

# Community Exposures and Health Risks Associated with Wildfire Smoke

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Industrial Hygiene Summit

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# Disclosures

- No conflicts of interest

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## November 2018

The Camp Fire is now the deadliest & most destructive fire in California history.

<https://wjla.com/news/nation-world/death-toll-wildfires-northern-southern-california>  
[https://upload.wikimedia.org/wikipedia/commons/b/b1/Camp\\_Fire\\_oli\\_2018312\\_Landsat.jpg](https://upload.wikimedia.org/wikipedia/commons/b/b1/Camp_Fire_oli_2018312_Landsat.jpg)



# 15 FIRES 8 COUNTIES

MENDOCINO

NAPA

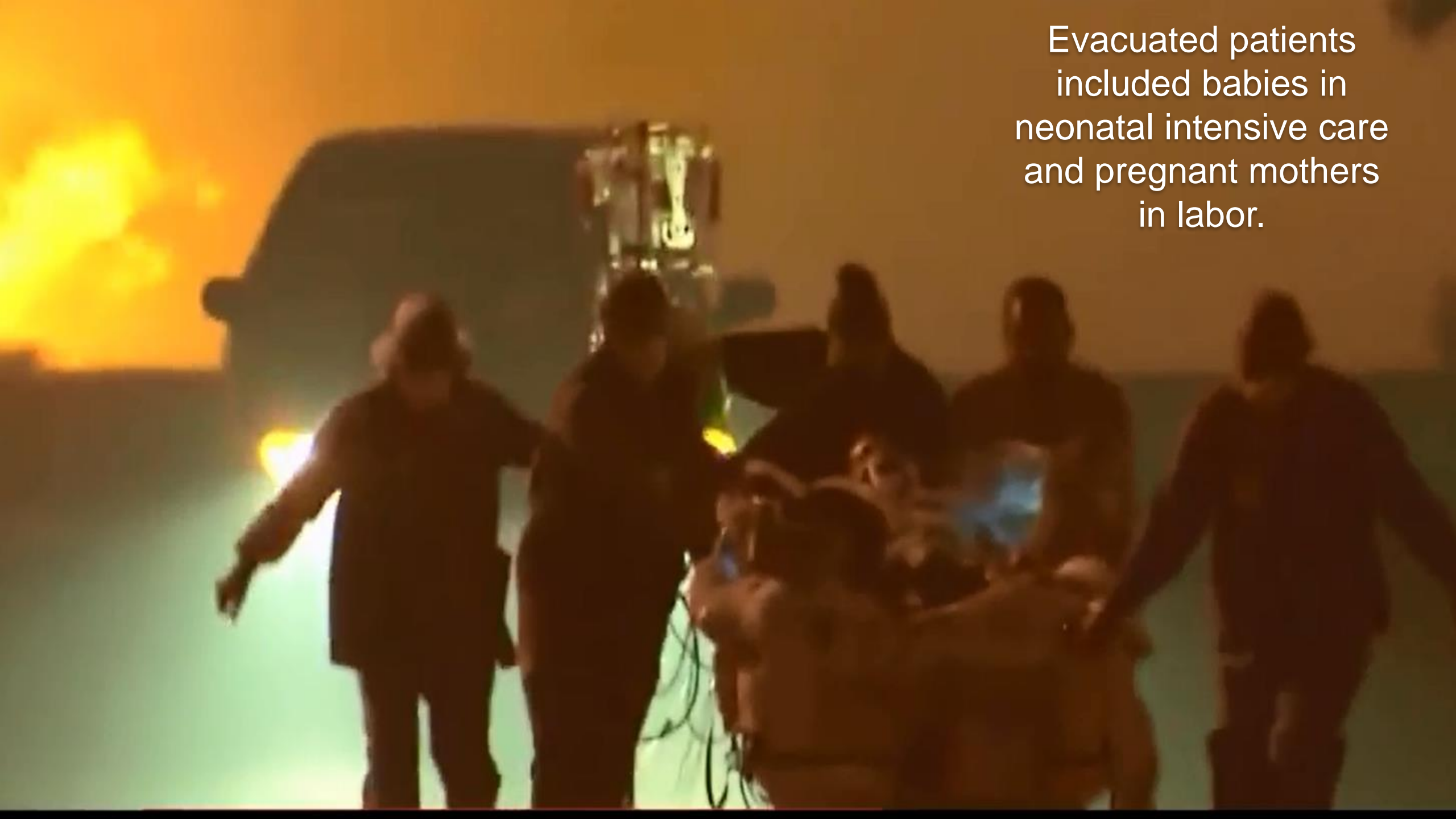
SONOMA

Multiple and fast spreading fires, easily jumped what would normally serve as a fire break, 6-lane Highway

