Associations of Mortality with Long-Term Exposures to Fine and Ultrafine Particles

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Collaborators

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Health Effects of Ultrafine Particles

- Toxicology and clinical studies suggest serious health consequences associated with exposure to ultrafine particles

- Epidemiological evidence of ultrafine particle health effects, especially from long-term exposure has been more difficult to establish
  - Difficult to estimate exposure spatially
  - Debate about the most appropriate metric

Our study combines:

- Health Data: California Teachers Study (CTS) Cohort

- Exposure Data on Fine and Ultrafine Particles and their Constituents and Sources: UCD/CIT Source Oriented Chemical Transport Model

California Teachers Study Cohort: Background

- Statewide cohort (133,479) of female members of State Teachers Retirement System
- Originally NIH-funded study on breast cancer
- Annual re-contact since inception in 1995

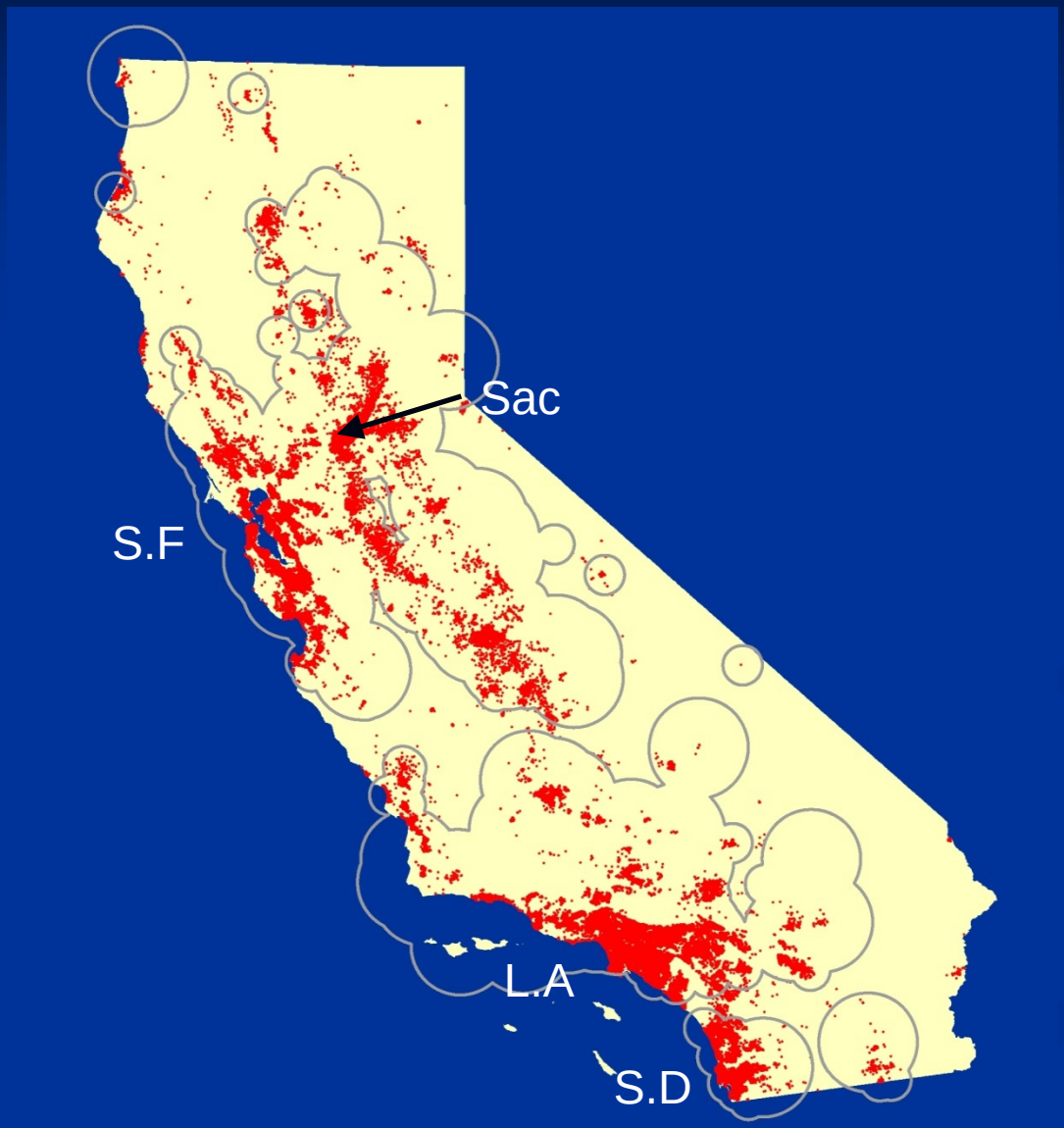
California Teachers Study Cohort: Characteristics

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

CTS Cohort Characteristics

- 86% Non-Hispanic white
- 90% teachers, 10% other professional school employees
- 35% retired
- N = 101,884 included in our study
- Ischemic Heart Disease mortality = 1,085

