Effects of Long-term Exposure to Fine and Ultrafine Particles: Evidence from California

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Collaborators

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Background: Long-Term Exposure

- Several cohort studies report associations between long-term (one-year or more) PM exposure and cardiopulmonary mortality: American Cancer Society, Harvard Six Cities, California Teachers Cohort, Netherlands Cohort Study on Diet and Cancer, Rome Longitudinal Cohort, ESCAPE

- Studies serve as basis for annual average PM2.5 standards for WHO, EU, U.S., and many countries

- Also generate large impacts in Global Burden of Disease: ~7 million deaths/year

Major Question: What is the relative toxicity of PM2.5 sources and components?

- U.S. National Academy of Sciences and EC II Position Paper on PM: Determining toxicity of different particle components and sources is a priority for future research
  - Very few epidemiologic studies have examined components or sources
  - Could help prioritize pollution control and reduce abatement costs
  - May help explain variation in study results

How to Best Measure Exposure?

- Probably greatest source of uncertainty
- Most studies use existing network of monitors to estimate city/county pollutant averages (Sometimes a single monitor represents large area)
- More recent efforts have used modeling (spatial interpolation of monitors), traffic metrics, land use regressions or satellite data
- Often no control for residential mobility
- Limited data on constituents of PM

Our study combines:

- Health Data: California Teachers Cohort

- Exposure Data: University of California, Davis and California Institute of Technology

California Teachers Study Cohort: Background

- Statewide cohort (133,479) of female members of State Teachers Retirement System
- Annual re-contact since inception in 1995

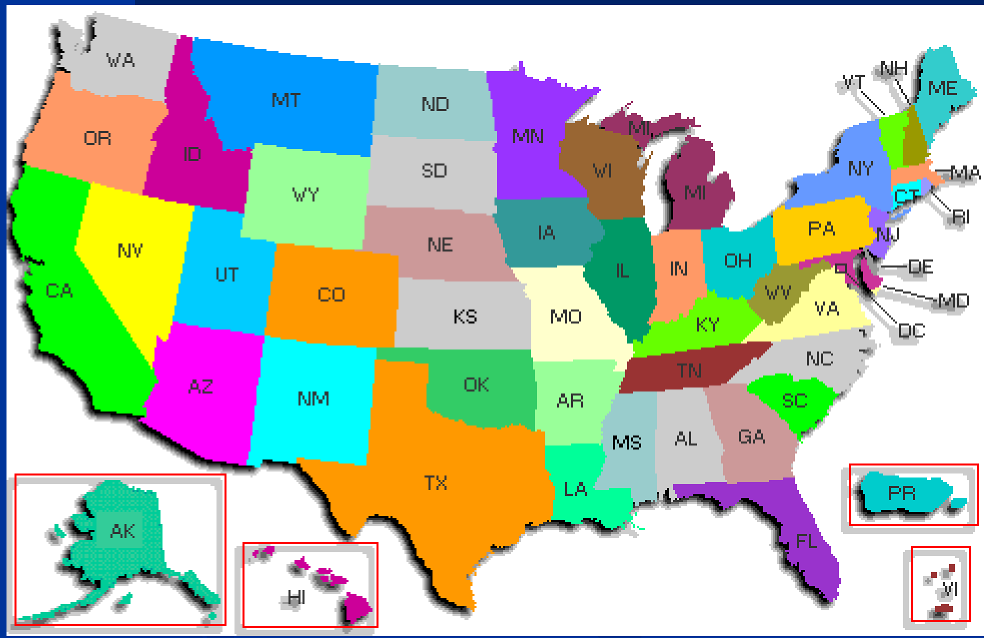
California Teachers Study Cohort: Advantages

- Low active smoking prevalence (5% at baseline)
- Aging cohort (average age 54 at inception) with many at risk for cardiovascular disease
- Little likelihood of significant occupational exposures or major SES differences
- Monthly residential history based on annual follow-up since 1995

CTS Cohort Baseline (1995) Characteristics

- Age: mean = 54
- 86% Non-Hispanic white
- 90% teachers, 10% other professional school employees
- 35% retired
- Post-menopausal = 56%
- Active smokers = 5%;
- Overweight (BMI ≥ 25) = 39%