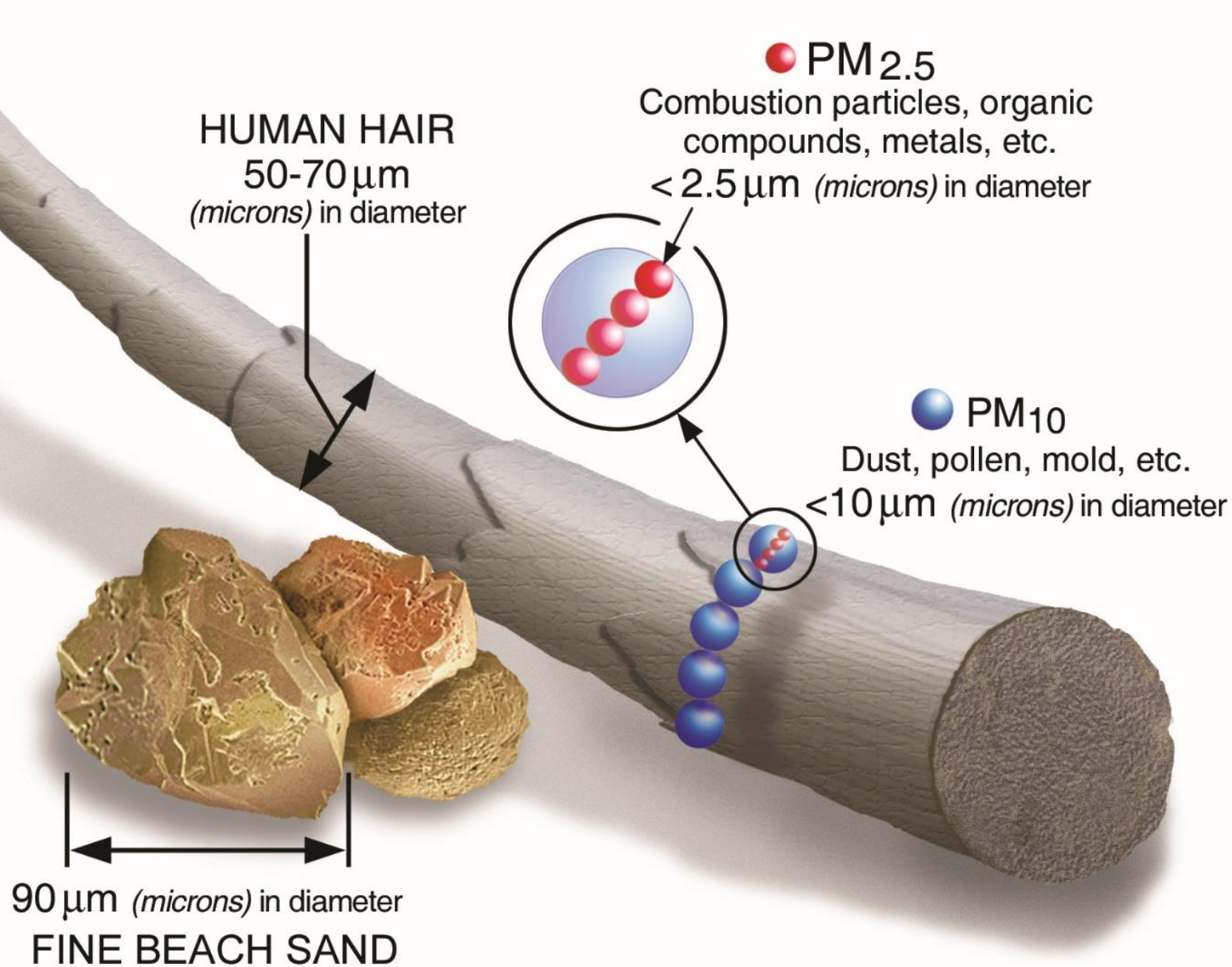
101

<https://www.youtube.com/watch?v=opVz7HZAXLo>

Evacuated patients  
included babies in  
neonatal intensive care  
and pregnant mothers  
in labor.







