

A photograph of a wildfire with tall pine trees in the foreground and a large fire in the background. The fire is intense, with bright orange and yellow flames rising from the ground and consuming the lower parts of the trees. Thick black smoke billows from the fire, filling the sky. The foreground shows the dark silhouettes of several tall pine trees, some of which are partially obscured by the fire and smoke.

Wildfire Smoke Exposure and Population Health

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Respiratory health effects

Health End Point	Direction of Effect	Selected Sources
Respiratory, all	↑↑	Henderson et al. 2011, Rappold et al. 2011, Tham et al. 2009, Thelen et al. 2013, Delfino et al. 2009, Martin et al. 2013, Morgan et al. 2010 and more
Asthma	↑↑	Vora et al. 2011, Elliott et al. 2013, Caamano-Isorna et al. 2011, Henderson et al. 2011, Rappold et al. 2011, Delfino et al. 2009, Martin et al. 2013, Morgan et al. 2010, and more
	↑	Arbex et al. 2000, Johnston et al. 2007
COPD	↑↑	Elliott et al. 2013, Caamano-Isorna et al. 2011, Rappold et al. 2011, Martin et al. 2013, Morgan et al. 2010, Delfino et al. 2009 and more
Pneumonia and bronchitis	↑↑	Rappold et al. 2011, Delfino et al. 2009, Morgan et al. 2010
	↑	Martin et al. 2013

Cardiovascular health effects

Health End Point	Direction of Effect	Selected Sources
Cardiovascular, all	↔	Henderson et al. 2011, Rappold et al. 2011, Morgan et al. 2010, Martin et al. 2013, and more
Ischemic heart disease	↑↑ ↑ ↔ ↓	Johnston et al. 2007 Mott et al. 2005, Martin et al. 2013 Morgan et al. 2010, Delfino et al. 2009, Johnston et al. 2007
Congestive heart failure/cardiac arrests	↑↑ ↑ ↔	Rappold et al. 2011, Dennekamp et al. 2011 Delfino et al. 2009 Morgan et al. 2010, Martin et al. 2013
Hypertension	↔	Henderson et al. 2011
Cardiac dysrhythmias/Arrhythmias	↔	Delfino et al. 2009, Martin et al. 2013
Cerebrovascular disease/stroke	↑	Delfino et al. 2009, Morgan et al. 2010,

Mortality

Health End Point	Direction of Effect	Selected Sources
Mortality		
All	↑↑ ↑	Shaposhnikov et al. 2014, Analitis et al. 2012 Sastry 2002, Johnston et al. 2011a, Morgan et al. 2010
Respiratory	↑↑ ↔	Analitis et al. 2012 Morgan et al. 2010, Johnston et al. 2011a
Cardiovascular	↑↑ ↑ ↔	Analitis et al. 2012 Johnston et al. 2011a Morgan et al. 2010

339,000 (260,000-600,000) annual deaths estimated to be due to exposure to PM_{2.5} from landscape fires globally (Johnston et al. 2012)

- Most in Sub-Saharan Africa and Southeast Asia
- Used chemical transport models and satellite data to make exposure estimates

Fires effect on birth weight

Table 2. Estimated effect of wildfire event during gestation on birth weight (g), by trimester.

Trimester of exposure	Unadjusted model		Adjusted model	
	Effect (g)	95% CI	Effect (g)	95% CI
Third (≥ 29 weeks)	-7.9	(-12.8, -3.1)	-7.0	(-11.8, -2.2)
Second (17–28 weeks)	-17.1	(-21.9, -12.3)	-9.7	(-14.5, -4.8)
First (1–16 weeks)	-3.9	(-7.8, 0.0)	-3.3	(-7.2, 0.6)
Any trimester	-8.8	(-11.5, -6.1)	-6.1	(-8.7, -3.5)

Adjusted model includes terms for fetal sex, gestational age, parity, maternal age, maternal education, maternal race/ethnicity, secular trend, and season.

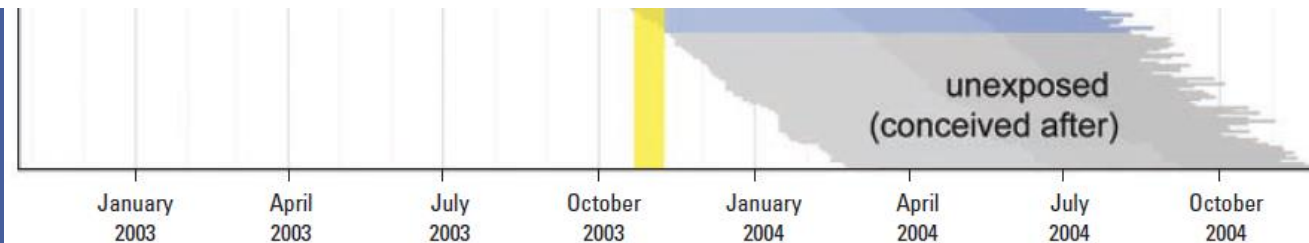


Figure 2. Schematic illustrating exposure assignment. Exposure status was assigned based on the overlap between the wildfire event (yellow) and estimated gestational intervals (horizontal segments). For clarity, gestational intervals are shown ordered from top to bottom by the LMP, and only a 0.1% sample from 2002–2004 is shown. Dates on the x-axis correspond to the beginning of quarters used to adjust for seasonality.

