Composition of Personal, Indoor and Outdoor Particulate Exposures

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Key Questions

- *Is ambient PM an appropriate exposure **surrogate**?*
- *Do exposures of **sensitive populations** differ from those of healthy populations?*
- *What exposure factors act as **effect modifiers** in epidemiological studies?*
- *What is the **PM component** responsible for the observed effects?*
- *Are observed PM associations in epidemiological studies due to **confounding** by other pollutants?*
- *Do we need to consider the effects of **indoor and outdoor PM** separately?*

Hypotheses

- *The composition of personal and indoor $PM_{2.5}$ exhibits significant inter- and intra-personal variation*
- *The personal-outdoor relationship differs by particulate component*
- *The composition of personal and indoor $PM_{2.5}$ and its relationship to that outdoors differs for individuals with COPD living in LA as compared to other individuals*

Approach

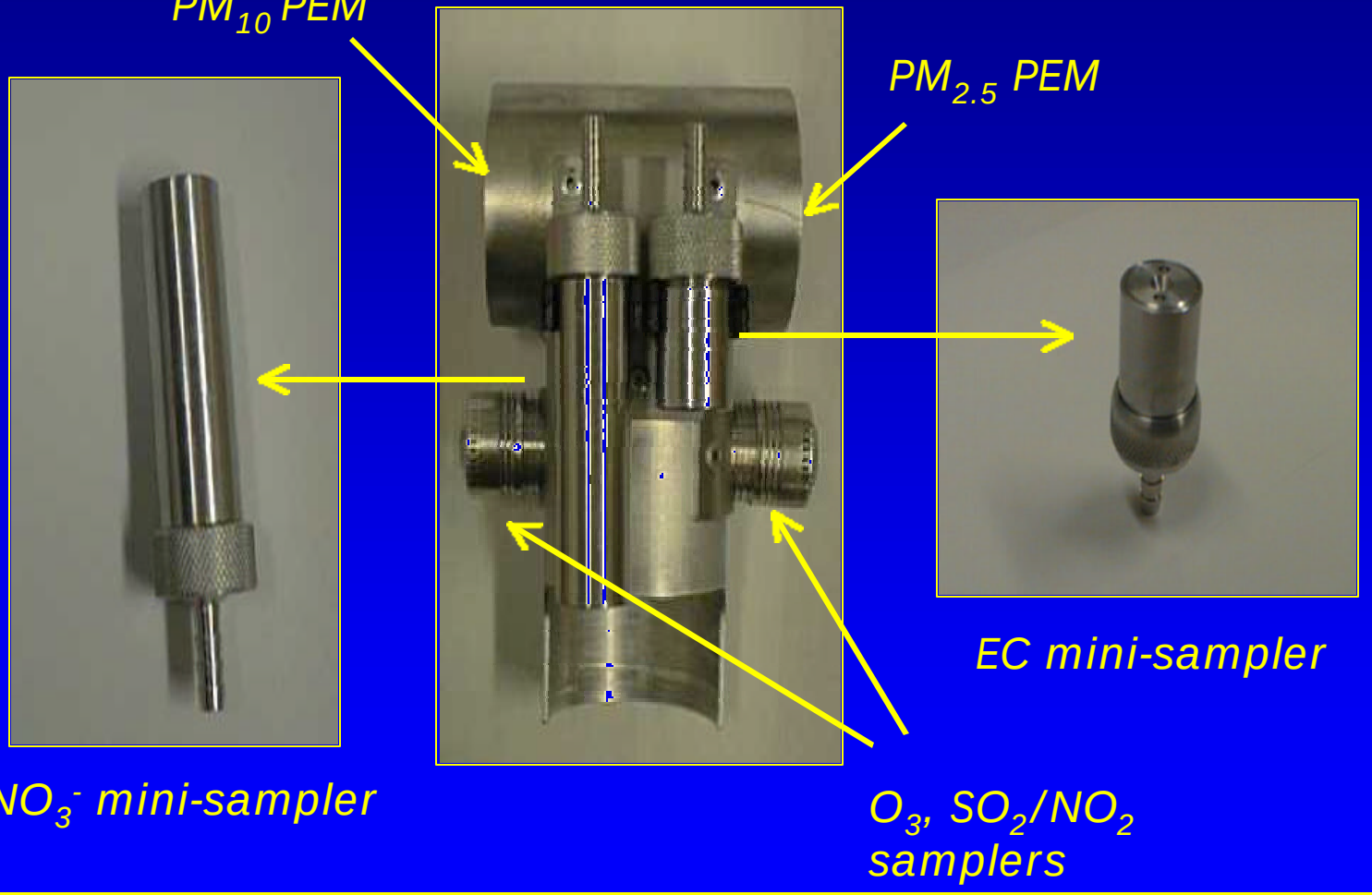
- ***Phase I**: Validate personal NO_3^- and EC samplers in laboratory and field tests*
- ***Phase II**: Conduct field study*
  - *Characterize composition of personal, indoor, and outdoor $PM_{2.5}$ for individuals with COPD*
  - *Examine relationship among personal, indoor and outdoor $PM_{2.5}$, NO_3^- and EC levels*
  - *Identify factors that may modify personal-outdoor, personal-indoor relationship*

EPA- and CARB-Sponsored Measurements

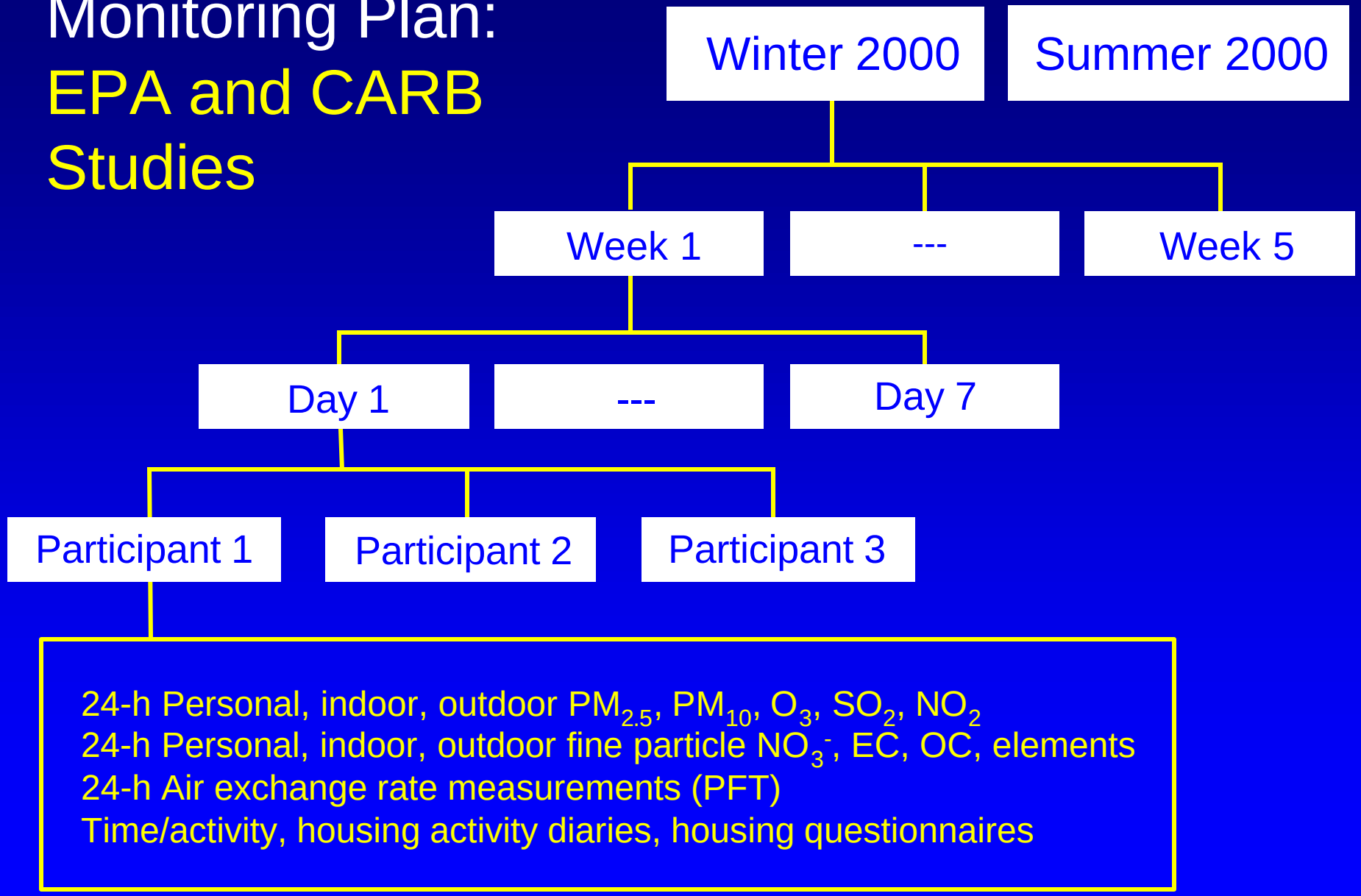
Measurement	Sponsor	
	EPA	CARB
Pollutant (24-h):[1]		
PM_{10}, $PM_{2.5}$	Π	
O_3, SO_2, NO_2	Π	
Elemental Carbon (EC)		Π
Nitrate (NO_3^-)		Π
Elements		Π
Other:		
Time-activity diaries	Π	
Air exchange rates	Π	
Housing characteristics	Π	

[1] *Includes personal, indoor, outdoor home, and SAM site measurements*

Multi-Pollutant Sampler



Monitoring Plan: EPA and CARB Studies



Participant Residences:

Winter and Summer 2000

Metropolitan Los Angeles

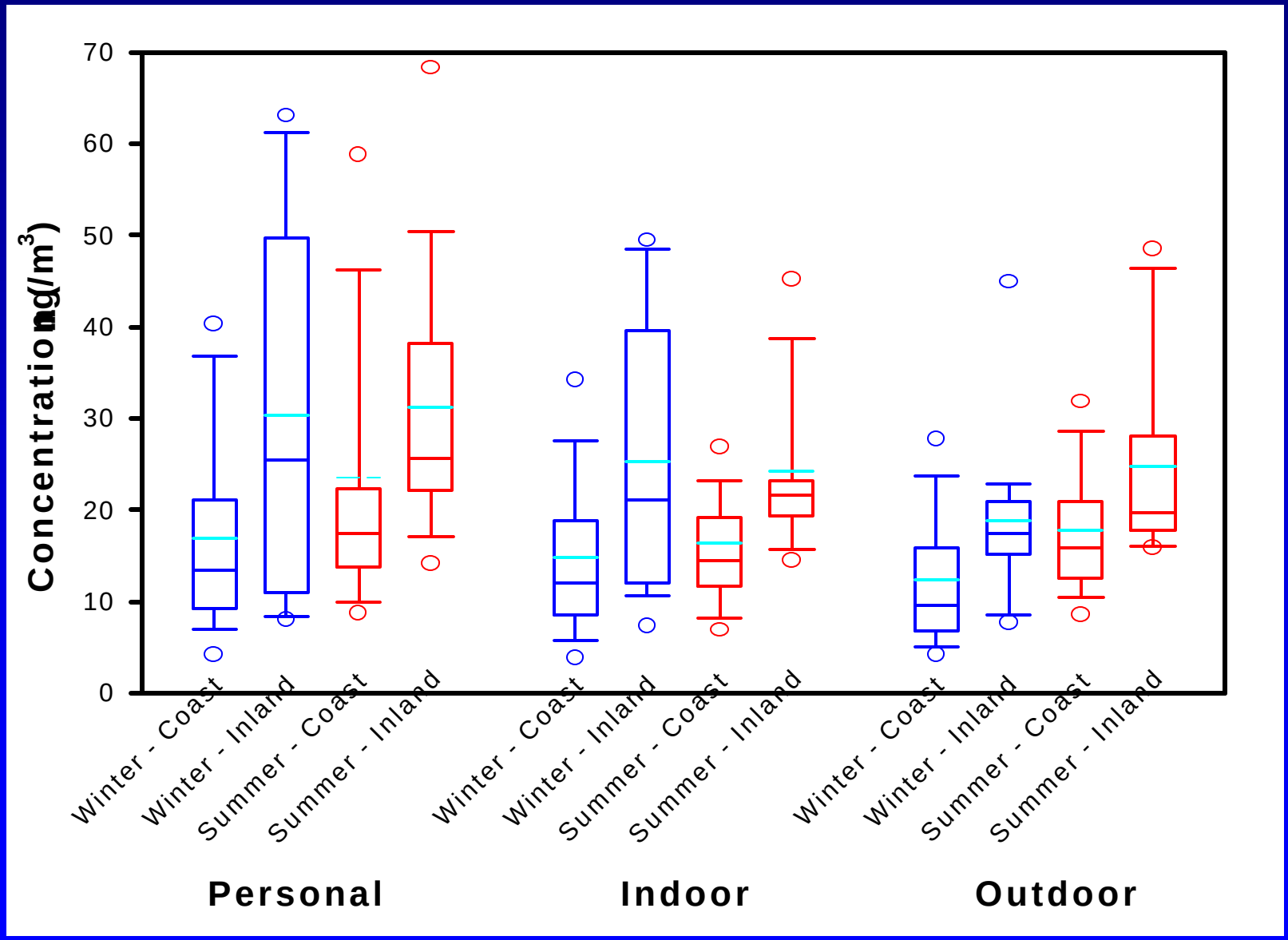
Participant and Location Profiles

Parameter	Season		
	Both	Winter	Summer
Sex: Male Female	0 8	1 14	2 13
Age (years)	63-84	60-84	55-84
Location: Coastal Inland	6 2	12 3	12 3
Population Density (persons/km^2)	173-9693	173-9693	49-9693
Distance from Road (m)	76-2029	65-2029	0-2098

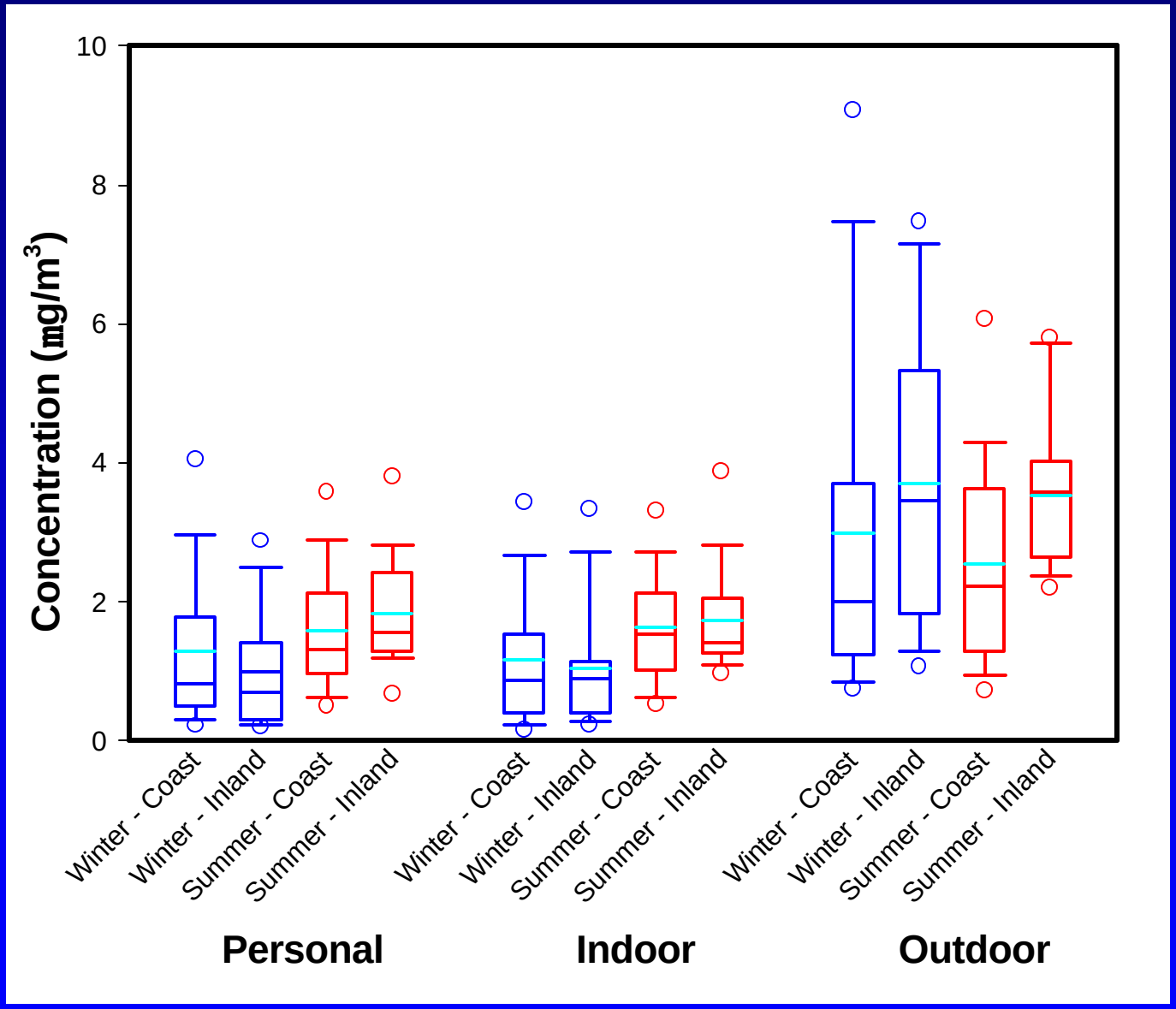
Housing Characteristics

Characteristic	Winter		Summer	
	Yes	No	Yes	No
Air conditioner use	3	12	4	11
Near busy road	11	4	13	2
Attached garage	8	7	7	8
Detached home	7	7	9	5
Gas stove	6	8	8	6
Clothes dryer	11	4	6	9

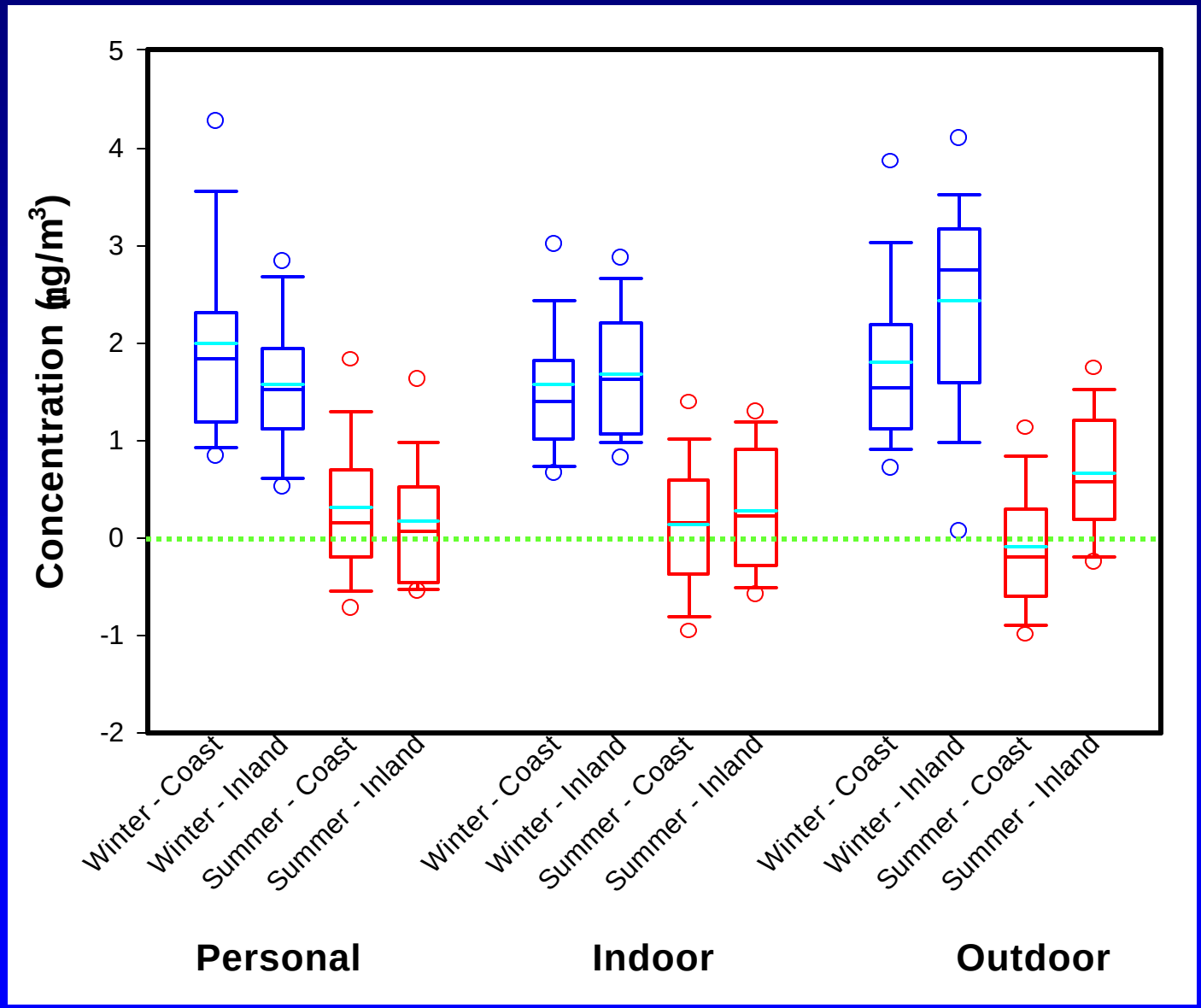
$PM_{2.5}$ Levels


Concentration (ng/m3)
70
60
50
40
30
20
10
0
Winter - Coast
Winter - Inland
Summer - Coast
Summer - Inland
Winter - Coast
Winter - Inland
Summer - Coast
Summer - Inland
Winter - Coast
Winter - Inland
Summer - Coast
Summer - Inland
Personal
Indoor
Outdoor