Study Particpant Locations

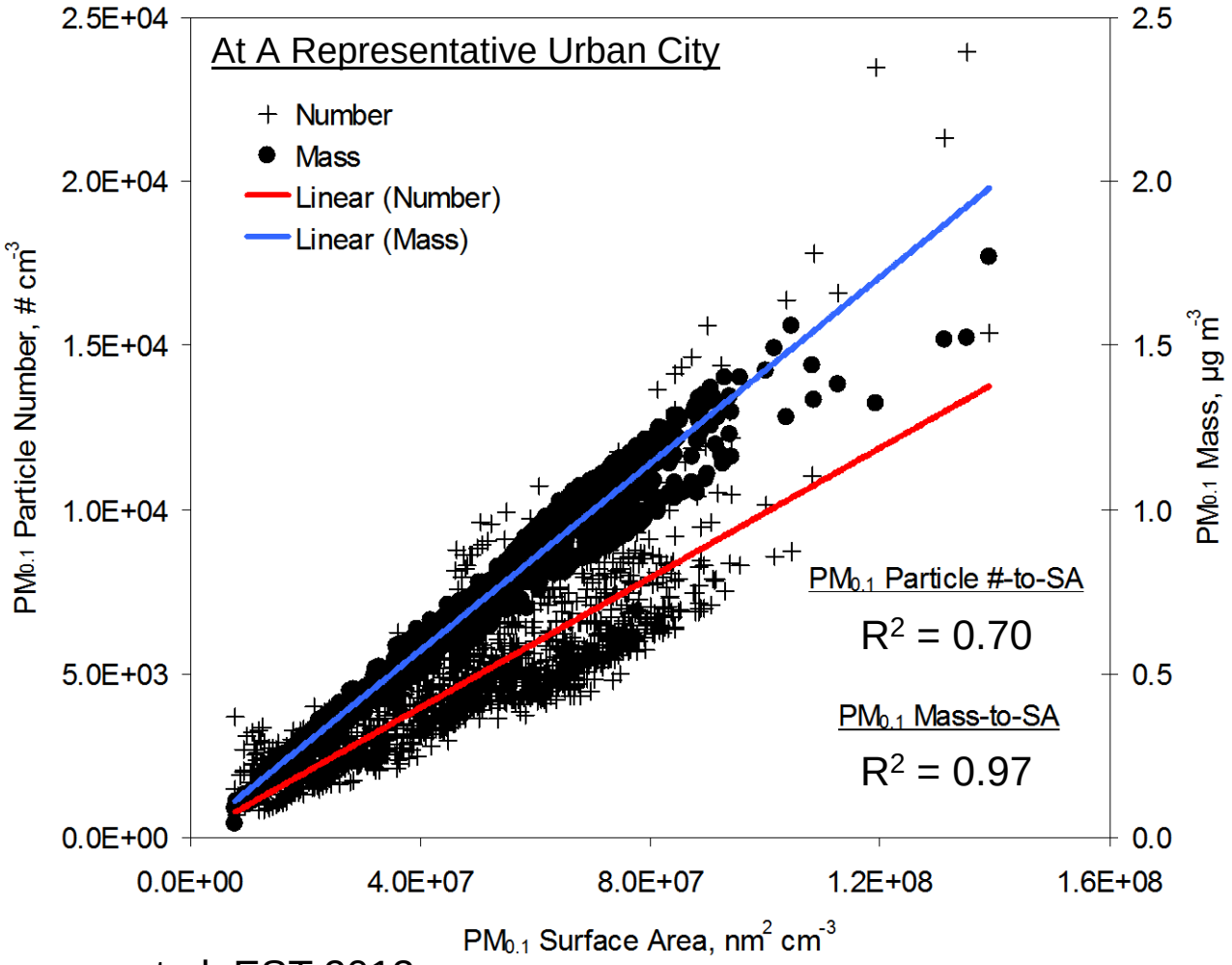


Wide range of PM exposures

Exposure Model

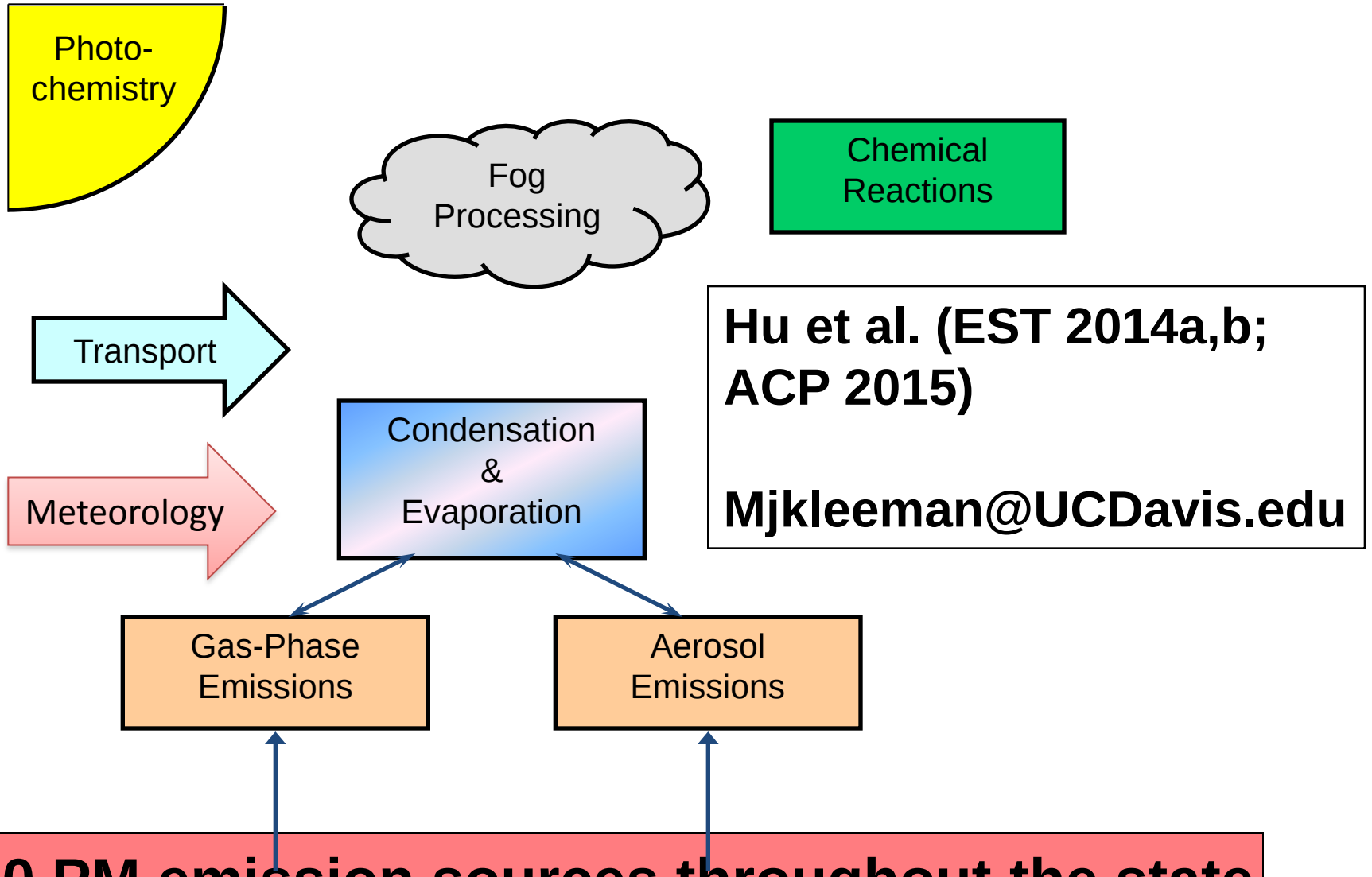
- Predicts $PM_{2.5}$ and $PM_{0.1}$ on daily basis for 2000 through 2007
- Mass, species and sources (using PMF)
- 4km grid cells
- Most of California included: about 85% of the population (15,000 cells)

