Estimating Air Pollution Infiltration Efficiencies for Exposure Assessment and Epidemiology

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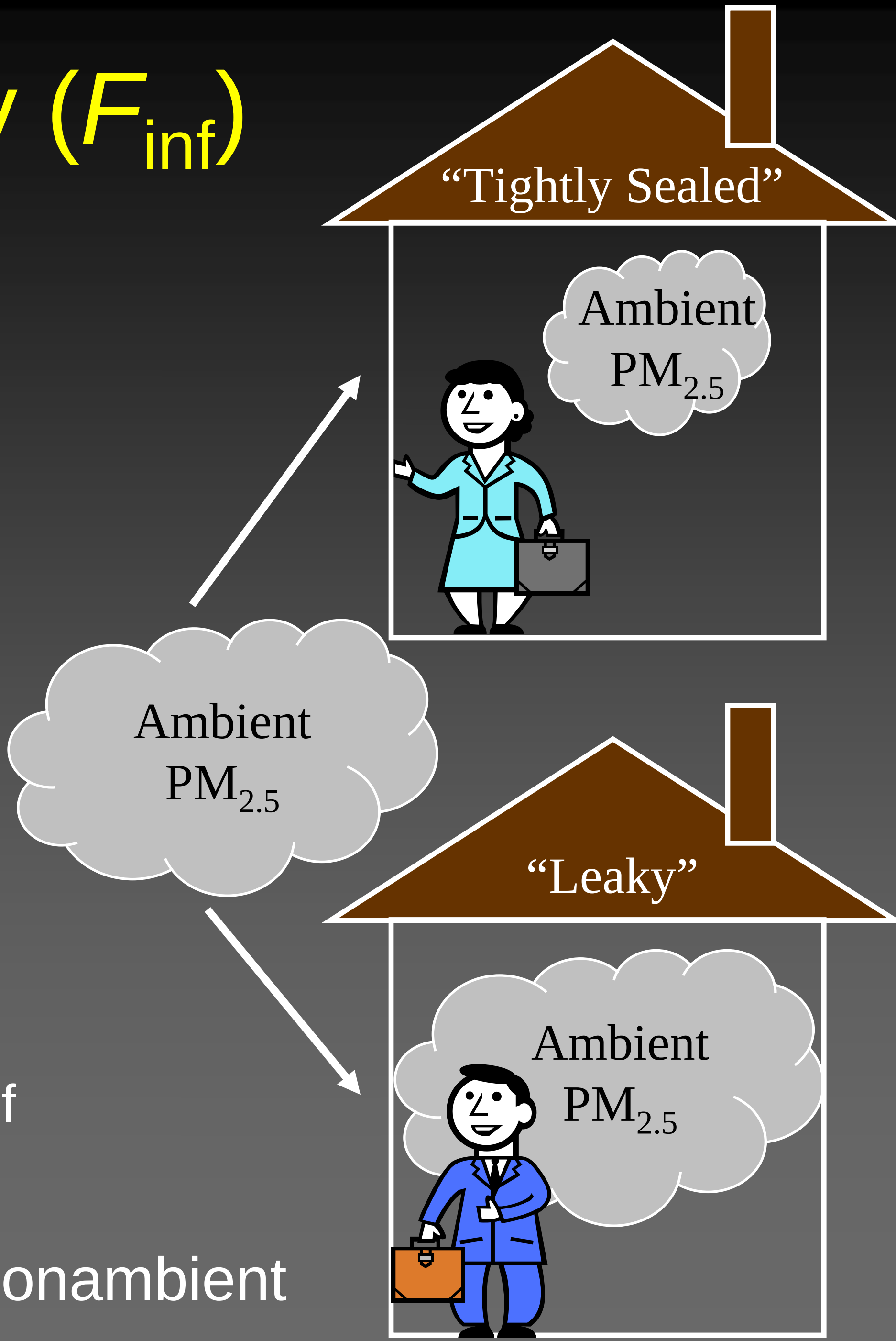
Overview

- Why estimate residential infiltration efficiencies?
- How?
  - Tracer
  - Recursive model
    - Description, validation, examples
- Application to epi
  - Panel studies
  - Model building for other study designs
- Windsor results
  - And possible future directions

Infiltration Efficiency (F_{inf})

- The fraction of the ambient concentration that penetrates indoors and remains suspended
- Function of AER, penetration, deposition
- Exposure to ambient pollution depends on F_{inf} & time spent outdoors
  - –Total exposure = ambient + nonambient



Why?

- To better interpret epi. results from different locations and/or from different seasons
- Reduce exposure misclassification in epi studies
- To tease apart health impacts of ambient vs. nonambient pollution

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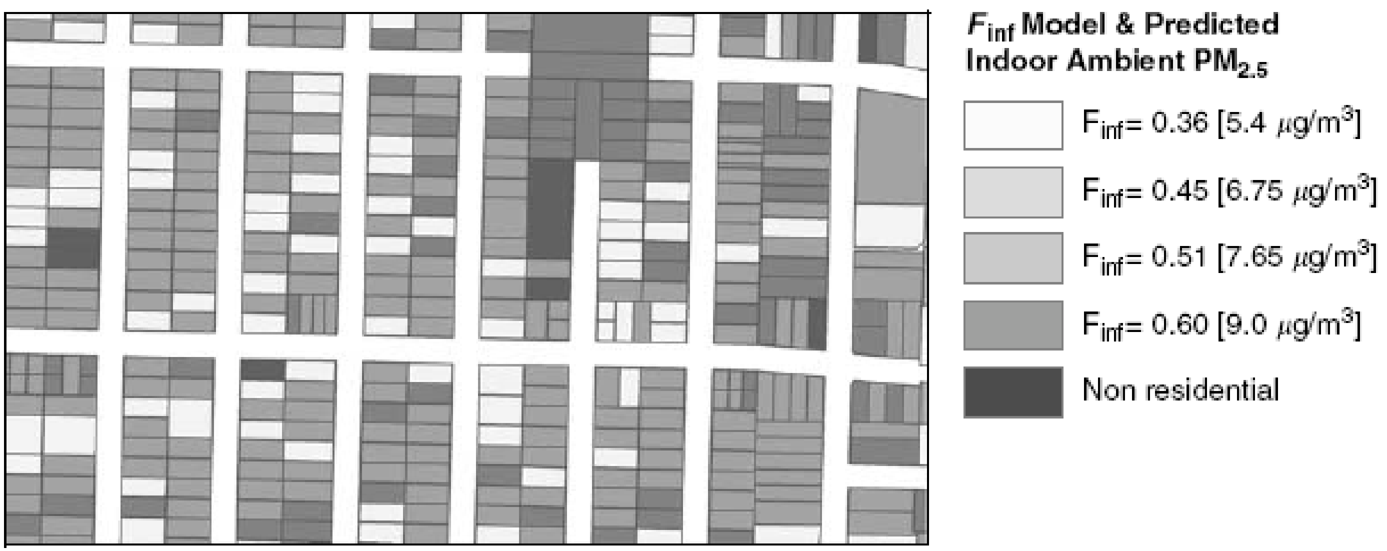

Figure 4. F_{inf} detached model results in the heating season and predicted indoor ambient $PM_{2.5}$ from outdoor ambient concentrations (15 μg/m^3).

