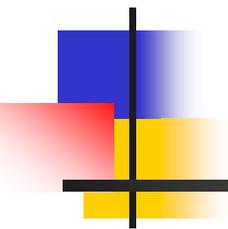


# Exposure and Health Assessment of Agricultural Burning Smoke

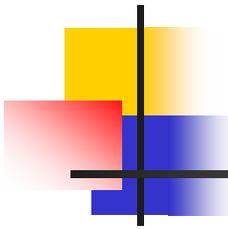


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Lee-Jane Sally Liu, Chang-Fu Wu, Tim Larson  
Lianne Sheppard, Kristin Shepherd  
Jeff Sullivan, Carol Trenga, Joel Kaufman  
Tim Gould, Sara Jarvis, Collen Marquist  
EPA NW Research Center for Particulate Air Pollution and  
Health, University of Washington

Candis Claiborn, Ranil Dhammapala, Jorge Jimenez  
Washington State University

For Pullman and Spokane town meetings (June 7, 2004)



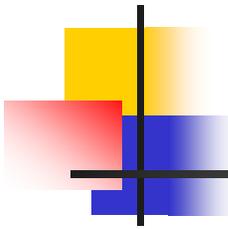
# General Scientific Questions

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Are episodes of increased particulate matter air pollution from agricultural burning associated with health effects in adults with asthma, as measured by:

- Increased pulmonary inflammation?
- Decrements in lung function?

Is pulmonary response modified by use of anti-inflammatory medication?

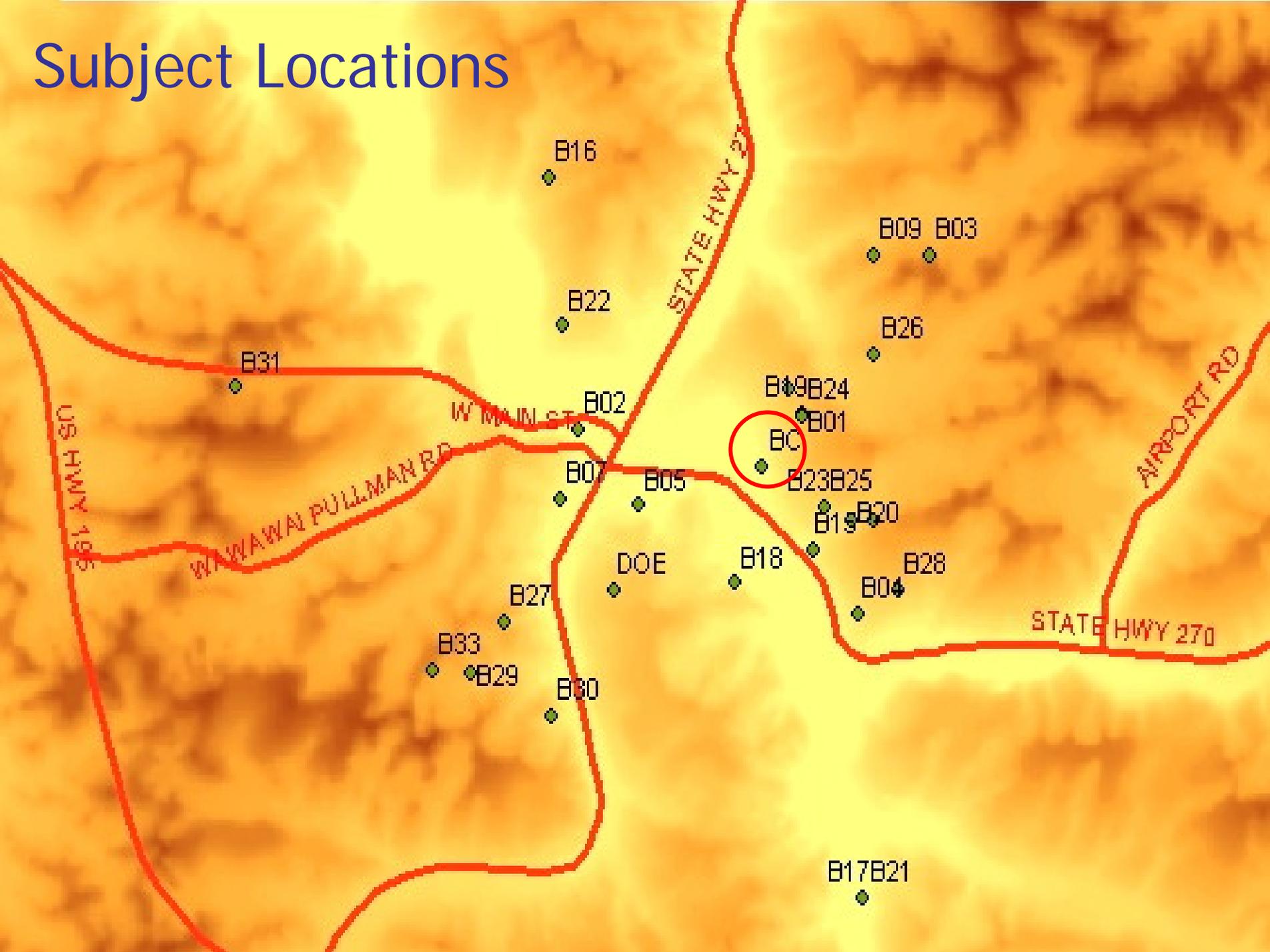


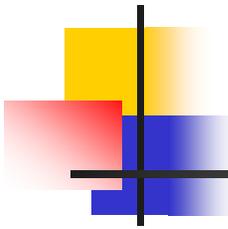
# Study Location and Population

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- Washington State University community, Pullman, WA.
- 33 adults, in the WSU community, with physician-diagnosed mild or moderate asthma
- Sample size was determined based on power simulations

# Subject Locations





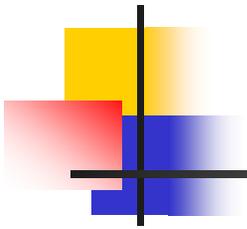
# Study Period

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- ~60-day period (Sept 3-Nov 1, 2002)
- 2 monitoring sessions, each session consisting of 33 subjects and 30 days of monitoring period.
- 33 subjects: 16 Active and 17 on-call
  - Those subjects who are active in session 1 become on-call in session 2

# Primary air measurements



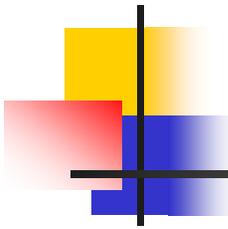


# Primary air measurements

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## Central Site Monitoring on WSU campus

- 12-hr PM<sub>2.5</sub> samples on quartz and Teflon filters with Harvard Impactor (8AM-8PM; 8PM-8AM)
- Real-time light scattering coefficient via nephelometer and DataRAM; PM<sub>2.5</sub> and PM<sub>10</sub> via TEOM; CO, CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>2</sub>, T, and RH