Why Are We Interested in $PM_{0.1}$ Mass?



Source: Kuwayama et al, EST 2013

UCD/CalTech Model Predicts Concentrations of $PM_{2.5}$ and $PM_{0.1}$ for Each 4km Grid Cell



Hu et al. (EST 2014a,b; ACP 2015)

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Computational Burden

- Run Time (produce daily, biweekly, monthly data)
  - Meteorology Simulations:
    - 2 month using 336 CPUs
  - Air Quality Simulations:
    - primary – 3 months using 672 CPUs
    - secondary – 3 months using 960 CPUs

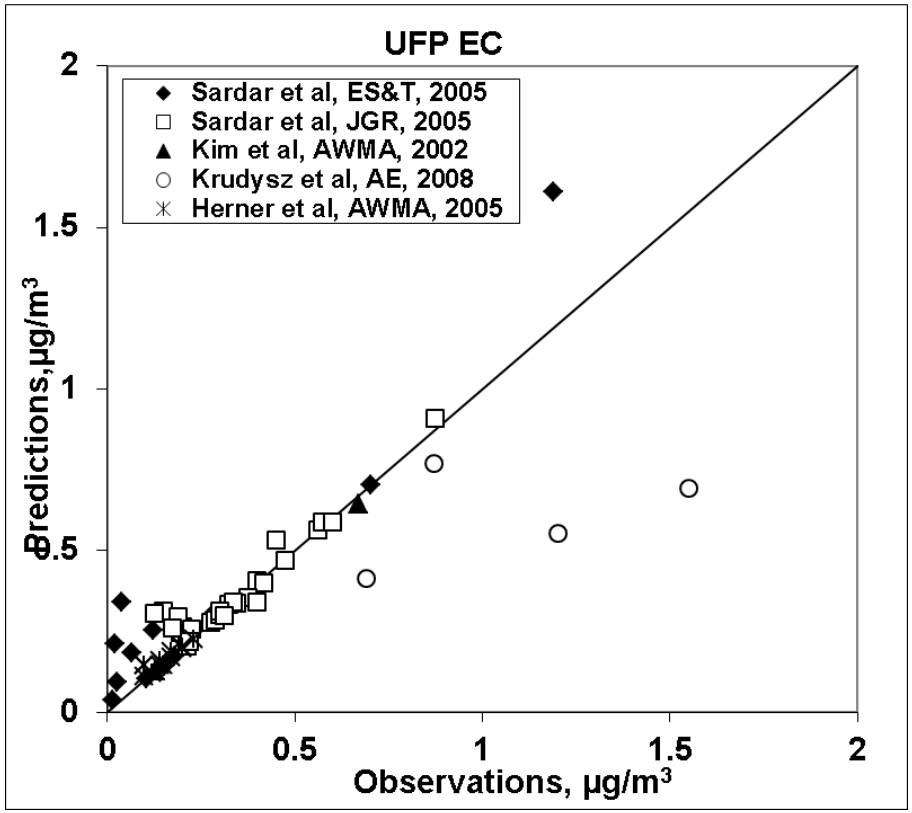
- Storage Space
  - ~5T meteorological data
  - ~1T emissions inputs
  - ~7T primary PM outputs
  - ~3T secondary PM outputs