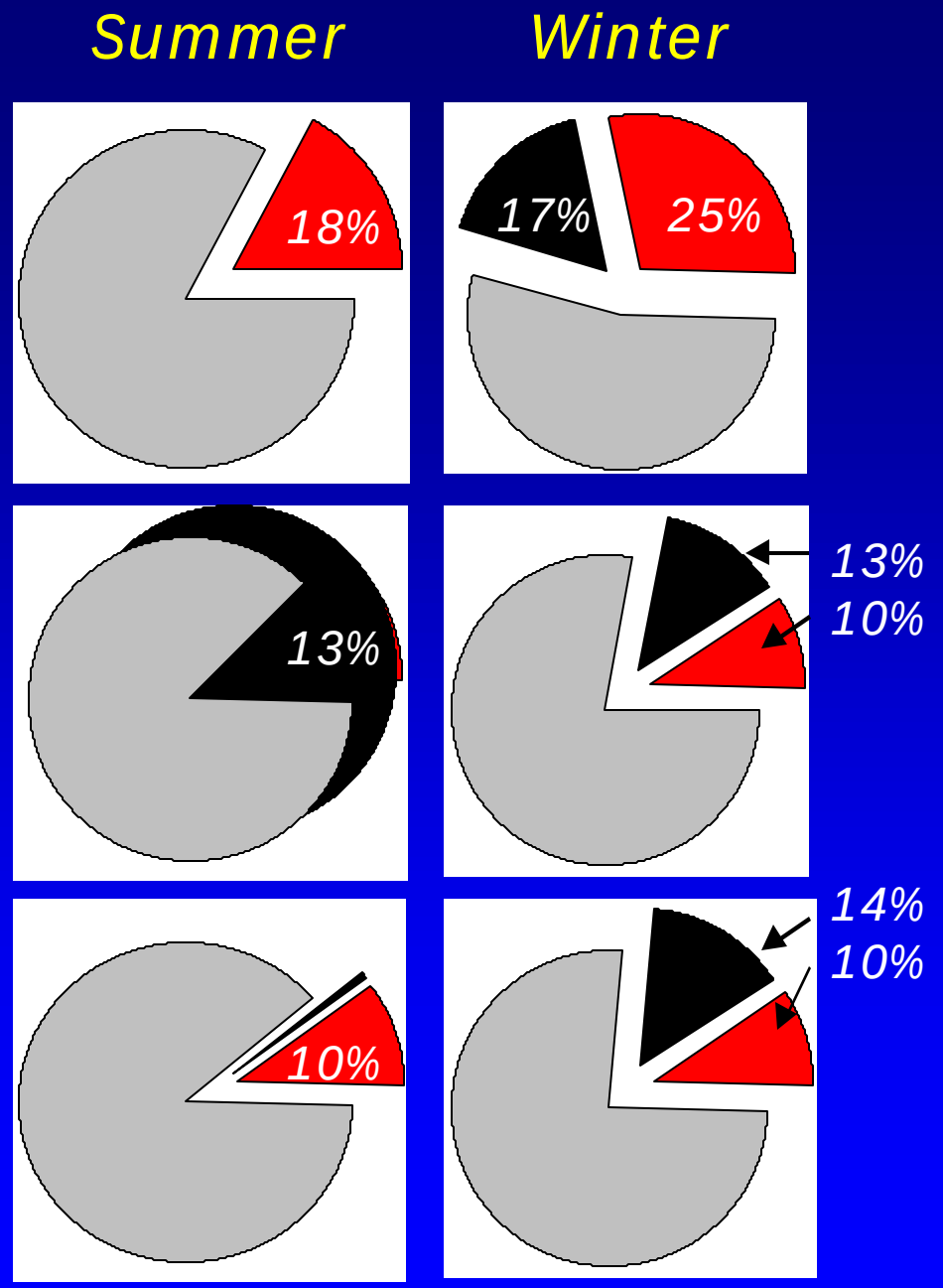
NO_3^- Levels


Concentration (mg/m3)
10
8
6
4
2
0
Winter - Coast
Winter - Inland
Summer - Coast
Summer - Inland
Winter - Coast
Winter - Inland
Summer - Coast
Summer - Inland
Winter - Coast
Winter - Inland
Summer - Coast
Summer - Inland
Personal
Indoor
Outdoor

EC Levels


Concentration (µg/m³)
5
4
3
2
1
0
-1
-2
Winter - Coast
Winter - Inland
Summer - Coast
Summer - Inland
Winter - Coast
Winter - Inland
Summer - Coast
Summer - Inland
Winter - Coast
Winter - Inland
Summer - Coast
Summer - Inland
Personal
Indoor
Outdoor

$PM_{2.5}$ Composition

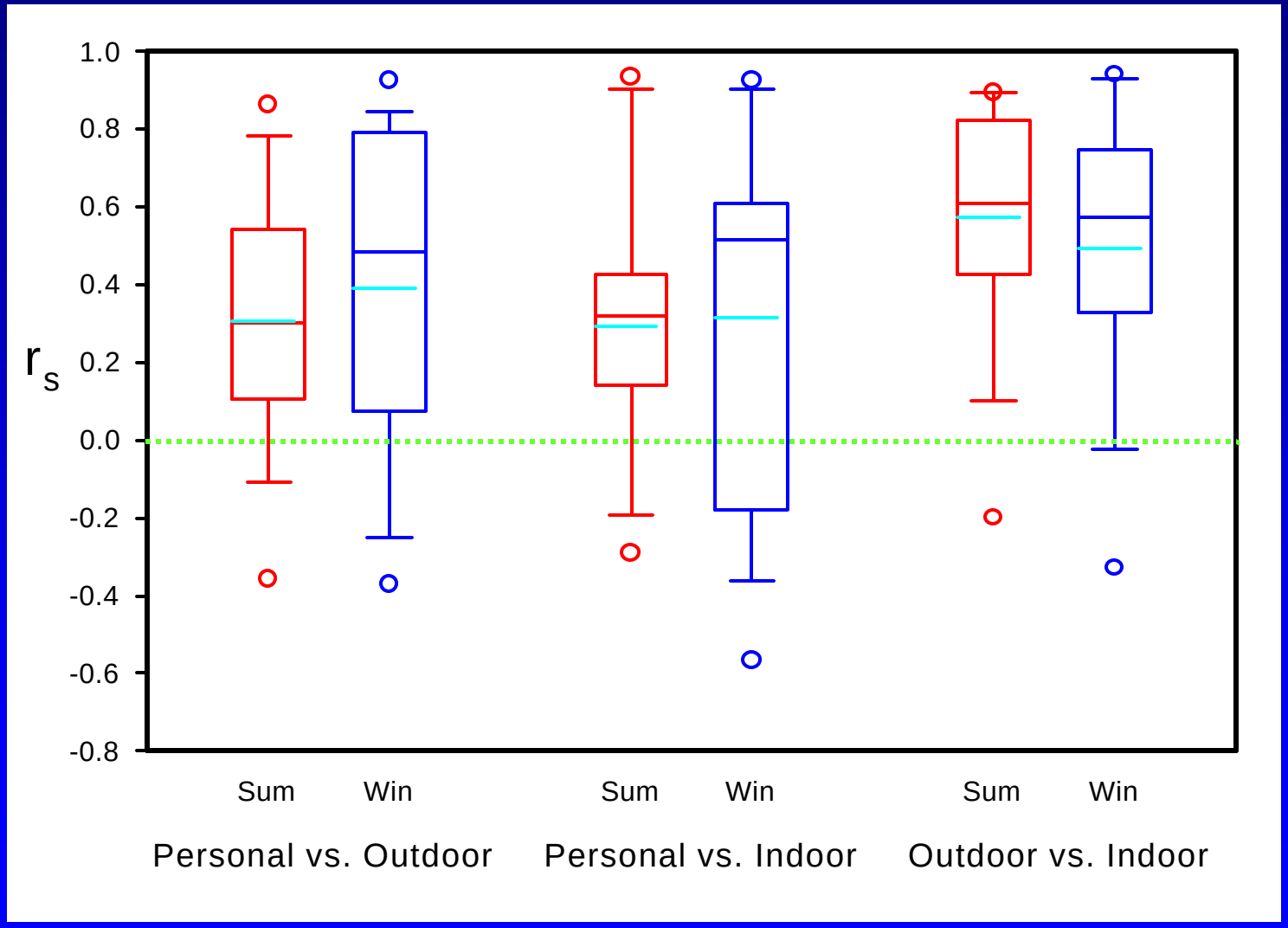


Exposure Error

When is ambient PM an appropriate exposure ***surrogate****?*

- ***Surrogate:*** *One that takes the place of another; a substitute*
  (The American Heritage® Dictionary)
- Epidemiological studies use **ambient concentrations** as a surrogate for exposures for their study populations
- Factors, such as activity patterns or housing characteristics, may impact ability of ambient PM to reflect exposures

