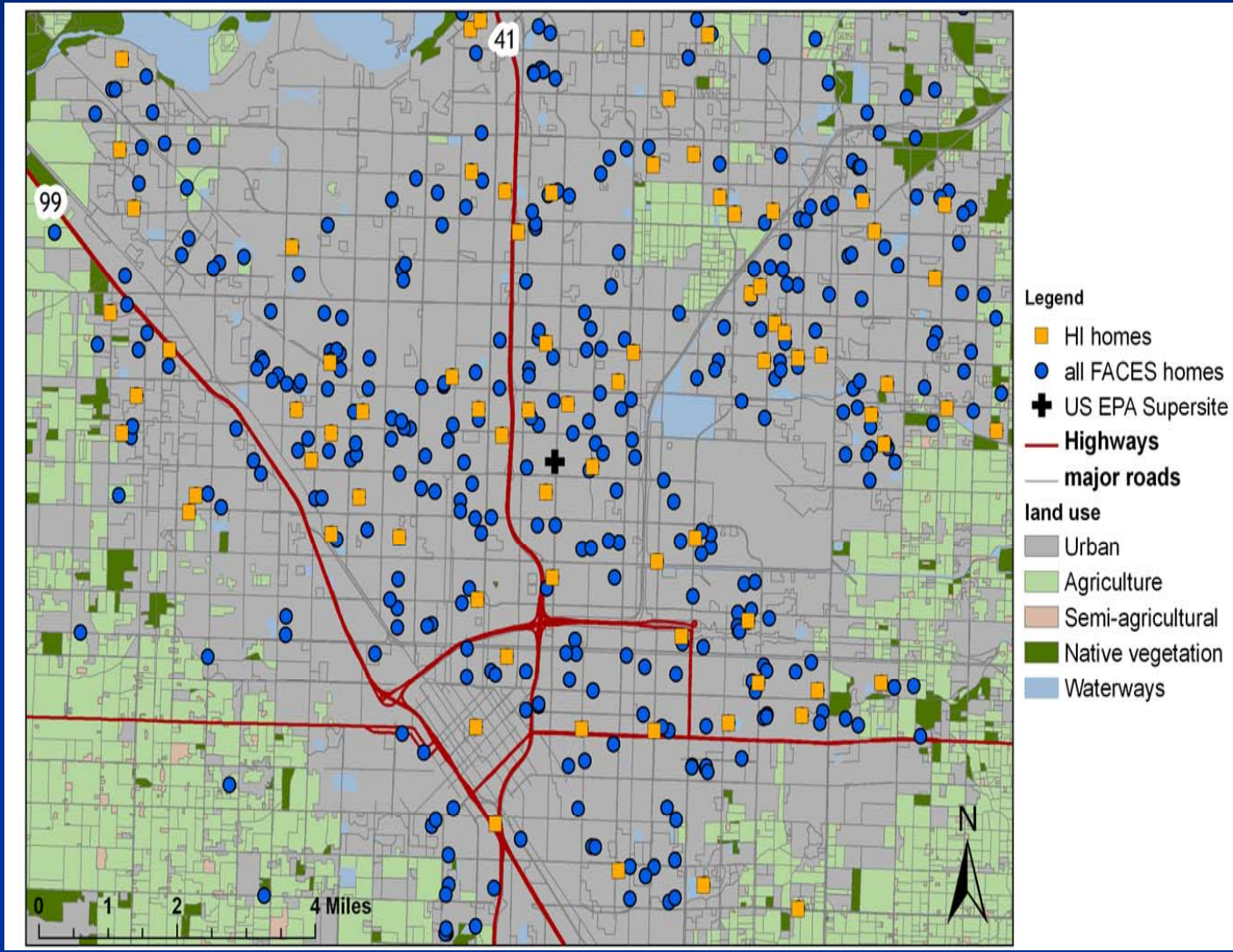
Spatial variability modeled using

- Air concentrations of total particle-bound PAHs measured continuously for 8 years at Supersite (EcoChem, PAS2000)
- Air concentrations of 16 target PAHs collected on filters & denuders at Supersite, homes, and schools on selected days, 2002-2003
  - up to 8 locations/day
  - Samples collected c. 2 days/week over 1 year
  - ~ 700 samples
- Pine needles collected concurrently at 100 locations