Study Particpant Locations



Fine (PM2.5) and Ultrafine (PM0.1) Pollutants Measured

- Mass

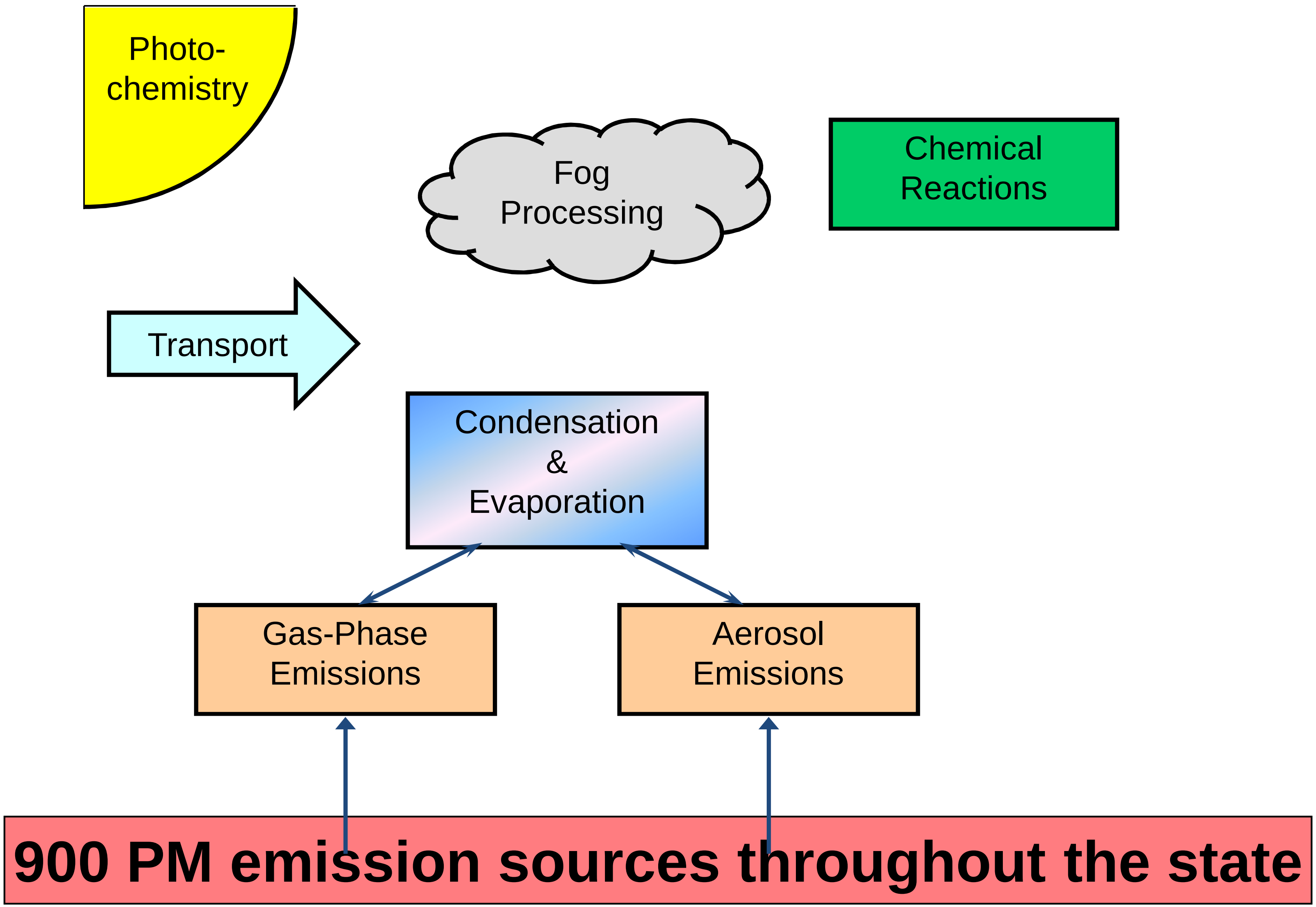
- Constituents: Copper, Iron, Manganese, Nitrate, Elemental Carbon, Organic Carbon, “other” metals, “other” compounds, anthropogenic and biogenic secondary organics

- Sources of mass from source apportionment: on- and off-road gasoline, on- and off-road diesel, wood smoke, meat cooking, high sulfur content fuel combustion, “other” sources (note: no large industrial source)

PAH-related Pollutants Examined (particularly UF and quasi-UF)

- Mass
- Constituents: Copper, Iron, Manganese, Nitrate, Elemental Carbon, Organic Carbon, “other” metals, “other” compounds, anthropogenic and biogenic secondary organics
- Sources of mass from source apportionment: on- and off-road gasoline, on- and off-road diesel, wood smoke, meat cooking, high sulfur content fuel combustion, “other” sources