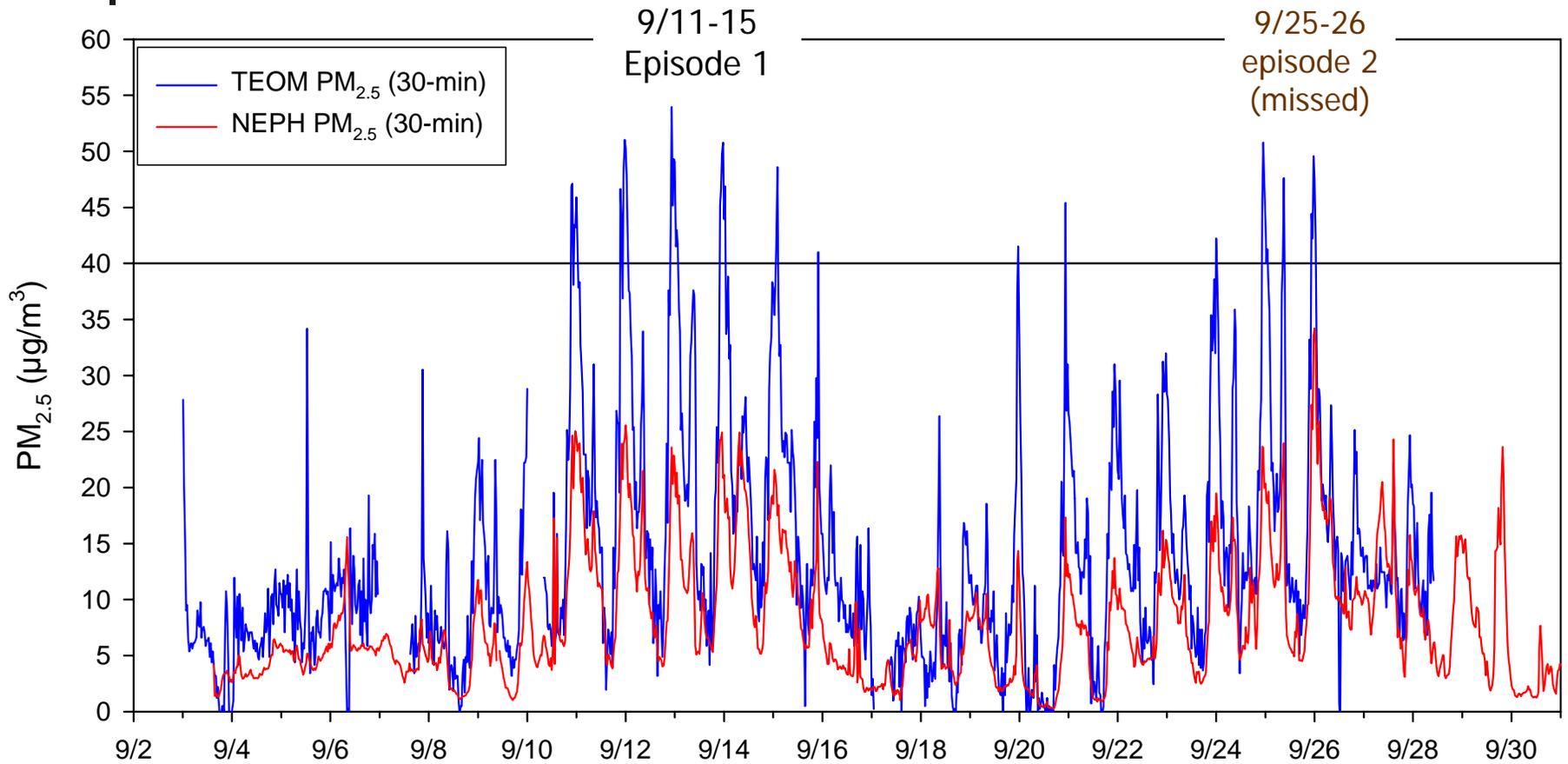


# Ag burn episode declaration

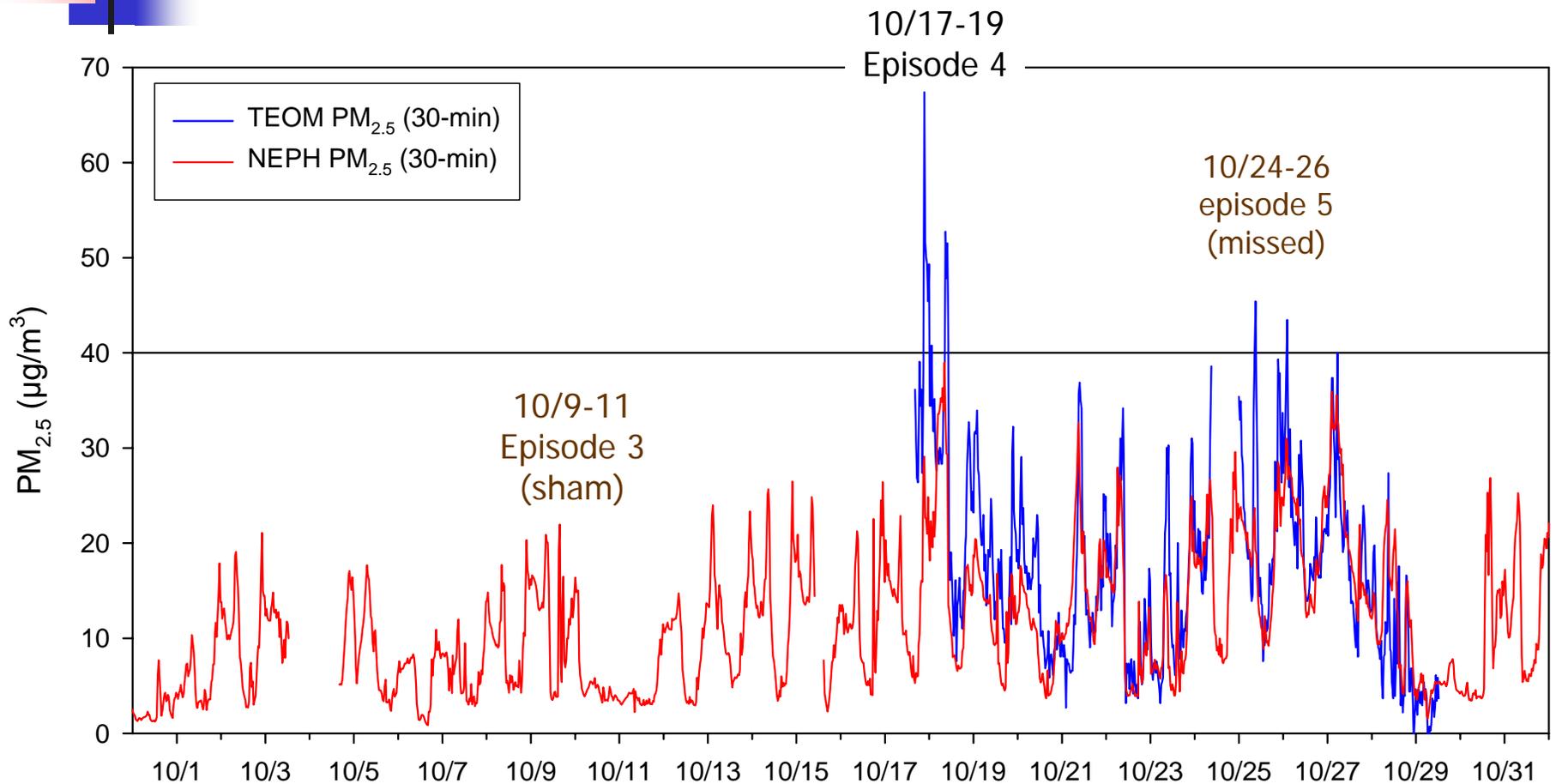
---

- Initial criterion: 5 or more 30-min average  $\text{PM}_{2.5}$  concentrations as measured by TEOM  $> 40 \mu\text{g}/\text{m}^3$  during **any** 24-hour period.
- Sufficient indication of agricultural burning smoke impacts were detected based on
  - TEOM, DataRAM, and neph, visual observation, smell, current and predicted meteorological conditions, and burn calls in the surrounding region.

# PM<sub>2.5</sub> concentrations at the central site in Sep 2002



# PM<sub>2.5</sub> concentrations at the central site in Oct 2002

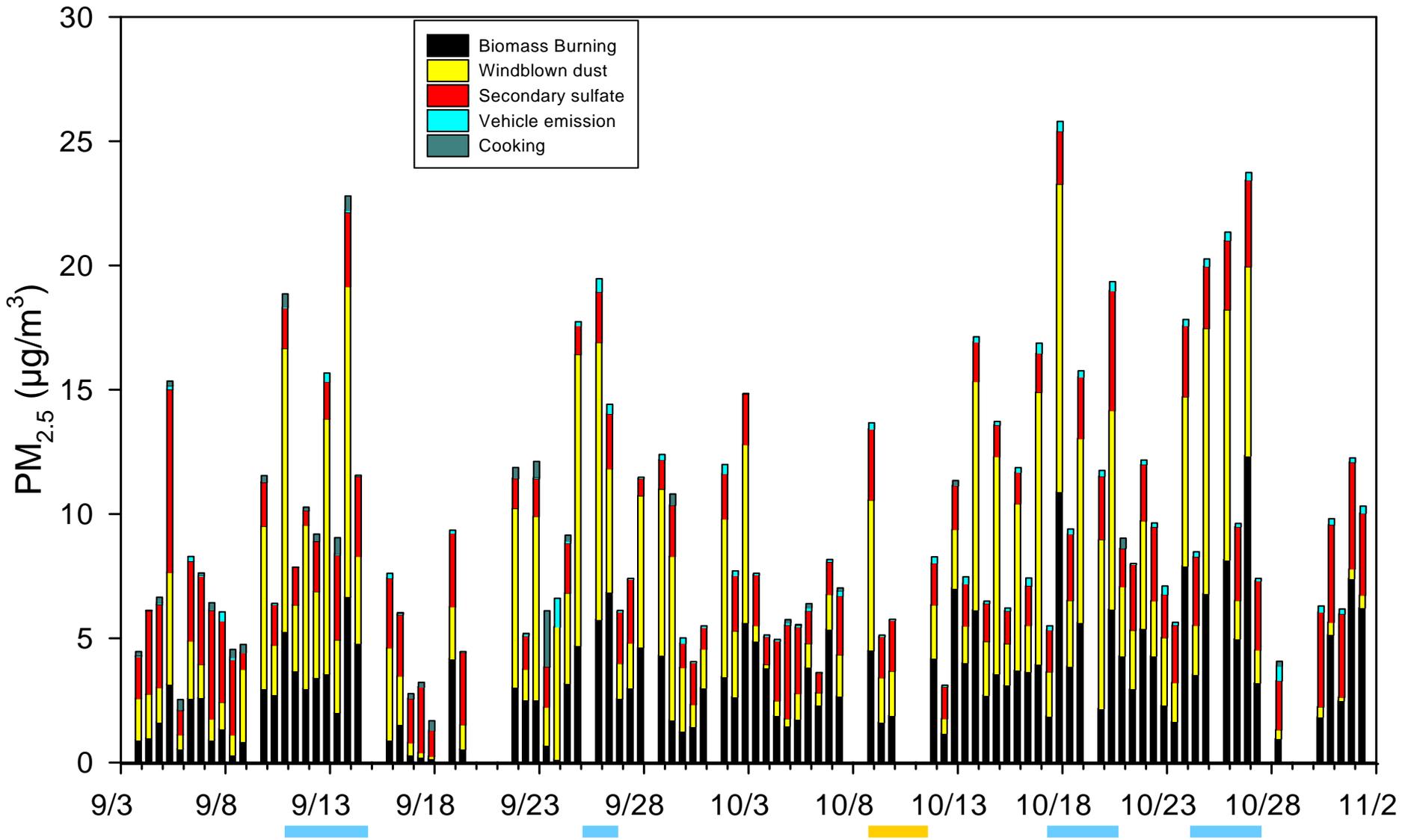


# One-hour Nephelometer PM<sub>2.5</sub> between Sep and Oct 2002

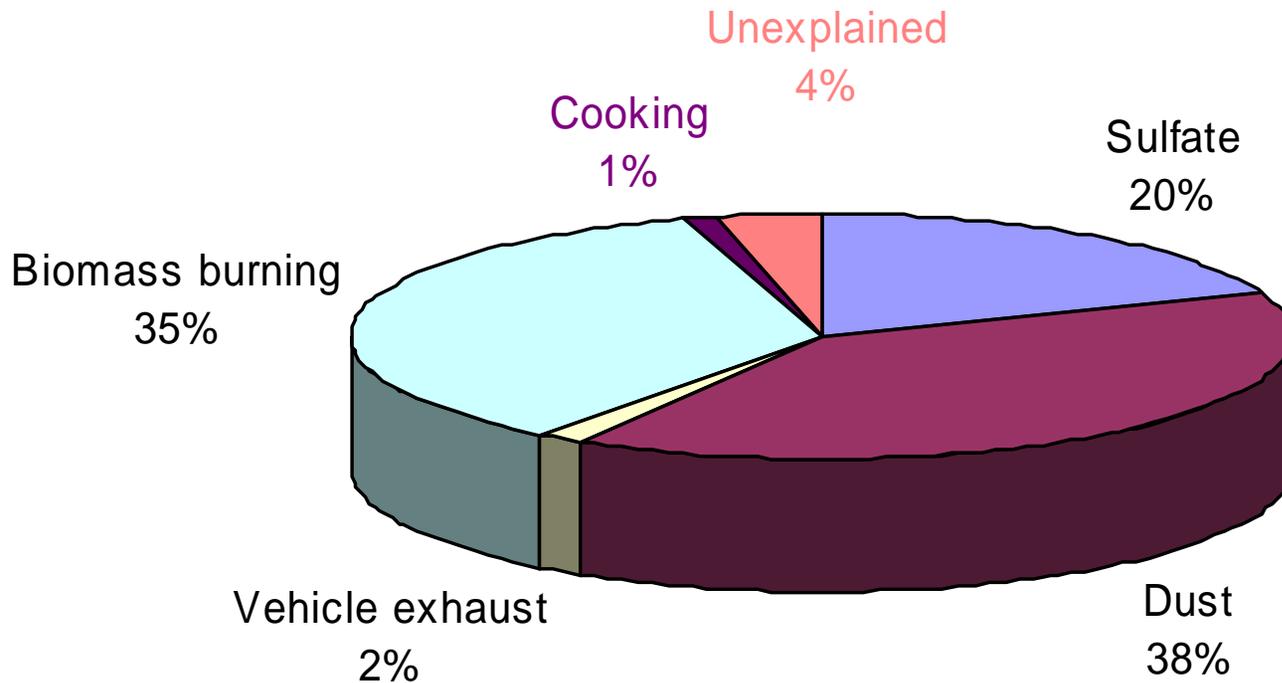
Range of PM <sub>2.5</sub>	Frequency	Percent
0 & PM < 20	1185	87
20 & PM < 30	154	11
30 & PM < 40	24	2
40 & PM < 50	2	0.2
	1365	100