Epidemiological Difficulties

- Fires tend to be
 - In rural areas → small populations
 - Short in duration
- This leads to low power to see a health effect if there is one
- You want a large fire that lasts a long time that covers large population centers



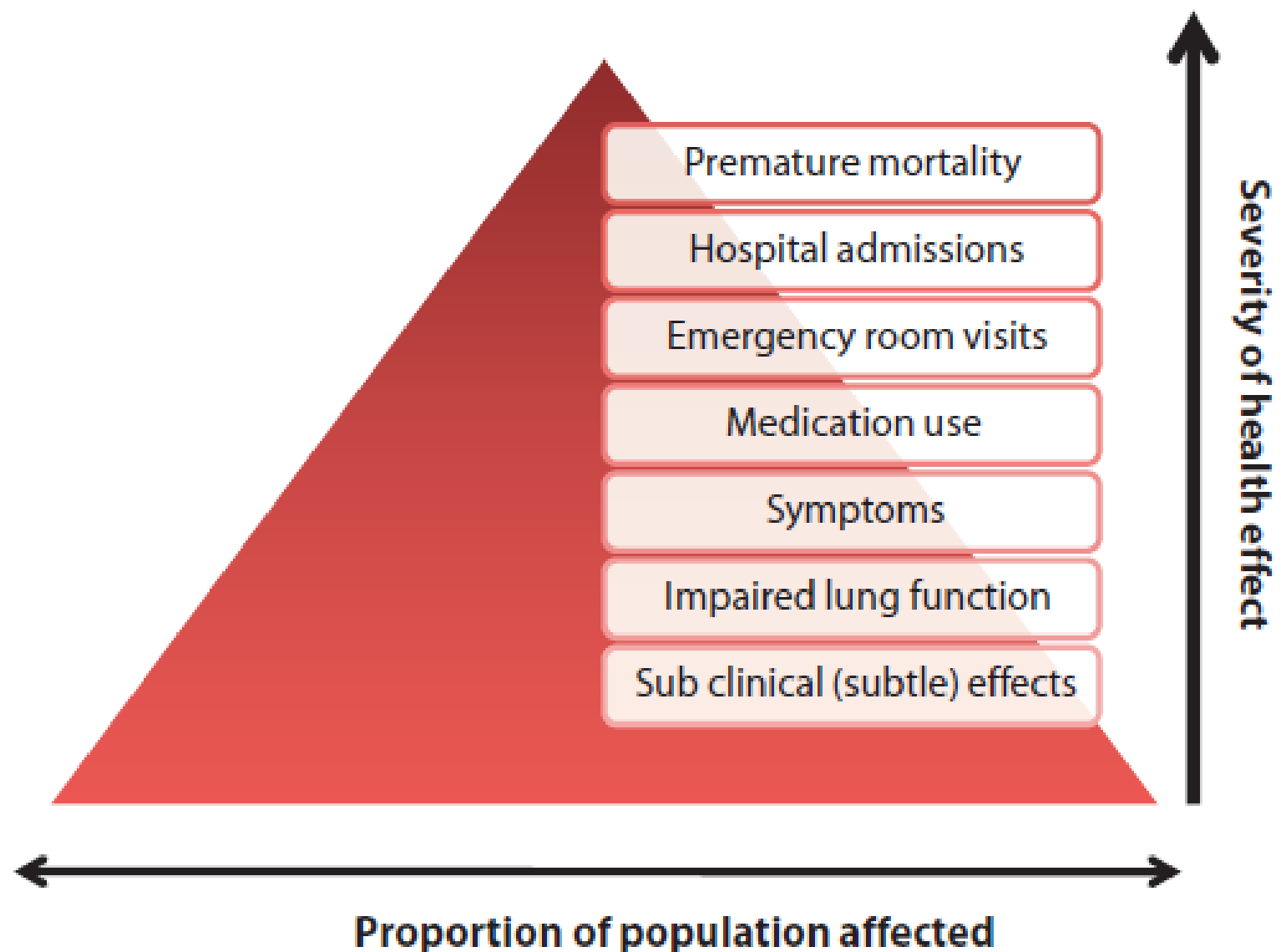


Figure 2 The air pollution health effects pyramid (adapted from American Thoracic Society 2000).⁴³