Exposure Prediction in Each 4k Grid Cell

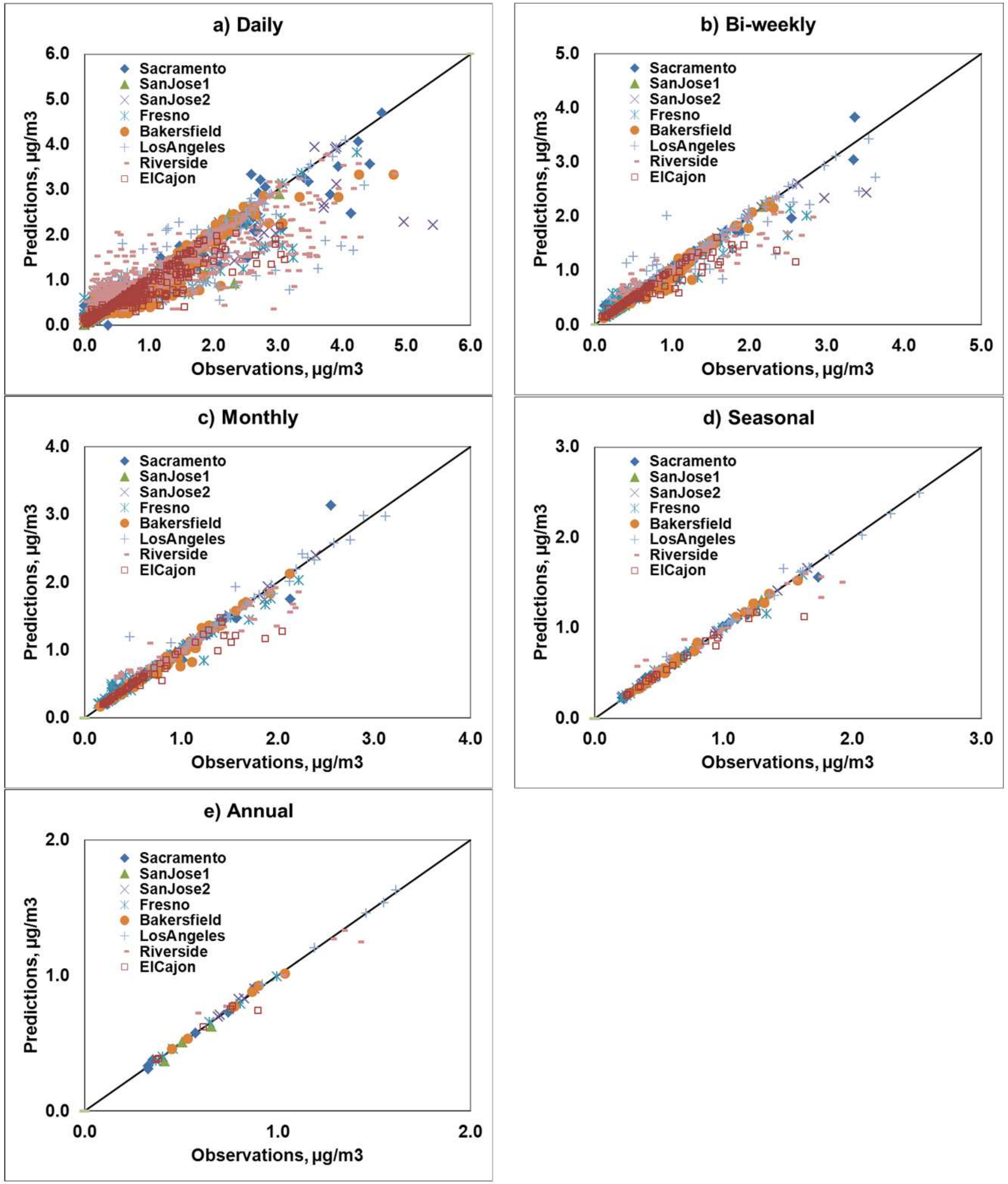


Model Evaluation: PM2.5 EC vs. Obs. at Different Averaging Times

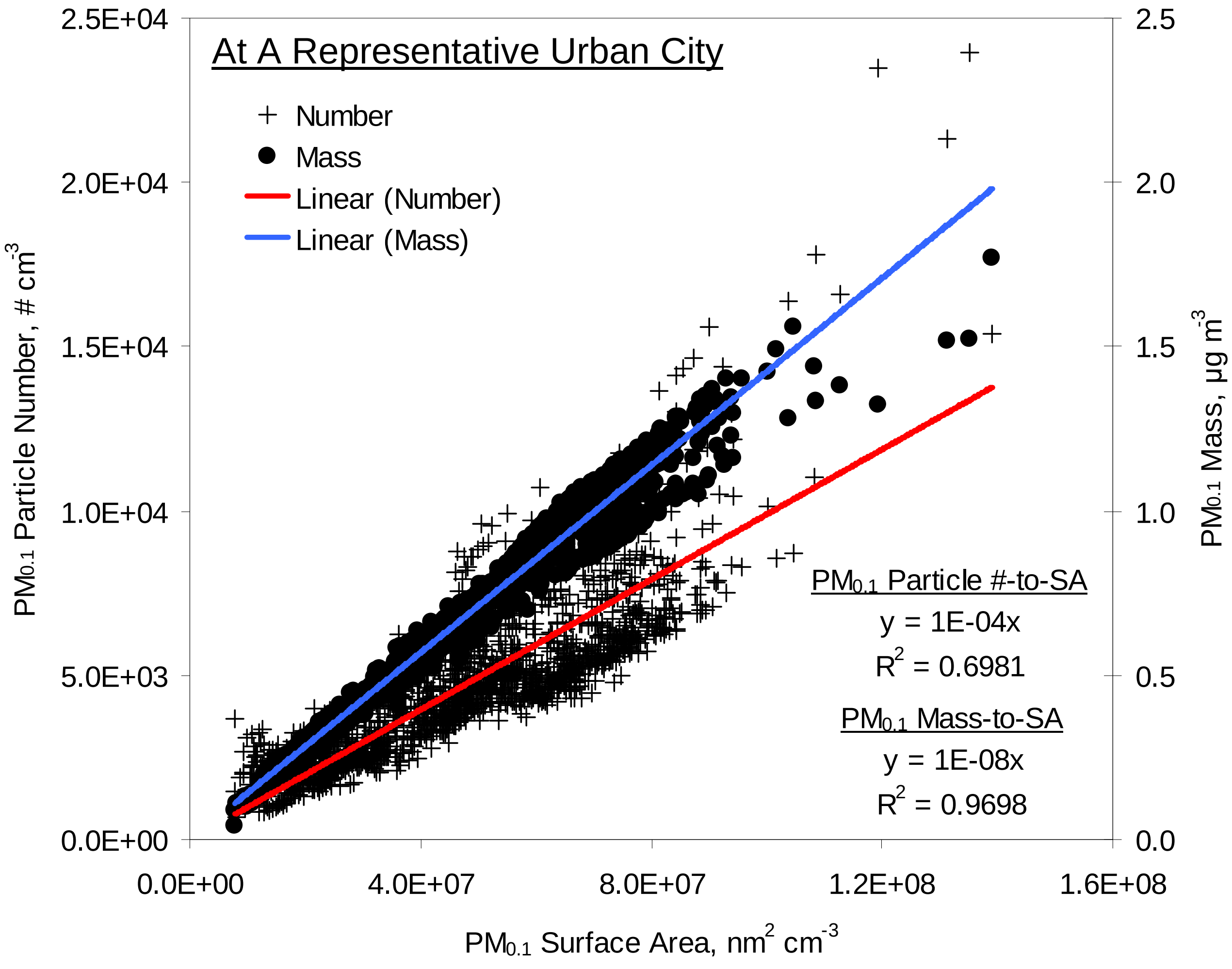
R^2:

Daily (0.82) < Biweekly < Monthly < Seasonal < Annual (0.95)