Year	N	Mean	Median	Min	Max	40< Peak <80	Peak & 80
2000	1464	11.1	7.7	-2.4	91.3	37	3
2001	1114	7.8	5.5	-2.6	206.9	11	3
2002	1365	11.0	9.0	-0.2	40.5	2	0

# PM<sub>2.5</sub> levels by source (12-h means)

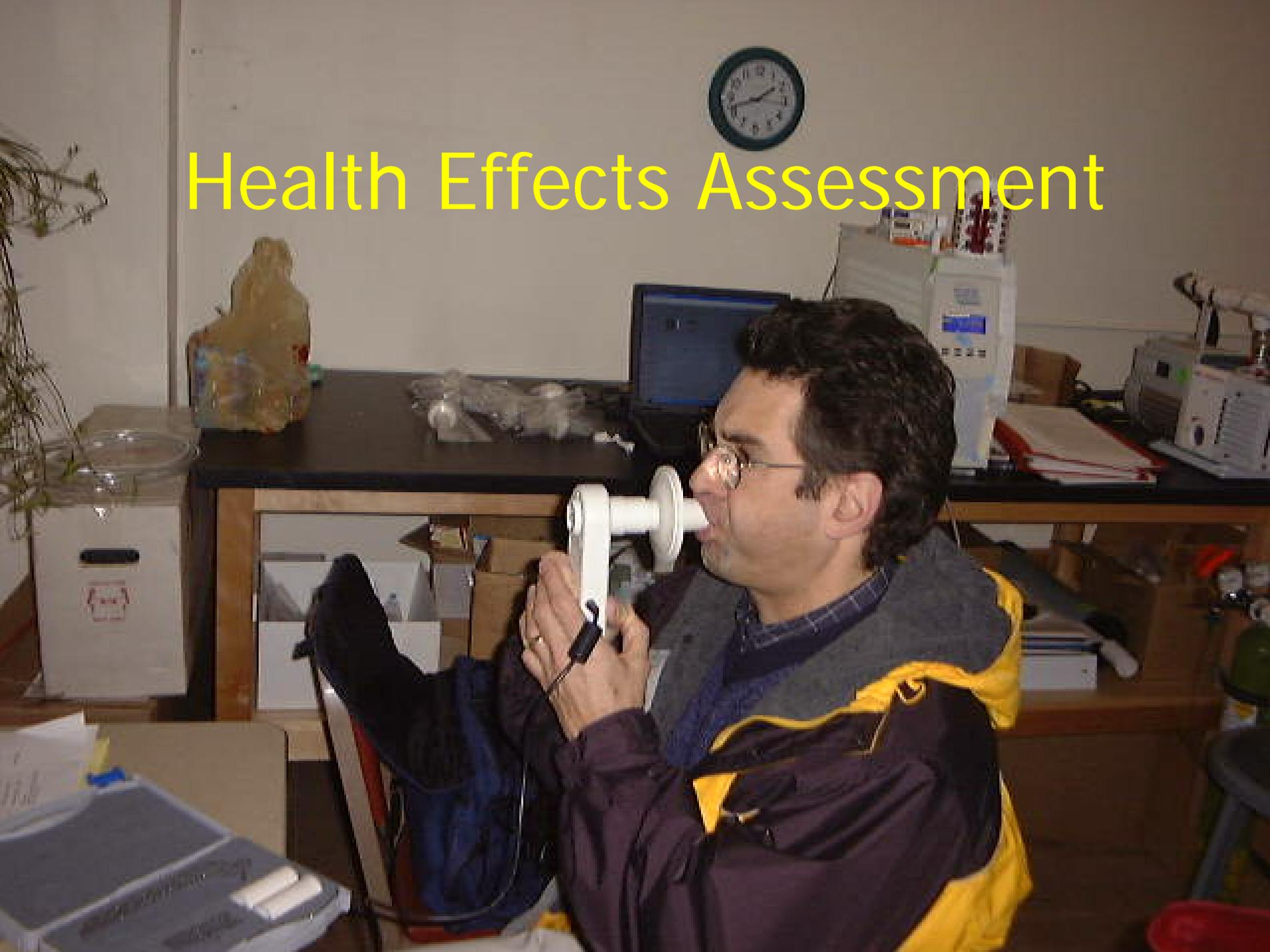


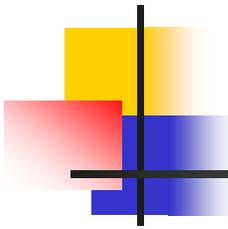
# PM<sub>2.5</sub> source contribution in Pullman (Sep-Oct 02)



\* Based on chemical mass balance analysis

# Health Effects Assessment

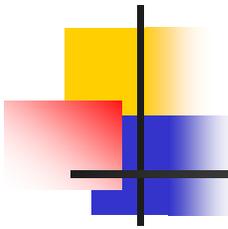




# Primary Hypothesis

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Adults with mild to moderate asthma who are not using anti-inflammatory medication will show an increase in exhaled nitric oxide (eNO) associated with the peak 1-hr average of central site PM<sub>2.5</sub> during the previous 24 hours.

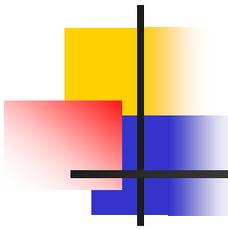


# Secondary Hypotheses

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These adults with asthma not using anti-inflammatory medication:

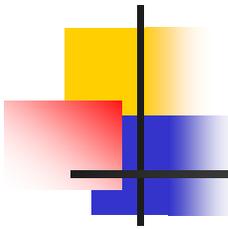
- Will show an increase in eNO associated with the peak 1-hr average of central site  $PM_{2.5}$  during 24 hour period *one day prior* (1 day lag) to measurement.
- Will show a decrease in lung function as measured by MEF and FEV1 associated with prior 24-hr and 1-day lagged peak 1-hr average of central site  $PM_{2.5}$ .
- Will show higher eNO and lower lung function (MEF, FEV1) on ag-burn episode days compared to non-episodic days.



# Health Measures

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- Exhaled nitric oxide (eNO), a sensitive marker for inflammation in the lungs
- Lung function tests
  - FEV<sub>1</sub>: forced expiratory volume in 1 second, an estimate of airflow obstruction
  - MEF: mid-expiratory flow, a measure of airflow from the small airways



# Health Effects Assessment

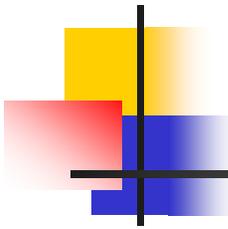
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## Active subjects – 3 lab visits/week

- Breath samples for eNO
- Coached pulmonary function tests (Micro DL)
- Symptom/medication and time-activity diaries

## On-call subjects – 3 lab visits/episode

- 3 consecutive-day lab visits (eNO, PFT, urine samples) during an “episode”
- Symptoms



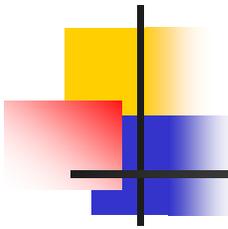
# Subjects Health Characteristics

	Overall	Prescribed anti-inflammatory med	
		No	Yes
Subjects	33	22	11
Female	21	14	7
Age	24 (18,52)	23.5 (18,47)	25 (18,52)
Height (m)	1.7 (1.5, 2)	1.7 (1.5, 2)	1.7 (1.6, 1.9)
Weight (kg)	75 (48, 159)	76 (48, 159)	73 (52, 127)
BMI	24 (18, 55)	24 (18, 55)	26 (19, 44)
Subj-days, All	611	405	206
Subj-days, with eNO	610	404	206
Subj-days, with LF	607	404	203

Note: Median and range given for quantitative variables

# Subject Symptom Reporting

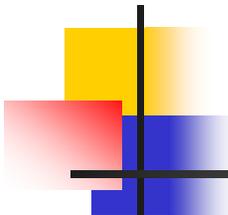
	Anti-Inflammatory Medications		Overall
	No	Yes	
Missing data	25 (6%)	16 (8%)	41(7%)
<b>Asthma severity code</b>			
No worsening	342 (84%)	141 (68%)	483(79%)
1-3 mild periods of worsening	31 (8%)	38 (18%)	69 (11%)
4 or more mild periods of worsening	7 (2%)	8 (4%)	15 (3%)
1 or more severe worsening	0	3 (1%)	3 (1%)
<b>Contacted provider for asthma</b>	0	0	0
<b>Missed class/work because of asthma</b>	0	0	0
<b>Rescue inhaler use (puffs/day)</b>			
0	366 (90%)	168 (82%)	534 (87%)
1	12 (3%)	11 (5%)	23 (4%)
2	2 (1%)	11 (5%)	13 (2%)



# Health Effect Model

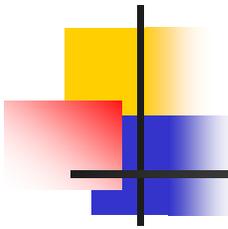
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- Mixed Effects Model
- Covariates (predictors):
  - Central Site Exposure Measure
  - Gender, Age, BMI, Medication, interaction between medication & exposure
  - Temperature,  $T^2$ , RH,  $RH^2$
- Controlled for repeated subject



