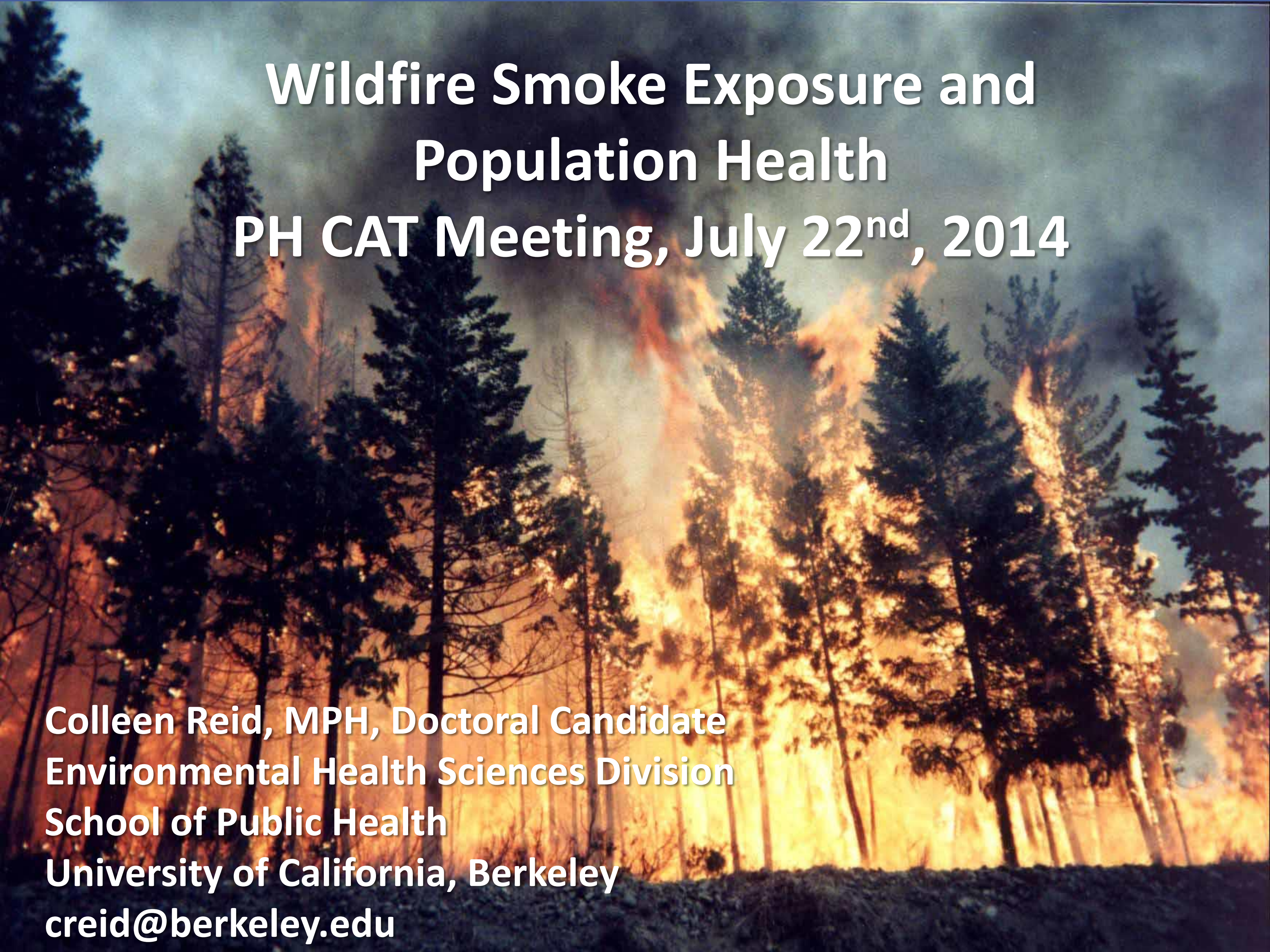


# Wildfire Smoke Exposure and Population Health
## PH CAT Meeting, July 22nd, 2014

Colleen Reid, MPH, Doctoral Candidate
Environmental Health Sciences Division
School of Public Health
University of California, Berkeley
creid@berkeley.edu

# 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** | ↑↑<br>↑ | 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<br>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** | ↑↑<br>↑ | Rappold et al. 2011, Delfino et al. 2009, Morgan et al. 2010<br>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** | ↑↑<br>↑<br>↔<br>↓ | Johnston et al. 2007<br>Mott et al. 2005, Martin et al. 2013<br>Morgan et al. 2010, Delfino et al. 2009,<br>Johnston et al. 2007 |
| **Congestive heart failure/cardiac arrests** | ↑↑<br>↑<br>↔ | Rappold et al. 2011, Dennekamp et al. 2011<br>Delfino et al. 2009<br>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