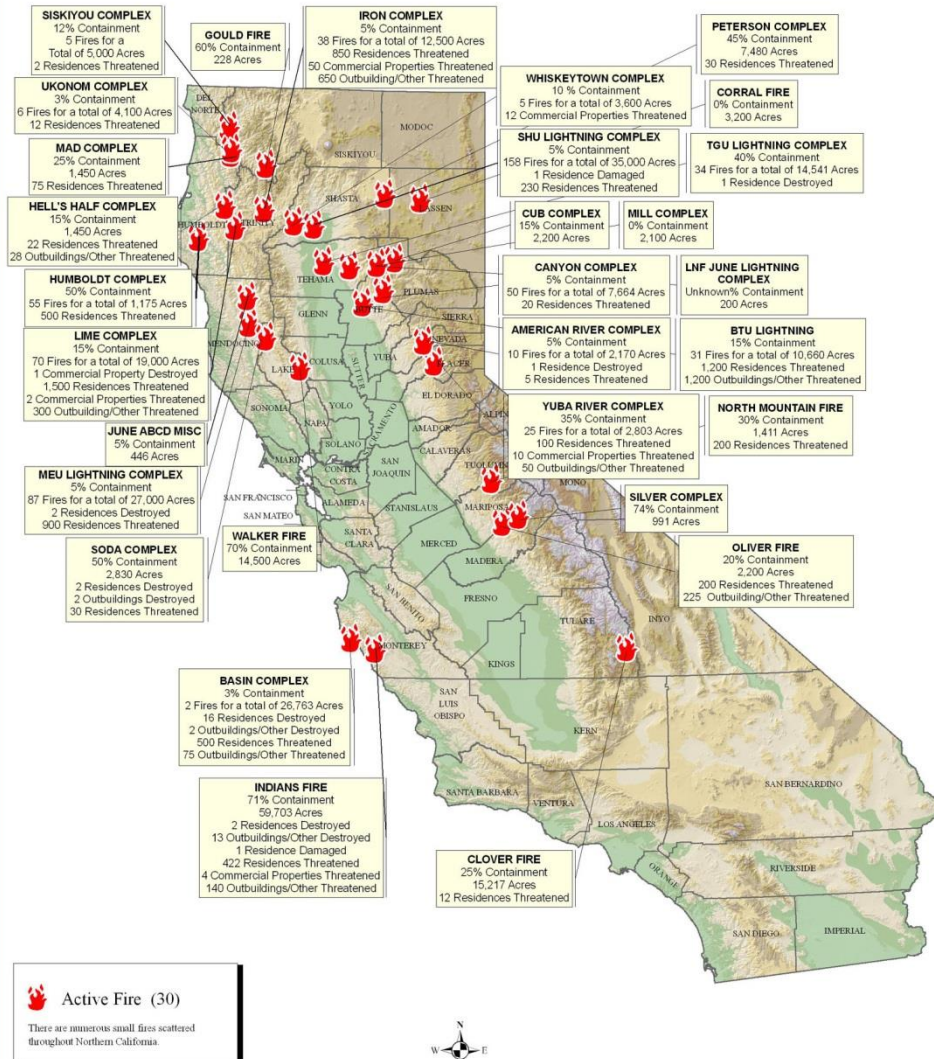
Exposure Assessment Difficulties

- Sparse monitoring network
- Many PM_{2.5} monitors only measure every sixth or third day
- Leads to spatial and temporal averaging of exposure measurements
 - But, smoke plumes migrate quickly, changing exposures over smaller spatial and temporal scales





CALIFORNIA WILDFIRES as of 06/27/08 0800 Hours



2008 northern California wildfires

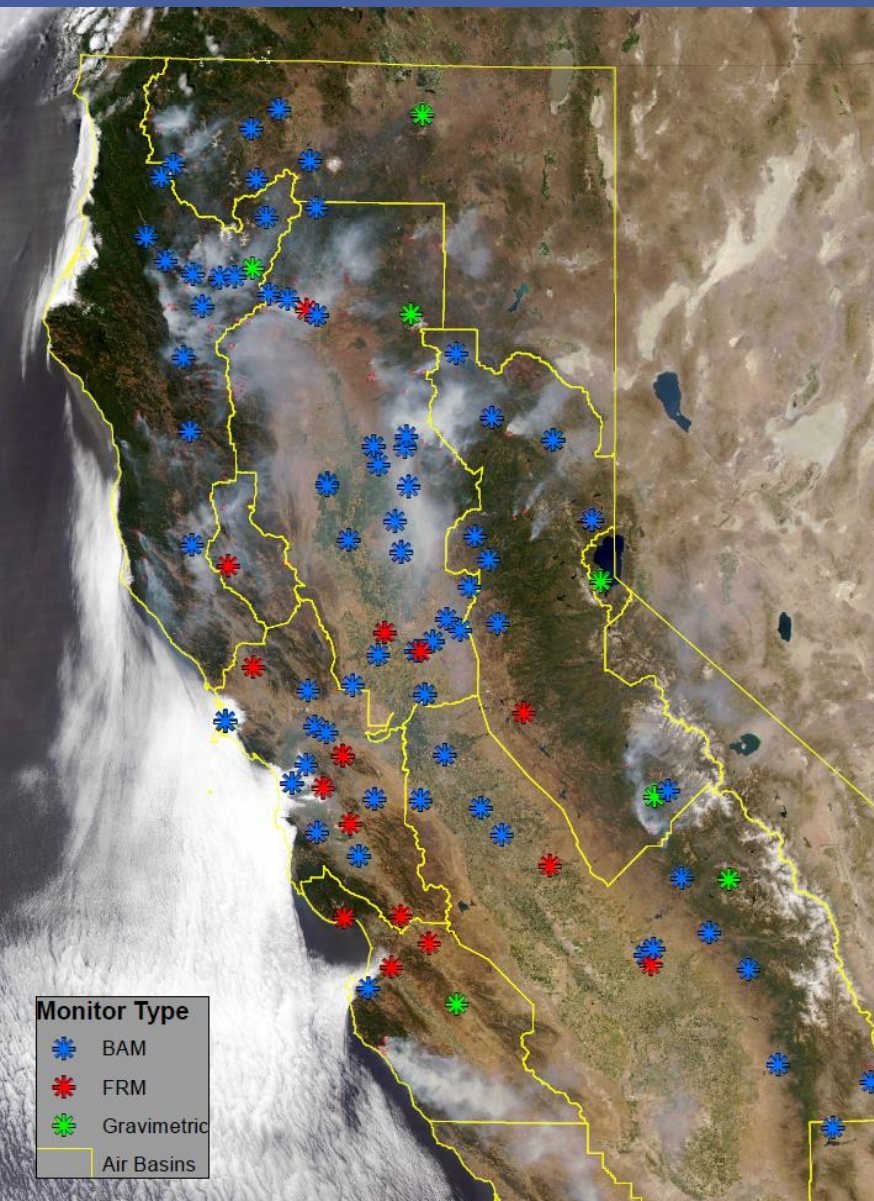
- Lightning storm on June 20-21, 2008
- Over 6000 lightning strikes
- Thousands of fires
- Smoke covered large population areas for weeks (est. 10-12 million people exposed)