FACES Research Questions

- Acute effects: in children who have asthma, in what ways and under what conditions (host factors and exposure conditions) do ambient air pollutants contribute to *acute* worsening of asthma (symptoms and lung function)
- Chronic effects: are children whose asthma is made worse by daily increases in air pollution more likely to have severe asthma and/or decreased lung function growth as they get older?

Locations of FACES Participants and the US EPA Supersite.

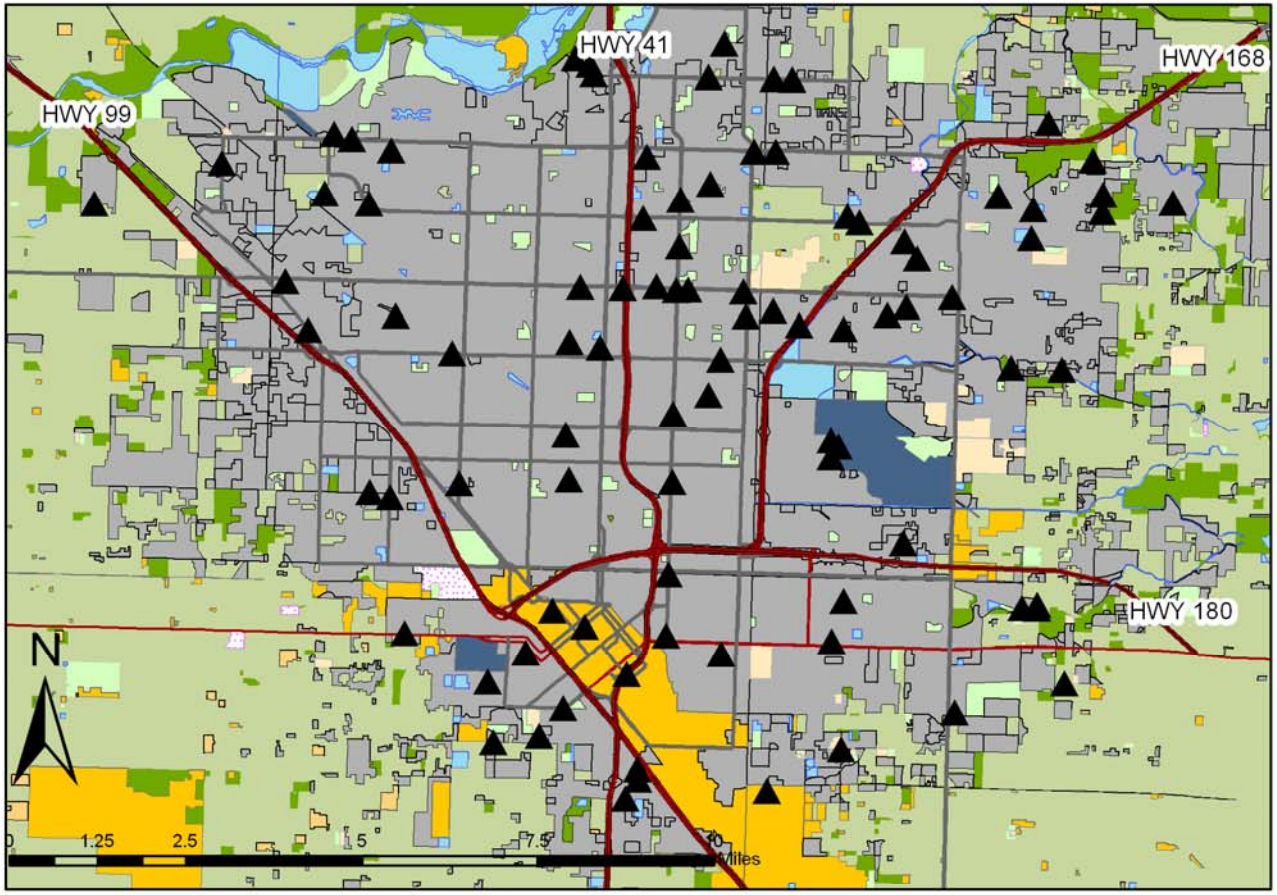


The Use of Pine Needles to Evaluate Spatial Distribution of PAHs

Vegetation Biomonitoring in Fresno

- Innovative way to understand spatial differences in PAH concentration
- Comparatively inexpensive to sample
- Jeffrey Pine trees distributed throughout the city
- Used for individual-level exposure estimates for PAH