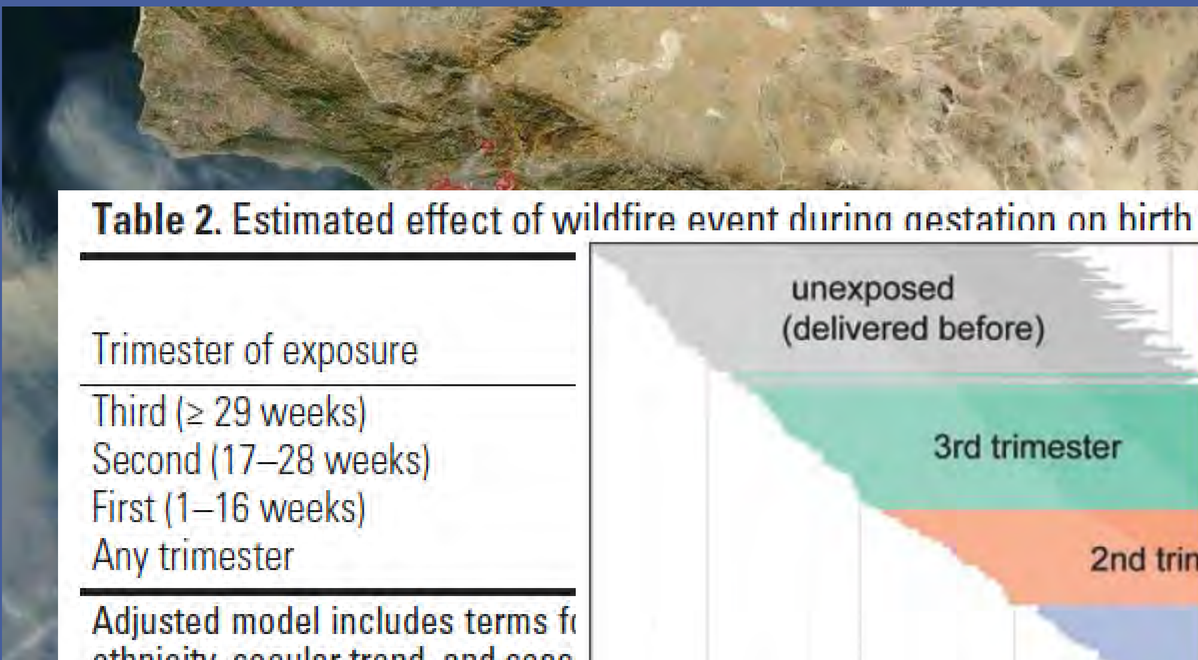


**Table 2.** Estimated effect of wildfire event during gestation on birth weight (g), by trimester.

| Trimester of exposure |
|---|
| Third (≥ 29 weeks) |
| Second (17–28 weeks) |
| First (1–16 weeks) |
| Any trimester |

Adjusted model includes terms f
ethnicity, secular trend, and seas

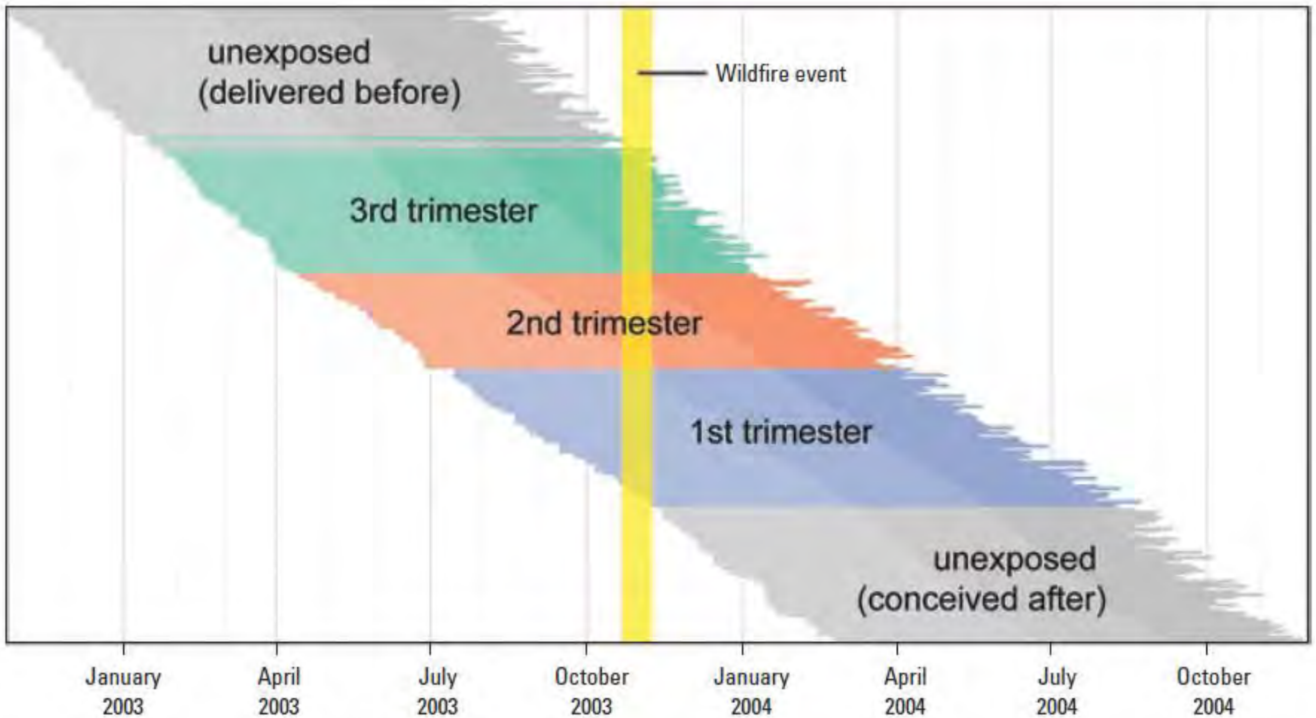



**Figure 2.** Schematic illustrating exposure assignment. Exposure status was assigned based on the overlap between the wildfire event (yellow) and estimated gestational intervals (horizontal segments). For clarity, gestational intervals are shown ordered from top to bottom by the LMP, and only a 0.1%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