Individual-Specific Spearman Correlation Coefficients for $PM_{2.5}$

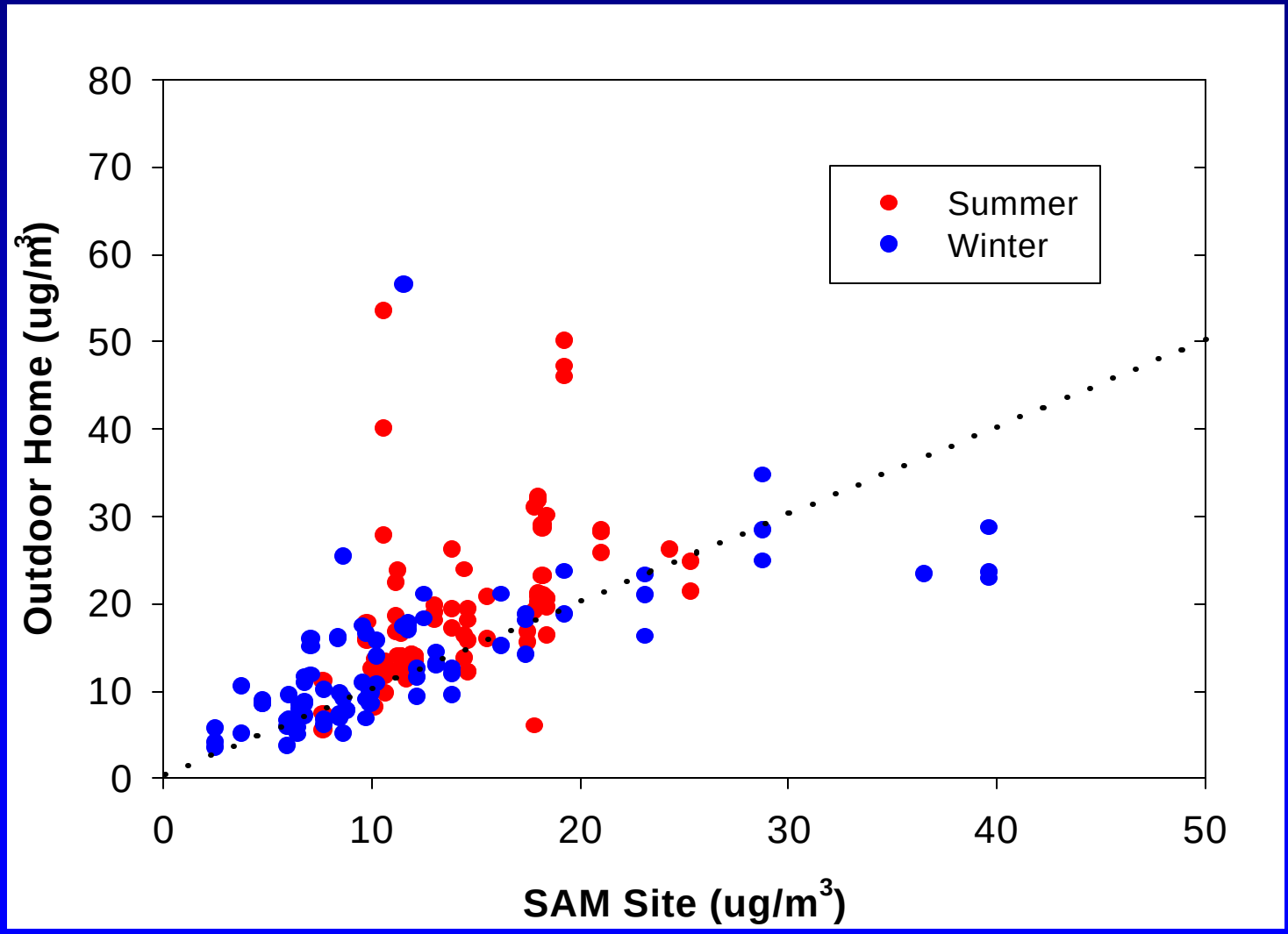


Relationship Among Personal, Indoor, and Outdoor $PM_{2.5}$

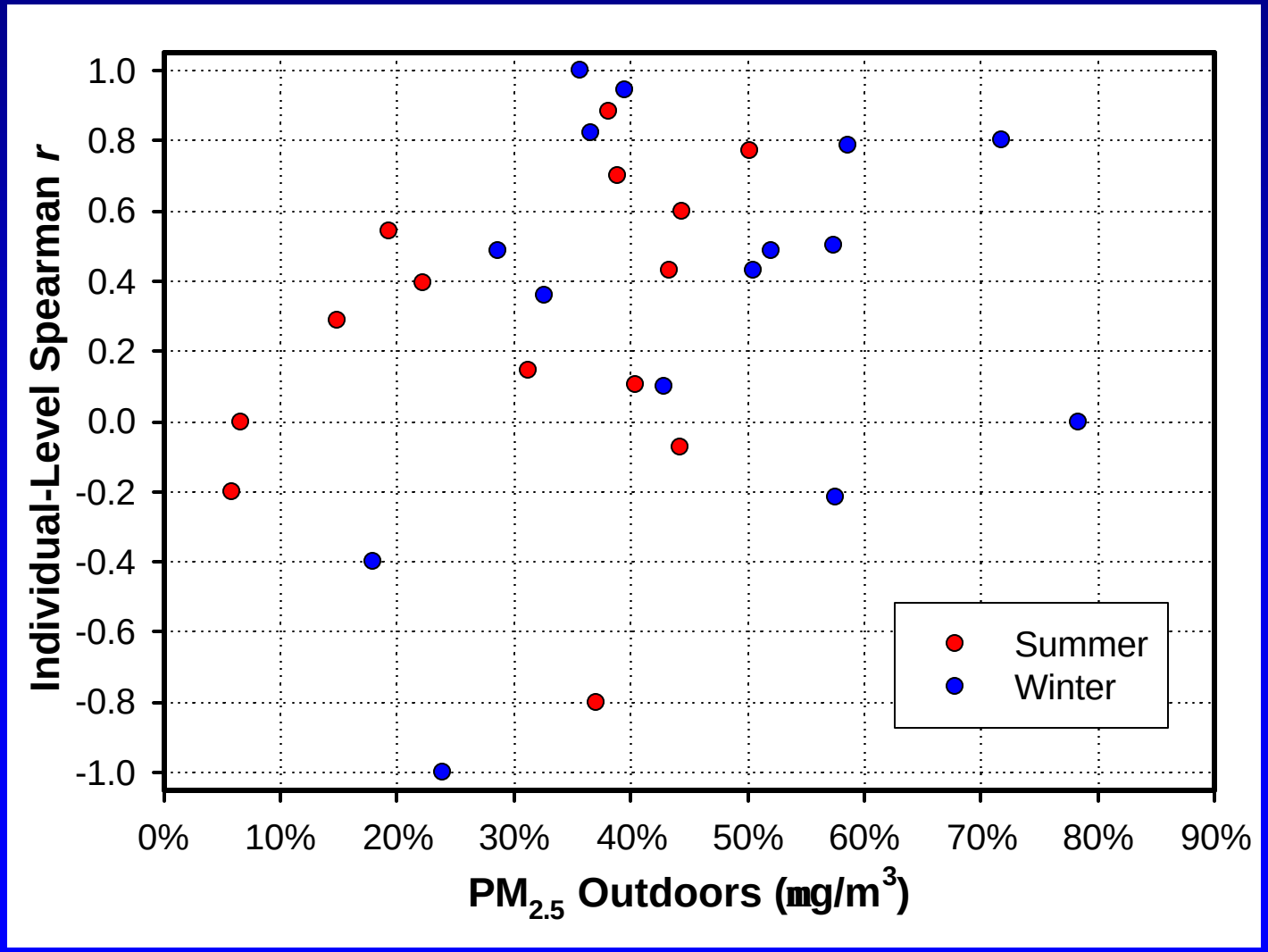
Comparison	N	Slope (se)	Intercept (s.e.)	Crude R^2
PER vs. OUT				
Winter	*82*	*0.5± 0.1*	*13.2 ± 3.5*	*0.19*
Summer	*90*	*1.3 ± 0.2*	*1.0 ± 4.7*	*0.30*
PER vs. IND				
Winter	*80*	*1.0 ± 0.1*	*2.5 ± 1.8*	*0.63*
Summer	*91*	*0.6 ± 0.2*	*15.0 ± 4.4*	*0.14*
IND vs. OUT				
Winter	*83*	*0.4 ± 0.1*	*11.3 ± 2.8*	*0.21*
Summer	*95*	*0.7 ± 0.1*	*4.6 ± 2.3*	*0.34*

Results from a generalized linear model that accounts for repeated measures.

Outdoor Home vs. SAM Site $PM_{2.5}$:
Los Angeles, CA

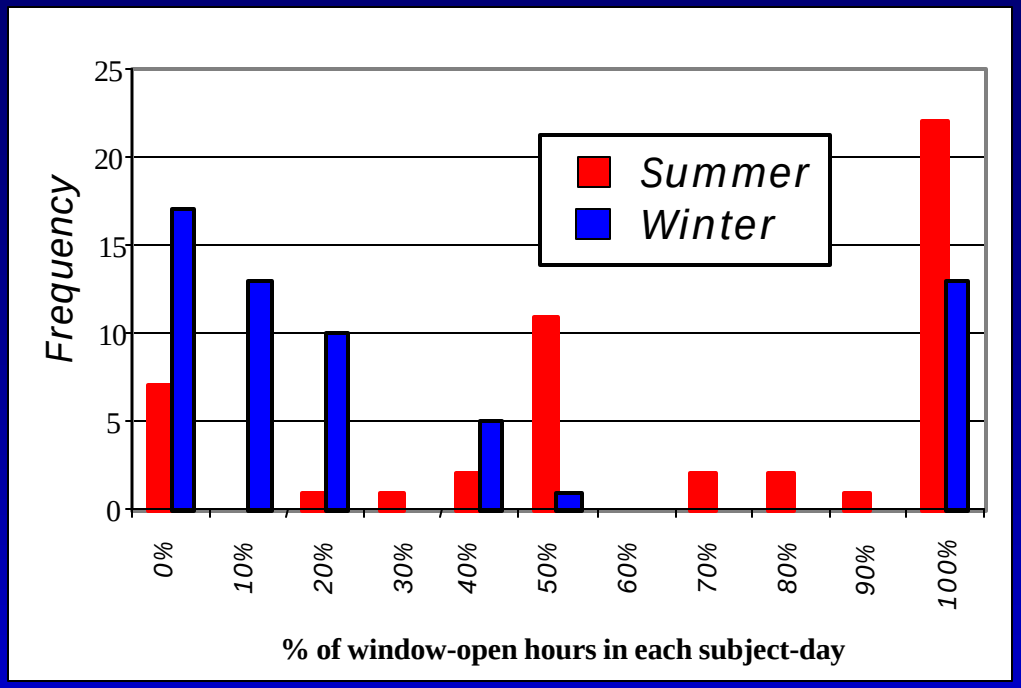


Individual-Specific Spearman Correlation Coefficients for $PM_{2.5}$: Personal-Outdoor Home Comparisons