## Particulate matter

**PM<sub>10</sub>** : inhalable particles, with diameters that are generally 10 micrometers and smaller

**PM<sub>2.5</sub>** : fine inhalable particles, with diameters that are generally 2.5 micrometers and

# Current AQI (Combined PM and O<sub>3</sub>)

Monday, October 09, 2017 7:00 AM PDT









# Current AQI (Combined PM and O<sub>3</sub>)

Monday, October 09, 2017 11:00 AM PDT











## Air-quality impacts extend hundreds of miles => distant urban areas

- Forest fires in Quebec, Canada, 2002
- Baltimore, Maryland, nearly 1,000 miles downwind
- 30-fold increase in airborne fine particle concentrations

Source: Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on the Terra satellite, Land Rapid Response Team, NASA/GSFC



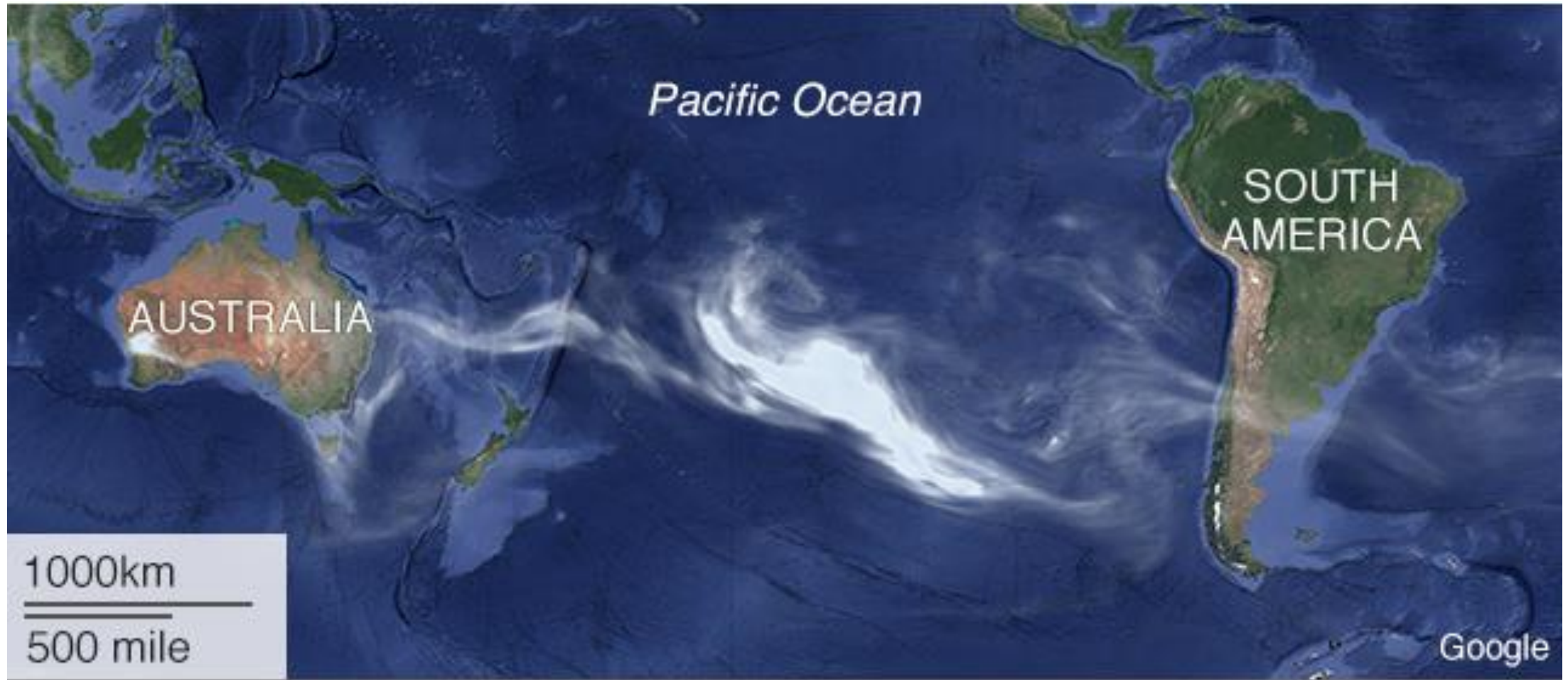
# Wildfires as source of air pollution



**Smoke  
From  
California  
Wildfires  
Spreading  
3,000 Miles  
To New  
York City.**

KPIX5/CBS SF Bay Area// <https://sanfrancisco.cbslocal.com/2018/08/10/smoke-california-wildfires-spreading-to-new-york-city/>