Hystad et al., *JESEE*, in press

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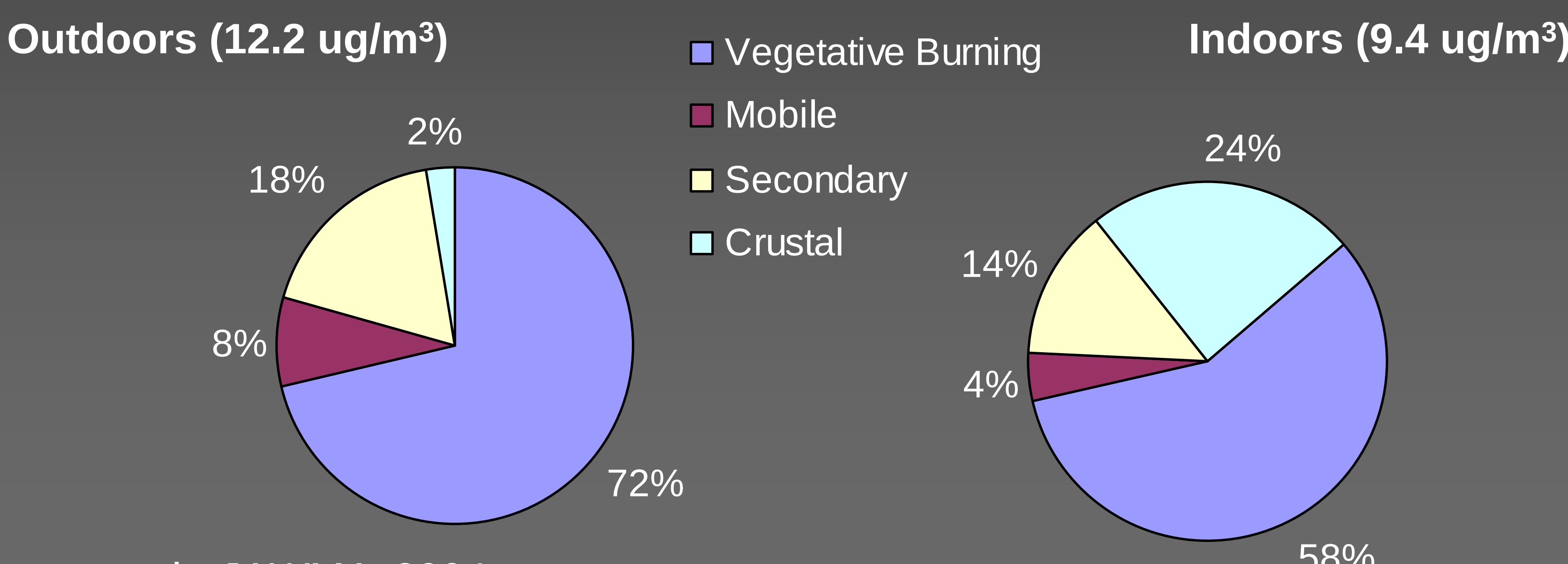


Larson et al., *JAWMA*, 2004

How?

- Tracer (most commonly sulfur or sulfate)
  - Requires that there be no (or few) indoor or personal sources
  - Indoor/outdoor ratio or slope gives F_{inf}
- Recursive model
  - Requires continuous indoor/outdoor measurements (e.g. nephelometer, DustTrak)
  - Does not require absence of indoor sources
  - Shows promise for estimating F_{inf} of pollutants without good tracers (e.g. ultrafines)

Recursive Model Technique

Average ***indoor concentration*** during the <u>hour</u> = Some fraction of the average ***outdoor concentration*** during the <u>hour</u> + Some fraction of the ***indoor concentration*** that remains from the <u>PREVIOUS hour</u> + Contribution from ***indoor sources*** during the <u>hour</u>

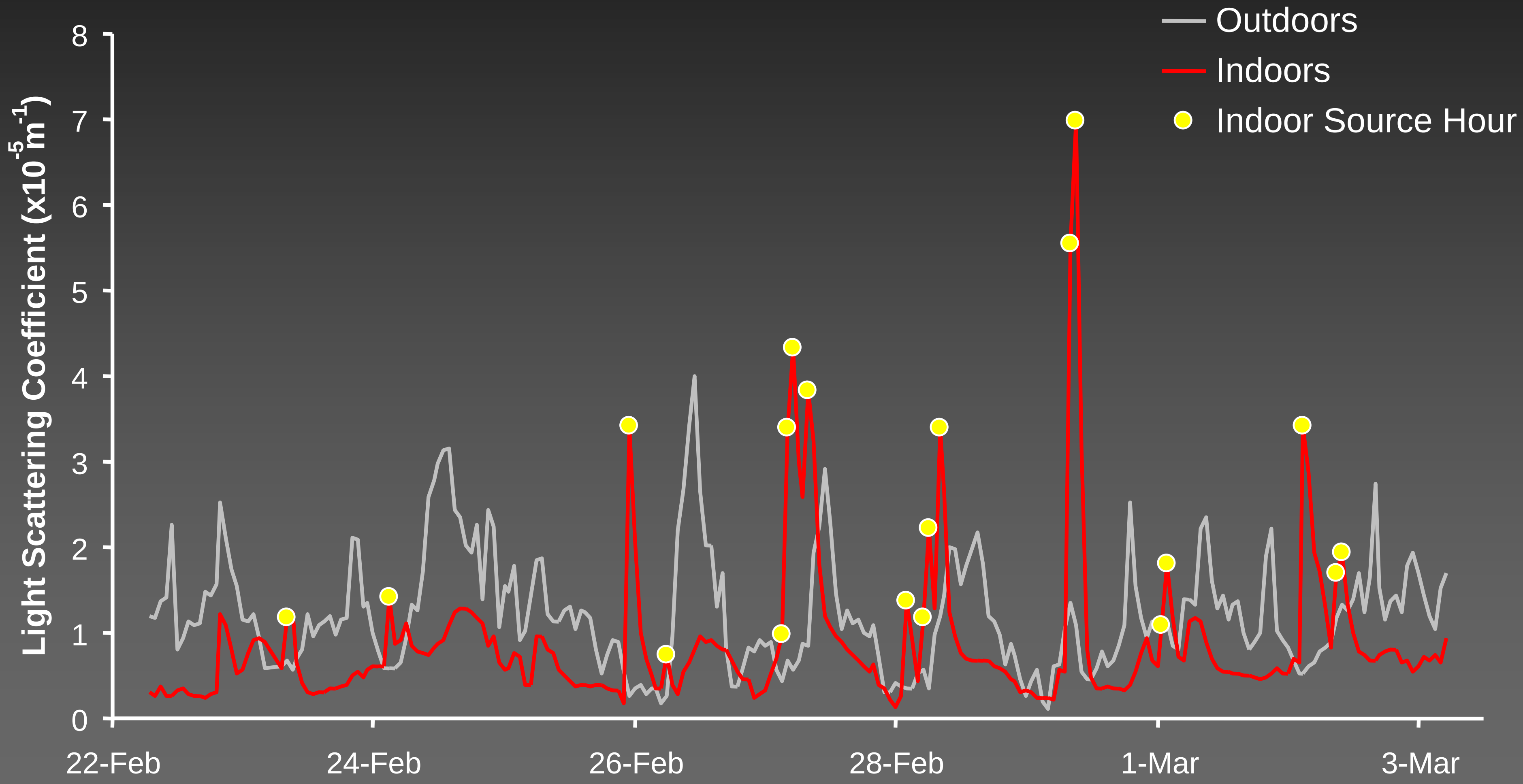
$$C_t^{in} = \beta_1 C_t^{out} + \beta_2 C_{t-1}^{in} + S_t^{in}$$