# Health Effects Results

Response	Pollutant	Not on Meds.	Overall
<b>eNO (ppb)</b>	1-h max PM <sub>2.5</sub>	0.79 (-0.90, 2.48)	0.26 (-1.45, 1.96)
<b>eNO</b>	1-h max PM <sub>2.5</sub> lagged 1day	0.35 (-1.33, 2.04)	-0.46 (-2.39, 1.47)
<b>MEF (l/min)</b>	1-h max PM <sub>2.5</sub>	0.54 (-0.71, 1.79)	0.54 (-1.01, 2.09)
<b>MEF</b>	1-h max PM <sub>2.5</sub> lagged 1 day	0.20 (-1.74, 2.14)	1.30 (-0.61, 3.20)
<b>FEV<sub>1</sub> (ml)</b>	1-h max PM <sub>2.5</sub>	3.92 (-4.70,12.55)	4.82 (-6.66,16.31)
<b>FEV<sub>1</sub></b>	1-h max PM <sub>2.5</sub> lagged 1 day	4.41 (-11.0,19.86)	8.50 (-9.80,26.80)



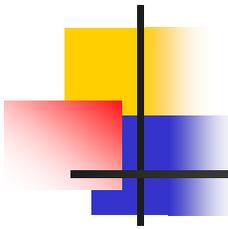
# Health Effects Results: episodes

## eNO effects (ppb)

	Real Episode	Non-episode
Overall	3.6 (-1.5, 8.8)	0
Declared	5.7 (-3.9, 15.2)	0
Not declared	0.2 (-4.4, 4.7)	0

## FEV<sub>1</sub> effects (ml)

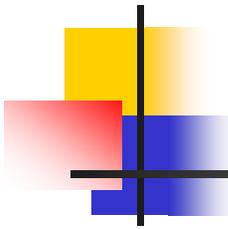
	Real Episode	Non-episode
Overall	22 (-12.2, 56.2)	0
Declared	-1.8 (-45.1, 41.6)	0
Not declared	38.2 (-7.2, 83.5)	0



# Health Effects Results: episodes

MEF effects (L/min)

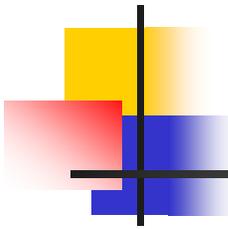
	Real Episode	Non-episode
Overall	2.5 (-1.9,7.0)	0
Declared	-2.9 (-6.9,1.0)	0
Not declared	3.4 (-2.5,9.4)	0



# Discussion: Why Were Effects Not Observed?

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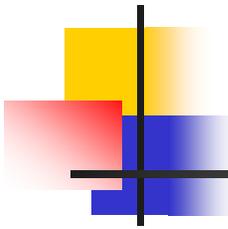
- Several potential reasons:
  - Young adults with asthma less susceptible?
  - Timing of Health Measures
  - No effects
  - Low and infrequent exposures
  - Uncertainties in exposure assessment



# Strengths of Study

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- Health outcomes
  - Exhaled nitric oxide
  - Pulmonary function
- Exposures measured dominated by agricultural burning
  - hourly maximum  $PM_{2.5}$
  - 1 day lagged  $PM_{2.5}$
  - episodes



# Study Limitations

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- Adults with asthma were chosen based on feasibility, population base, residential and monitoring locations
- Difficult to precisely define agricultural burning component
- Low peak exposure levels
- Diurnal and spatial exposure variation

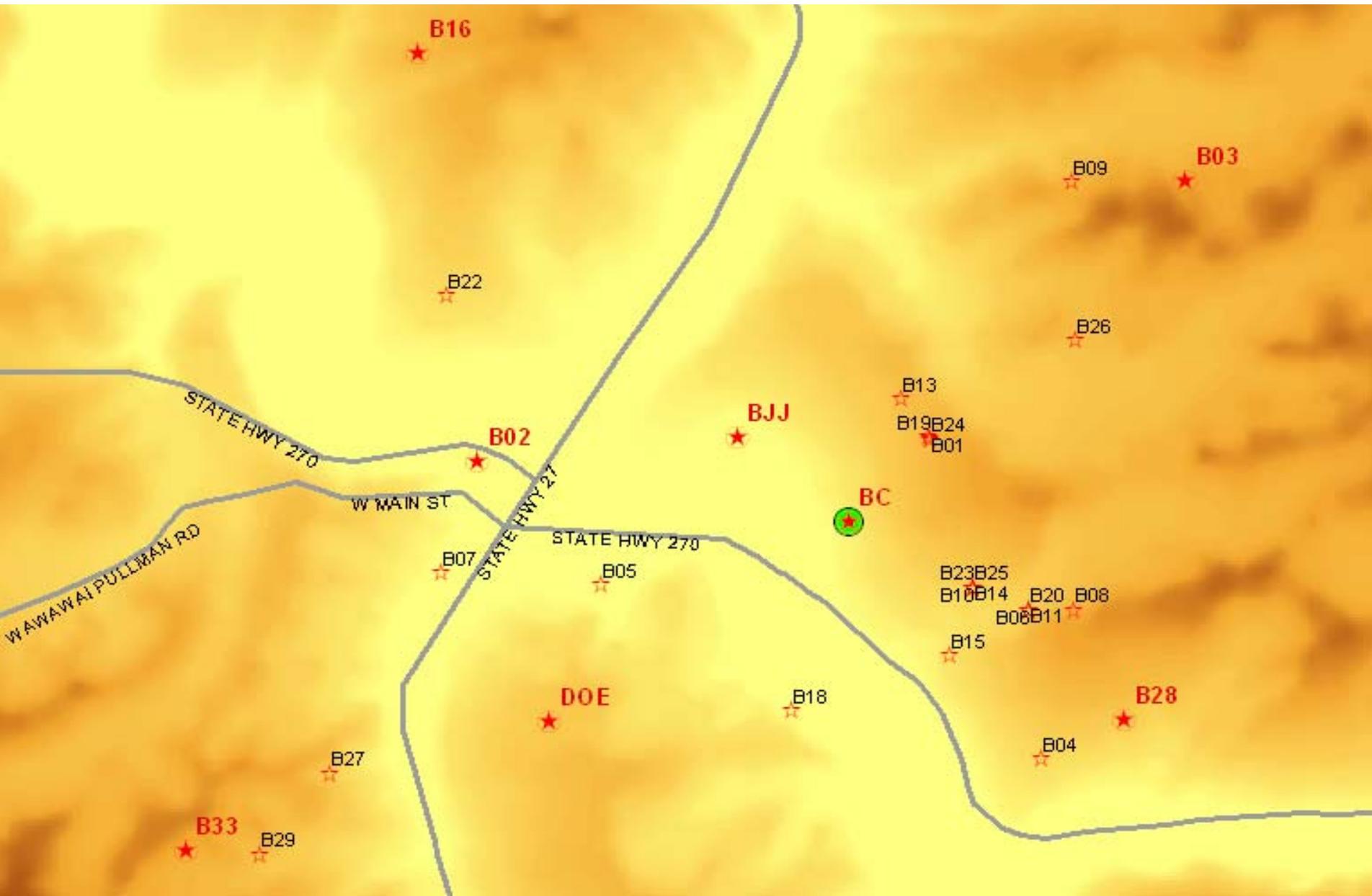
# Refinements in Exposure Assessment



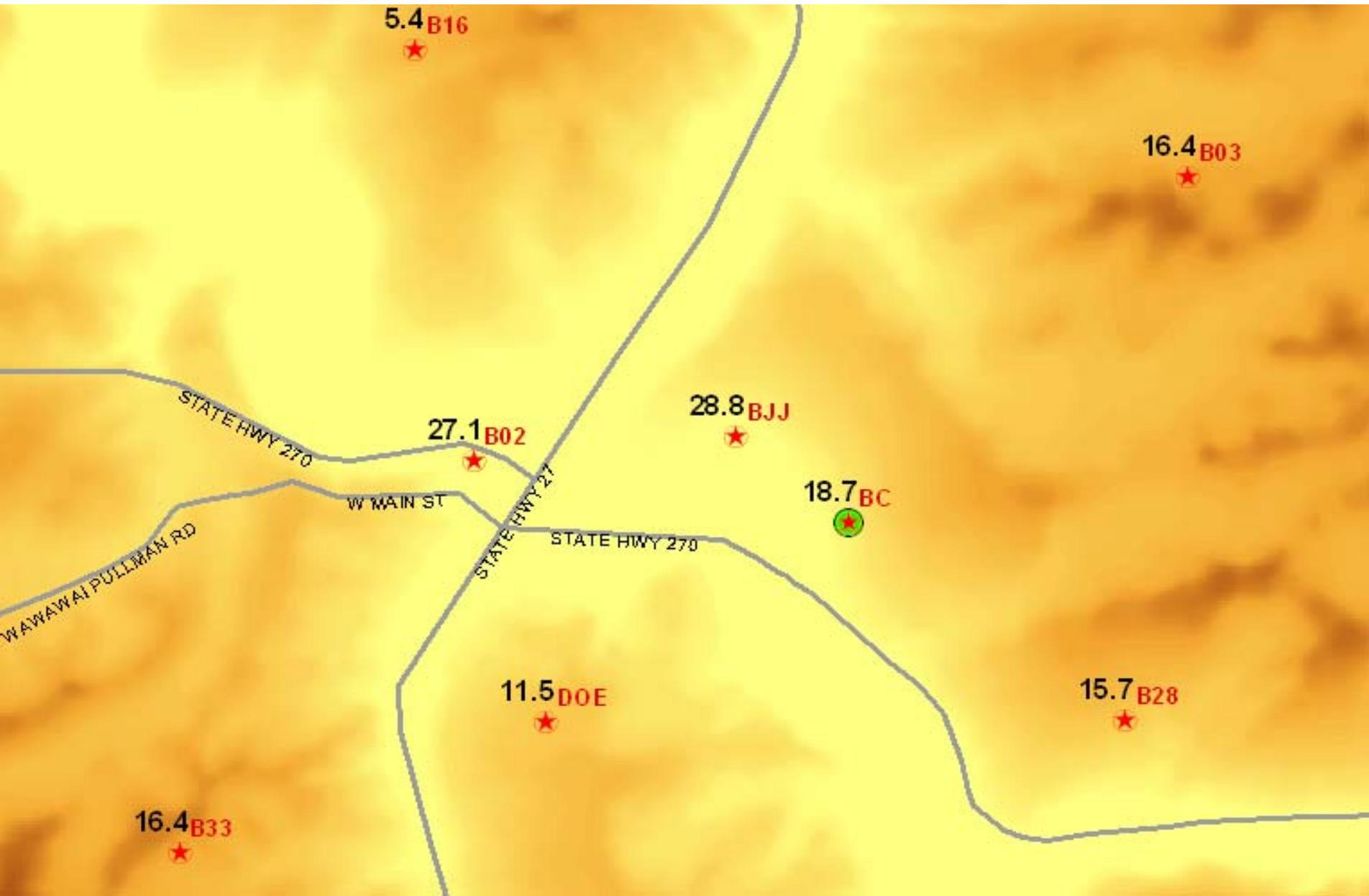
Address uncertainties due to:

- Spatial variation
- Diurnal variation
- Individual activities

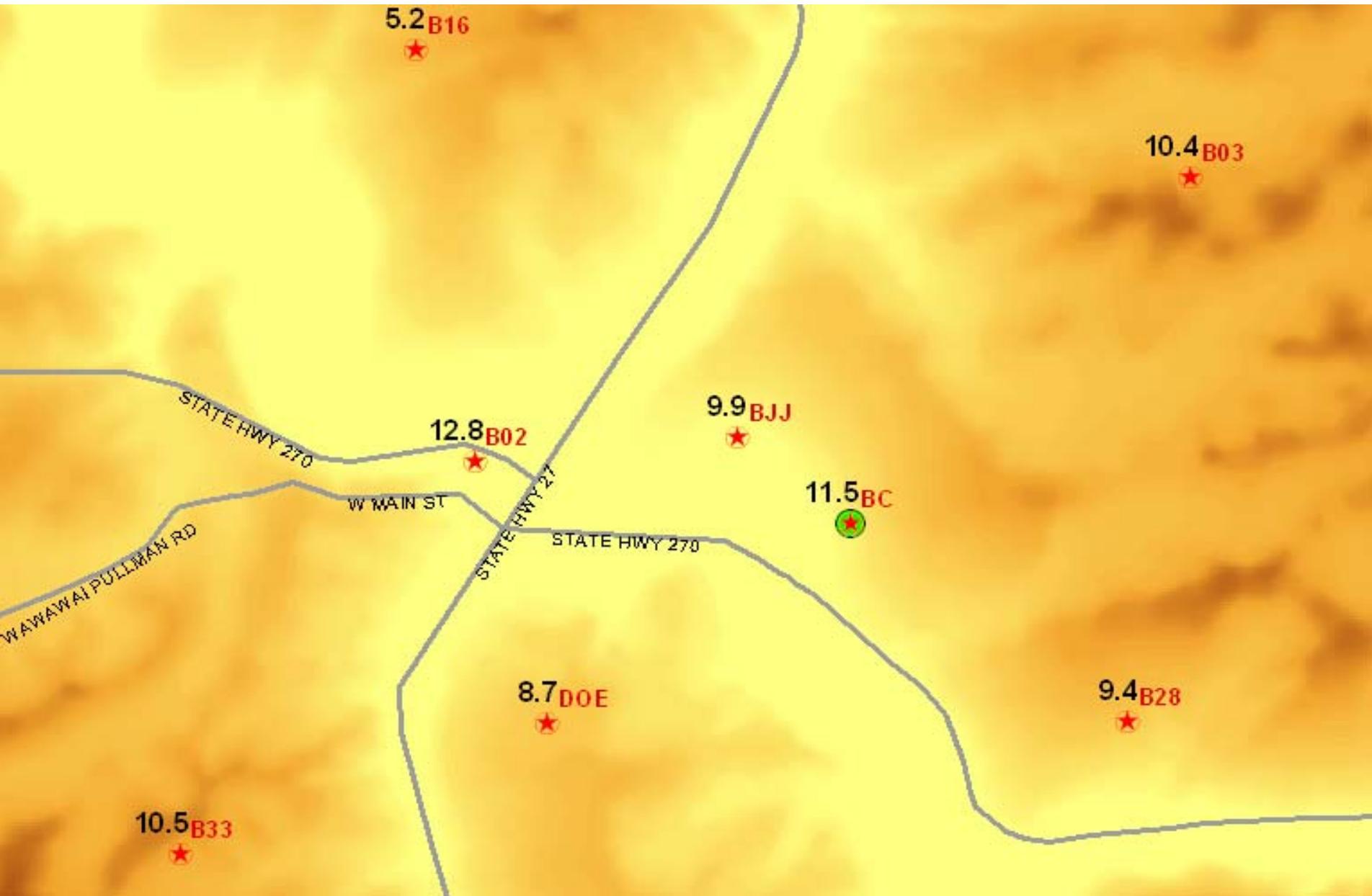
# Outdoor Sites (Marked with red IDs)



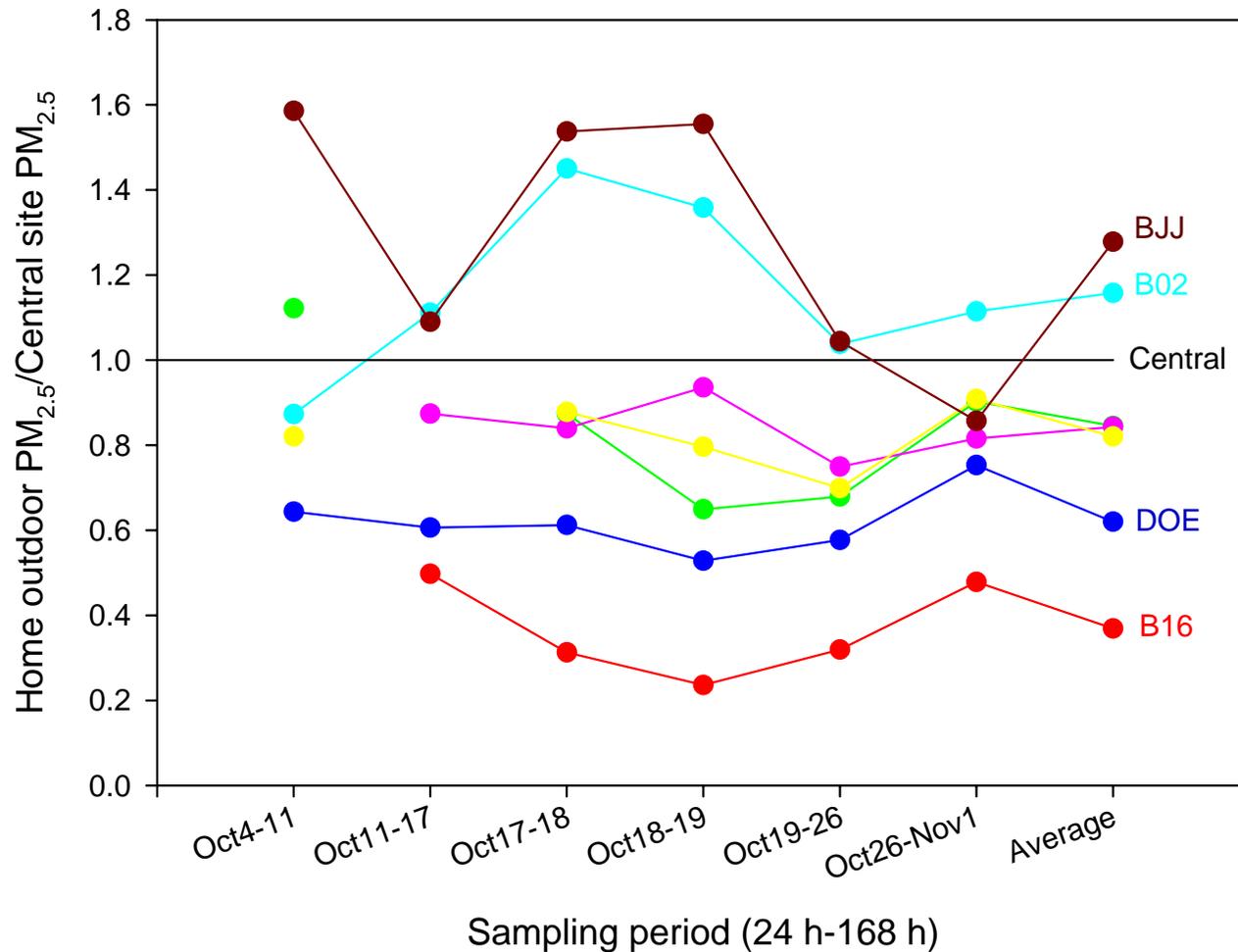
# 24-h Outdoor PM<sub>2.5</sub> (in $\mu\text{g}/\text{m}^3$ ), Oct 17-18