Please Note: Fire locations are rough estimates based upon various field sources

Created by OES - GIS, Kris Higgs
June 27, 2008 Source: EAMVEB 2008
active_incidentfires2008 statewide_fire_locations
June Projects statewide_062708_0800_a.mxd



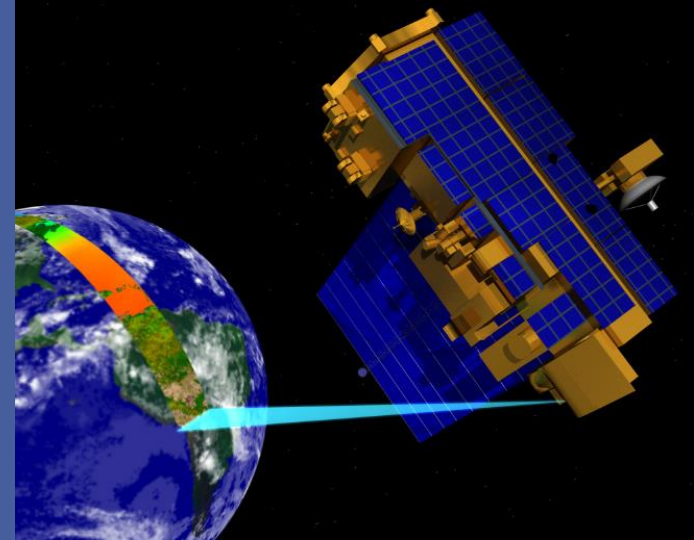
PM_{2.5} Monitoring Data



- 121 PM_{2.5} Monitors
 - EPA, CARB, USFS
 - 38 FRM
 - 16 other gravimetric
 - 67 BAMs
- Co-located FEM monitors agree with FRM (Pearson r values 0.94 – 1.00).