$PM_{2.5}$ and $PM_{0.1}$ Pollutants Examined

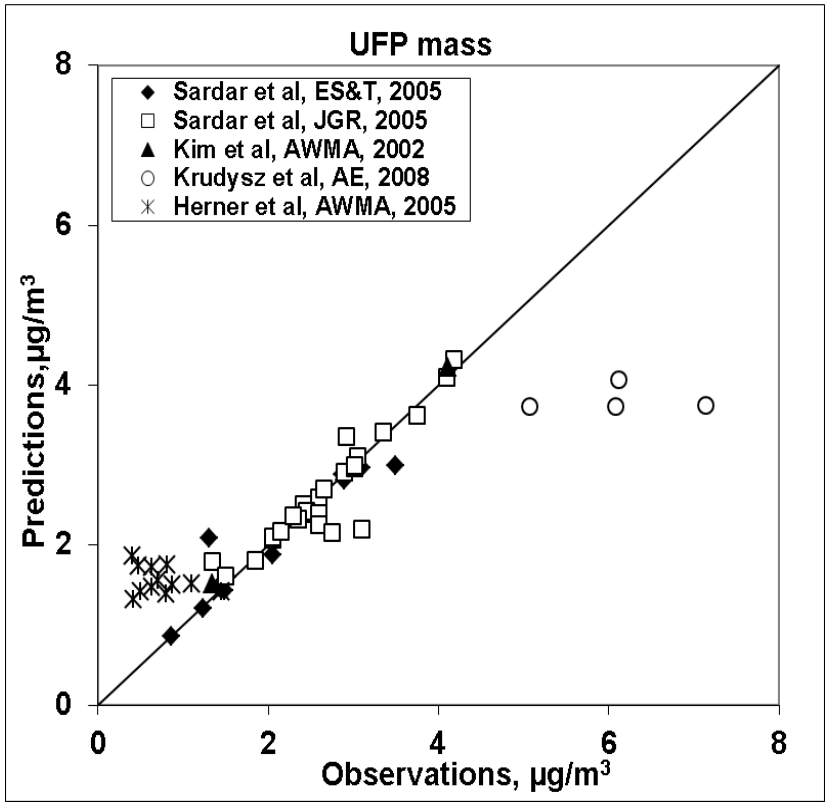
- Mass
- Constituents*: Cu, Fe, Mn, other metals, nitrate, EC/OC, other compounds, biogenic SOA, anthro SOA (derived from long alkanes, xylenes, toluenes, benzene, oligomerization)
- Sources of Mass from: on- and off-road gasoline, on- and off-road diesel, woodsmoke, meat cooking, high sulfur content fuel combustion, biogenic sources, other anthropogenic

* Selection based on certainty of estimates, mass, correlates, biologic plausibility. No large industrial sources