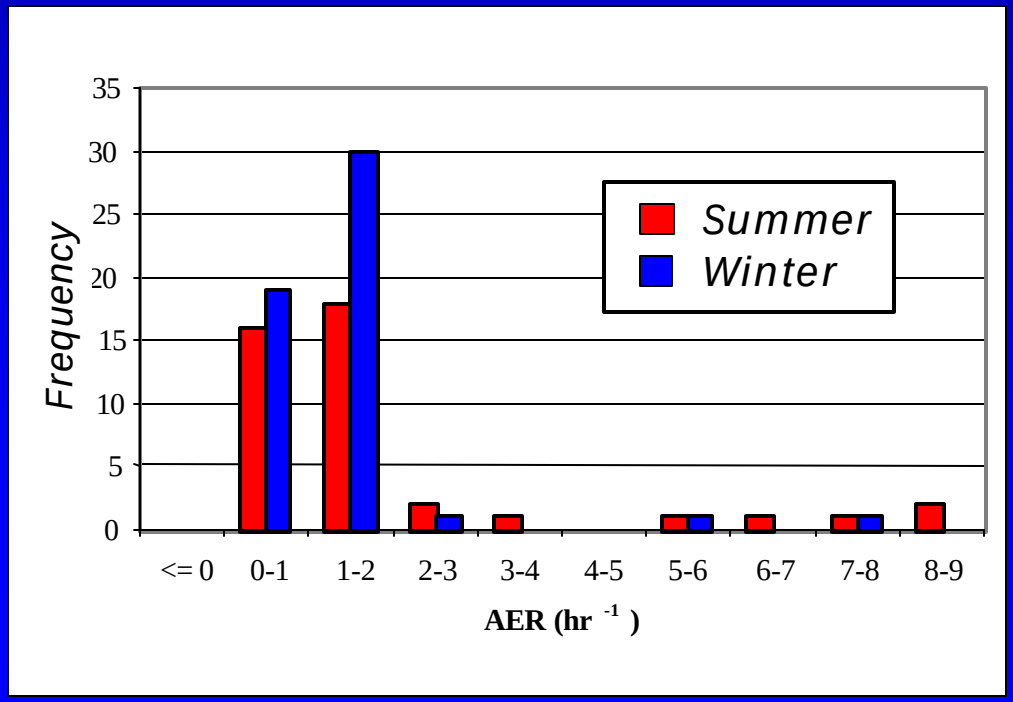


Home Ventilation Patterns

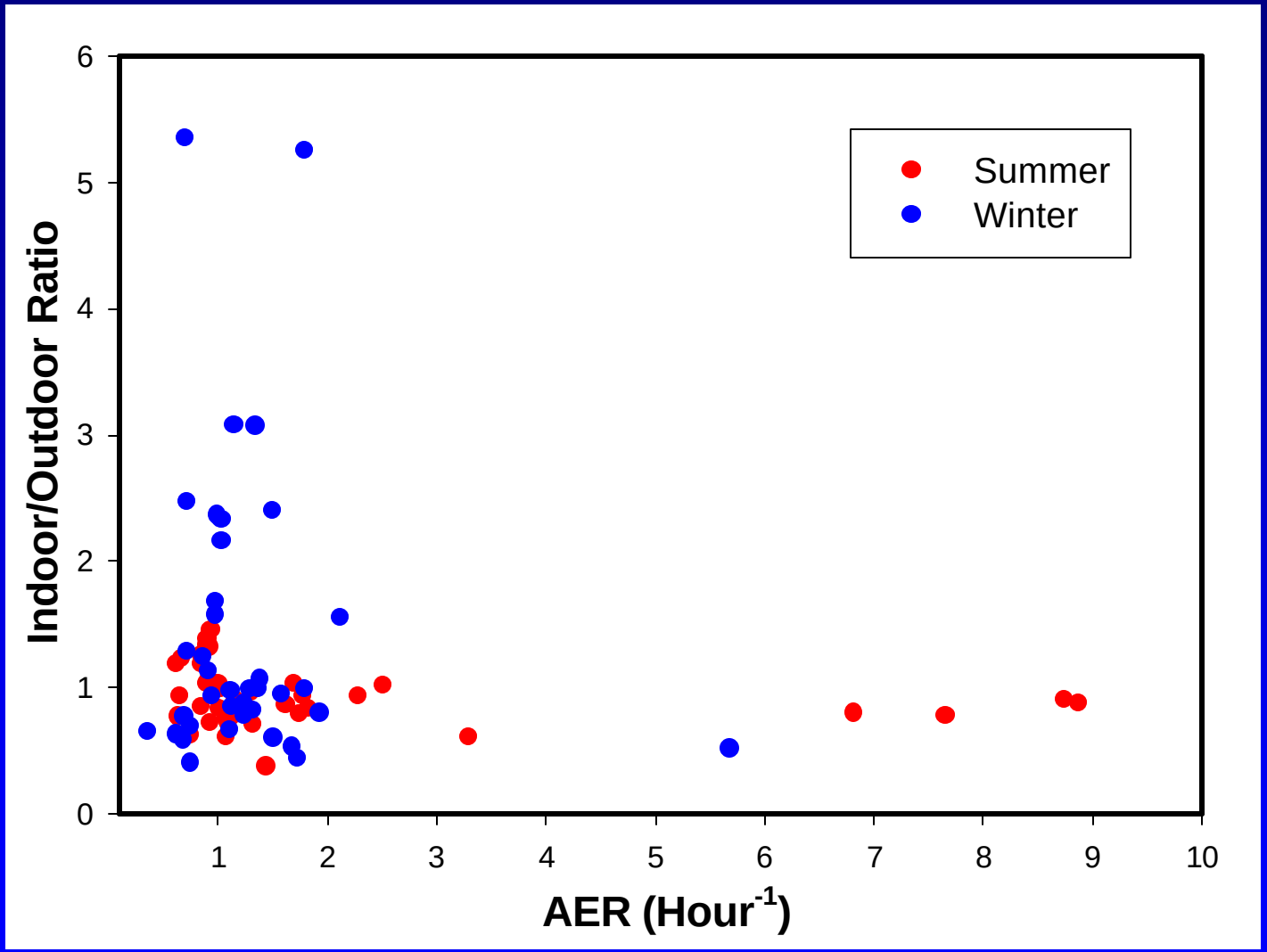
Open Window Use



Air Exchange Rates



Indoor/Outdoor $PM_{2.5}$ vs. Air Exchange Rates



Note: Includes data only from detached homes

Factors Influencing Indoor and Personal Levels

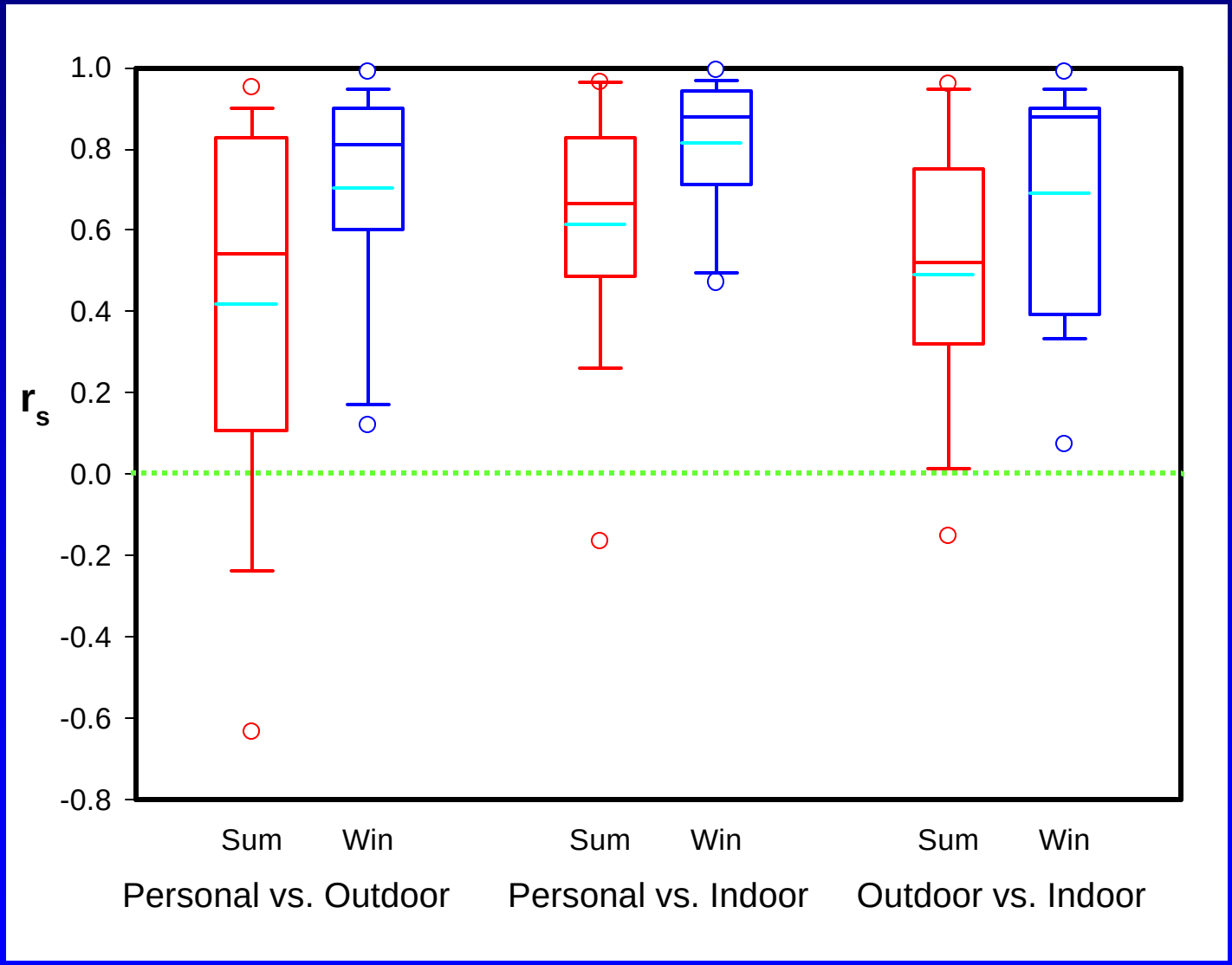
- ***Indoors:***
  - *no home or activity factors were identified as important predictors*
  - *few particle generating activities were conducted*
- ***Personal:***
  - $f_i C_i$: *both seasons, all species*
  - f_{ETS}: $PM_{2.5}$ *in winter*
  - $f_o C_o$: *EC in summer,* NO_3^- *in winter*