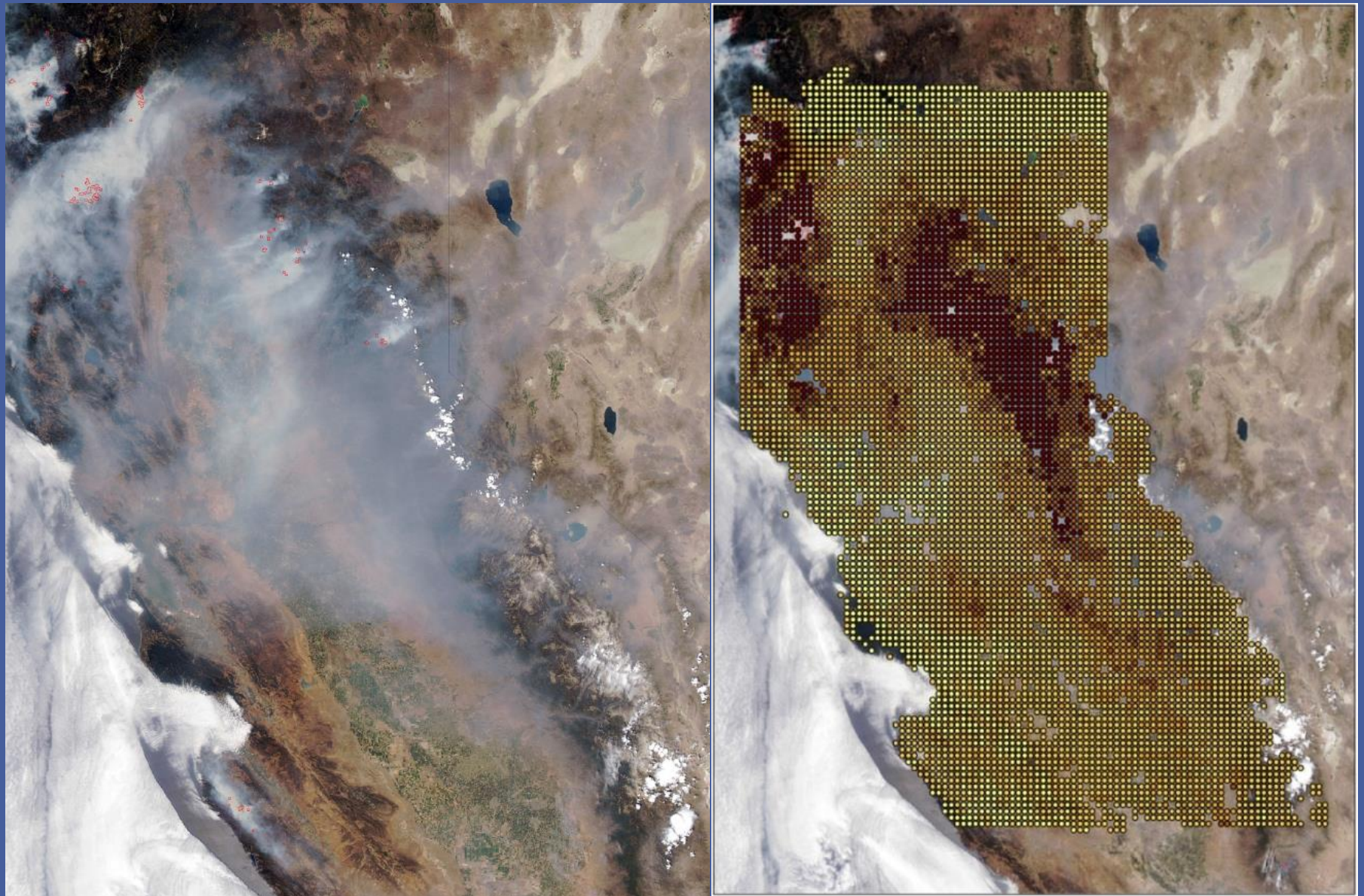
Methods - Data

- Use spatiotemporal data
 - Aerosol optical depth
 - (GASP, MODIS, STI)
 - Chemical transport model (WRF-Chem from NCAR, Gabi Pfister)
- Use other covariates that should influence $PM_{2.5}$
 - Meteorological variables, land-use characteristics, elevation, traffic metrics, time and space indicators



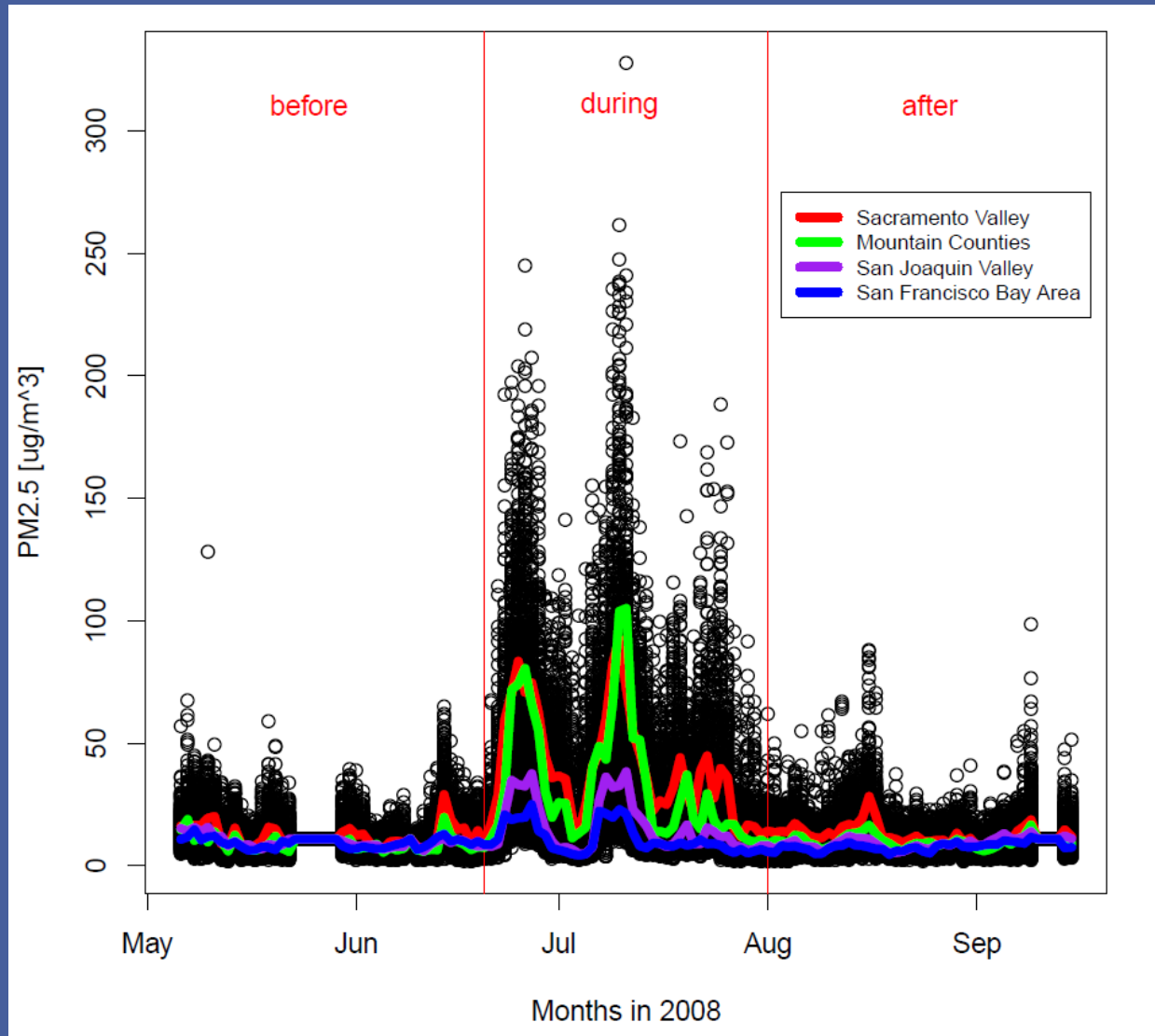
http://www.ntsg.umd.edu/sites/ntsg.umd.edu/files/imce/EOS_AM1_scan.jpg