Holstius et al. 2012

# 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

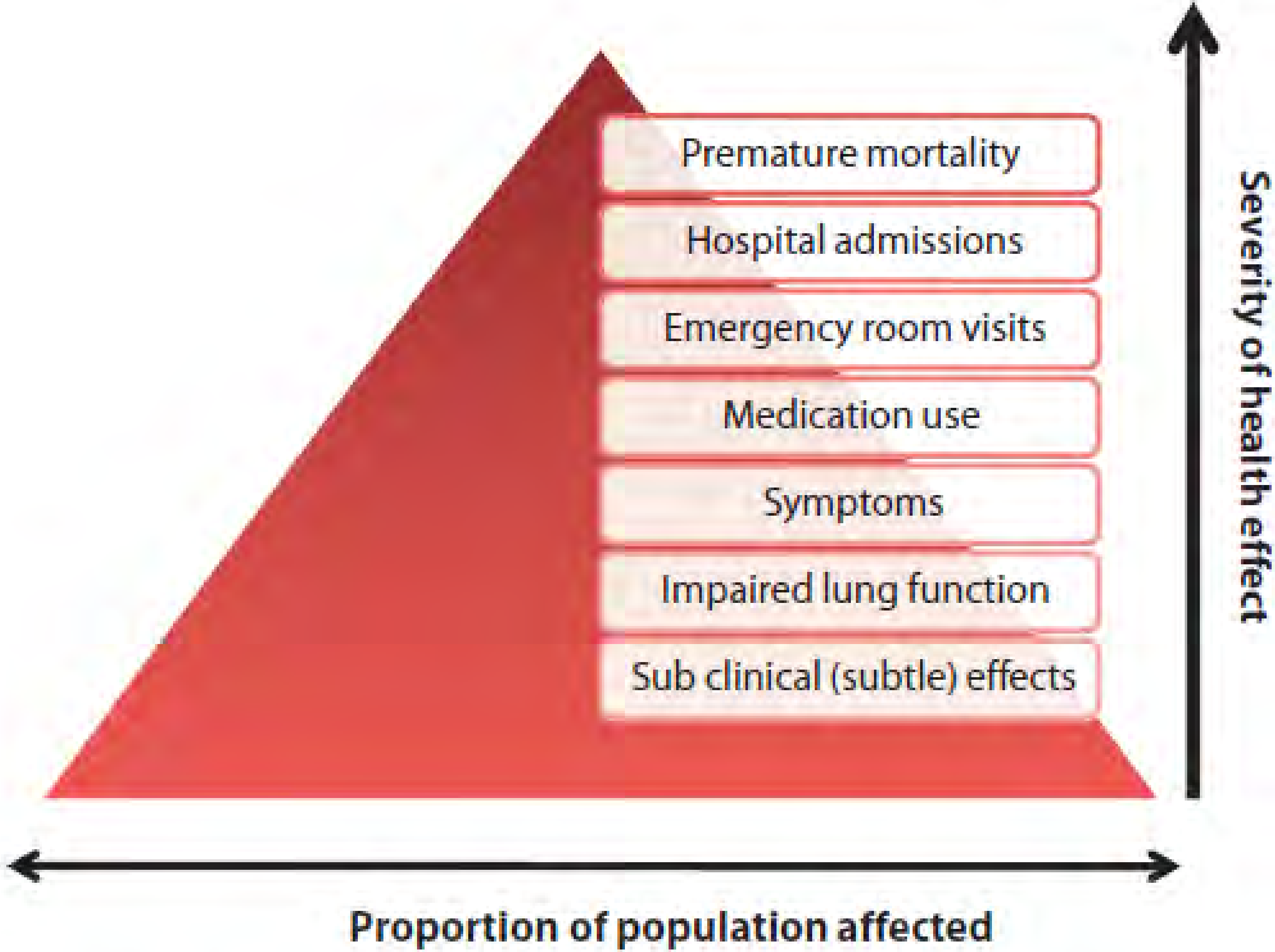
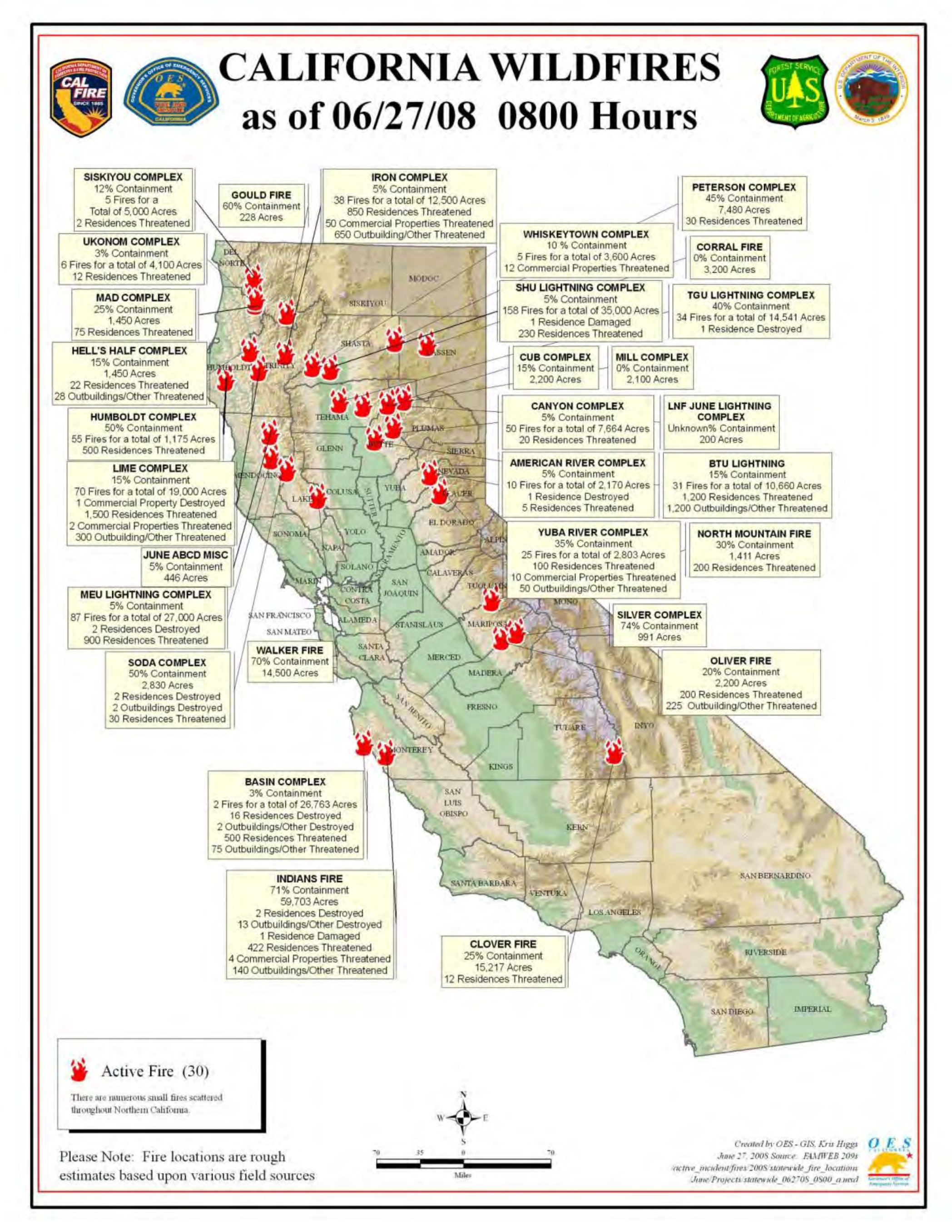