# 6-d Outdoor PM<sub>2.5</sub> (in $\mu\text{g}/\text{m}^3$ ), Oct 26-Nov 1



# Ratio of home outdoor to central site $PM_{2.5}$ at 7 outdoor sites

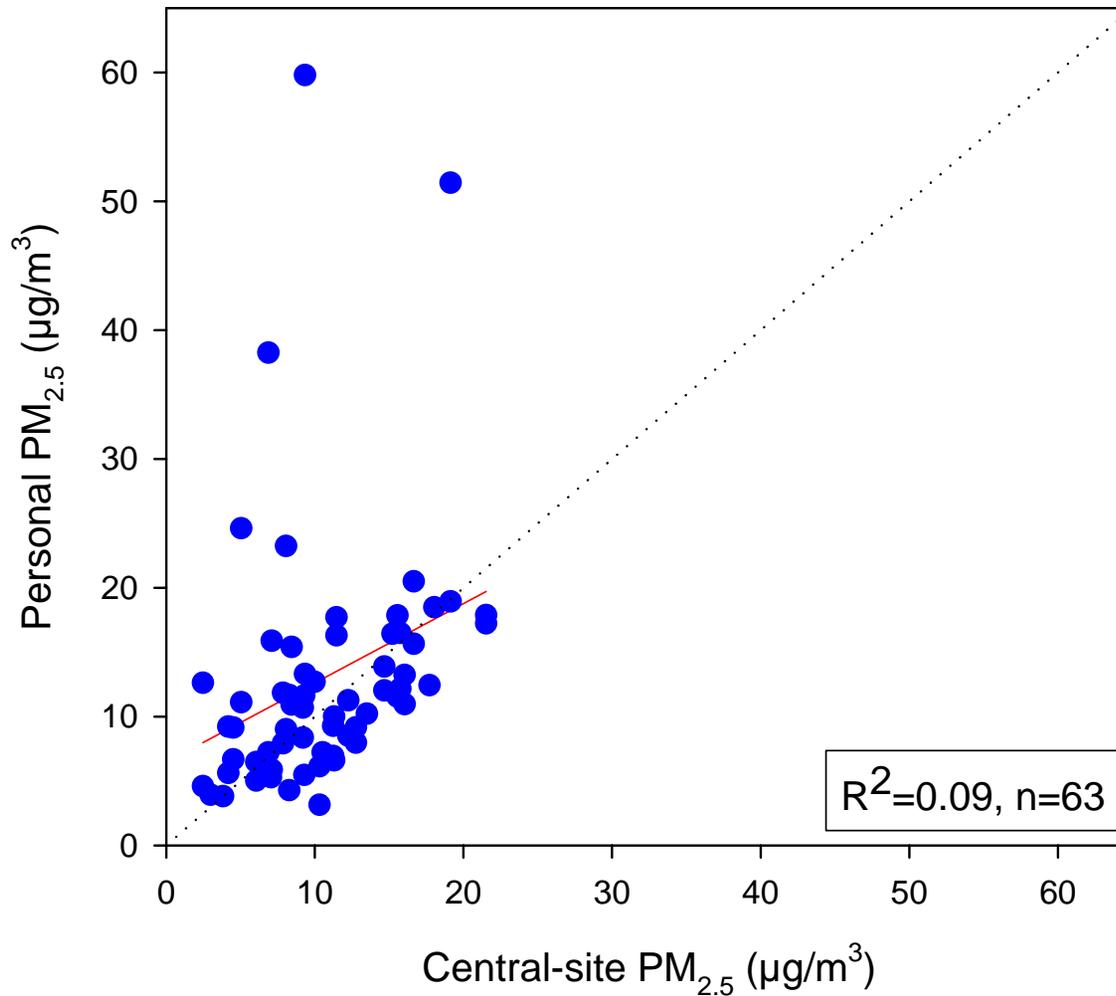


# Personal Exposure Assessment

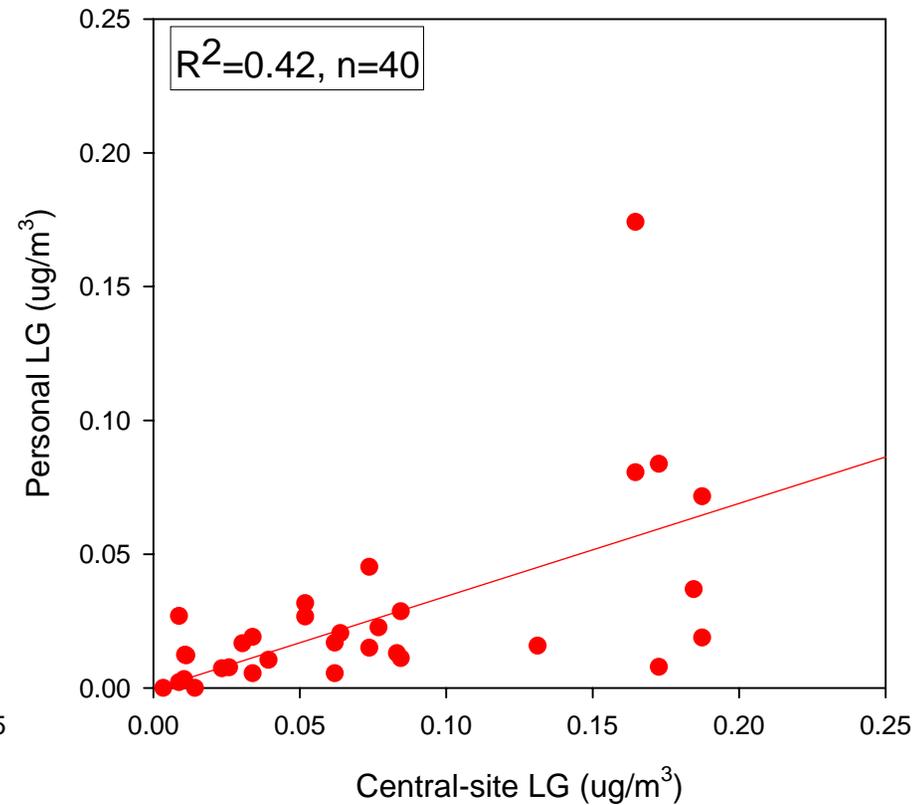
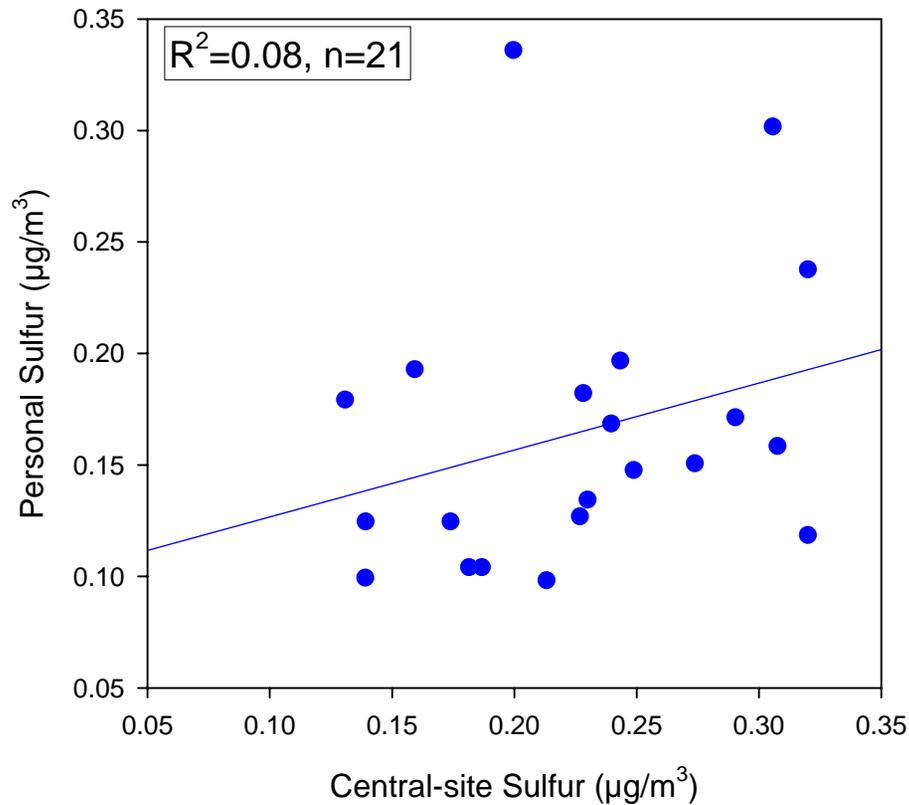
- Time-activity diary
  - From every subject everyday, 10-min resolution
- Personal sampling:
  - 2/d, 2 HPEMs/subject (Teflon for XRF, quartz for EC/OC)