Model Evaluation
Annual Average $PM_{0.1}$ EC and Mass

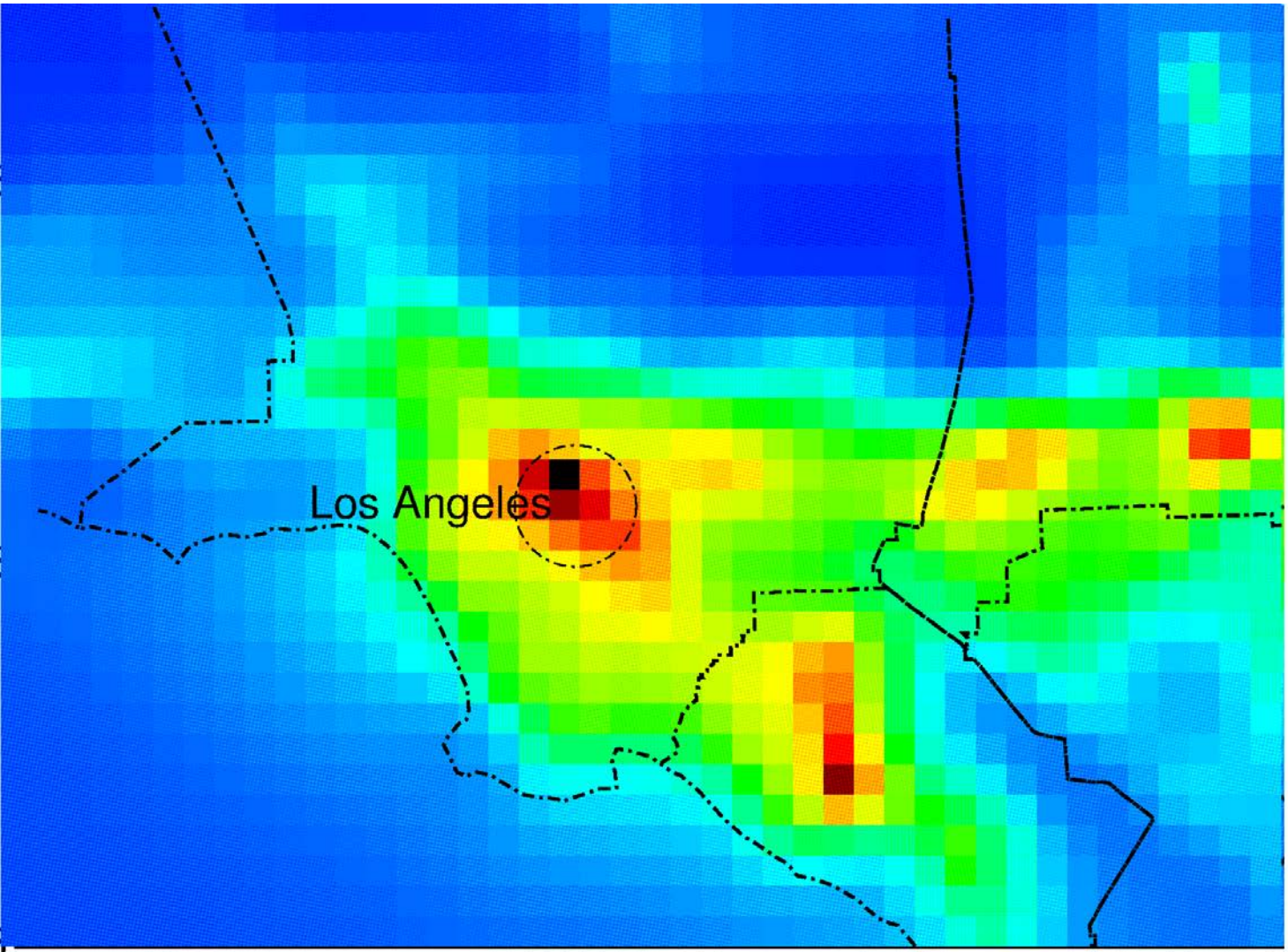


correlation=0.94



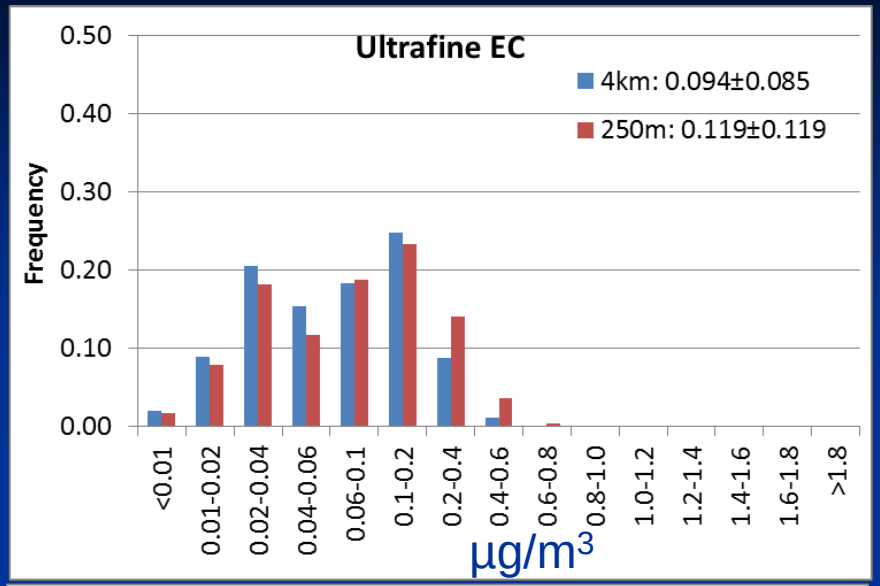
correlation=0.81

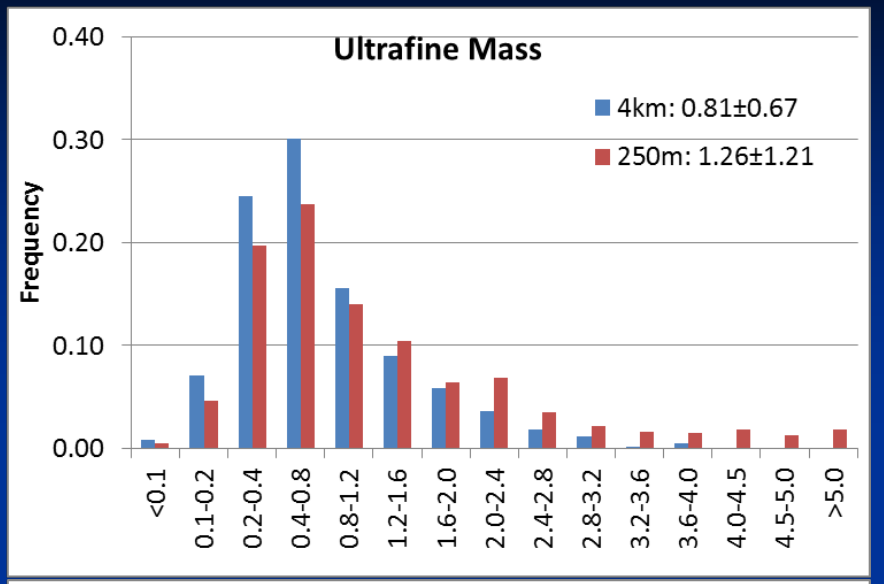
Spatial representation of concentrations of Ultrafine EC in Los Angeles and Surrounding Counties (µg/m³)