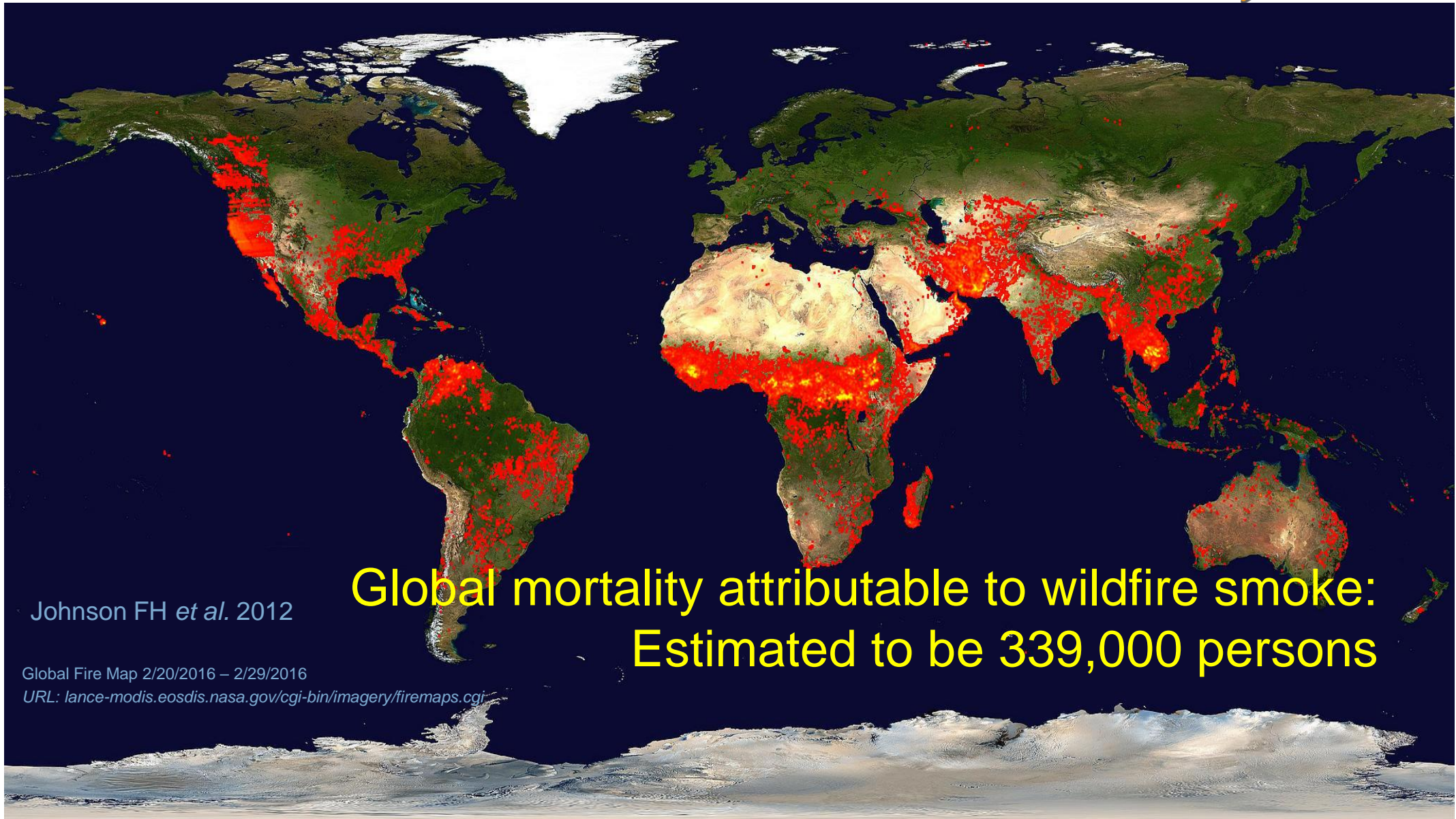
Smoke plumes from fires in Australia have traveled more than 7,000 miles