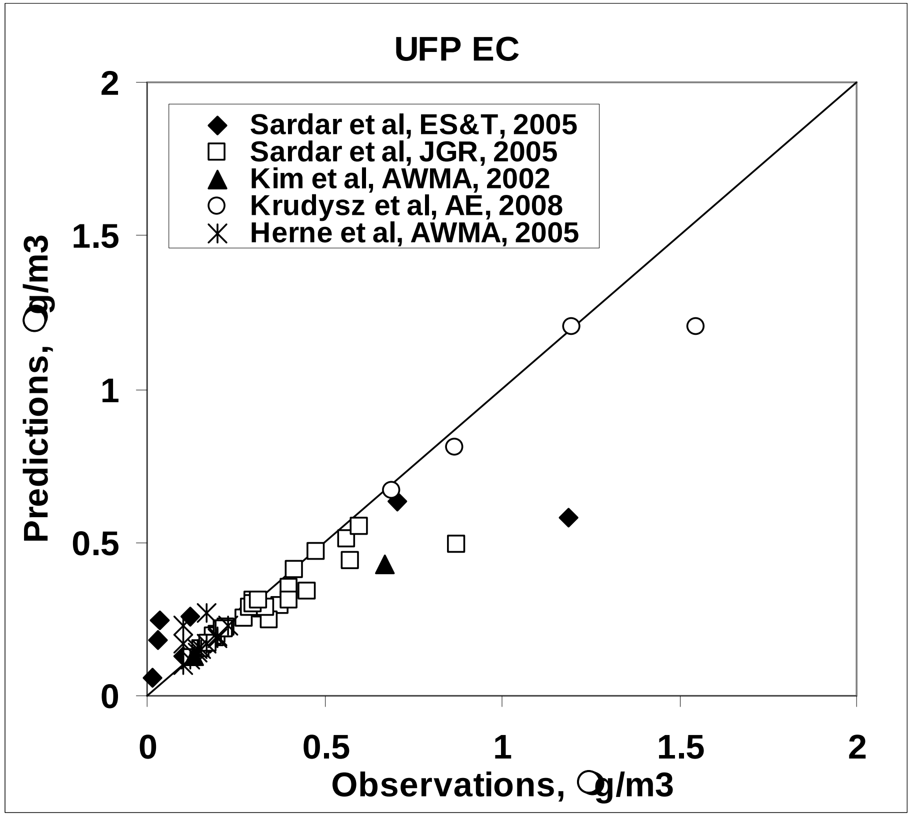
Model results agree better with measurements at longer averaging times

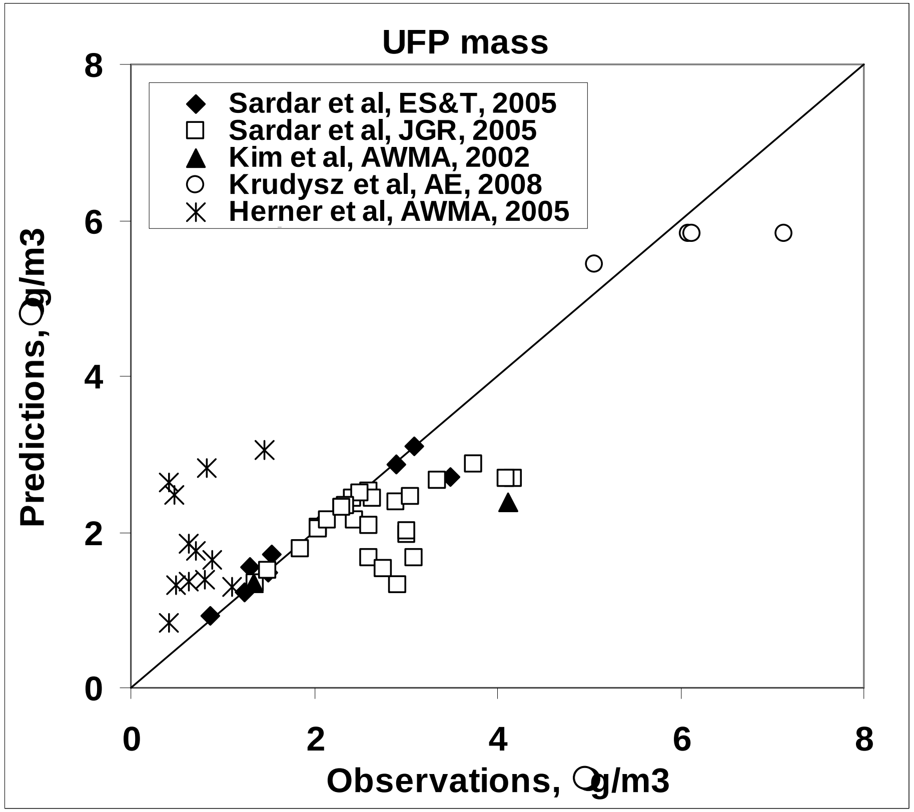


Why Are We Interested in PM0.1 Mass?