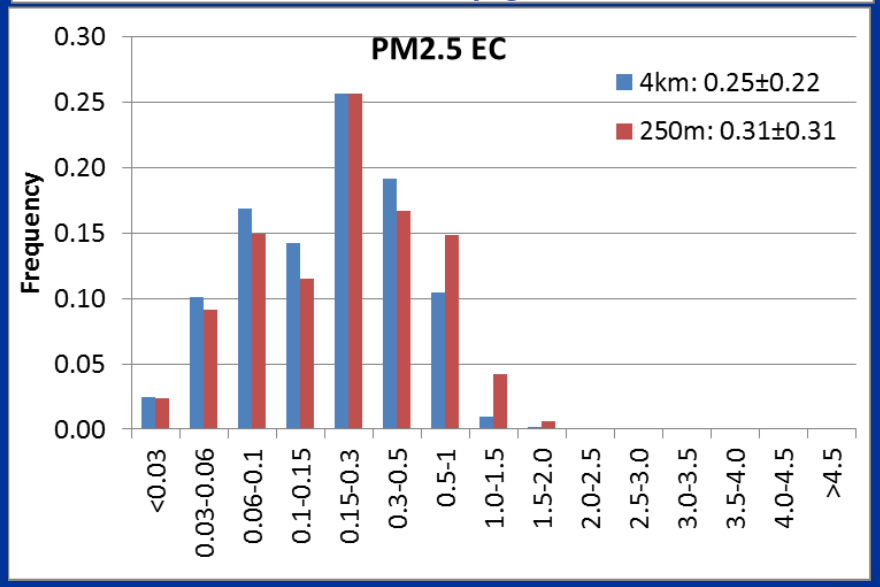


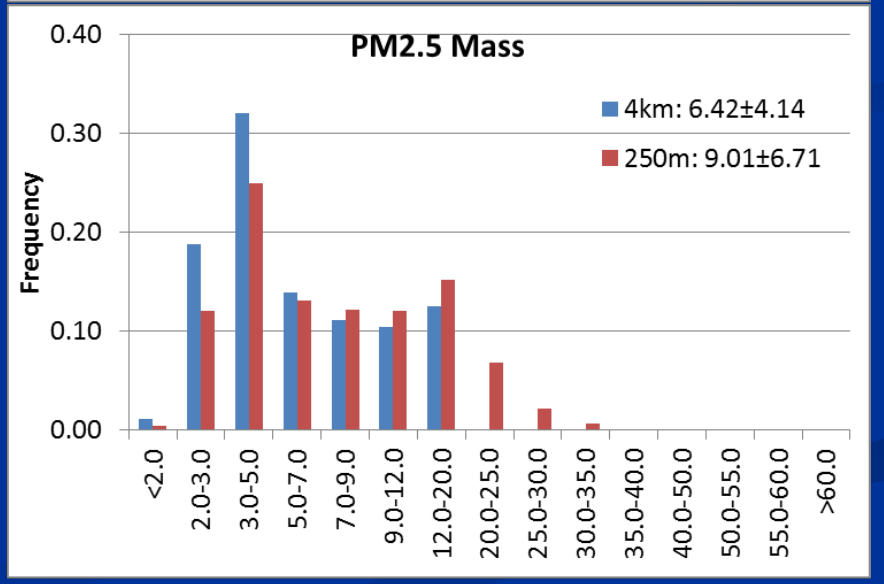
Results indicate that central monitor may not be representative of exposure for nearby population.

What about near source exposures?