**Figure 2** The air pollution health effects pyramid (adapted from American Thoracic Society 2000).[43]

# Exposure Assessment Difficulties

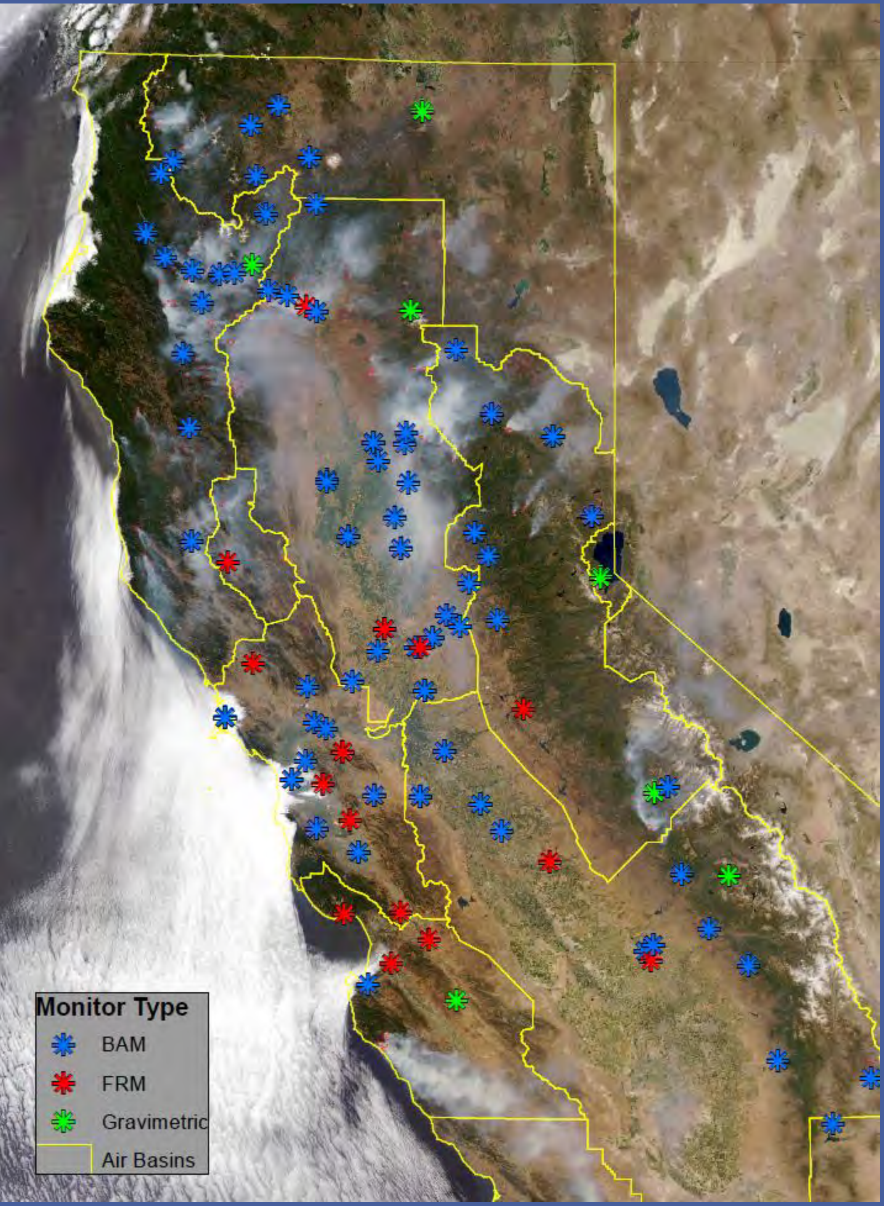
- Sparse monitoring network
- Many $PM_{2.5}$ monitors only measure every sixth or third day
- Leads to spatial and temporal averaging of exposure measurements
  - But, smoke plumes migrate quickly, changing exposures over smaller spatial and temporal scales




# 2008 northern California wildfires

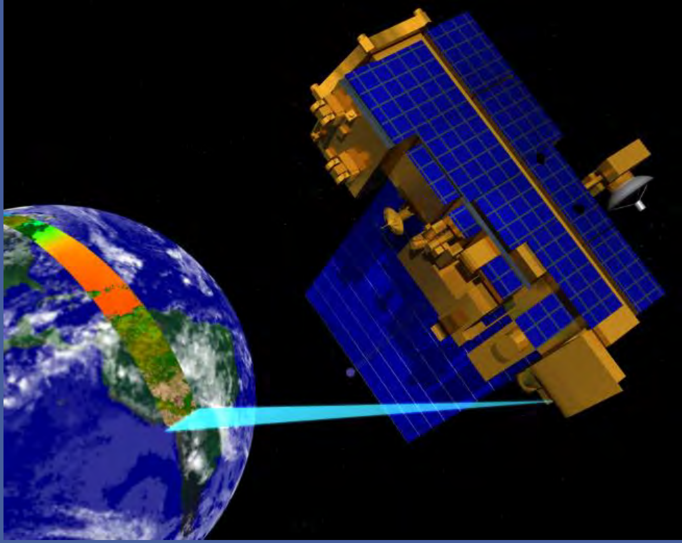
- Lightning storm on June 20-21, 2008
- Over 6000 lightning strikes
- Thousands of fires
- Smoke covered large population areas for weeks (est. 10-12 million people exposed)