Sampling sites for Pine Needles February 20, 2008



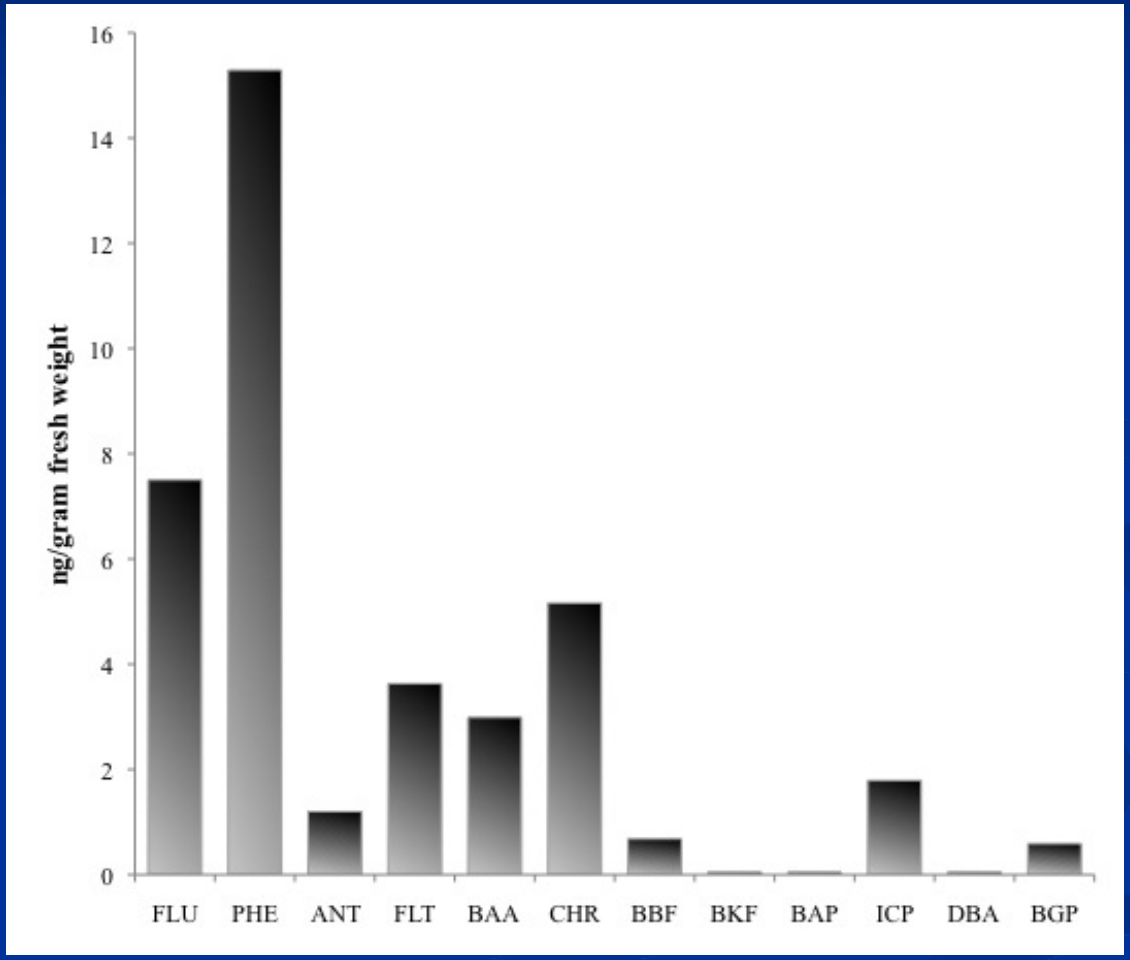
Legend

- sample sites
- highways
- Major roads

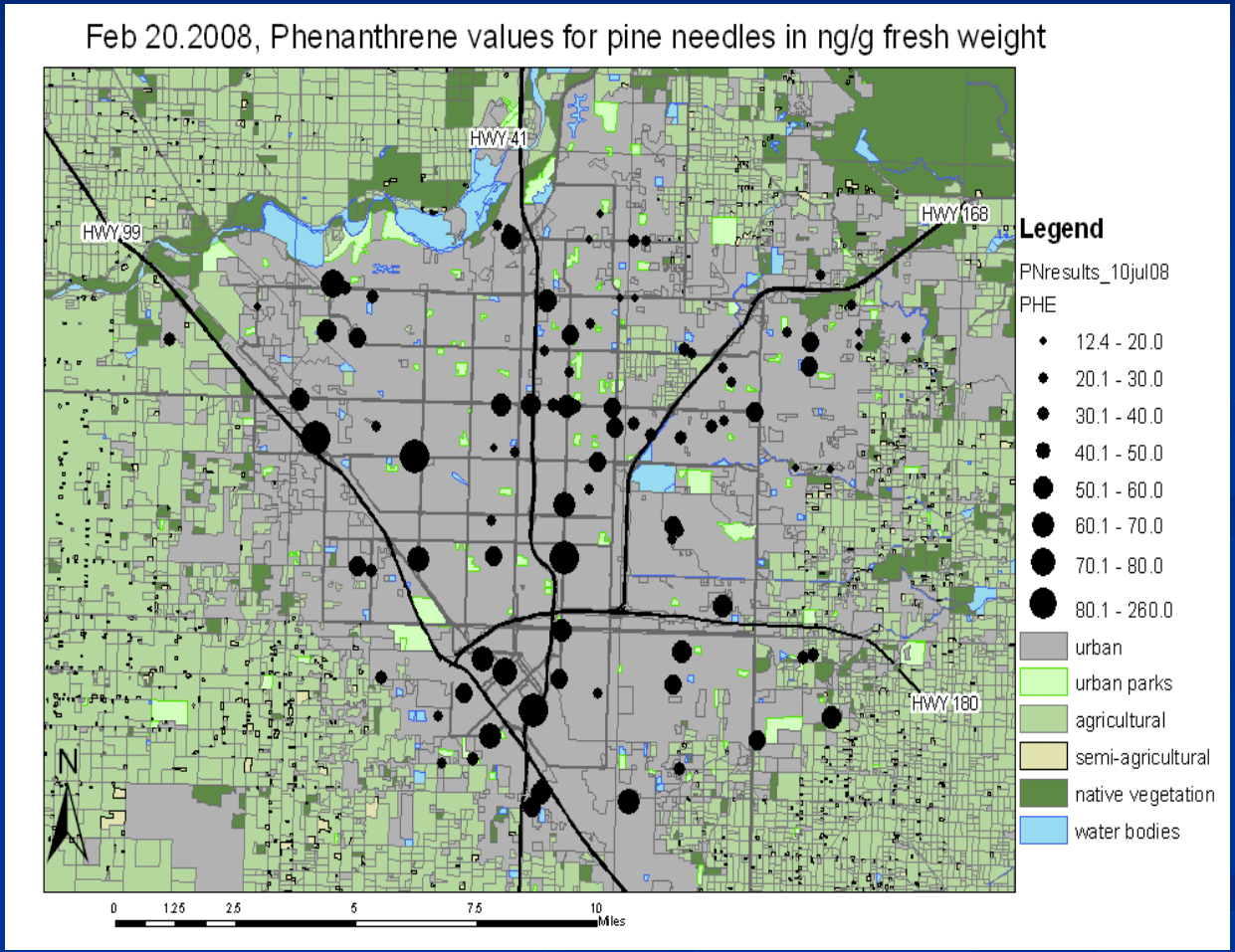
Land Use

- agricultural area
- water
- open space
- livestock feedlots, dairies, poultry farms
- Urban & Residential
- Commercial & Institutional
- Industrial
- parks & golf courses
- cemetaries
- railroad
- airports