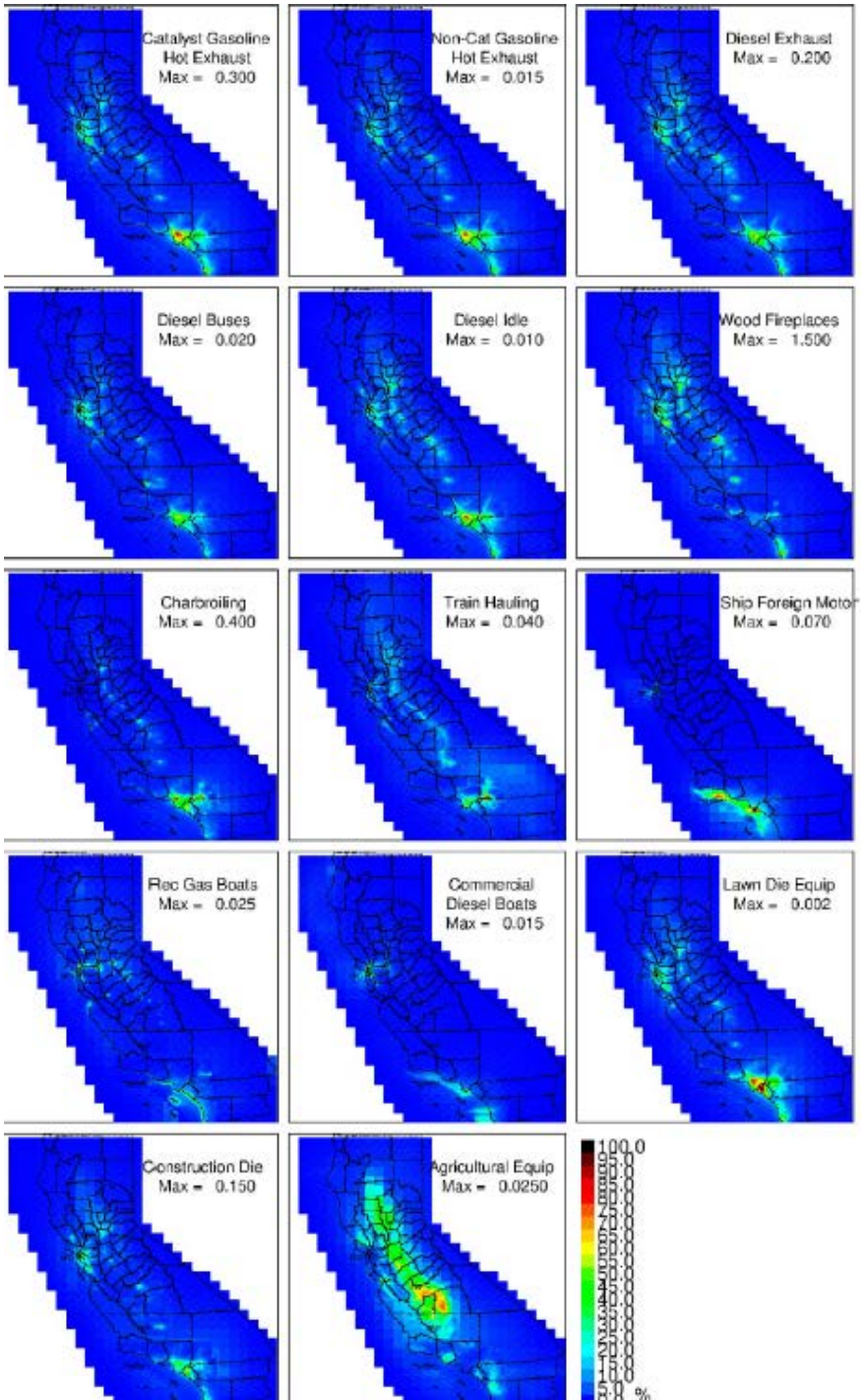




The 4km resolution captures the majority of the variance across the exposure concentrations in Oakland, CA.

Additional Model Findings

- Increasing averaging time improved the agreement between predictions and measurements
- Given modeling results, confidence in source contribution estimates at times and locations without monitoring data
- Average inter-species correlation = 0.6
- Predicted annual average spatial distributions showed significant heterogeneity among $PM_{0.1}$ species and sources



Primary predicted $PM_{0.1}$ mass concentrations

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, hormone replacement therapy use, medications (total of 47 terms) (+ 6 neighborhood variables)
- Cumulative average of each pollutant from 2000 to event then added to model
- Risks using Interquartile range (IQR) (75^{th} -25^{th})
- Focus on Ischemic Heart Disease (IHD)

Mortality Results for $PM_{2.5}$ using 4km grids

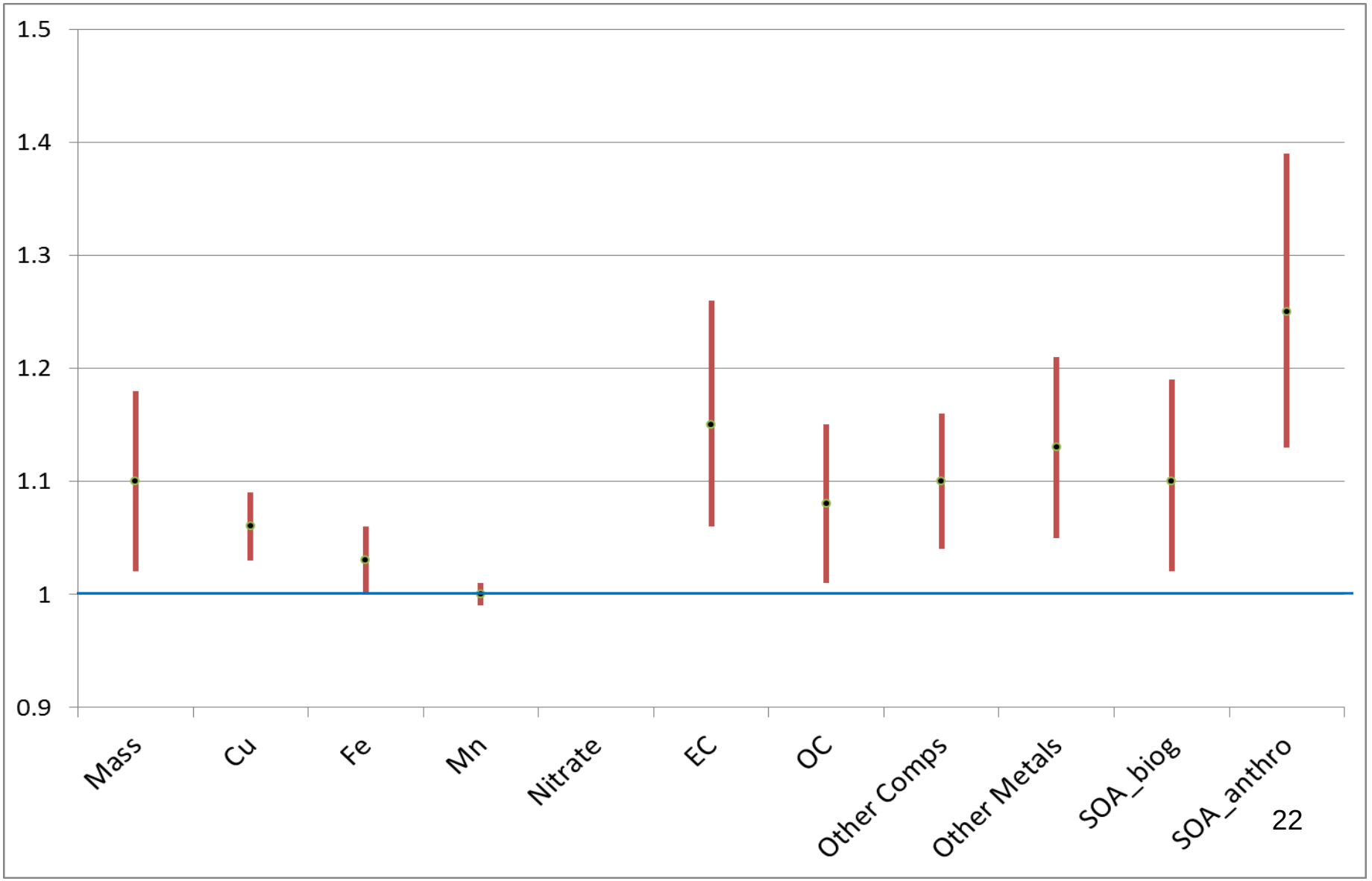
(Proof of Concept)