Model Evaluation
PM0.1 EC and Mass



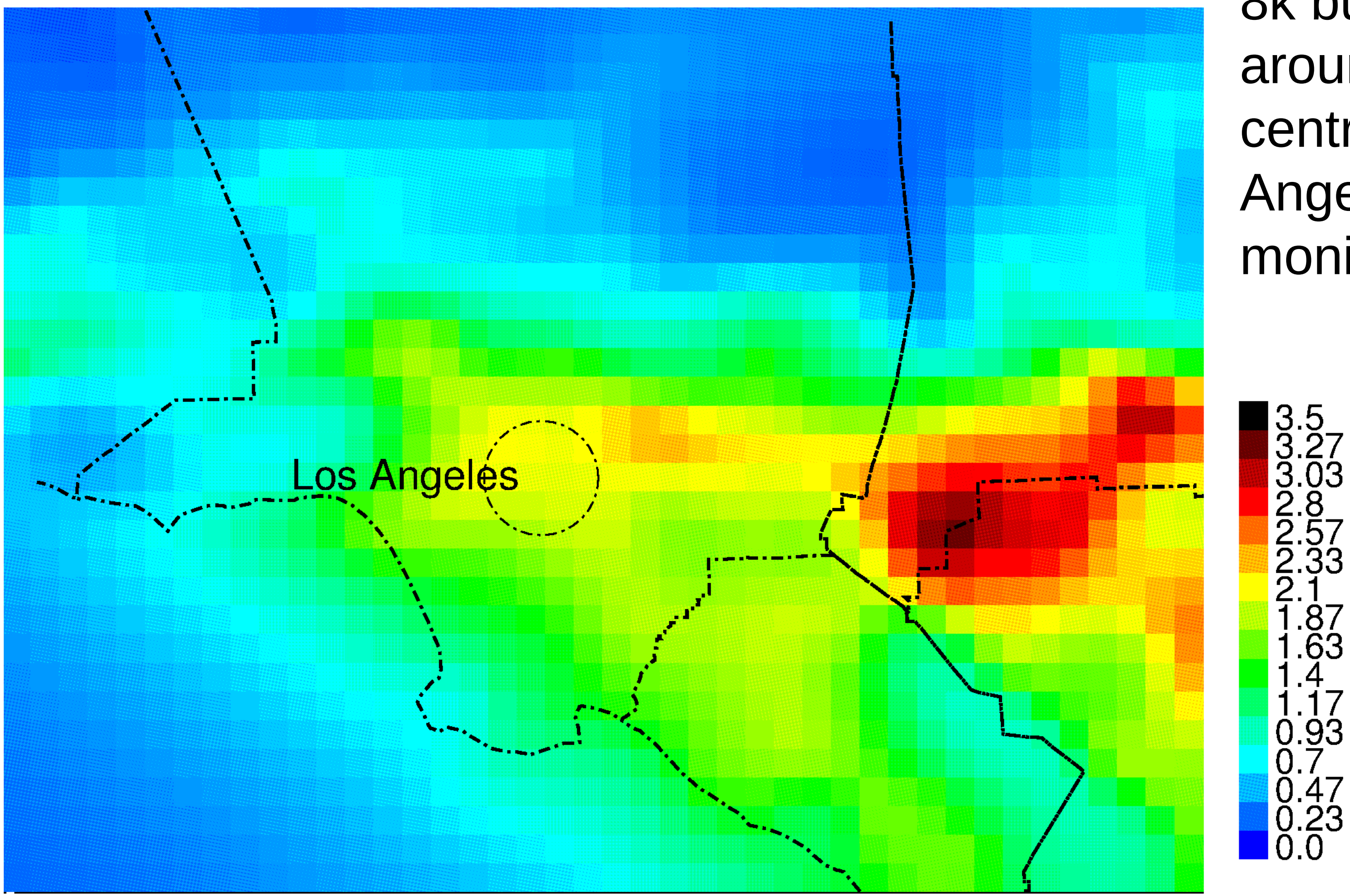


R^2=0.88

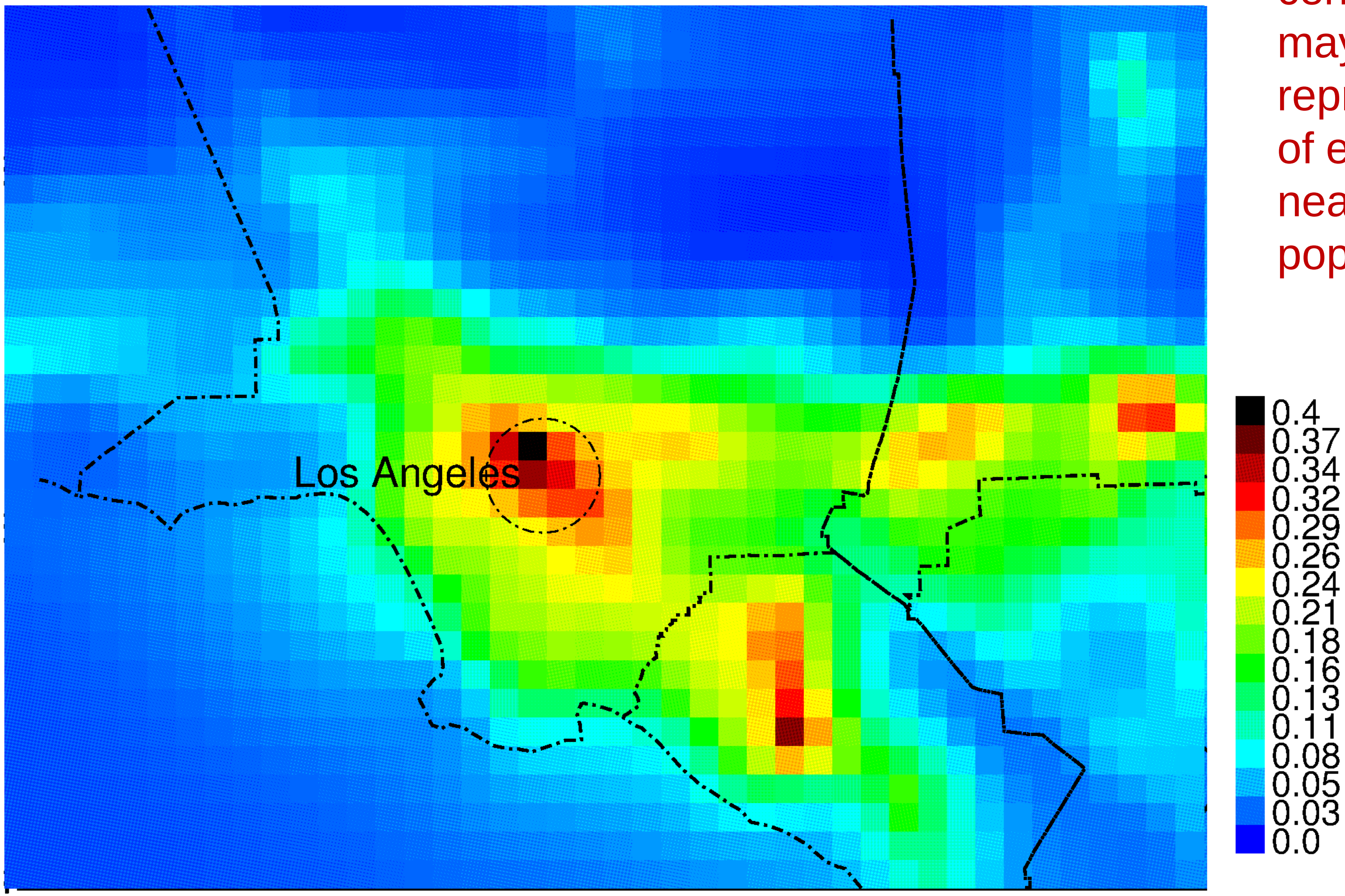
R^2=0.66

Spatial representation of concentrations of PM2.5 Nitrate in Los Angeles and Surrounding Counties ($\mu g/m^3$)

Circle indicates 8k buffer around central Los Angeles air monitor



Spatial representation of concentrations of Ultrafine EC in Los Angeles and Surrounding Counties (µg/m^3)



Results indicate that central monitor may not be representative of exposure for nearby population.