$S_t^{in} \to \sim 0$

$$F_{\inf} = \frac{Pa}{a+k} = \frac{\beta_1}{1-\beta_2}$$

Allen et al., *ES&T*, 2003

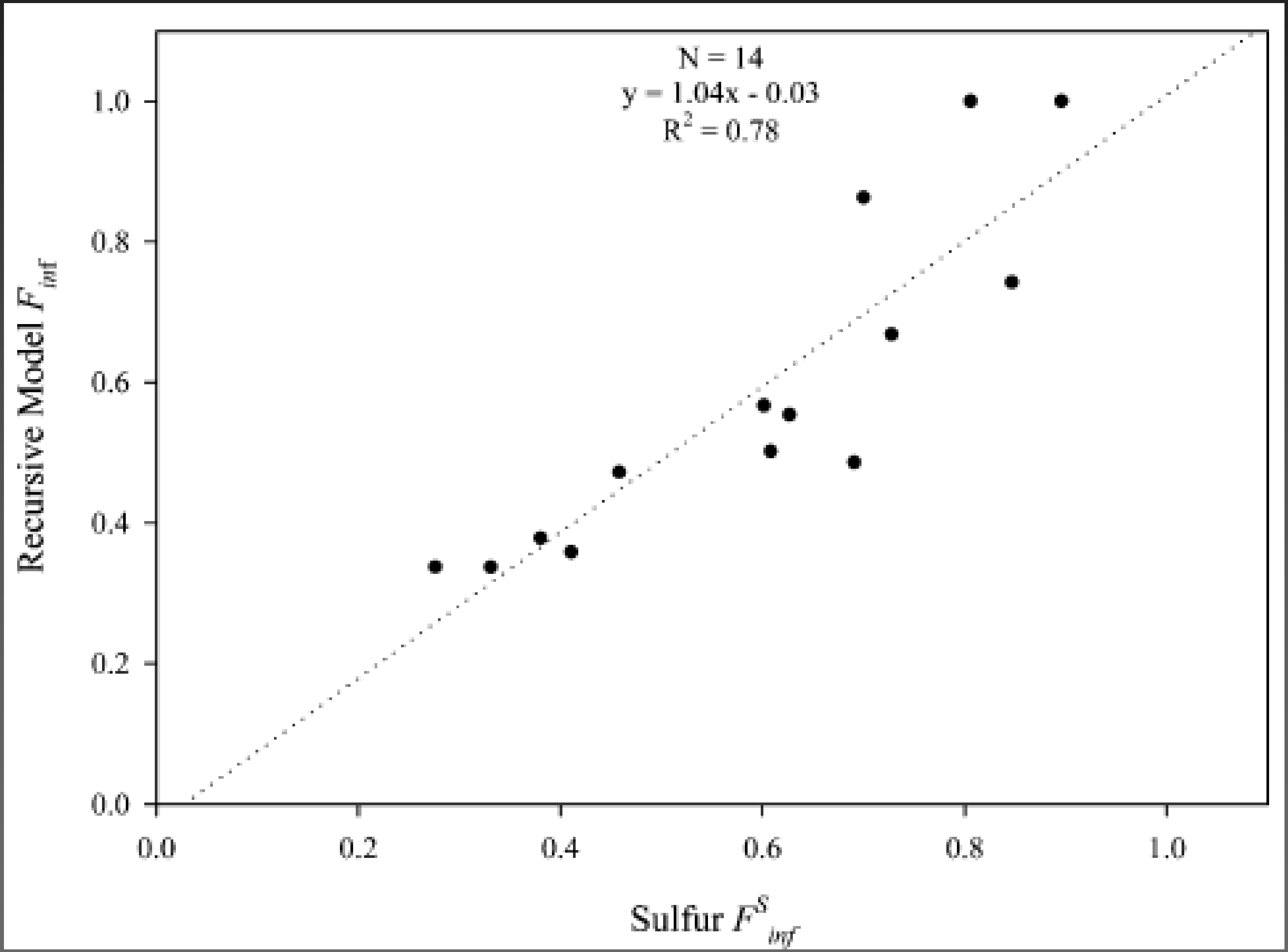
Recursive Model Technique



Allen et al., *ES&T*, 2003

Recursive Model Technique

Validation



Allen et al., *ES&T*, 2003