PAH Distribution Profile in Pine Needles Fresno, CA

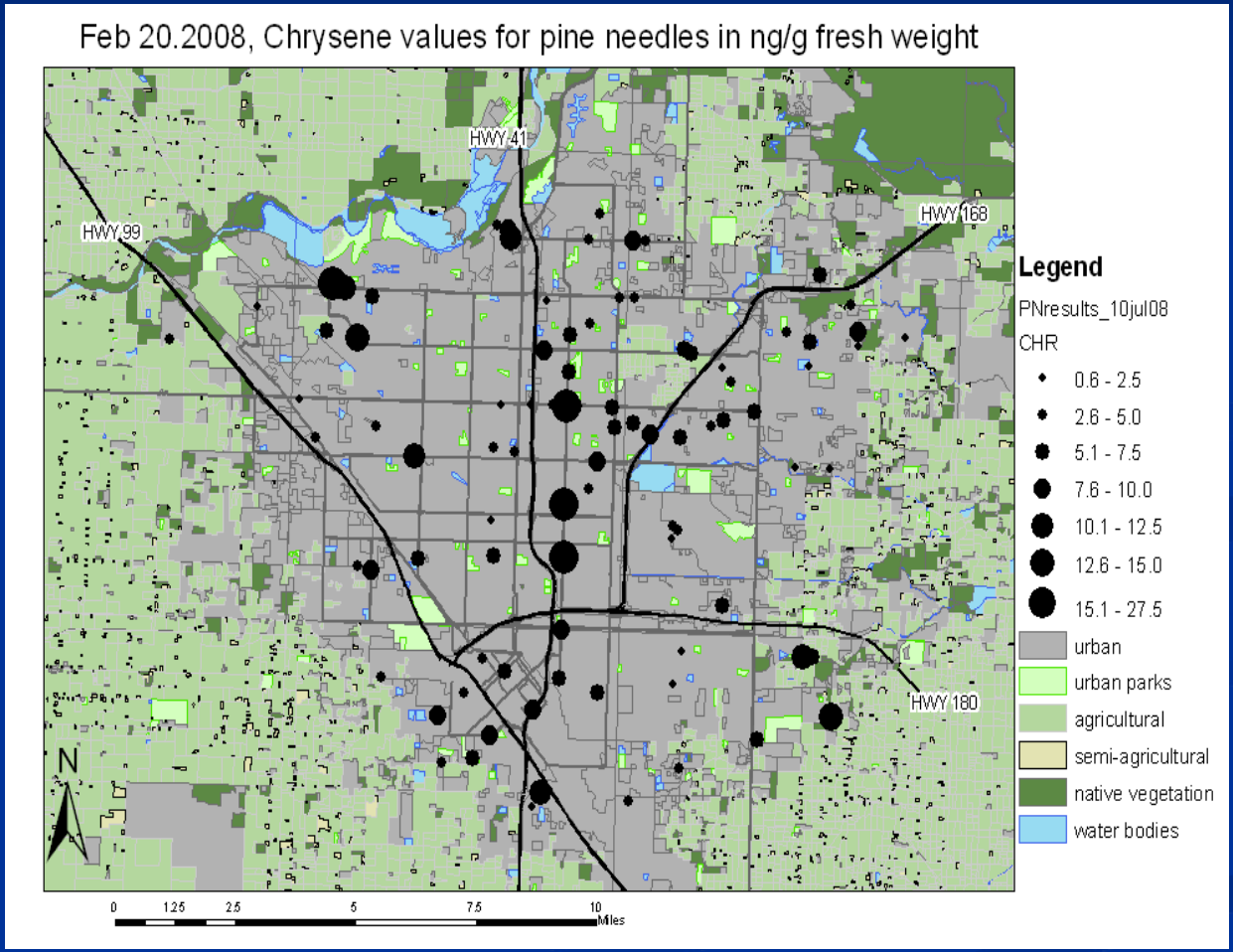


Spatial Distribution of Phenanthrene on Pine Needles



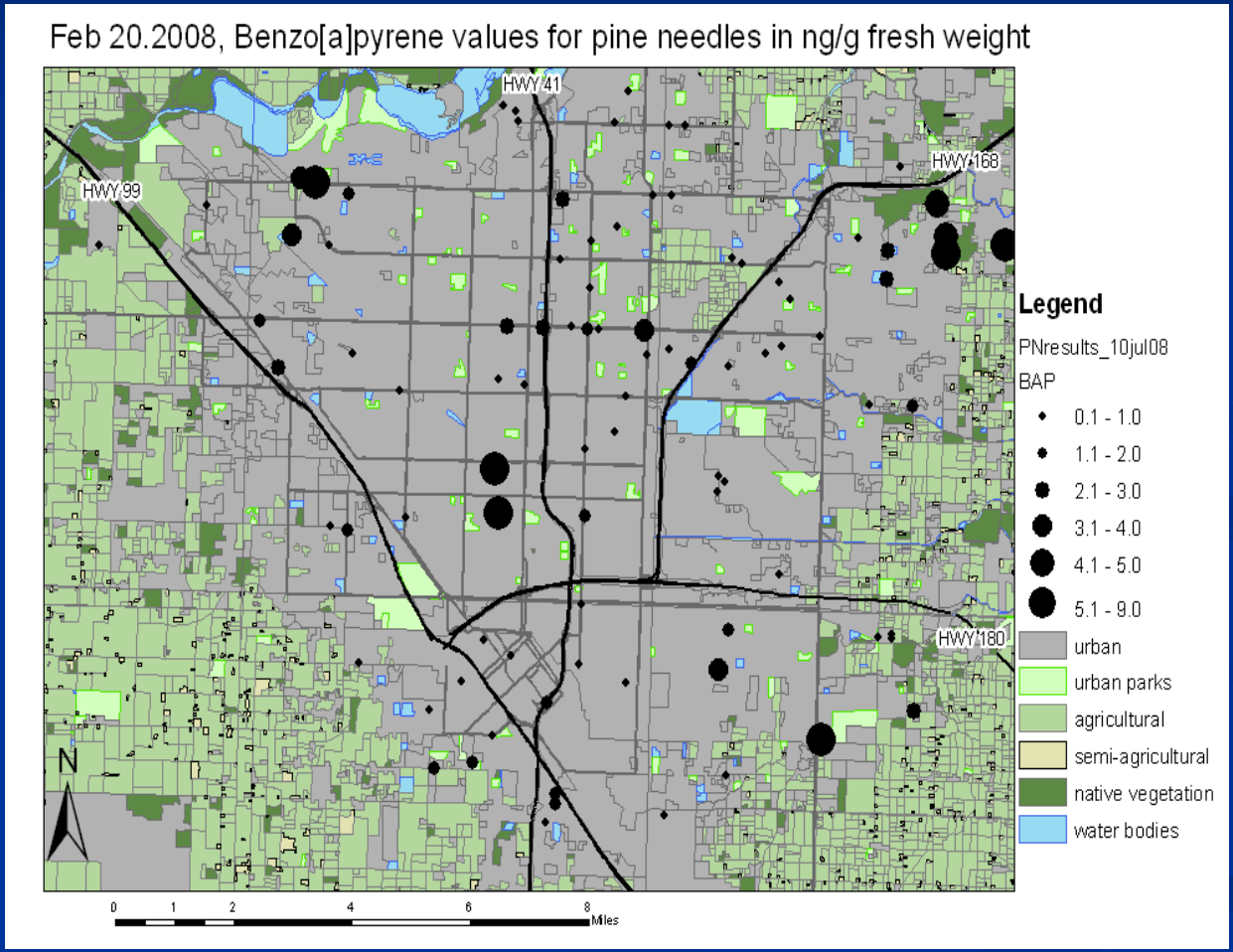
February 20, 2008 in Fresno, CA

Spatial Distribution of Chrysene on Pine Needles



February 20, 2008 in Fresno, CA

Spatial Distribution of Benzo[a]pyrene on Pine Needles



February 20, 2008 in Fresno, CA

Pine Needle Results

February 20, 2008, ng/gram fresh weight

	N	% below LOQ	mean	stdev	CV	median	ratio 90:10
Phenanthrene	91	0%	**41.0**	28.47	0.69	36.86	**3.3**
Fluoranthene	91	0%	**10.7**	7.12	0.67	9.90	**5.0**
Benzo[a]anthracene	91	8%	**1.7**	1.38	0.83	1.28	**6.6**
Chrysene	91	0%	**5.94**	4.47	0.75	5.20	**5.9**
Benzo[b]fluoranthene	91	13%	**1.38**	1.38	1.00	0.97	**22.1**
Benzo[k]fluoranthene	91	53%	**0.44**	0.53	1.21	0.24	**16.1**
Benzo[a]pyrene	91	35%	**1.34**	1.62	1.21	0.82	**34.9**
Indeno[1,2,3-cd]pyrene	91	22%	**1.18**	1.30	1.11	0.80	**23.8**