Methods – Statistical Analysis

- Cox Proportional Hazards regression used to generate RR estimates for exposures from 2000 to 2007 using the cohort from 2001 to 2007.
- Model adjusts for age, race, smoking status, pack-years, BMI, marital status, alcohol use, second-hand smoke, diet, physical activity, menopausal status, HRT use, medications (total of 47 terms)
- Age stratified, Time-varying exposures
- Pollutants entered separately
- Interquartile range IQR (75^{th} -25^{th}) used

Outcomes

- All-cause (non-traumatic) mortality
- Cardiovascular mortality
- Ischemic heart disease mortality (IHD)
- Pulmonary mortality

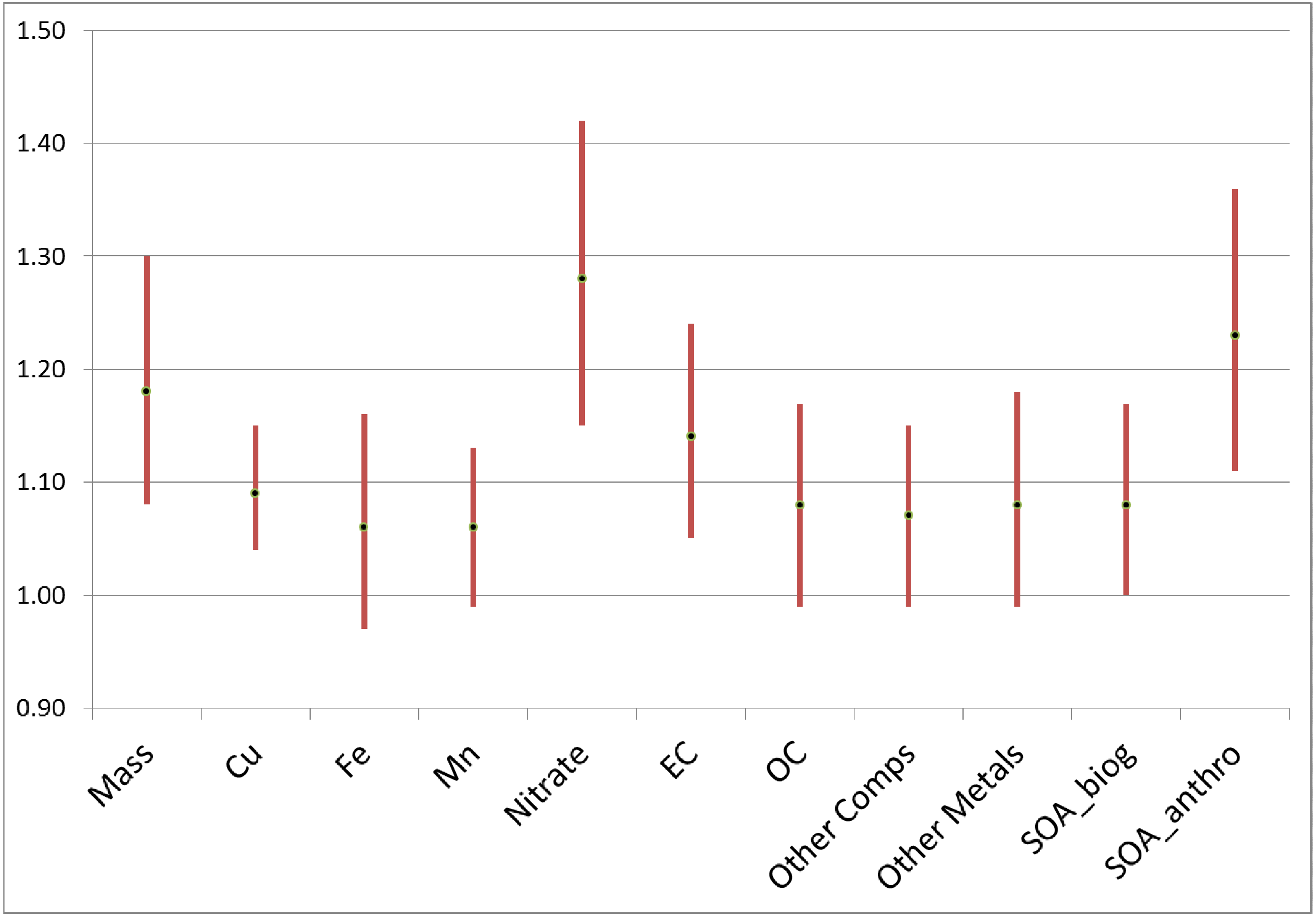
Mortality Results for PM2.5 using 4km grids

Comparison for Ischemic Heart Disease Mortality

Cohort	Lead Author	Hazard Ratio
Am Cancer Society (National)	Pope (2002)	1.18 (1.14, 1.23)
Am Cancer Society (California)	Jerrett (2013)	1.11 (1.05, 1.18)
Harvard Six Cities	Laden (2006)	1.26 (1.08, 1.47)
Women's Health Initiative	Miller (2007)	F:1.67 (0.98, 2.85)
Nurses Health Study	Puett (2009)	F:2.02 (1.07, 1.77)
All Canada	Crouse (2012)	1.31 (1.27, 1.35)
CTS (PM & cohort:2000-05, smoothed surface of 80 monitors)	Lipsett (2011)	F: 1.20 (1.02, 1.41)
CTS (PM: 2000-2007)	Current	F: 1.18 (1.08, 1.30)
Rome Cohort (age < 60)	Cesaroni (2013)	1.23 (1.08, 1.40)