Recursive Model Technique

Validation

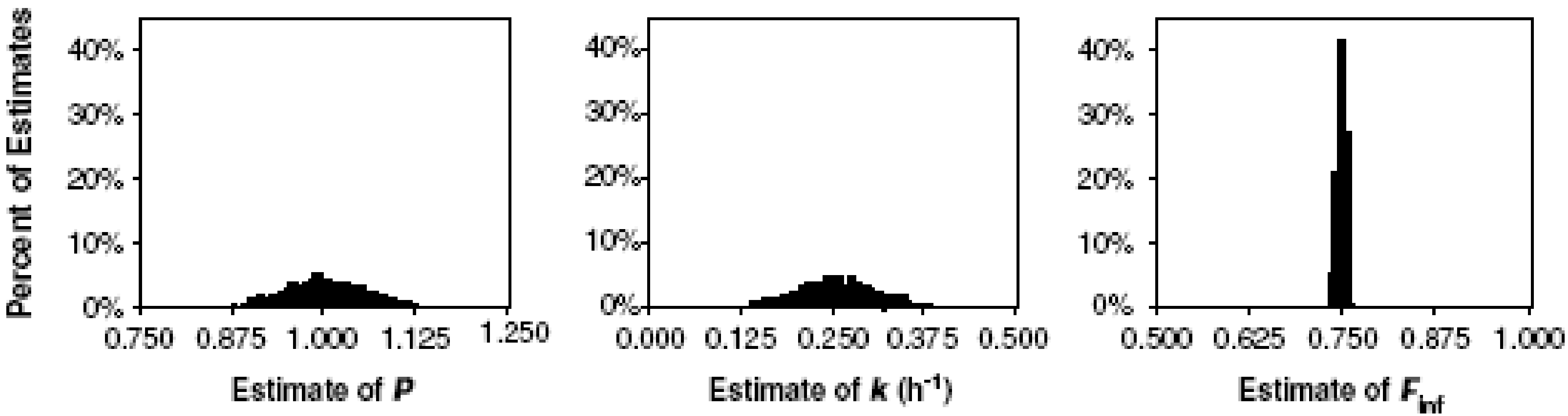


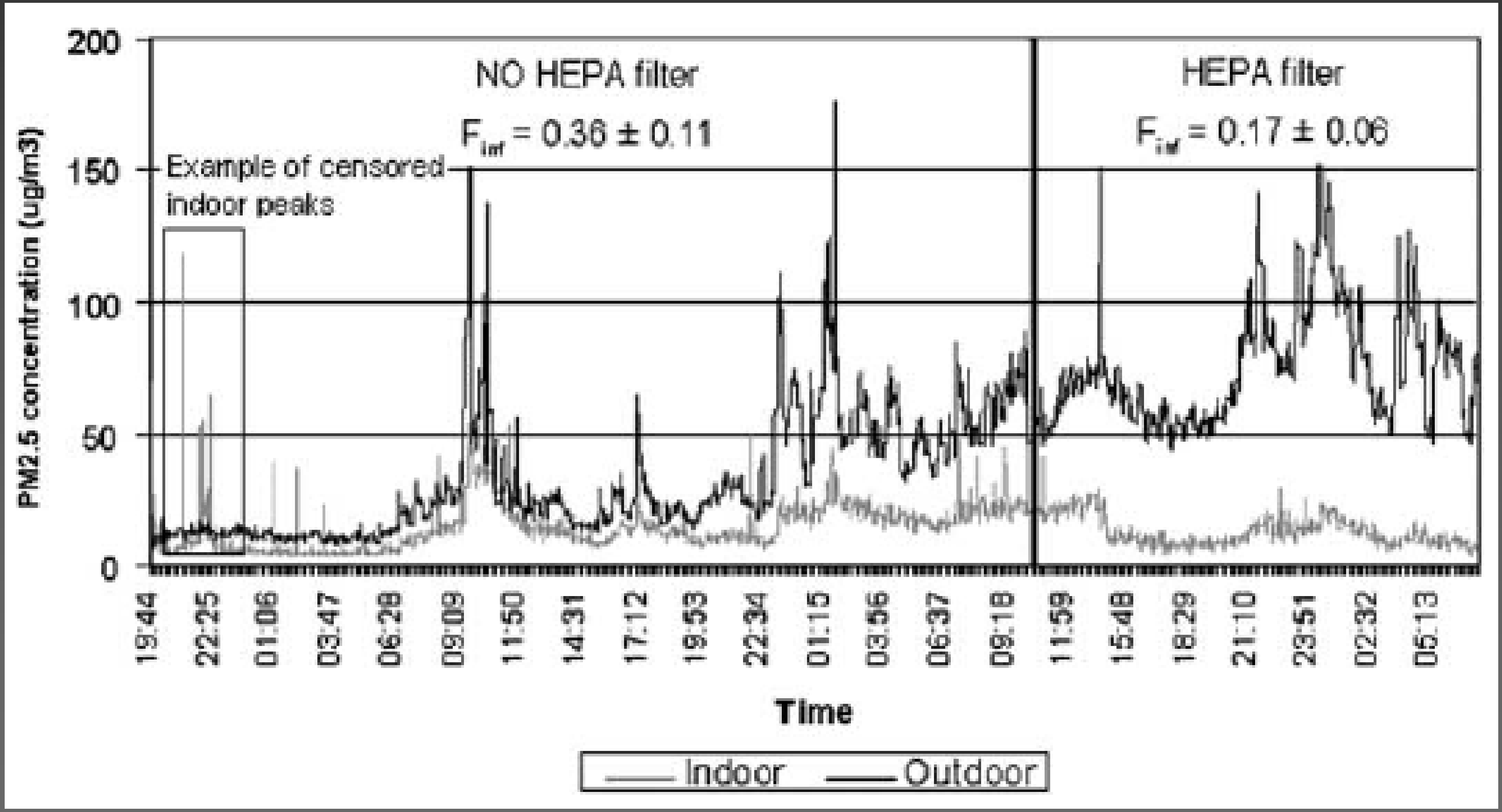
Figure 3. Distributions of 1000 estimates of P, k, and F_{inf} at 5% measurement error. True values used in simulations were $P = 1.00$, $k = 0.25\,h^{-1}$, and $F_{inf} = 0.75$.