→ *suggests that time patterns are important*

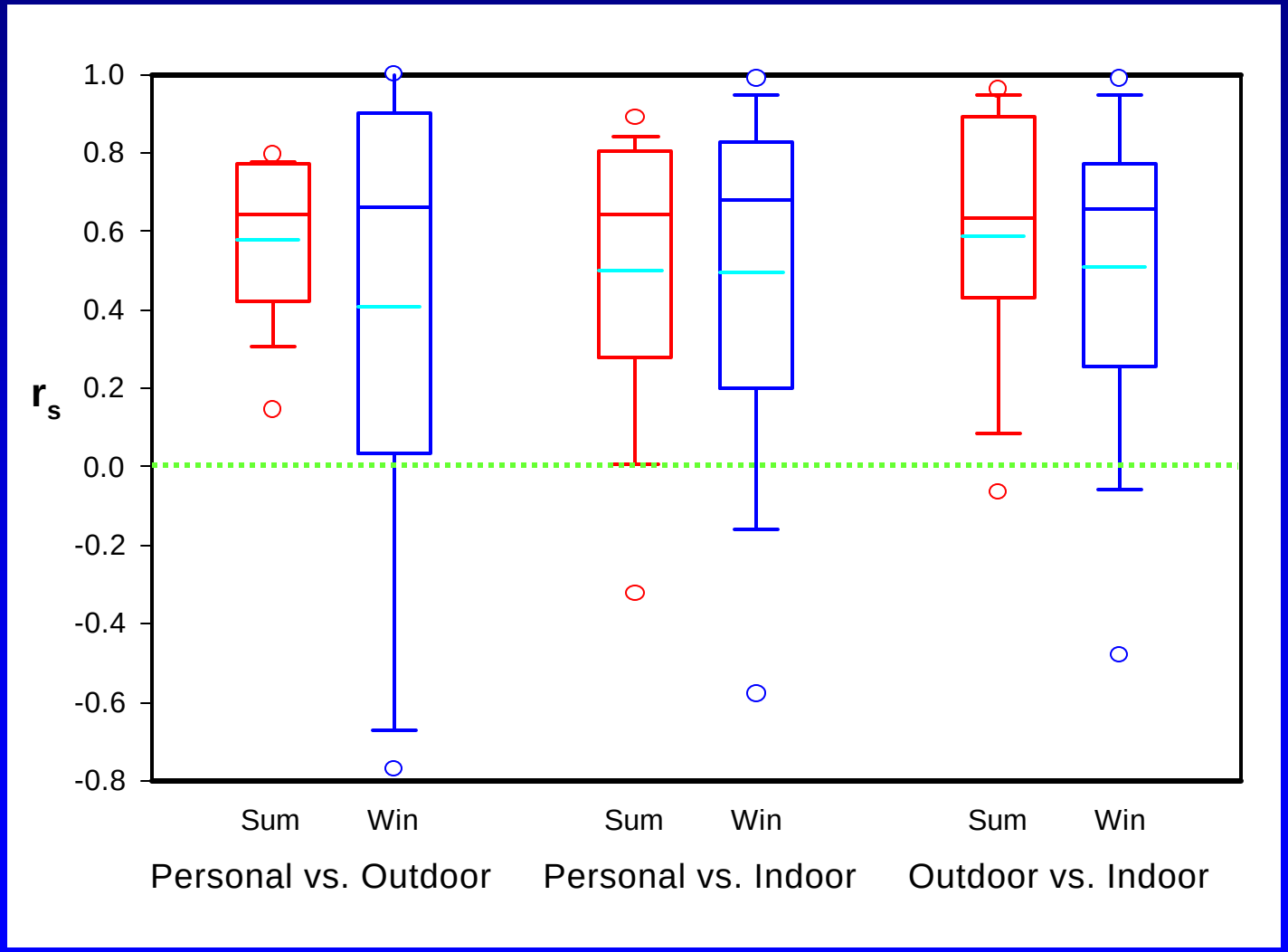
Frequency of Selected Particle-Generating Activities

Activity	N	Mean ± Std. Dev.	Median	Maximum
Near smoking				
Winter	103	0.004 ± 0.02	0	0.22
Summer	98	0.001 ± 0.003	0	0.02
Near cooking				
Winter	103	0.04 ± 0.03	0.03	0.14
Summer	98	0.03 ± 0.04	0.02	0.3
Near cleaning				
Winter	103	0.02 ± 0.03	0	0.21
Summer	98	0.01 ± 0.03	0	0.18

Individual-Specific Spearman Correlation Coefficients: NO_3^-



Individual-Specific Spearman Correlation Coefficients: EC



Factors Influencing Indoor and Personal Levels

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  - *no home or activity factors were identified as important predictors*
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  - $f_i C_i$: *both seasons, all species*
  - f_{ETS}: $PM_{2.5}$ *in winter*
  - $f_o C_o$: *EC in summer,* NO_3^- *in winter*

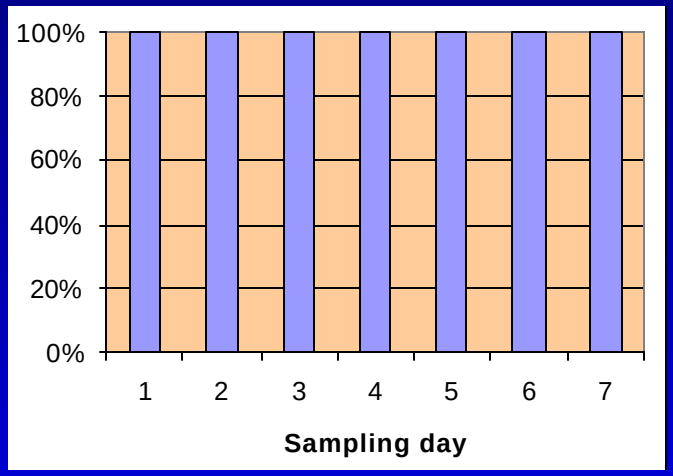
→ *suggests that time patterns are important*

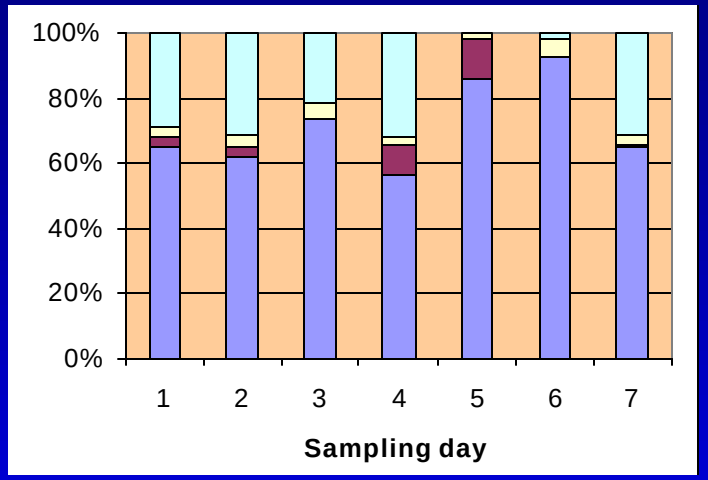
Time-Activity Patterns: % Time In Microenvironments