Hazard ratios Comparison for Ischemic Heart Disease Mortality per 10 µg/m^3

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, IDW smoothed surface of 80 monitors)	Lipsett (2011)	F: 1.20 (1.02, 1.41)
CTS (PM: 2000-2007)	Present	F: 1.18 (1.08, 1.30)

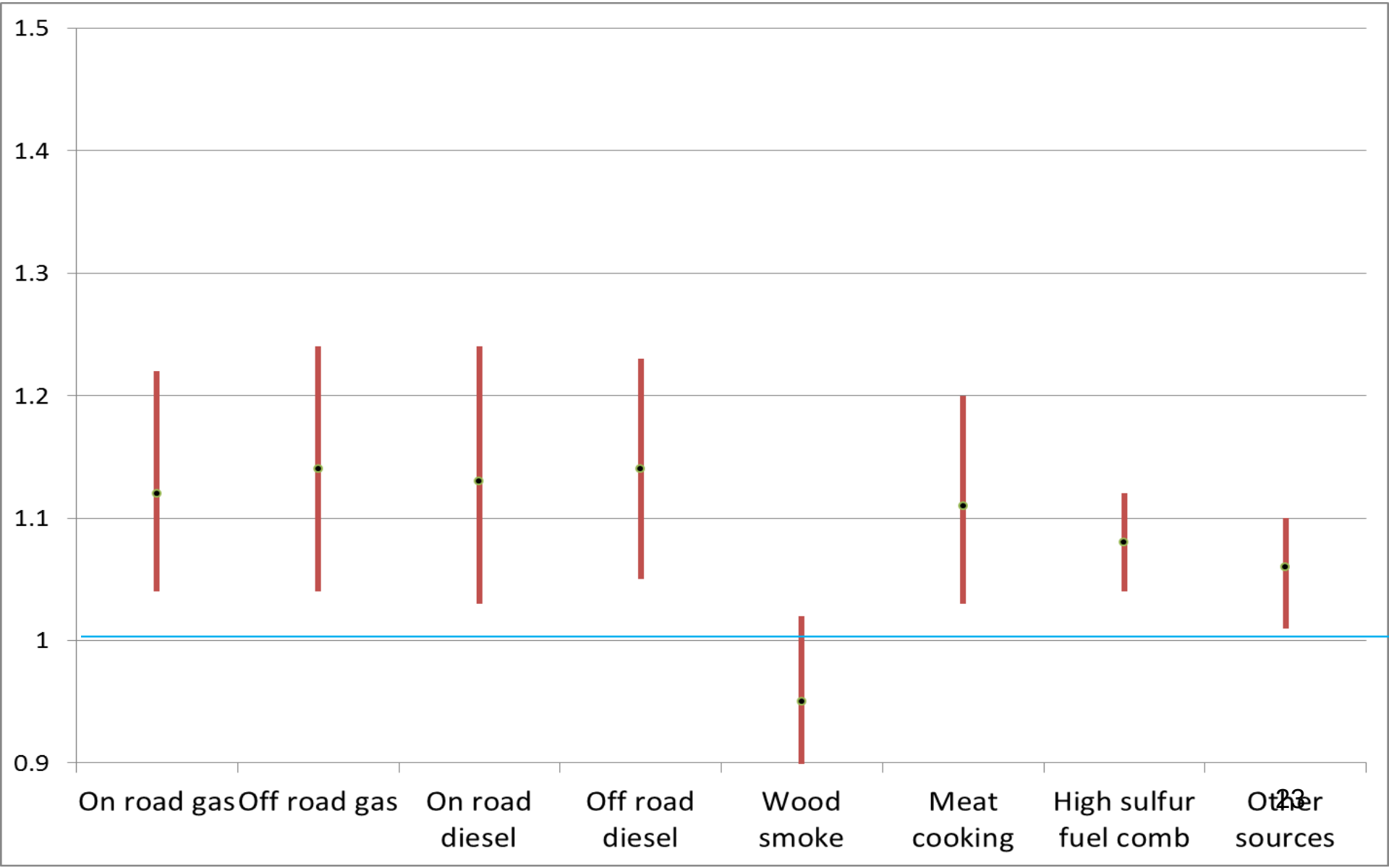
Association of $PM_{0.1}$ Constituents with IHD Mortality

(Hazard Ratios and 95% CI Using IQR)



Association of $PM_{0.1}$ Sources with IHD Mortality

(Hazard Ratios and 95% CI Using IQR)



Additional Analyses of $PM_{2.5}$ and UF constituents

1. Generally each of the UF species fit the data better than corresponding $PM_{2.5}$

2. Examined two pollutant models for species with largest risk estimates: UF_SOA
   - SOA statistically significant in all 2 poll models
   - Cu also significant

3. Correlation of NO_2 with UF_mass (0.89), UF_EC (0.70) and UF_SOA (0.20)

Conclusions

1. Estimating long-term exposure to UF appears promising
2. $PM_{2.5}$ and UF mass and species associated with IHD
3. UF species provide slightly better fit of the data than $PM_{2.5}$ species
4. Some species have higher risk estimates than mass

Future Research

- Estimate UF mass, PNC, Surface Area at 1km grid
- More years (1995-2015)
- Improved accuracy of exposure models, greater spatial resolution and more years may reduce high inter-correlations among species and sources
- Conduct studies of $PM_{0.1}$ and PNC with inflammatory markers, cognitive function?