Allen et al., *JESEE*, 2007

Recursive Model Technique

Examples

- Air cleaner effectiveness in woodsmoke and forest fire impacted community

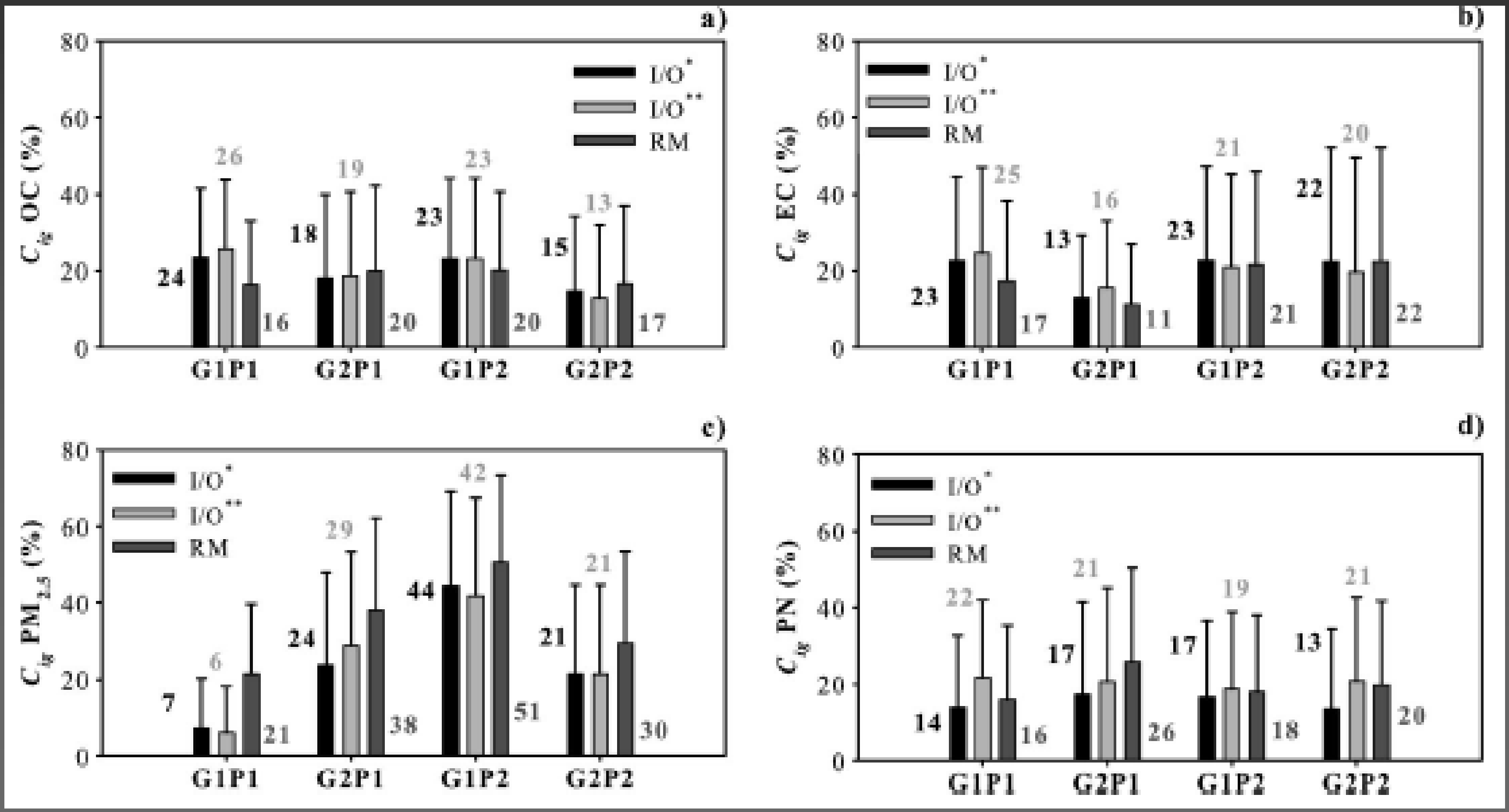


Barn et al., *JESEE*, 2008

Recursive Model Technique

Examples

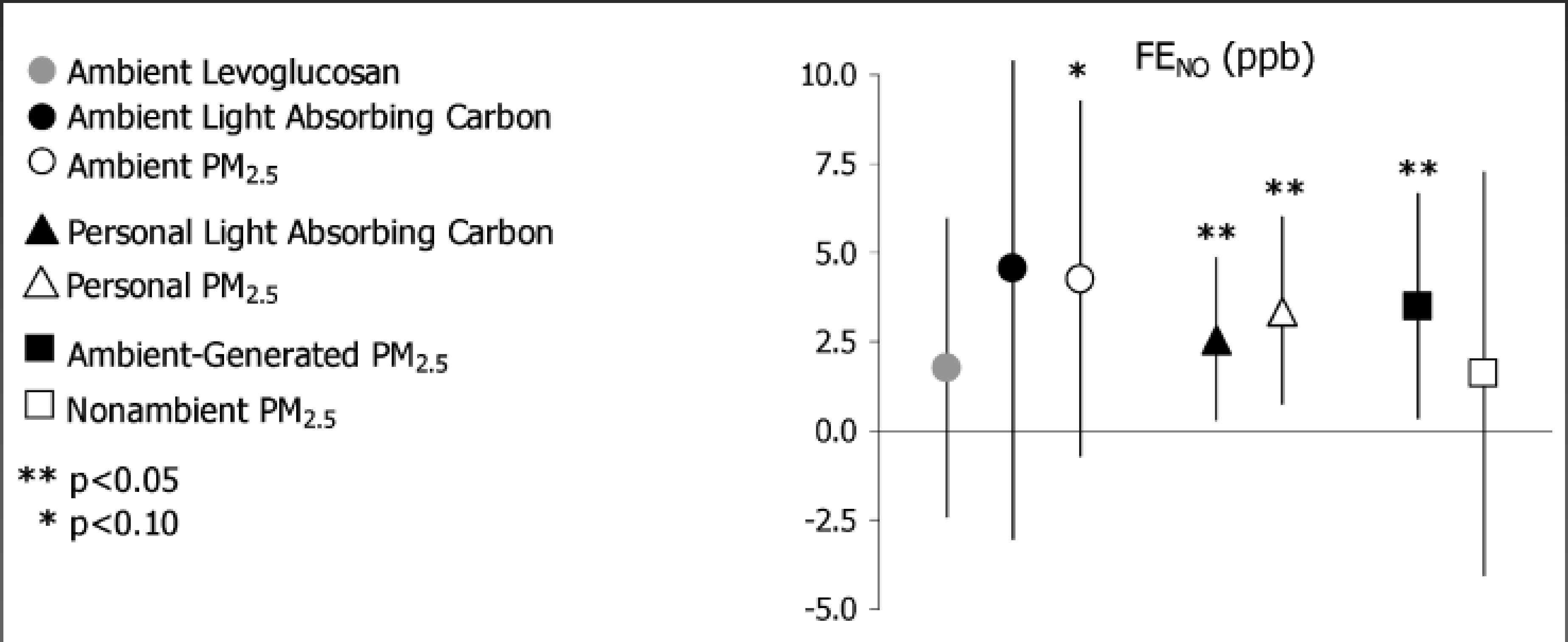
- Contributions of ambient and nonambient sources at retirement facilities in southern CA