Least Active

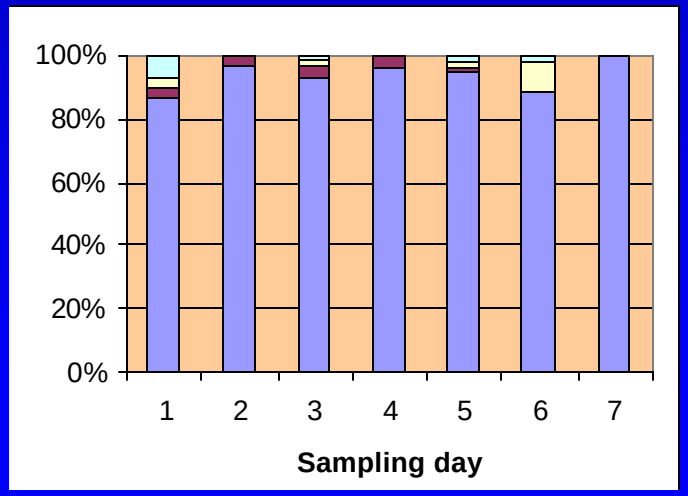
Most Active

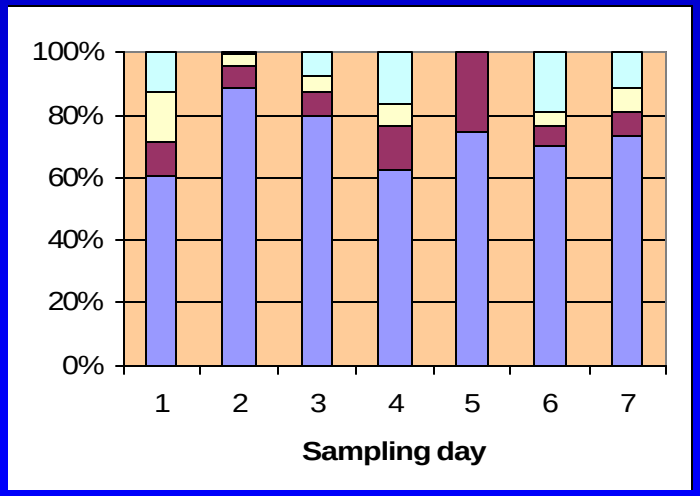
Winter





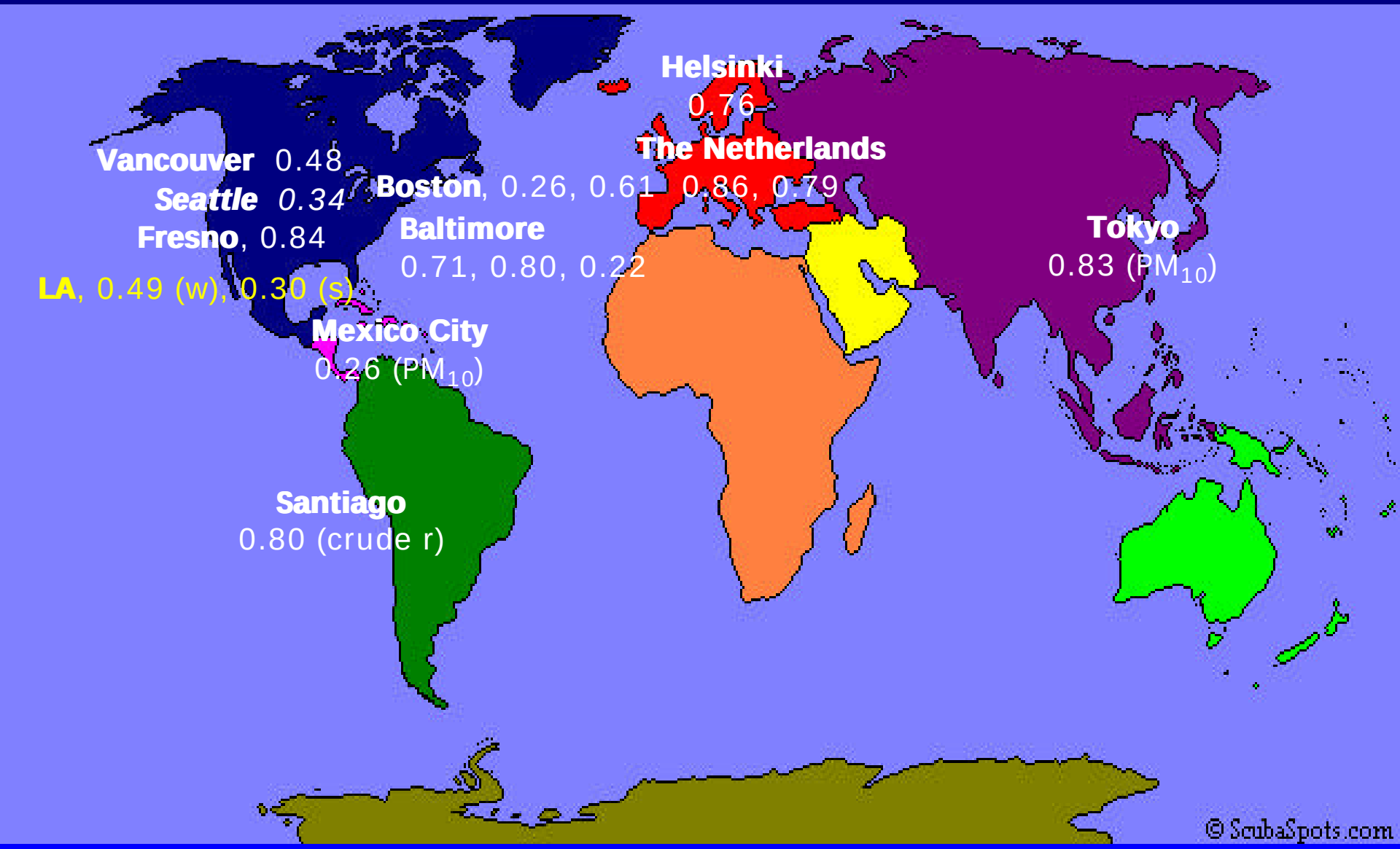
Summer





Indoor home Outside In transit Indoor other

Longitudinal Personal-Ambient Correlation Coefficients for $PM_{2.5}$



* Median correlation coefficients for study participants

Personal vs. Ambient $PM_{2.5}$: r Values

Cohort		No. of Subj.	Days/ Subj.	R value	
				Median	Range
COPD:	**Los Angeles (s)**	**15**	**7**	**0.30**	**-0.43 – 0.89**
	Los Angeles (w)	**15**	**7**	**0.49**	**-0.40 – 0.94**
	Vancouver, BC (s)[1]	16	7	**0.48**	-0.68 – 0.83
	Boston, MA (s)[2]	18	12-18	0.61	0.10 – 0.93
	Boston, MA (w)[3]	15	7	0.26	-0.46 – 0.67

[1] Ebelt et al., 2000; [2] Rojas et al., 2000 (12-h samples); [3] Brown et al., 2002 (unpublished)

Personal vs. Ambient/Outdoor $PM_{2.5}$

Cohort		No. of Subj.	Days/ Subj.	R value	
				Median	Range
COPD:	**Los Angeles (s)**	**15**	**7**	**0.30**	**-0.43 – 0.89**
	Los Angeles (w)	**15**	**7**	**0.49**	**-0.40 – 0.94**
Elderly:	**Fresno, CA (w)[1]**	5	24	**0.80**	0.41 (amb)
	Fresno, CA (spr)[1]	16	12	**0.80**	0.84 (amb)
	Seattle, WA	85		**0.34**	0.29 (amb)
	Baltimore, MD (s)[2]	15	12	0.71	-0.21 – 0.95
	Baltimore, MD(s)[3]	21	5-22	0.80	0.38 – 0.98
	Baltimore, MD (w)[2]	15	12	0.22	-0.43 – 0.84
	Boston, MA (s)	15	7	0.61	0.18 – 0.95
	Boston, MA (w)	15	7	0.43	-0.33 – 0.83

[1] Pooled r values with outdoor concentrations (Evans et al., 2000); [2] Sarnat et al., 2000; [3] Williams et al., 2000; [4] Brown et al., 2002 (unpublished)

Summary of Results

- *Personal $PM_{2.5}$ exposures were higher than indoor and outdoor concentrations.*
- *Outdoor NO_3^- and EC were higher than indoor and personal levels in both seasons.*
- *For $PM_{2.5}$ and EC, greater contribution of outdoor particles in summer; greater indoor source contribution in winter.*

Summary of Results (cont'd)

- *Personal exposures and indoor and outdoor $PM_{2.5}$, NO_3^-, EC were significantly correlated*
  - *Substantial inter-individual variability*
  - *Lower individual-specific personal-ambient $PM_{2.5}$ correlations than eastern U.S. cities*
  - *Closer to values observed in Vancouver for individuals with COPD*
  - *Correlations unaffected by AERs and activities*
- *Personal exposures most strongly associated with indoor as compared to outdoor concentrations*

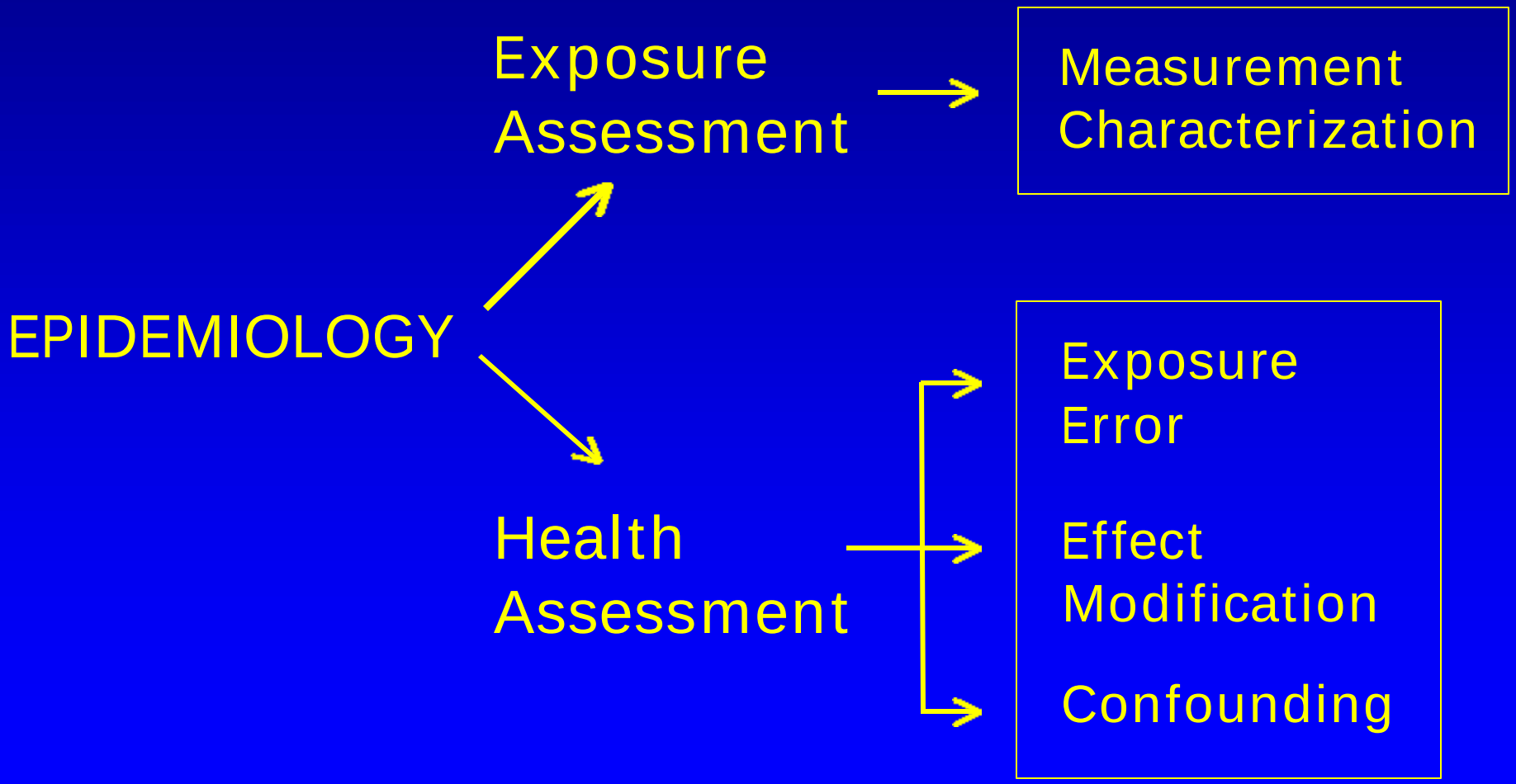
Summary of Results (cont'd)

- *Limited ability of ICP-MS to determine elemental concentrations at low sampling volumes*
- *For detected elements (Al, B, Ba, Cr, Mn, Ni, Pb, Zn), personal, indoor, and outdoor levels varied by season*
- *Except for Al, significant and positive correlations between personal exposures and indoor and outdoor concentrations found in both seasons.*
  - *Strongest associations: Ba, Ni*
  - *$PM_{2.5}$ and elemental levels positively correlated; correlations strongest for indoor and outdoor samples*

Recommendations

- *Perform additional exposure studies in Western US*
  - *to determine whether correlation coefficients are actually lower in Western US*
  - *to provide additional information about relationships among personal, indoor ambient levels for specific particle components*
  - *to examine effect of various housing factors and activity patterns on personal exposures*
- *Develop improved methods to determine elemental concentrations at low sampling flow rates*