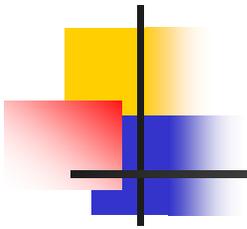


# Central site vs. Personal PM<sub>2.5</sub>



# Personal vs. central site tracers: Sulfur and levoglucosan (LG)





# Total Personal Exposure ( $E_t$ ) Model

$$E_t = E_{ag} + E_{ig} + \text{“personal cloud”}$$

Exposure to ambient  
generated PM:  $E_{ag} = \alpha C_a$

Exposure to indoor generated  
PM:  $E_{ig} = (1-y)(C_{ig})$

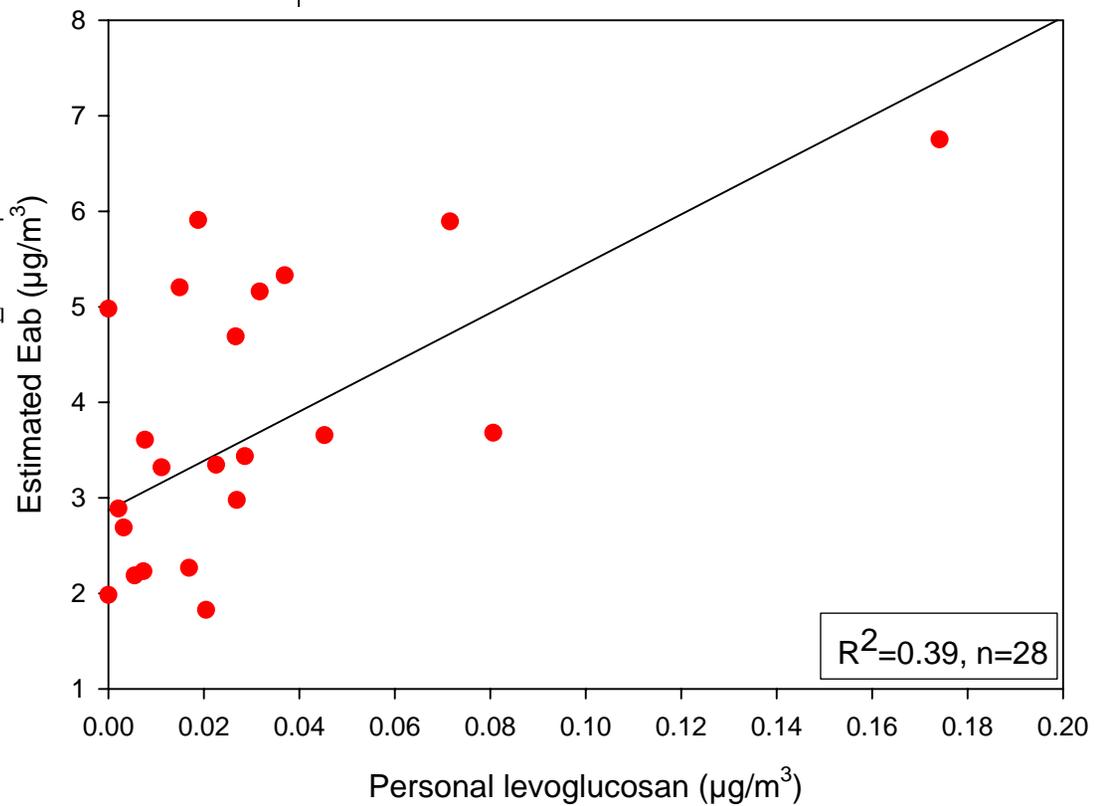
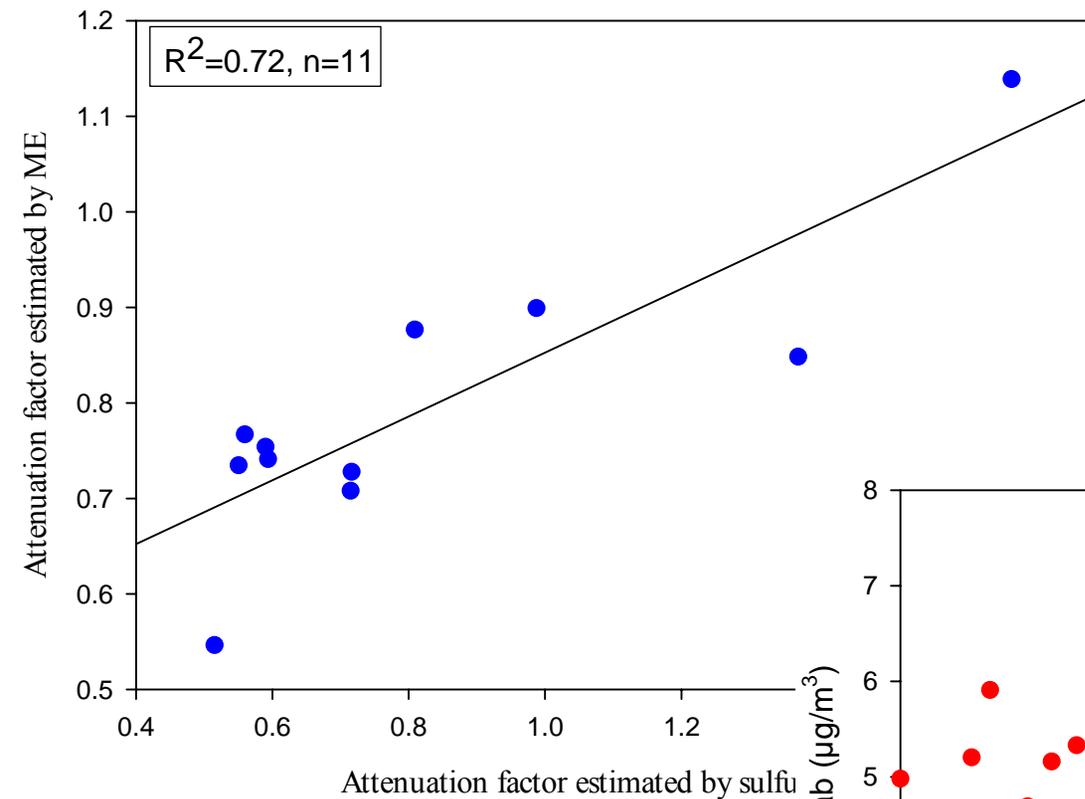
$$\alpha = \text{“attenuation factor”} = [y + (1-y)(F_{inf})]$$

$C_a$  = ambient (outdoor) concentration

$y$  = fraction of time spent outdoors

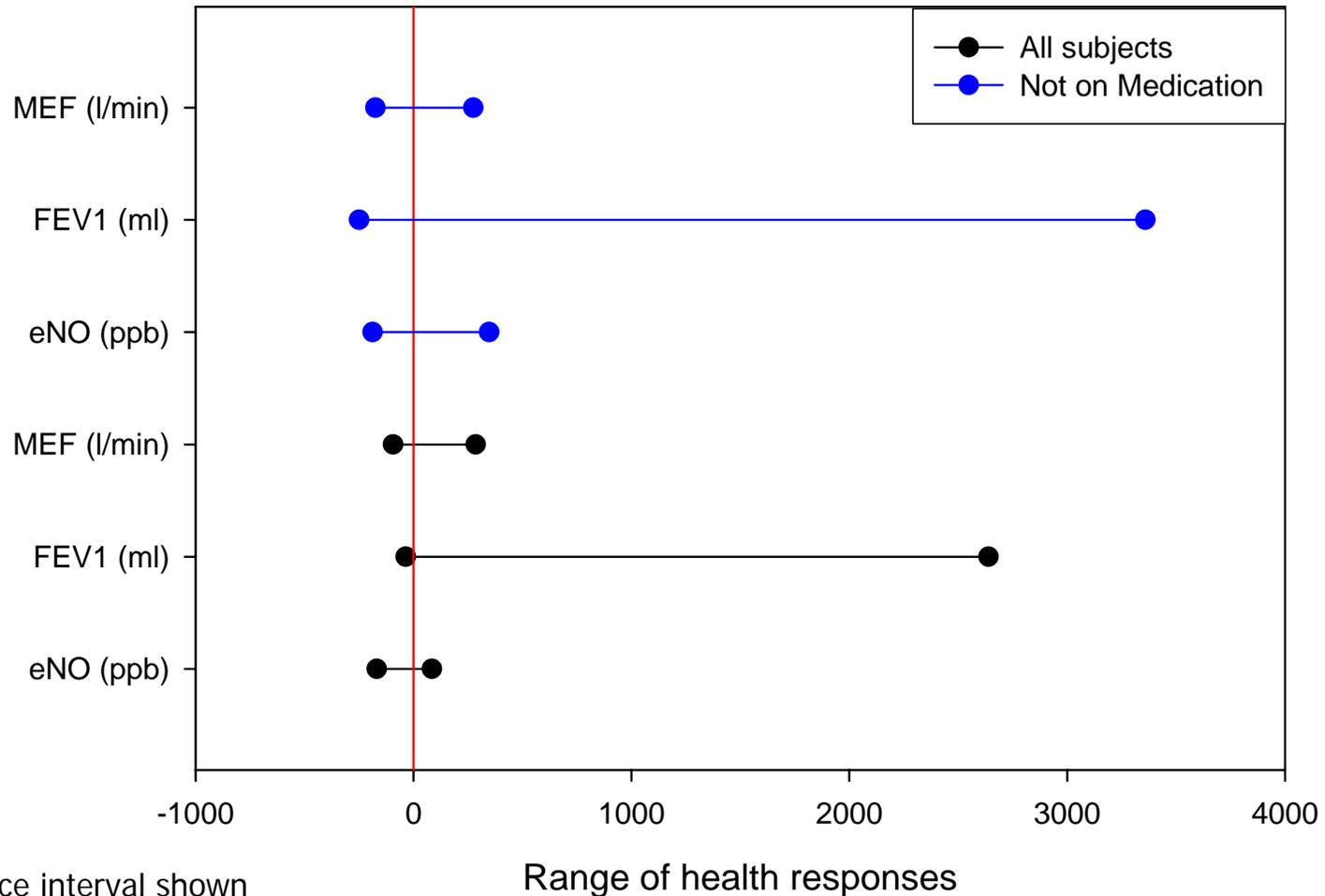
$$C_{ig} = \text{indoor-generated concentration} = C_i - C_a(F_{inf})$$

# Performance of personal exposure estimates



# Sensitivity Analysis:

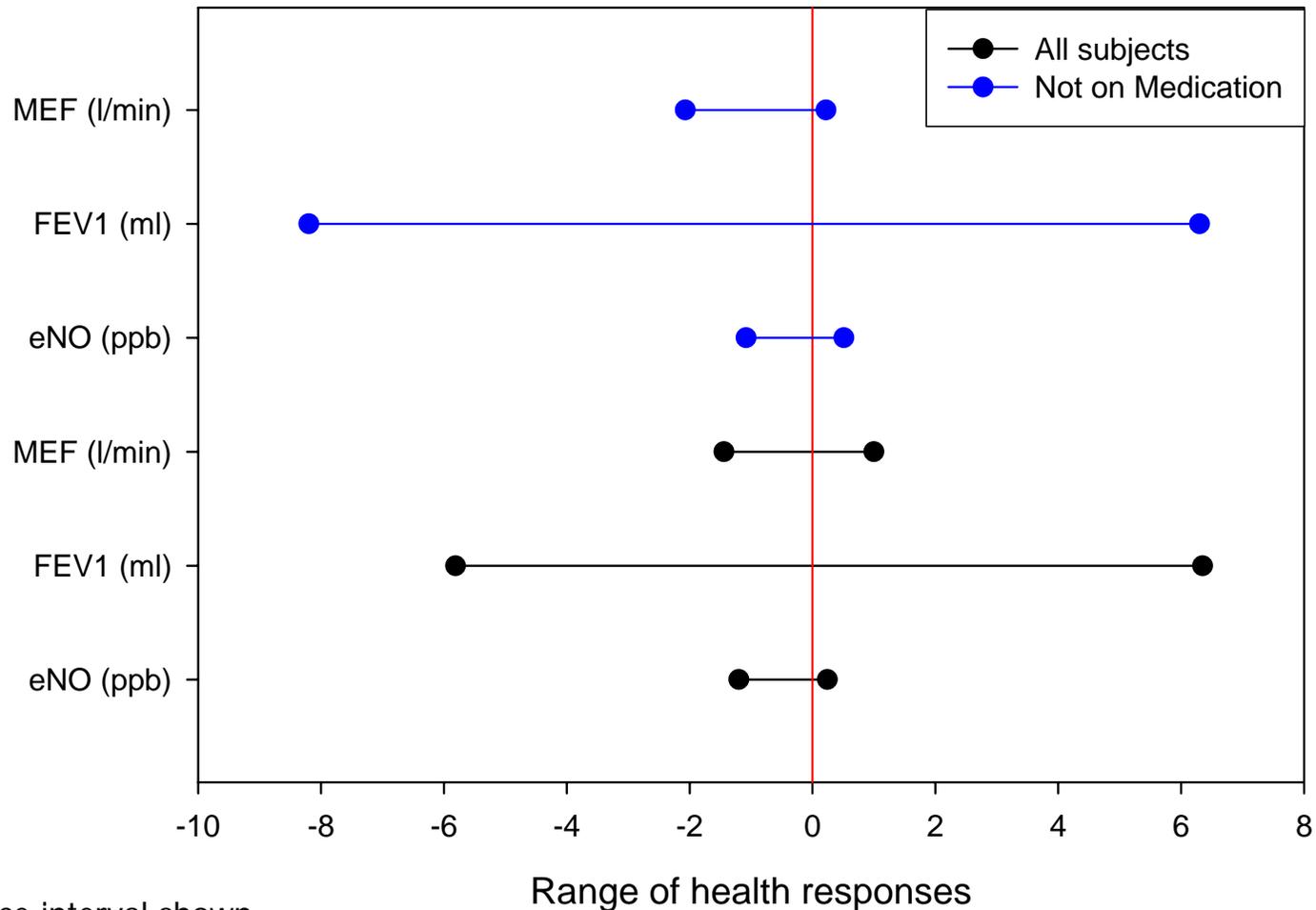
## Responses to last 12-h central-site LG