Polidori et al., *JAWMA*, 2007

Application of F_{inf} to Epidemiology

Panel Studies

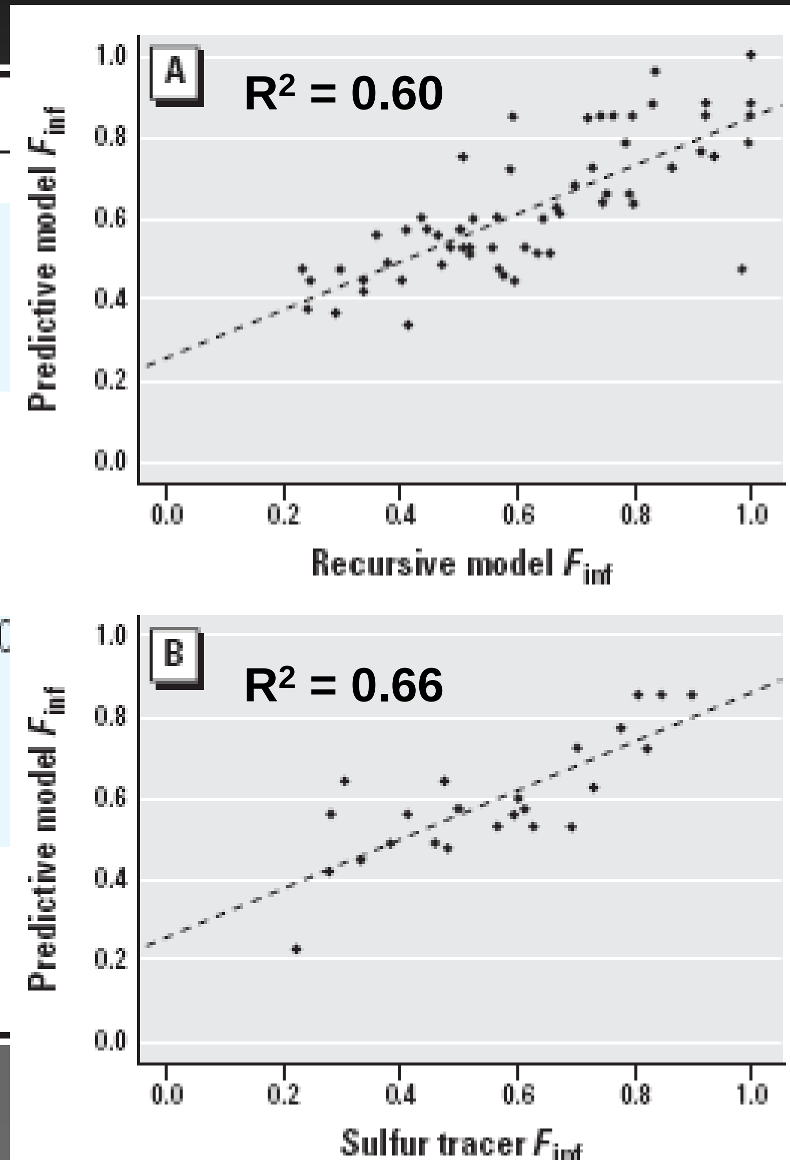


Allen et al., *Inhal. Tox.*, 2008

Application of F_{inf} to Epidemiology

Model Development for Large Studies

Parameter	95% CI	*p*-Value
Intercept	.28 to 0.54	< 0.001
Residence type		
Private home (reference)		
Private apartment	.08 to 0.14	0.61
Group home	.07 to 0.31	< 0.01
Air cleaner		
None (reference)		
Ion generator	.16 to 0.02	0.14
Filter	.22 to 0.05	0.23
Electrostatic precipitator	.22 to 0.00	0.05
Average outdoor temperature (°C		
< 4 (reference)		
4–8	.06 to 0.32	< 0.01
8–12	.18 to 0.45	< 0.001
≥ 12	.31 to 0.58	< 0.001
Average daily rainfall (inches)[b]		
< 0.5 (reference)		
0.05–0.1	.16 to 0.02	0.13
> 0.1	.26 to –0.04	< 0.01



Koenig et al., *EHP.*, 2005

Application of F_{inf} to Epidemiology

Model Development for Large Studies

- Victoria, BC
- Spatial property assessment data (SPAD)
- Model including season predicts 54% of total variance
- Potentially allows F_{inf} to be estimated in many homes without I/O monitoring

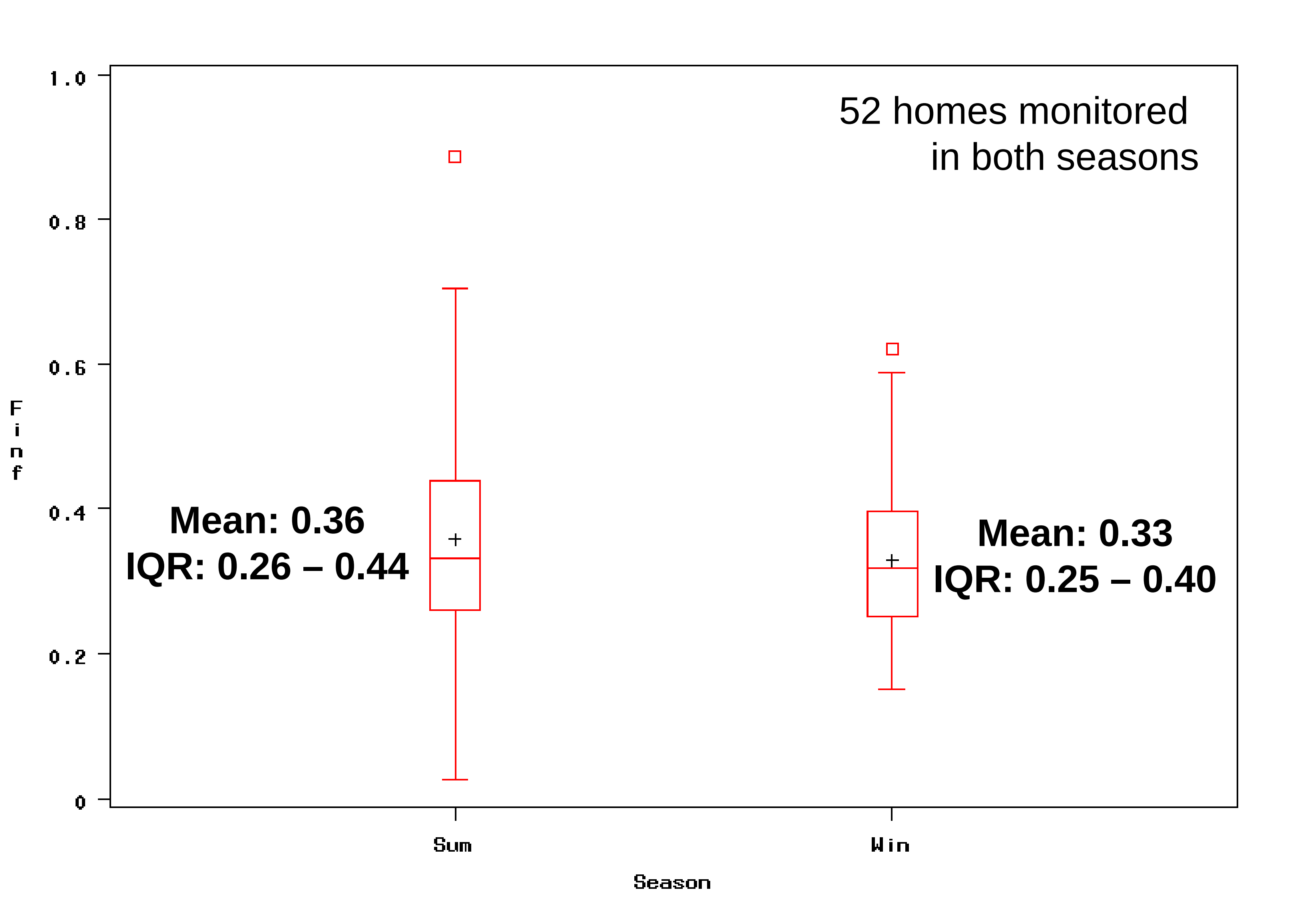
Table 4. Multiple regression model of F_{inf} during the heating season ($n=44$, $R^2=0.37$).