# $PM_{2.5}$ 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).

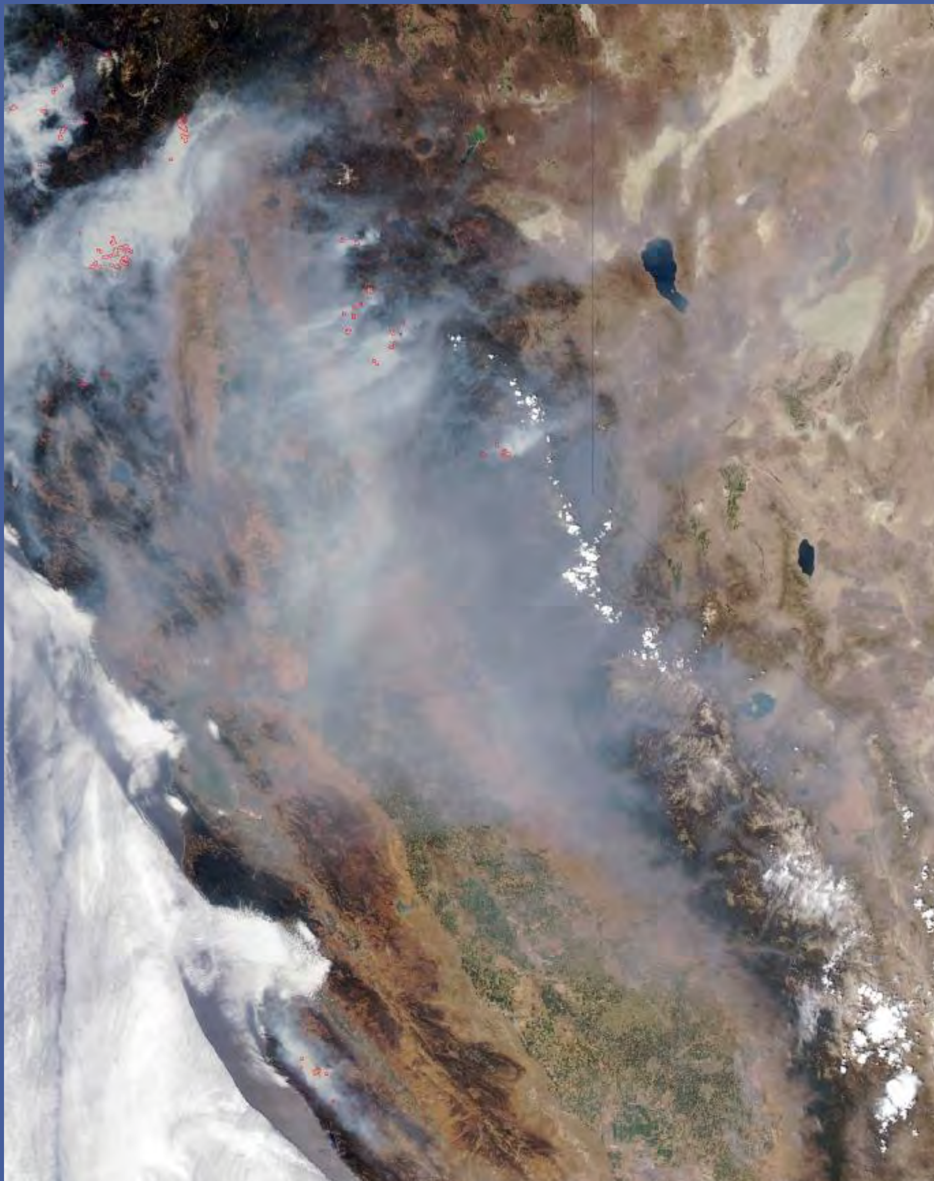
# Methods - Data

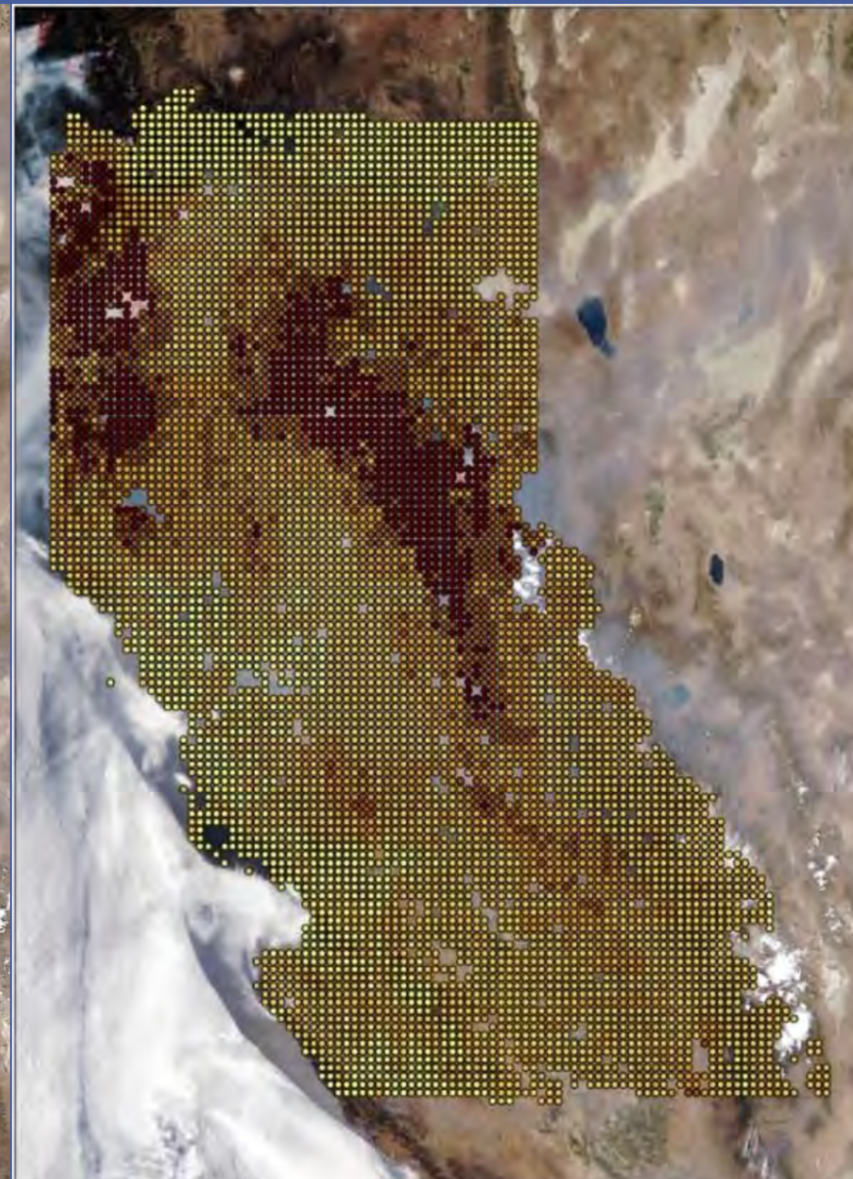


http://www.ntsg.umt.edu/sites/ntsg.umt.edu/files/imce/EOS_AM1_scan.jpg

- 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

July 11, 2008

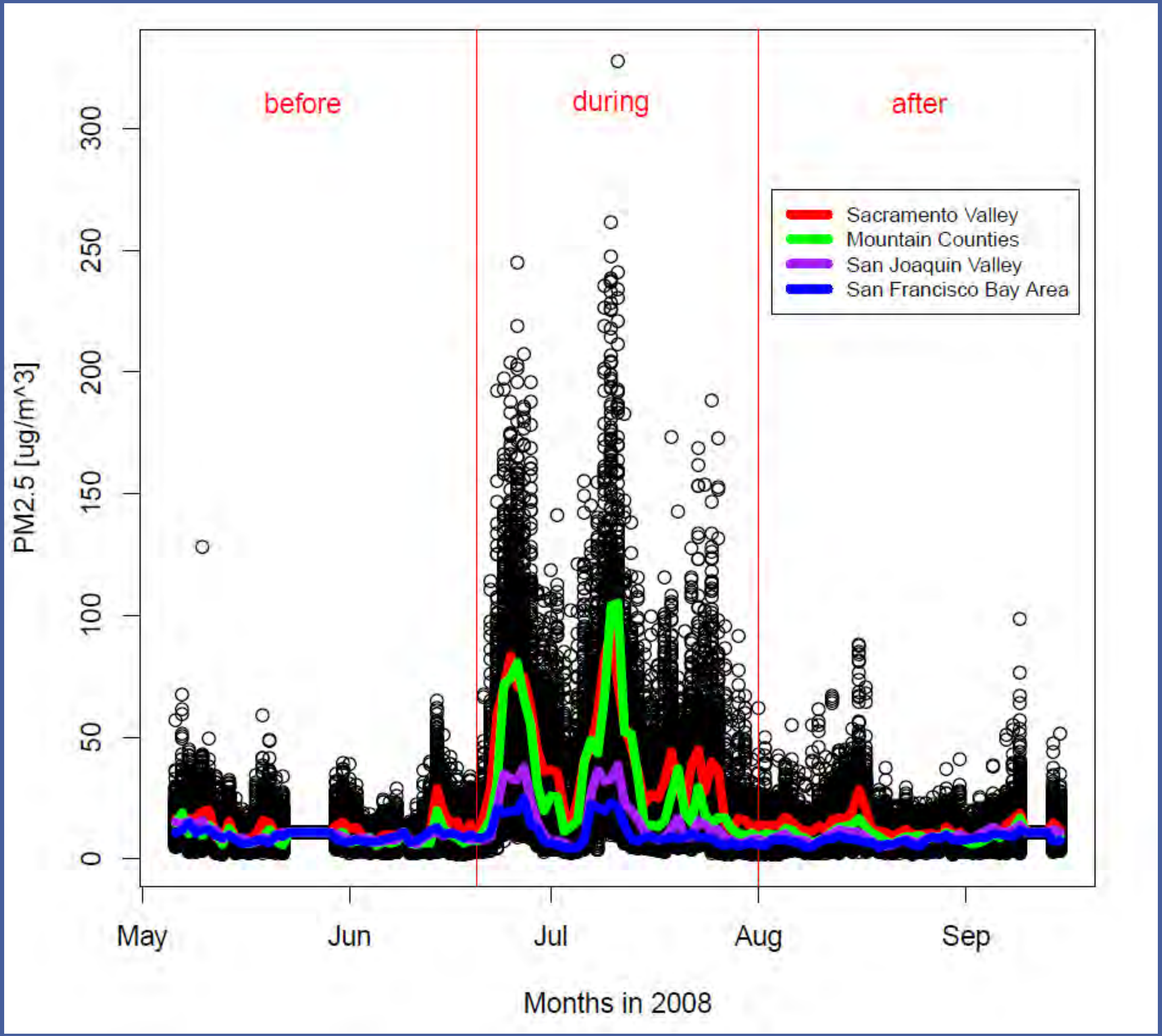




| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ○ | <15 | ○ | 15-35 | ○ | 35-55 | ○ | 55-75 | ○ | >75 | µg/m$^3$ |