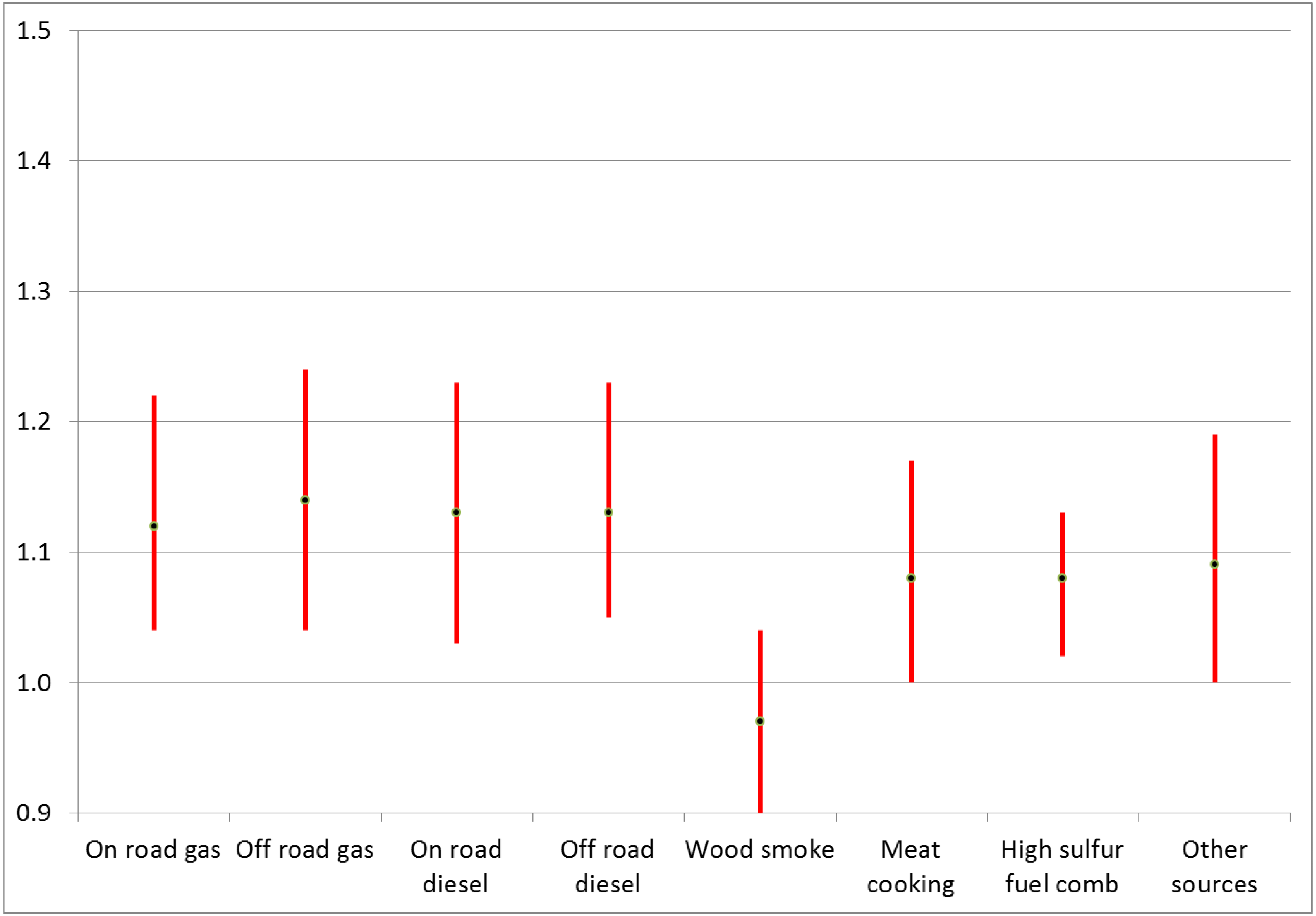
Association of PM2.5 Constituents with IHD Mortality

(Hazard Ratios and 95% CI Using IQR)



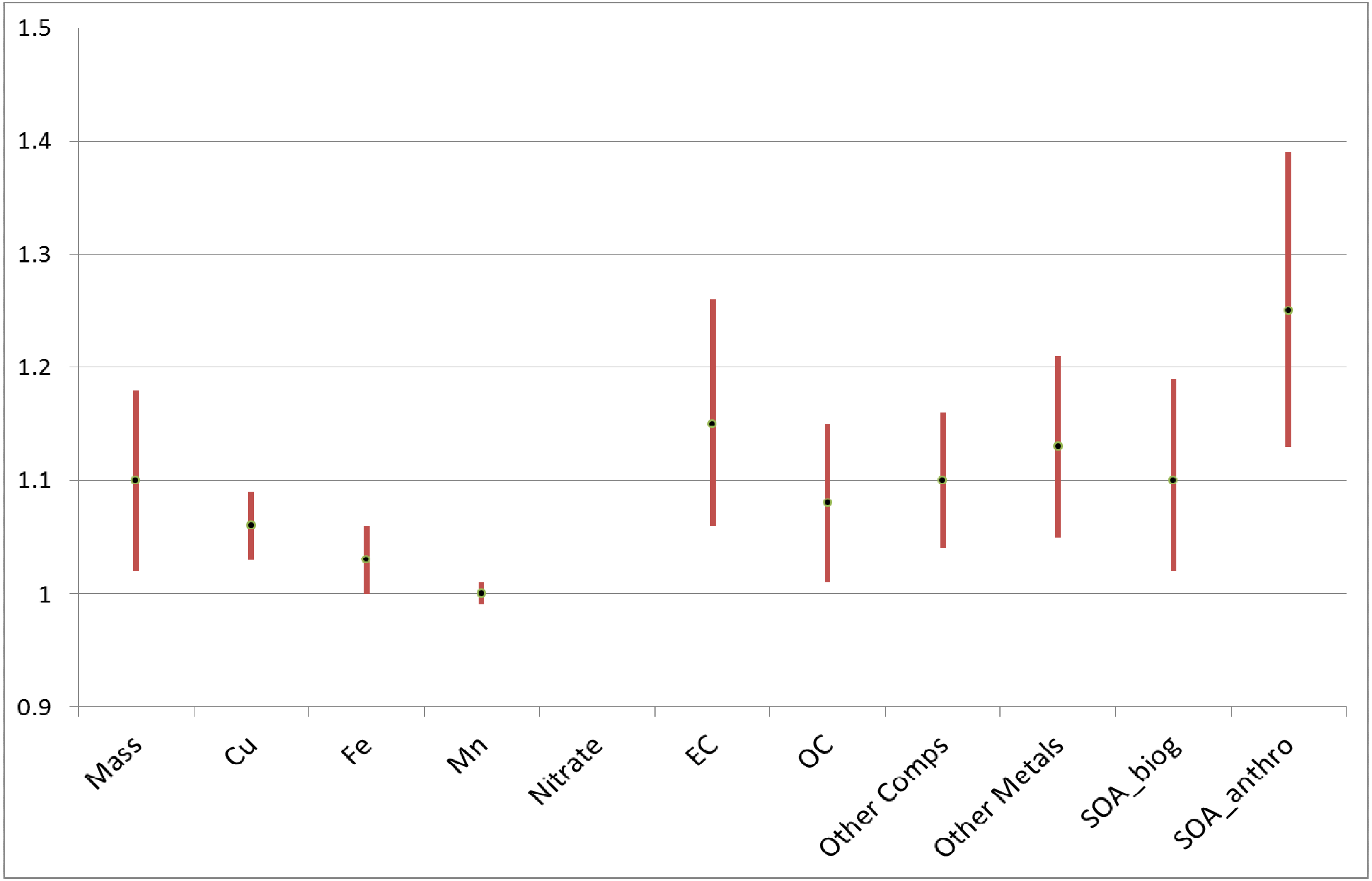
Association of PM2.5 Sources with IHD Mortality