Source: Nasa Earth Observatory, 9 January 2020, 22:30 UTC







# Global mortality attributable to wildfire smoke: Estimated to be 339,000 persons

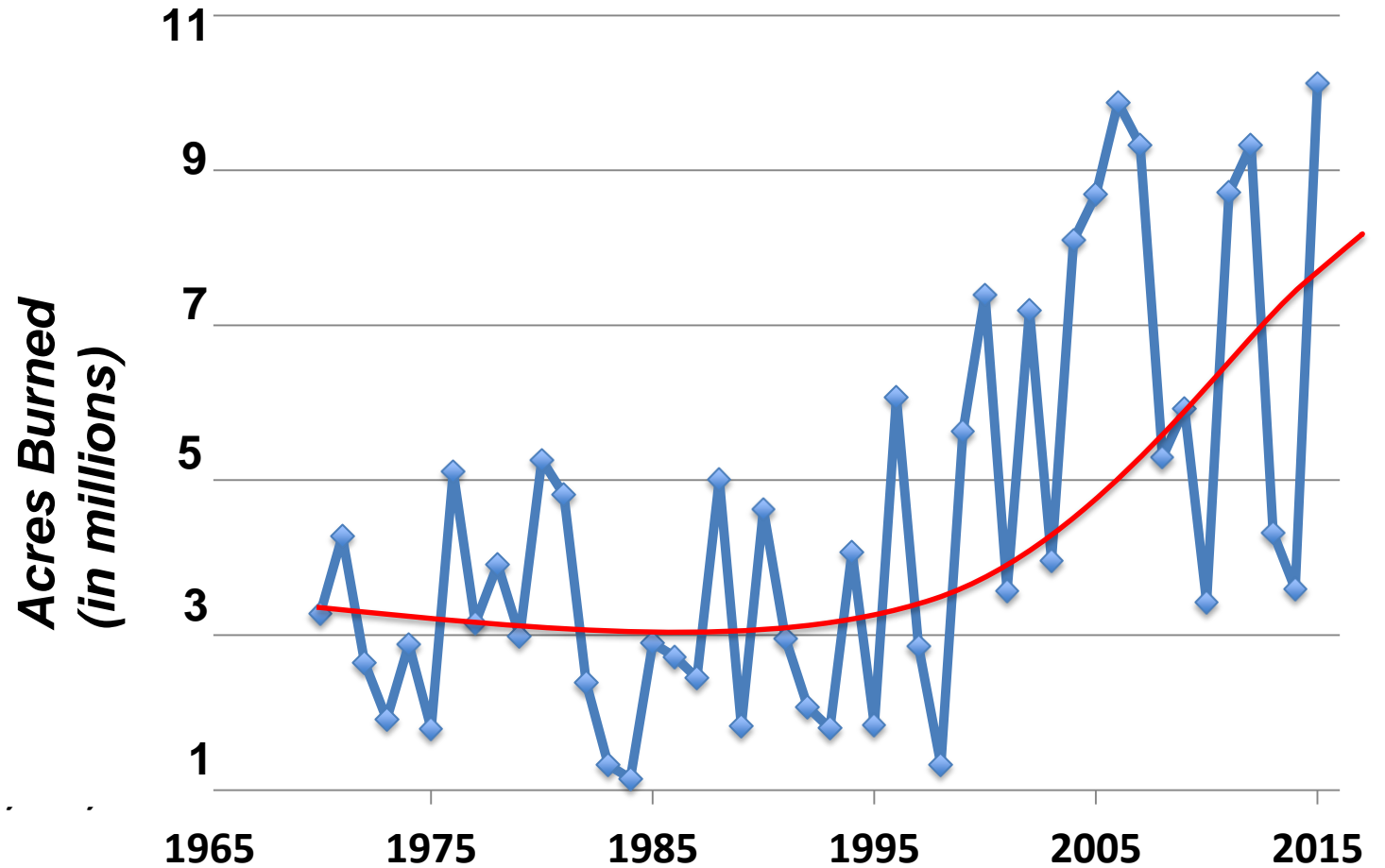
Johnson FH *et al.* 2012

Global Fire Map 2/20/2016 – 2/29/2016

URL: [lance-modis.eosdis.nasa.gov/cgi-bin/imagery/firemaps.cgi](http://lance-modis.eosdis.nasa.gov/cgi-bin/imagery/firemaps.cgi)