Dibenz[a,h]anthracene	91	36%	**0.87**	1.40	1.61	0.40	**47.3**
Benzo[g,h,i]perylene	91	13%	**1.17**	1.11	0.95	0.81	**20.3**

Land Use Regression of Phenanthrene

Spatial variables in model building:

- Traffic
- Land Use
- Industrial sources
- Other sources
- Neighborhood characteristics

Phenanthrene Regression Model

- 4 traffic variables
- Agricultural burning
- 1 other source variable
- 2 land use variables
- 5 neighborhood variables

- $R^2 = 0.70$

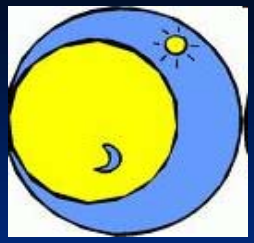
Agents of Interest

- Particles by size
  $PM_{2.5}$, PM_{10}
  - Mass
  - OC/EC
  - Sulfate, nitrate, & ammonium ions
  - Metals, potassium
- Gases
  - NO, NO_2
  - Ozone
  - SO_2
- Biological agents
  - Pollen grains
  - Fungal spores
  - *Airborne endotoxin*
  - Allergens in house dust
    - **Dust mites**
    - **Cat dander**
    - **Dog dander**
    - **Cockroach eggs**
- Second hand smoke
- ***PAHs***

EZ1 & Health Outcome

on each day

+



Each Child's Exposure

on each day

?

Relationship between Exposure and Health Outcome

Acknowledgement of Funders

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The initial PAH work was supported by **US Environmental Protection Agency Office of Transportation and Air Quality** (P.O. No. 2A-0540-NASX) and the analysis of the home intensive filters and the modeling analysis was supported by **Mickey Leland National Urban Air Toxics Research Program**
The research described in this talk was funded by the Mickey Leland National Urban Air Toxics Research Center (NUATRC), an organization jointly funded by the United States Environmental Protection Agency (EPA) and private industry sponsors. The contents of this talk do not necessarily reflect the views of NUATRC, or its sponsors, nor do they necessarily reflect the views and policies of the EPA or any of the private industry sponsors.

National Institutes of Health Division of Lung Diseases, 2006-2011
NHLBI Grant # R01 HL081521

Thank you!