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

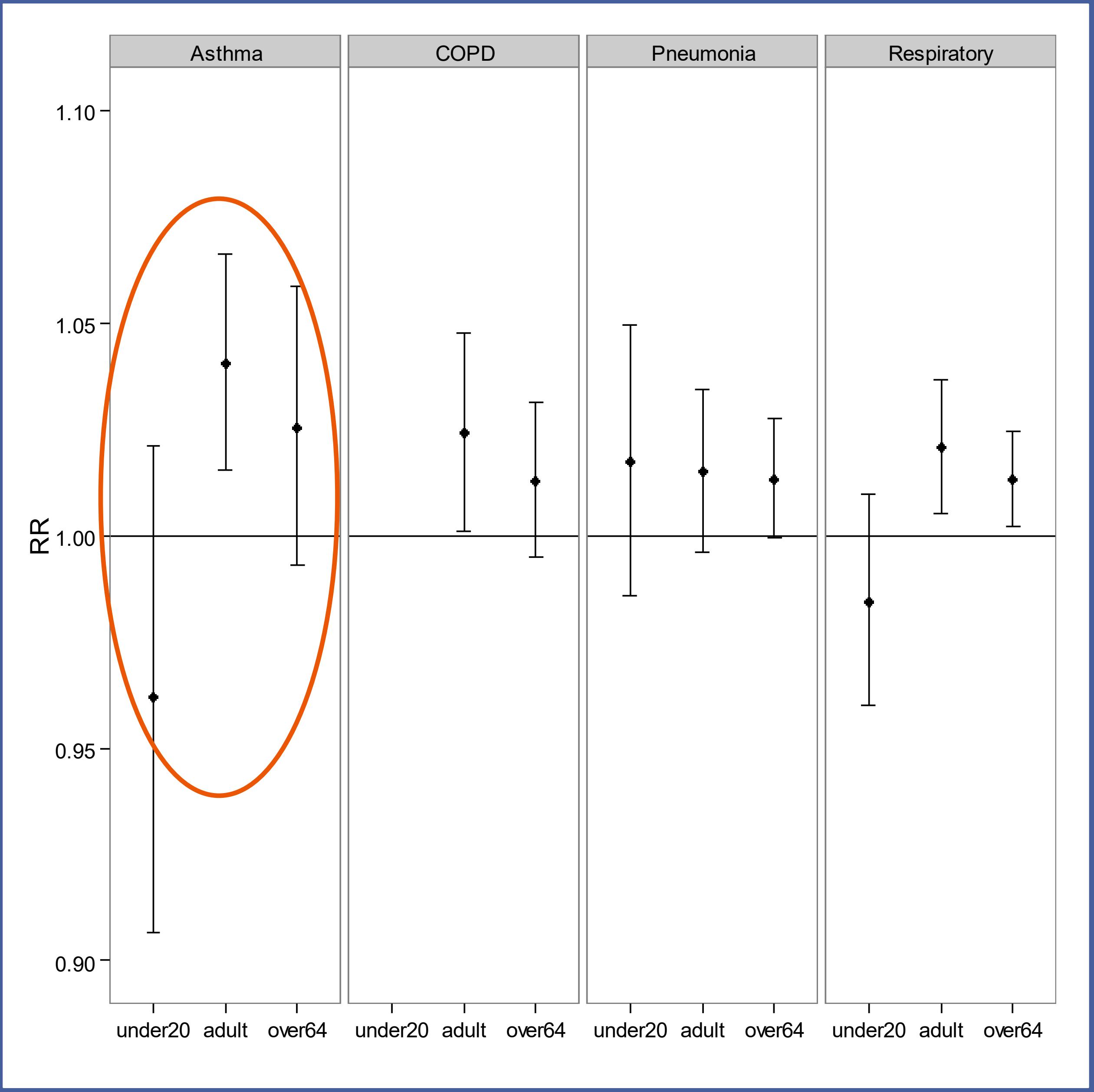


# Relative risks of hospitalization associated with $PM_{2.5}$ before, during, and after the 2008 northern California wildfires

| | RR for a 5 $\mu g/m^3$ 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) | *0.985 (0.973, 0.996)* | 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 |