Parameter	Estimate	SE	P-value
Intercept	0.36	0.03	<0.00
Improved value (> median reference)			
<Median	0.15	0.04	<0.00
Heating (no FHA reference)			
FHA	0.09	0.04	0.01

Abbreviation: FHA, forced hot air.

Hystad et al., *JESEE.*, In Press

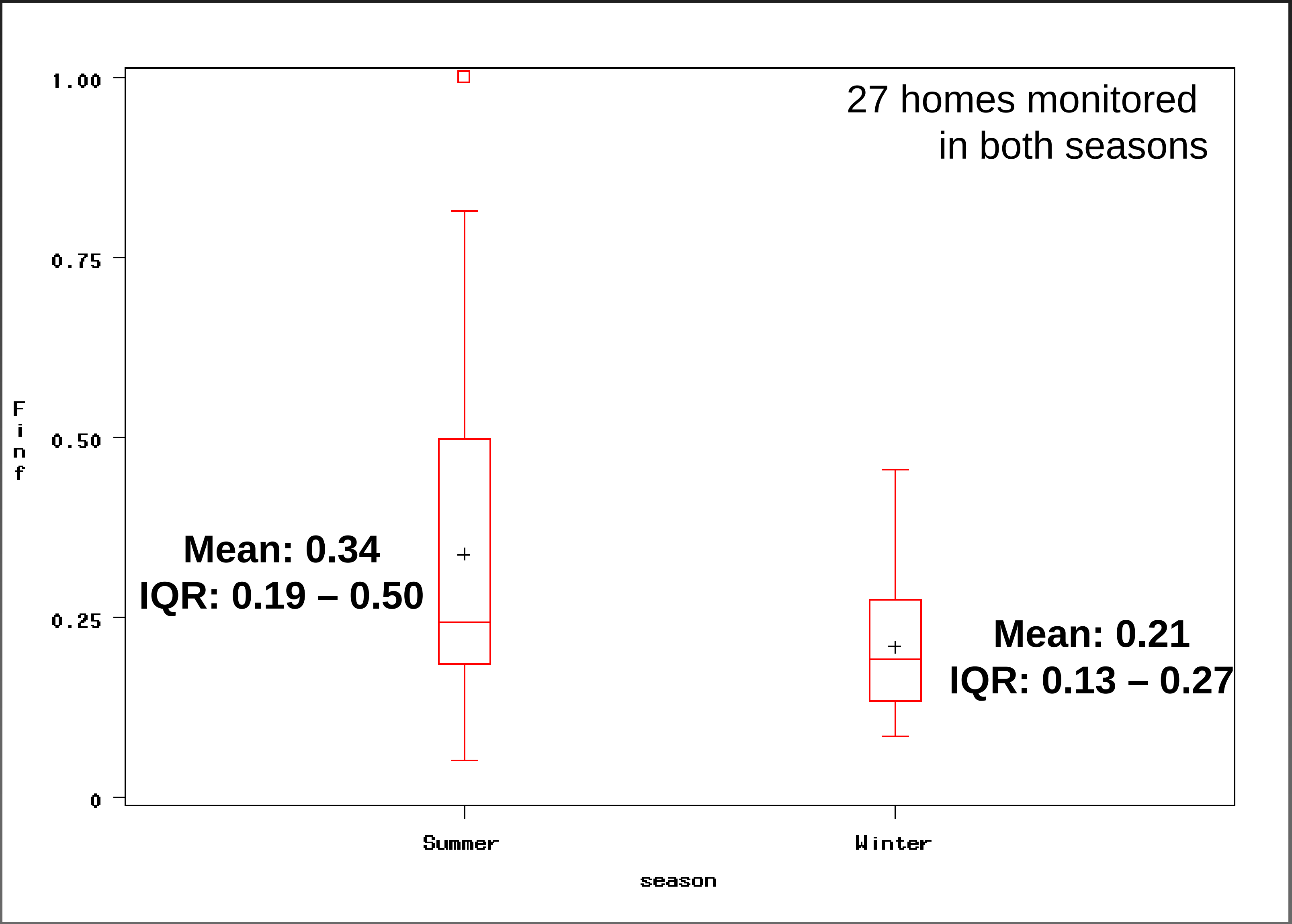
Windsor $PM_{2.5}$ F_{inf}



Windsor $PM_{2.5}$ F_{inf} Models

Season	Predictor(s)	R^2
Summer	I-O Temp Diff, Window Opening	0.36
Winter	Building age, air cleaner use	0.20