July 11, 2008



Large circles are observed values at monitors, small circles are predicted values

PM_{2.5} exposure estimates by ZIP code by day for the 2008 northern California wildfires

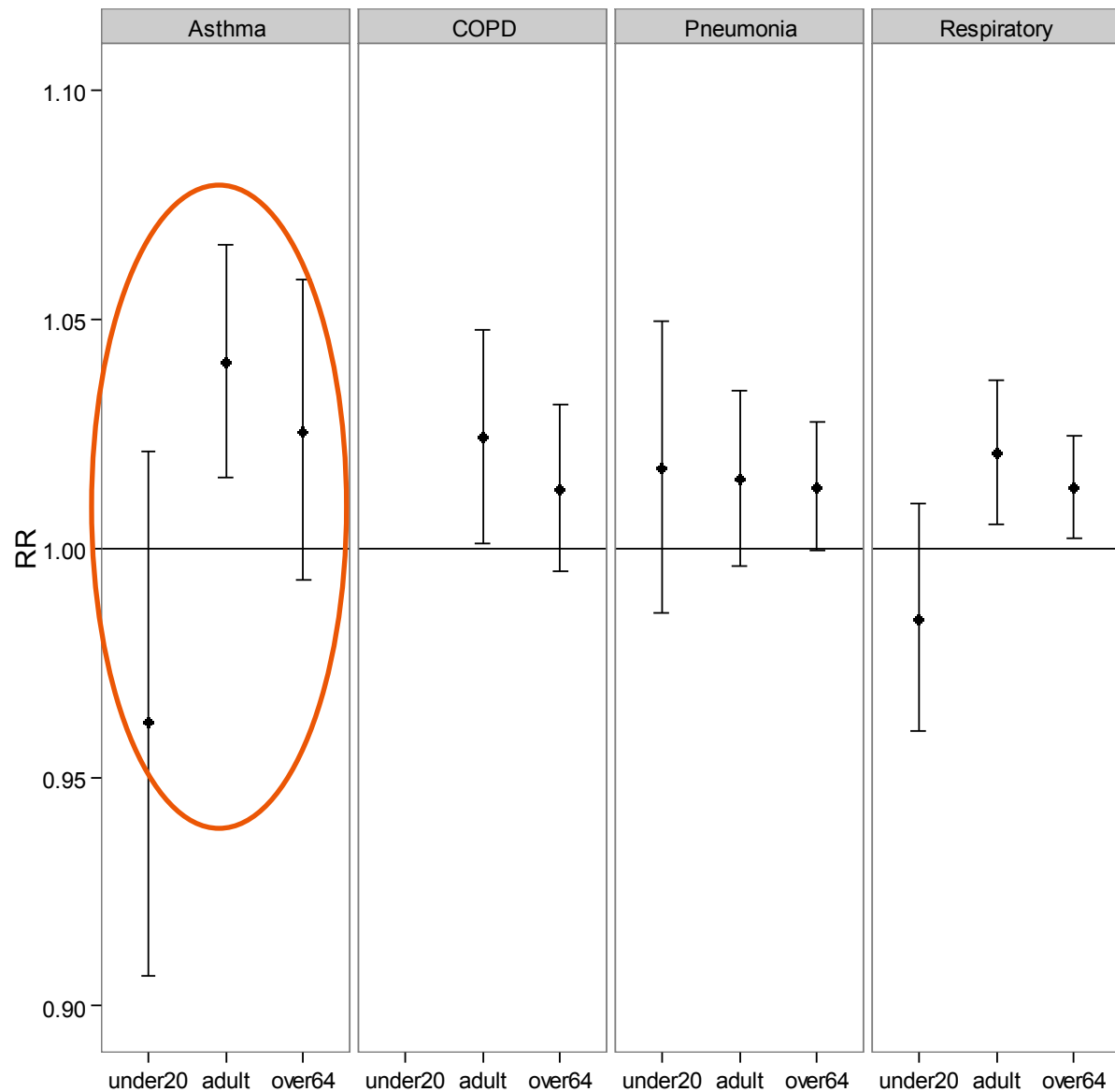


Relative risks of hospitalization associated with PM_{2.5} before, during, and after the 2008 northern California wildfires