Role of Exposure Assessment

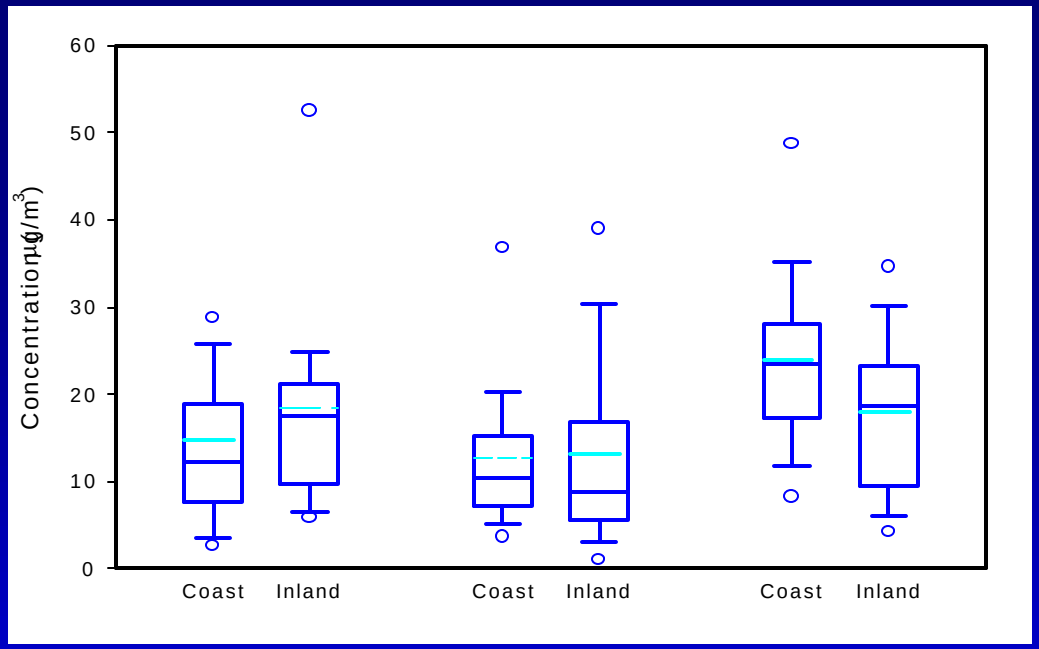


Part. ID	Age	Sex	City	Location	Population Density (#/km2)*	Dist. to Major Road (m)**	Season	
							Winter	Summer
1	73	F	Palos Verdes Estates	Coastal	173	2029	X	X
2	84	F	El Segundo	Coastal	4108	252	X	X
3	69	F	Hawthorne	Coastal	3568	696	X	X
4	60	M	Wilmington	Coastal	4504	146	X	
5	NA	F	Torrance	Coastal	3417	256	X	
6	68	F	Hawthorne	Coastal	9693	89	X	X
7	NA	F	Torrance	Coastal	2588	1196	X	
8	NA	F	Redondo Beach	Coastal	5118	598	X	X
9	73	F	Redondo Beach	Coastal	5441	228	X	X
10	68	F	Bellflower	Inland	3911	65	X	
11	NA	F	Downey	Inland	3466	76	X	X
12	63	F	Lynwood	Inland	4647	401	X	X
13	NA	F	Torrance	Coastal	660	1045	X	
14	62	F	Redondo Beach	Coastal	450	93	X	
15	61	F	Carson	Coastal	2226	604	X	
16	NA	M	Torrance	Coastal	3737	683		X
17	NA	F	Carson	Coastal	292	425		X
18	NA	F	Norwalk	Inland	5587	26		X
19	NA	F	Torrance	Coastal	4588	470		X
20	NA	F	Wilmington	Coastal	2855	0		X
21	75	M	Palos Verdes Estates	Coastal	49	2098		X
22	55	F	Rancho Palos Verdes	Coastal	522	191		X

Housing Characteristics (cont'd.)

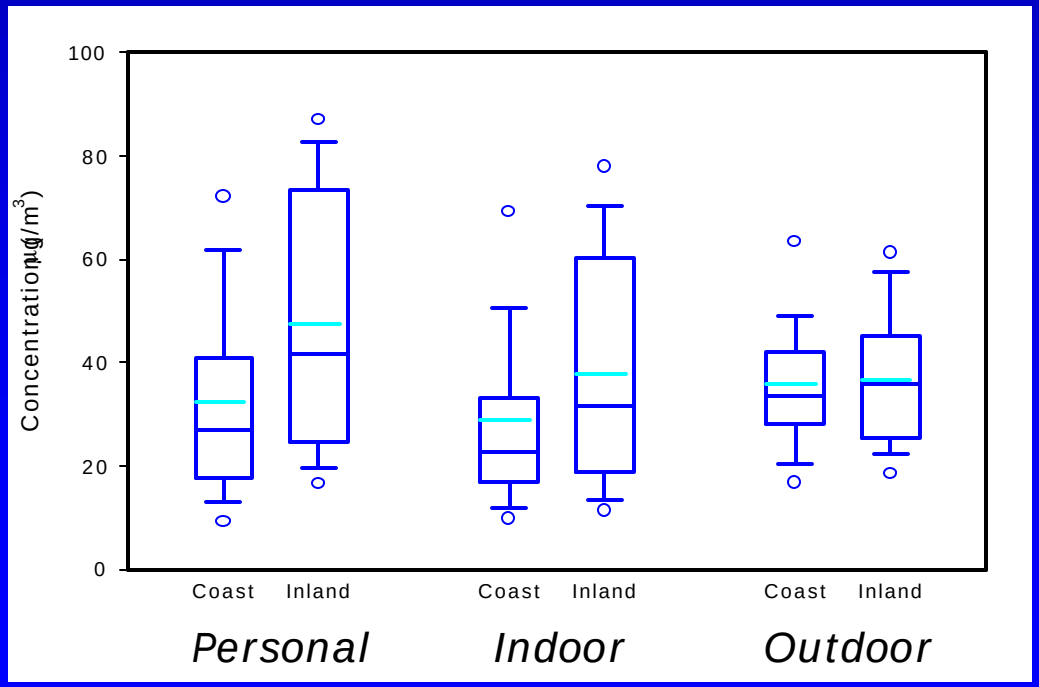
Characteristic		Number of Homes	
		Summer	Winter
Dwelling:	Detached house	9	7
	Apartment	4	6
	Other	2	2
Heating:	Forced air	9	9
	Gas furnace	2	1
	Gas wall heater	2	2
	Other	2	3
Cooking:	Electric	7	9
	Gas	8	6

Winter $PM_{2.5-10}$

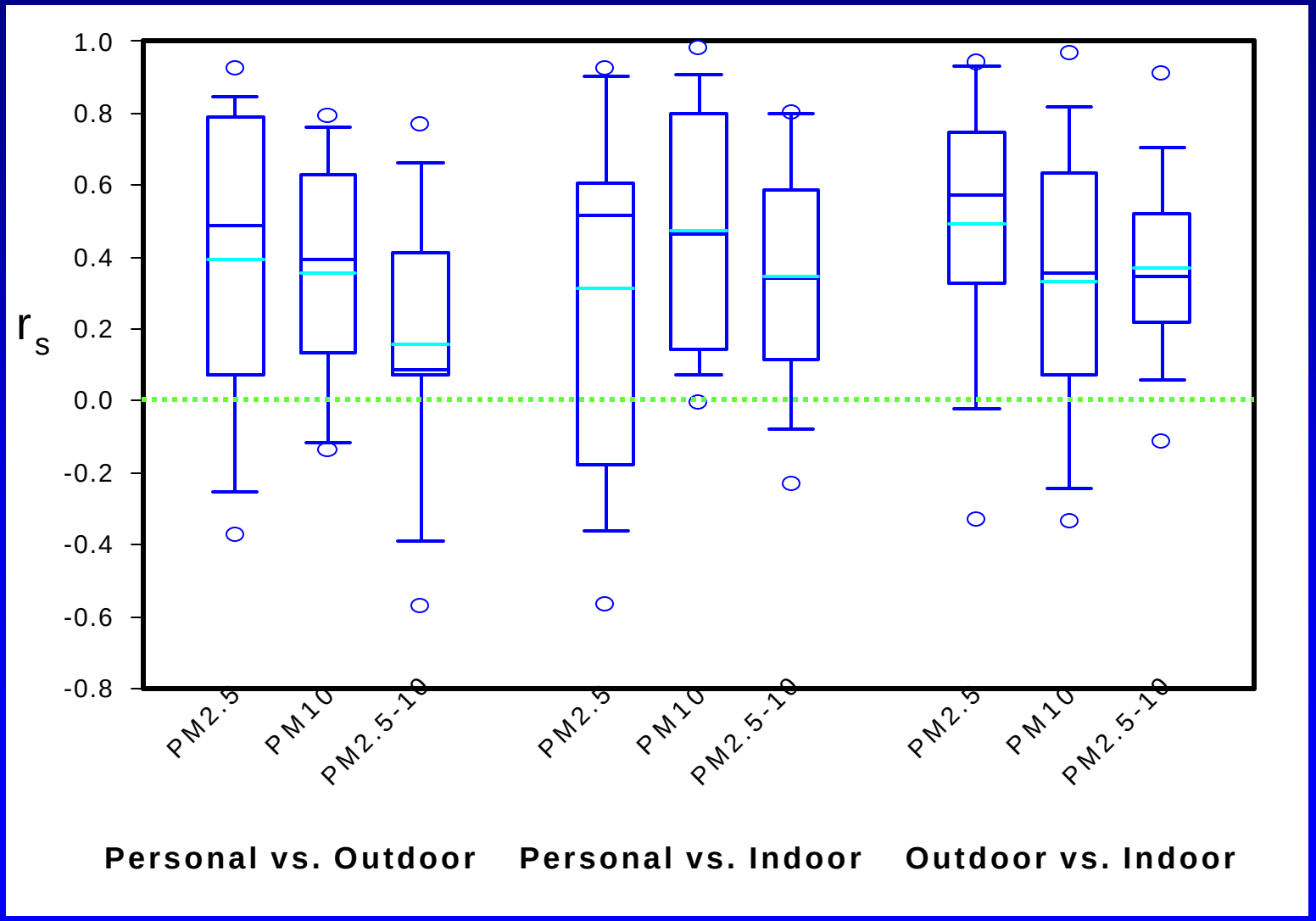


$PM_{2.5-10}$ and PM_{10} Levels:

Winter PM_{10}



Winter Individual-Specific Spearman Correlation Coefficients: $PM_{2.5-10}$ and PM_{10}



Geographic Factors Influencing Outdoor Home $PM_{2.5}$ Concentrations

Factor	n	Estimate (se)	t-stat
Winter			
Coastal		-5.6 (1.4)	-4.2
Road (250m)	83	0.3 (1.7)	0.9
Road (100m)		1.0 (1.9)	0.5
Pop. Density		-0.6 (1.7)	-0.3
Summer			
Coastal		-6.5 (2.5)	-2.5
Road (250m)	86	3.4 (2.4)	0.2
Road (100m)		5.9 (2.2)	2.7
Pop. Density		3.7 (2.5)	1.5

Results from generalized linear model that accounts for repeated measures. Factors significant at the 0.05 level shown in yellow.

PM Composition

Components:
- NO_3^-
- *EC*
- *Elements*

Personal-Ambient Association

- ***Ambient origin: strong***
  - ***Sulfate:*** *strong correlations*[1]
  - ***EC:*** *strong, but may vary by traffic-related factors*
- ***Other elements*** *(non-sulfur):*
  - *limited data*
  - *correlations vary by element:* $0.5 < r < 0.9$[2]
  - *As and Pb: strong*[3]

[1] Suh et al., 1992, 1993; Waldman et al., 1993; Sarnat et al., 2000; Ebelt et al., 2000; Oglesby et al., 2000
[2] Ozkaynak et al., 1996; [3]Clayton et al., 1999

Exposure Effect Modifiers

Definition:
Exposures vary by levels of another factor, causing this factor to modify exposure-health association

- *Location*
  - *Geographic location*
  - *Population density*
- *Seasonal Variation*
- *Sensitive Cohort*
- *Traffic*
  - *Distance from roadway*
- *Ventilation*