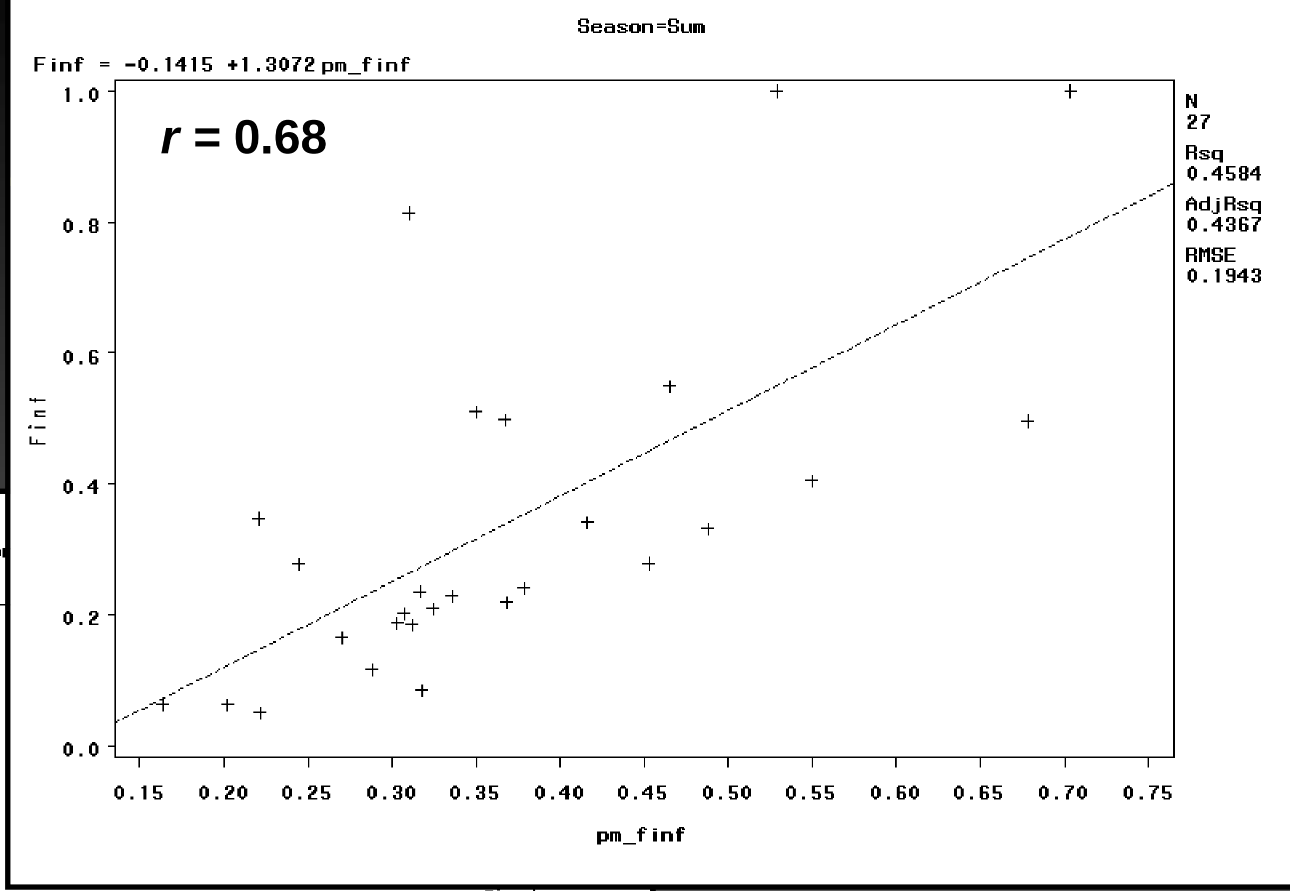
Windsor UFP F_{inf}



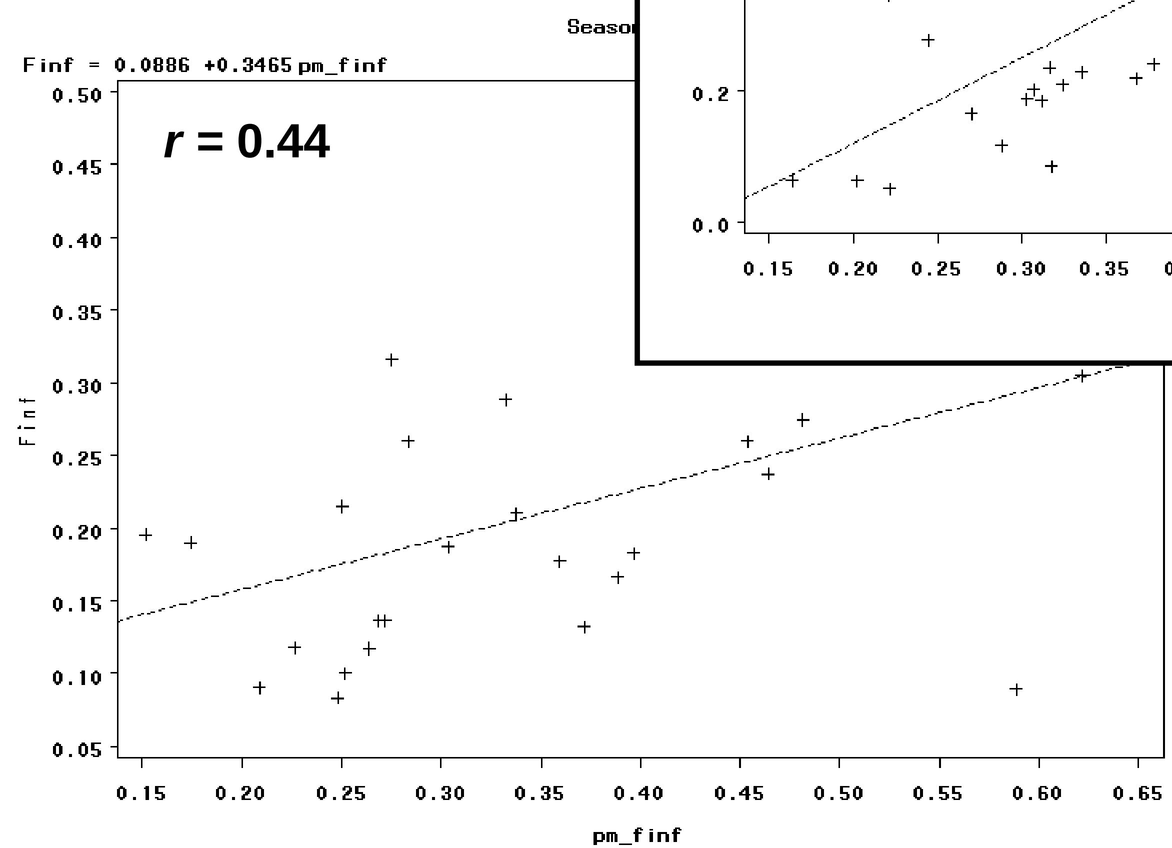
Windsor UFP F_{inf} Models

Season	Predictor(s)	R^2
Summer	Outdoor Temp, Window Opening	0.56
Winter	-----	-----

PM$_2$



Season=Sum
Finf = -0.1415 +1.3072 pm_finf
r = 0.68
N
27
Rsq
0.4584
AdjRsq
0.4367
RMSE
0.1943
Finf
pm_finf



Finf = 0.0886 +0.3465 pm_finf
r = 0.44
Finf
pm_finf

Other Possibilities for Windsor Data

- Continue development of F_{inf} models
- Comparison of F_{inf} for different PM species
  - $PM_{2.5}$
  - UFP
  - LAC
- Health effects
  - Ambient / nonambient PM vs. lung function