	RR for a 5 µg/m ³ change in PM _{2.5}					
	Before Fires RR (95% CI)	During Fires RR (95% CI)	After Fires RR (95% CI)	p-value comparing during and before	p-value comparing after and before	p-value comparing after and during
All respiratory	1.010 (0.973, 1.048)	1.013 (1.003, 1.023)	1.013 (0.968, 1.060)	0.854	0.898	0.997
Asthma	0.964 (0.881, 1.055)	1.024 (1.004, 1.045)	0.892 (0.778, 1.022)	0.188	0.338	0.046
COPD	1.036 (0.969, 1.108)	1.019 (1.002, 1.035)	1.040 (0.962, 1.125)	0.619	0.933	0.585
Pneumonia	1.009 (0.964, 1.057)	1.013 (1.001, 1.025)	1.057 (1.002, 1.115)	0.868	0.185	0.112
Cardiovascular Disease	1.008 (0.978, 1.039)	0.999 (0.992, 1.006)	1.017 (0.987, 1.047)	0.542	0.648	0.224
Congestive Heart Failure	0.972 (0.919, 1.028)	<i>0.985 (0.973, 0.996)</i>	1.005 (0.946, 1.067)	0.647	0.415	0.504
Ischemic Heart Disease	1.024 (0.975, 1.077)	0.999 (0.988, 1.009)	0.996 (0.949, 1.046)	0.308	0.405	0.912
Dysrhythmias	1.028 (0.973, 1.087)	1.011 (0.999, 1.024)	1.048 (0.988, 1.111)	0.565	0.658	0.230
Cerebrovascular Disease	1.017 (0.965, 1.072)	1.002 (0.991, 1.014)	1.031 (0.981, 1.084)	0.593	0.685	0.278
Hypertension	0.938 (0.848, 1.038)	0.994 (0.969, 1.021)	0.961 (0.865, 1.068)	0.259	0.737	0.528

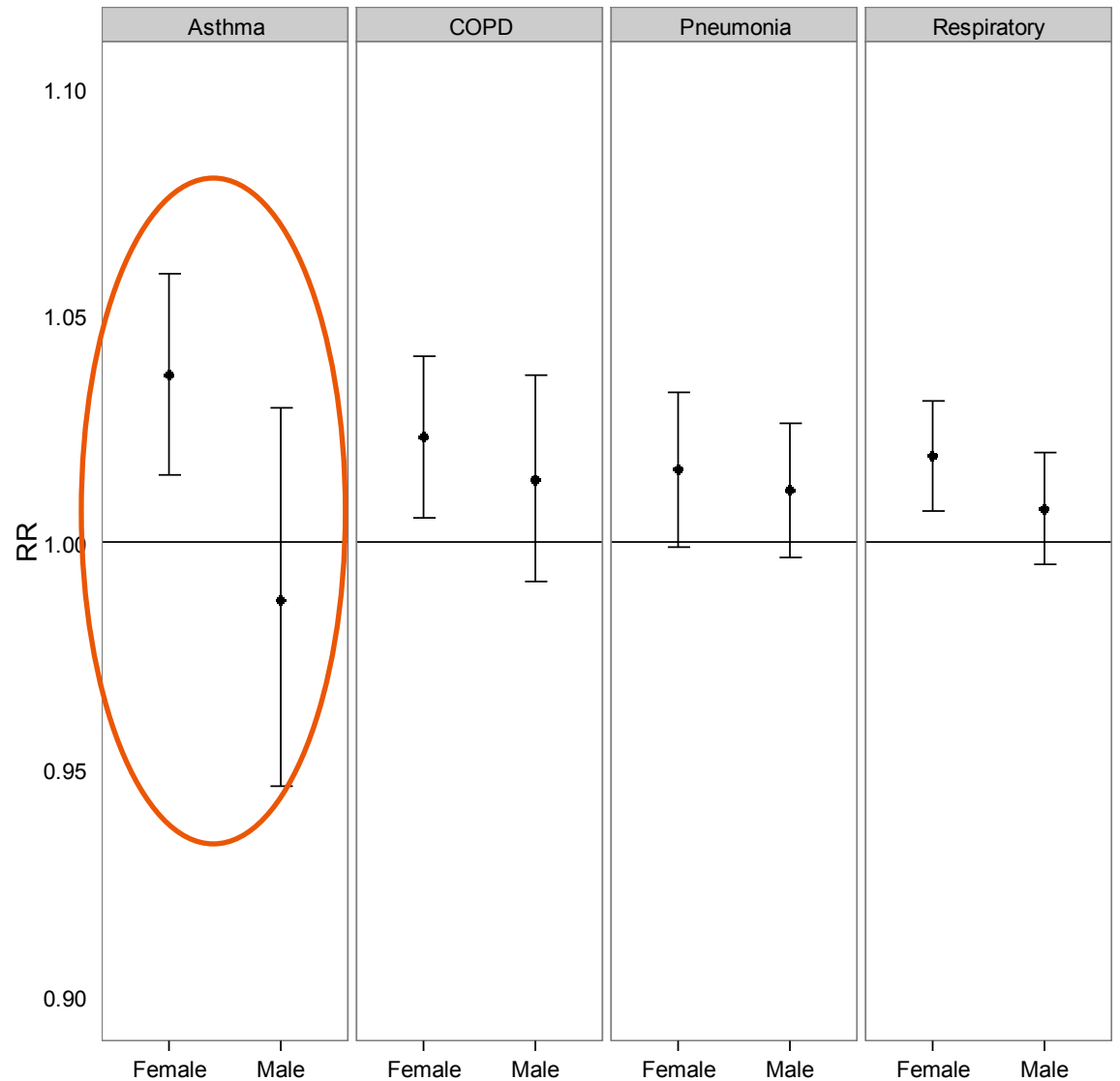
*all models are for the two-day moving average of PM_{2.5} controlling for time trend, day of week, heat index, median income, and percent of population over 65