\* 95% confidence interval shown  
\* No effects observed with 1-d lag

# Sensitivity Analysis:

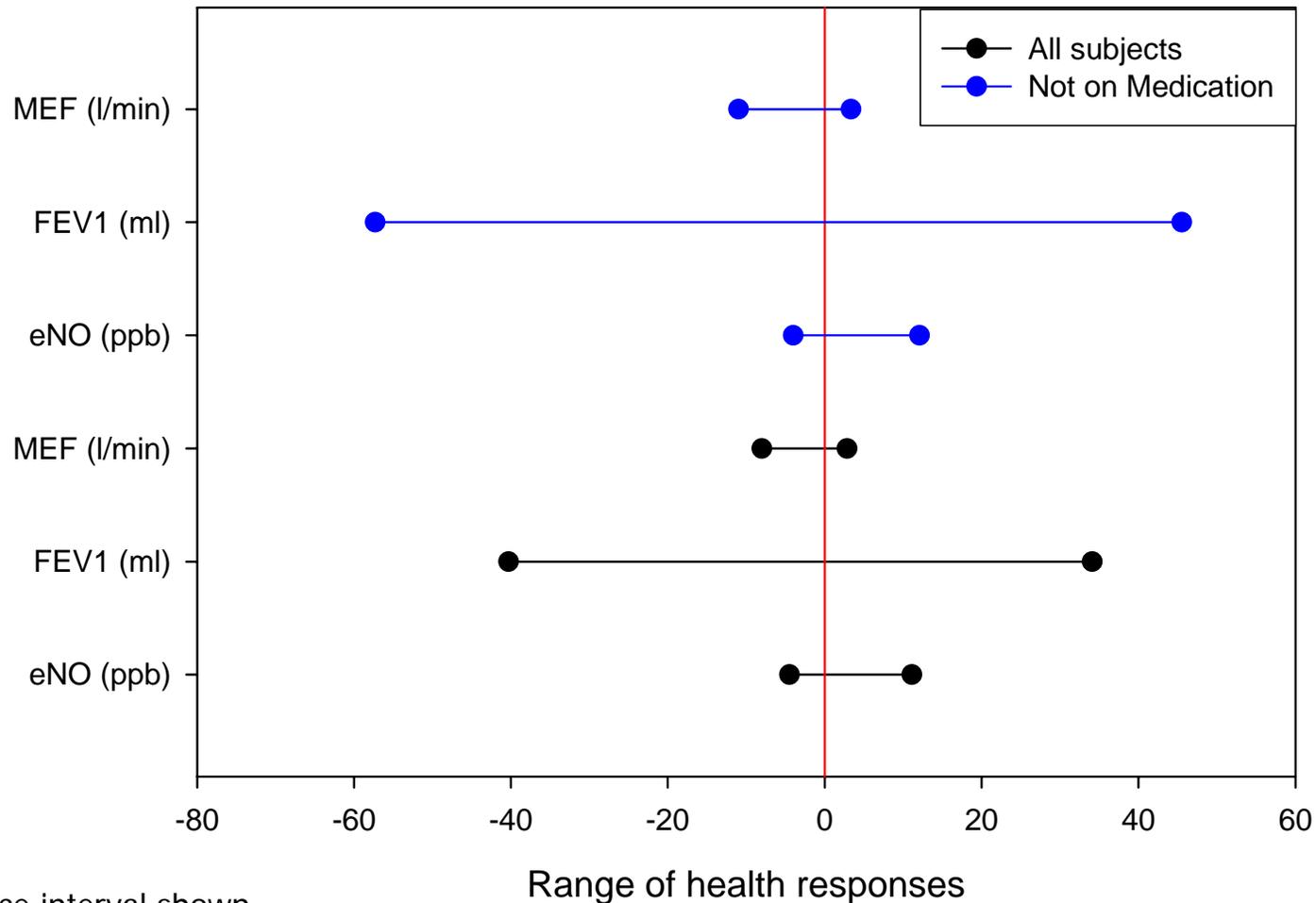
## Responses to last 12-h mean indoor PM<sub>2.5</sub>



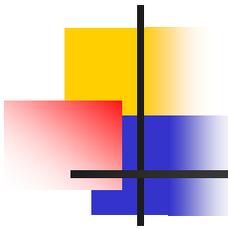
\* 95% confidence interval shown  
\* No effects observed with 12-h lag

# Sensitivity Analysis:

## Responses to last 12-h PM<sub>2.5</sub> exposure originated from outdoor sources



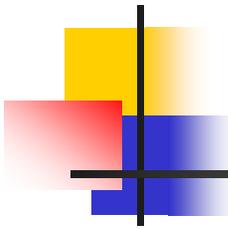
\* 95% confidence interval shown  
\* No effects observed with 12-h lag



# Conclusions – Health Assessment

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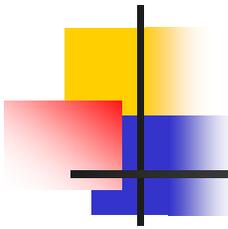
- Adverse health effects were not observed in association with observed particulate matter concentrations in adults with asthma
  - These results should be interpreted with caution due to uncertainties and limitations



# Slides will be available on the PM Center Website

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- [http://depts.washington.edu/pmcenter/res\\_projects.html](http://depts.washington.edu/pmcenter/res_projects.html)

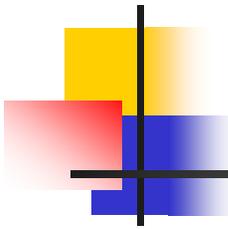


# Acknowledgement

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- Study subjects
- EPA/Northwest Research Center for Particulate Air Pollution and Health Effects
- WA Department of Ecology
- U.S. EPA Region 10





# Sensitivity Analysis: within subject differences

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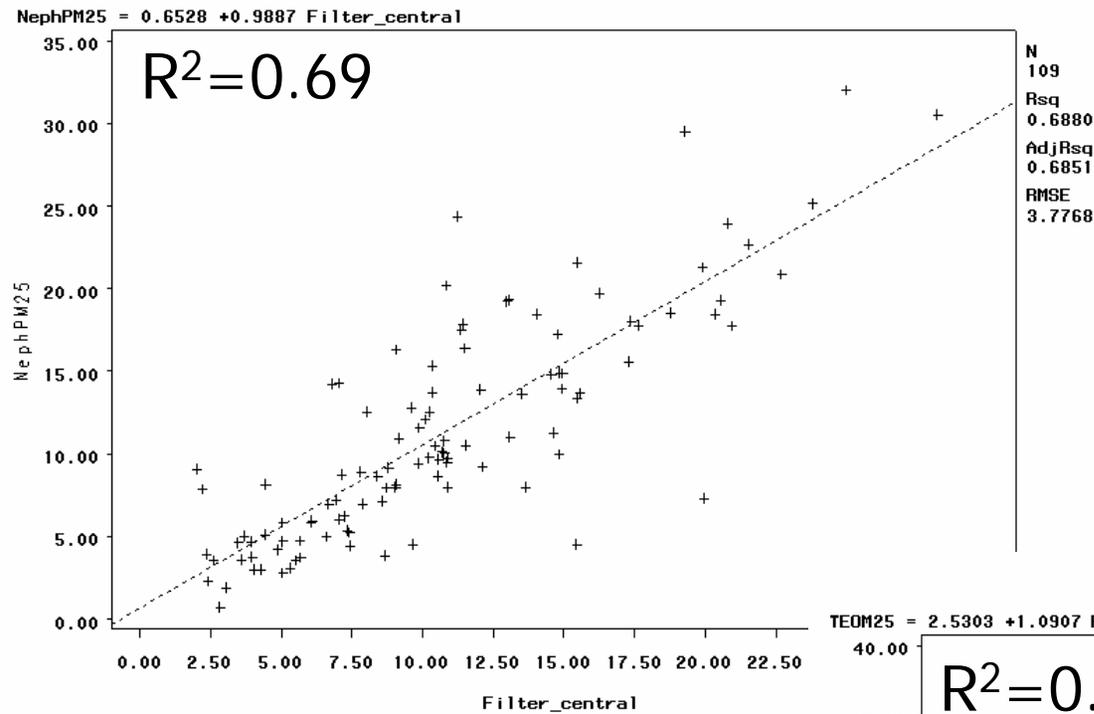
Response	Pollutant	Overall	Not on meds
eNO (ppb)	1-h maximum PM <sub>2.5</sub>	0.69 (-0.54, 1.93)	0.15 (-1.27, 1.56)
FEV1 (ml)		8.00 (-0.06, 16.06)	8.86 (-2.04, 19.75)
MEF(l/min)		0.63 (-0.44, 1.71)	0.63 (-0.82, 2.08)

# Sensitivity Analysis: with nephelometer data only

Response	Pollutant	Overall	Not on meds
eNO (ppb)	1-h max PM <sub>2.5</sub>	0.93 (-1.48, 3.33)	1.16 (-1.90, 4.23)
	1-h max PM <sub>2.5</sub> , lagged 1 day	0.24 (-2.21, 2.69)	0.48 (-2.98, 3.94)
MEF (l/min)	1-h max PM <sub>2.5</sub>	0.46 (-1.18, 2.11)	0.07 (-1.95, 2.09)
	1-h max PM <sub>2.5</sub> , lagged 1 day	-0.80 (-3.18, 1.58)	0.50 (-2.04, 3.04)
FEV1 (ml)	1-h max PM <sub>2.5</sub>	1.53 (-9.60, 12.65)	1.64 (-14.0, 17.29)
	1-h max PM <sub>2.5</sub> , lagged 1 day	-2.35 (-22.3, 17.62)	2.76 (-21.7, 27.19)

# Neph vs. HI<sub>2.5</sub>

Comparisons of  
PM<sub>2.5</sub> Measurements  
at central site  
(12-h averages)



# TEOM<sub>2.5</sub> vs. HI<sub>2.5</sub>