(Hazard Ratios and 95% CI Using IQR)



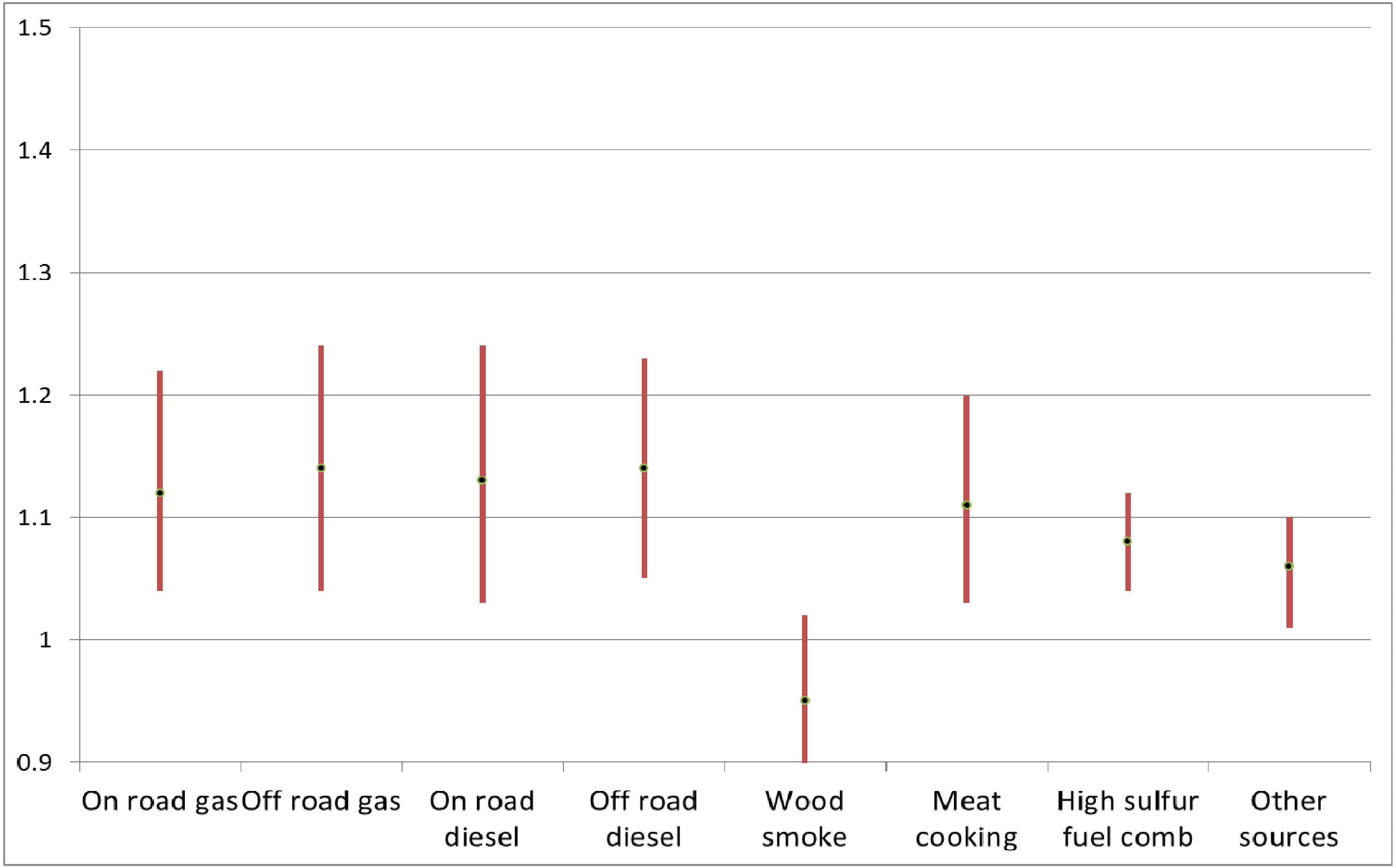
Association of UF Constituents with IHD Mortality

(Hazard Ratios and 95% CI Using IQR)



Association of UF Sources with IHD Mortality

(Hazard Ratios and 95% CI Using IQR)



Comparison of PM2.5 and UF species

Better fit for UF except for mass and SOA_ant

Conclusions

1. Our PM2.5 estimates based on UC Davis model yield consistent results for IHD mortality using the California Teachers cohort

2. PM2.5 and UF mass and species associated with IHD

3. Some PM2.5 and UF species have higher risk estimates than mass

4. UF species provide slightly better fit of the data than PM2.5 species

5. Mobile sources especially important

6. Evidence that sources of PAH are important