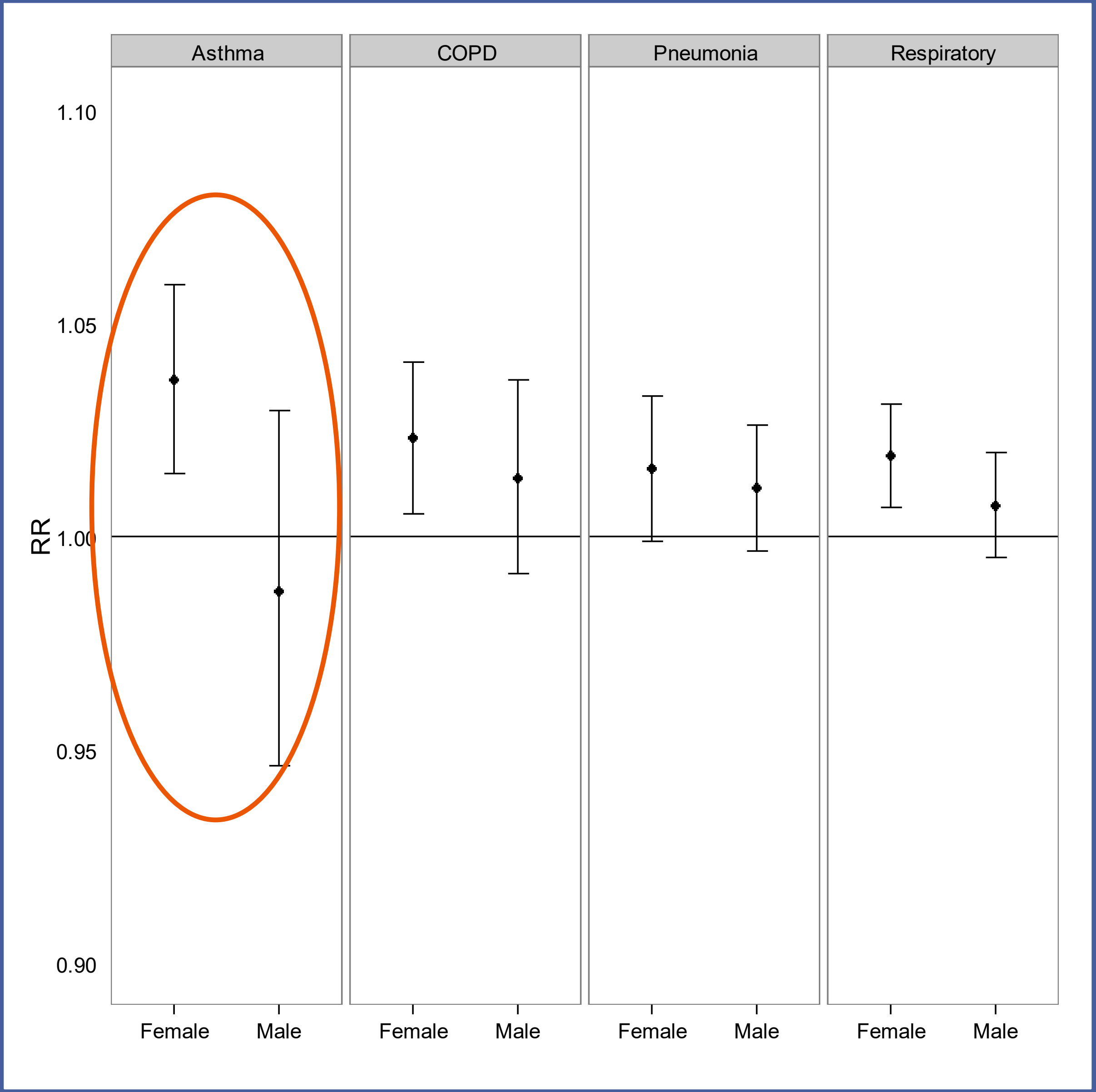
*all models are for the two day moving average of $PM_{2.5}$ controlling for time trend, day of week, heat index, median income, and percent of population over 65

Relative risks for a 5 μg/m$^3$ increase in $PM_{2.5}$ during the fires by age group for respiratory hospitalizations