Relative risks for
a $5 \mu\text{g}/\text{m}^3$
increase in $\text{PM}_{2.5}$
during the fires
by age group for
respiratory
hospitalizations

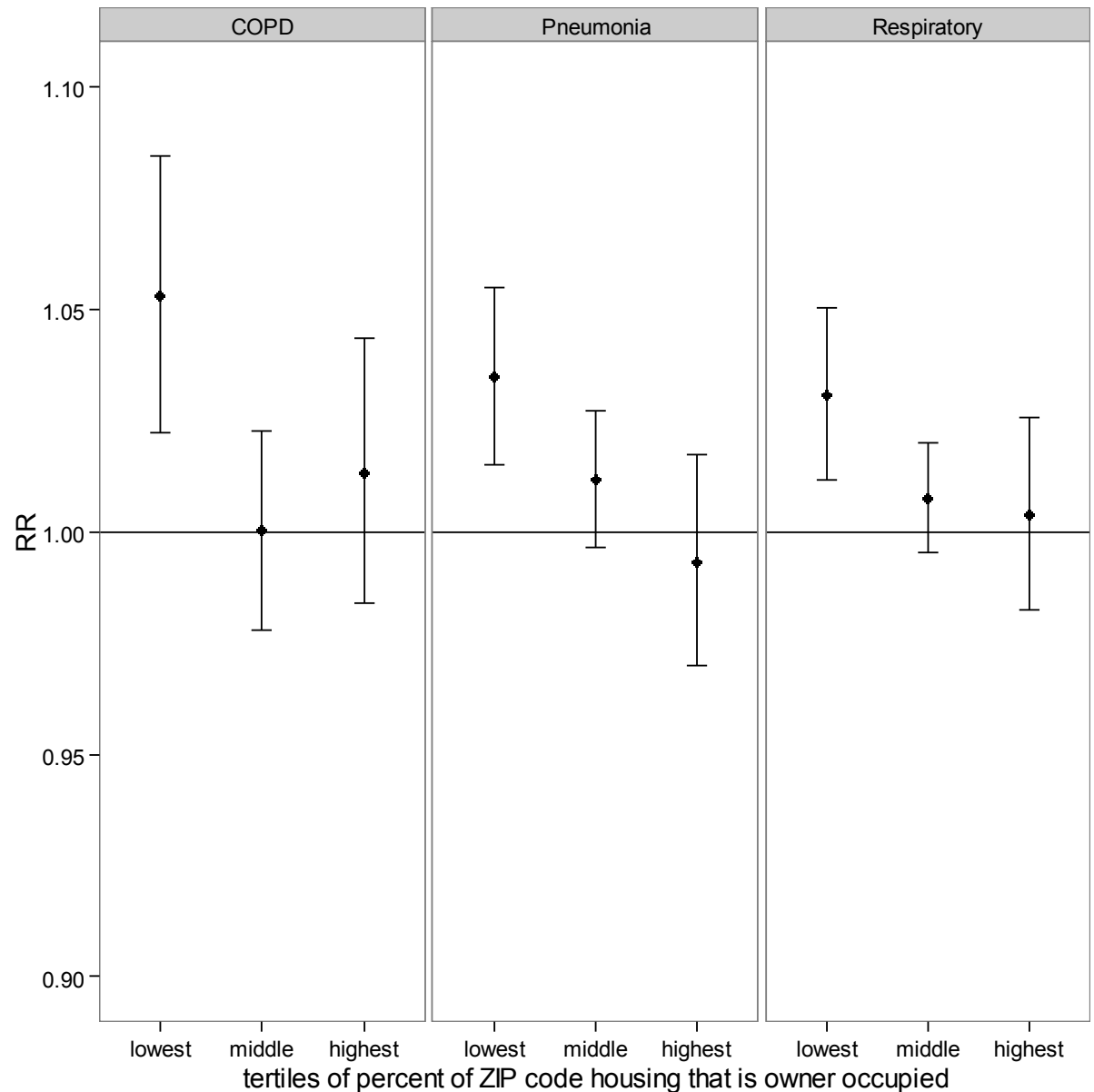


*there were so few COPD hospitalizations for the under 20 age group that we did not investigate this effect by that age group

Relative risks for a 5 $\mu\text{g}/\text{m}^3$ increase in $\text{PM}_{2.5}$ during the fires by sex for respiratory hospitalizations



Relative risks for
a $5 \mu\text{g}/\text{m}^3$
increase in
 $\text{PM}_{2.5}$ during the
fires by tertiles
of owner
occupied
housing at the
ZIP code level
for respiratory
hospitalizations



Conclusions

- Wildfire smoke exposure affects respiratory health
- More research is needed into other health endpoints
- Very little is known about which populations are most vulnerable

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