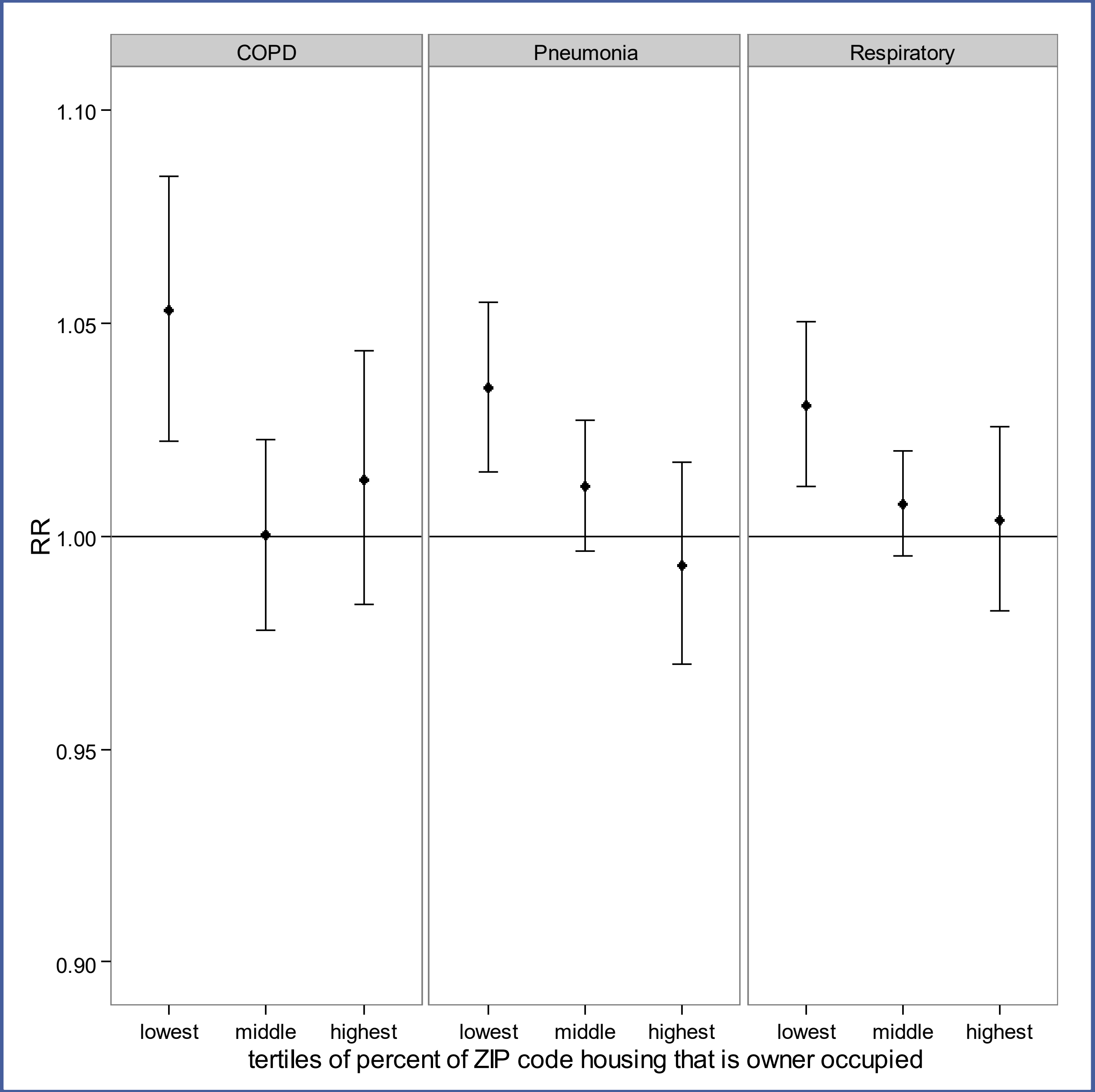



*there were so few COPD hospitalizations for the under 20 age group that we did not investigate this effect by that age group

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



Relative risks for a 5 $\mu g/m^3$ increase in $PM_{2.5}$ 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

# Acknowledgements


- Dr. Michael Jerrett
- Dr. John Balmes
- Dr. Ira Tager
- Dr. Maya Petersen
- Philip Morefield (EPA)
- Dr. Sean Raffuse (Sonoma Technologies Inc.)
- Dr. Gabriele Pfister (NCAR)
- Dr. Christine Wiedinmyer (NCAR)
- Dr. Ricardo Cisneros (UC Merced)

This research was supported under a cooperative agreement from the Centers for Disease Control and Prevention (CDC) through the Association of Schools of Public Health (ASPH) Grant Number CD300430 and an EPA STAR Fellowship Assistance Agreement no. FP-91720001-0 awarded by the U.S. Environmental Protection Agency (EPA).

# Selected References


- Henderson SB, Johnston FH. 2012. Measures of forest fire smoke exposure and their associations with respiratory health outcomes. Curr Opin Allergy Clin Immunol 12:221 227.
- Holstius DM, Reid CE, Jesdale BM, Morello Frosch R. 2012. Birth weight following pregnancy during the 2003 southern California wildfires. Environ Health Perspect 120:1340 1345.
- Johnston FH, Henderson SB, Chen Y, Randerson JT, Marlier M, Defries RS, *et al.* 2012. Estimated global mortality attributable to smoke from landscape fires. Environ Health Perspect 120:695 701.
- Johnston F, Hanigan I, Henderson S, Morgan G, Bowman D. 2011. Extreme air pollution events from bushfires and dust storms and their association with mortality in Sydney, Australia 1994 2007. Environ Res 111:811 816.
- Martin KL, Hanigan IC, Morgan GG, Henderson SB, Johnston FH. 2013. Air pollution from bushfires and their association with hospital admissions in Sydney, Newcastle and Wollongong, Australia 1994 2007. Aust N Z J Public Health 37:238 243.
- Naeher LP, Brauer M, Lipsett M, Zelikoff JT, Simpson CD, Koenig JQ, *et al.* 2007. Woodsmoke health effects: A review. Inhal Toxicol 19:67 106.
- Wegesser TC, Franzi LM, Mitloehner FM, Eiguren Fernandez A, Last JA. 2010. Lung antioxidant and cytokine responses to coarse and fine particulate matter from the great California wildfires of 2008. Inhalation toxicology 22:561 570.
- Wegesser TC, Pinkerton KE, Last JA. 2009. California wildfires of 2008: Coarse and fine particulate matter toxicity. Environmental health perspectives 117:893 897.
- Miller LA, Schelegle ES, Capitanio JP, Clay CC, Walby WF. 2013. Persistent immune effects of wildfire PM exposure during childhood development. California Air Resources Board Contract Number 10 303
- Henderson SB, Brauer M, Macnab YC, Kennedy SM. 2011. Three measures of forest fire smoke exposure and their associations with respiratory and cardiovascular health outcomes in a population based cohort. Environ Health Perspect 119:1266 1271.
- Morgan G, Sheppeard V, Khalaj B, Ayyar A, Lincoln D, Jalaludin B, *et al.* 2010. Effects of bushfire smoke on daily mortality and hospital admissions in Sydney, Australia. Epidemiology 21:47 55.
- Rappold AG, Stone SL, Cascio WE, Neas LM, Kilaru VJ, Carraway MS, *et al.* 2011. Peat bog wildfire smoke exposure in rural North Carolina is associated with cardiopulmonary emergency department visits assessed through syndromic surveillance. Environ Health Perspect 119:1415 1420.
- Brook RD, Rajagopalan S, Pope CA, 3rd, Brook JR, Bhatnagar A, Diez Roux AV, et al. 2010. Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the american heart association. Circulation 121:2331 2378.