# Increasing Wildfire Risk in the U.S.

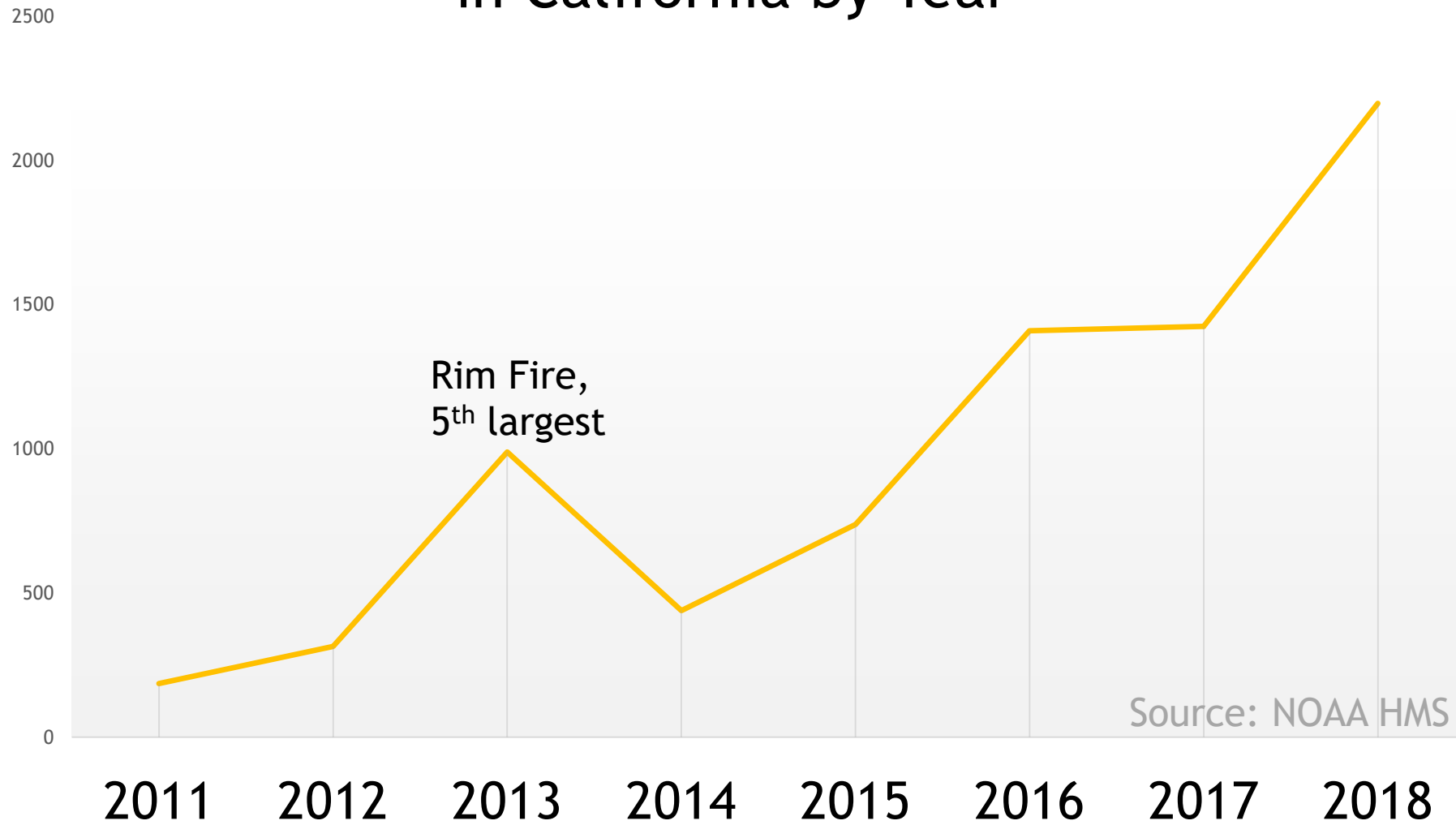
Acres  
Burned in  
the U.S.  
Annually





## Person-Day Exposure to Wildfire Smoke in California by Year

MILLIONS PERSONS UNDER SMOKE PLUME





# Drought -- 129 Million Dead Trees





# Increasing Wildfire Risk to Human Populations: Wildland– Urban Interface (“WUI”)

- 38% of U.S. housing units near wildland



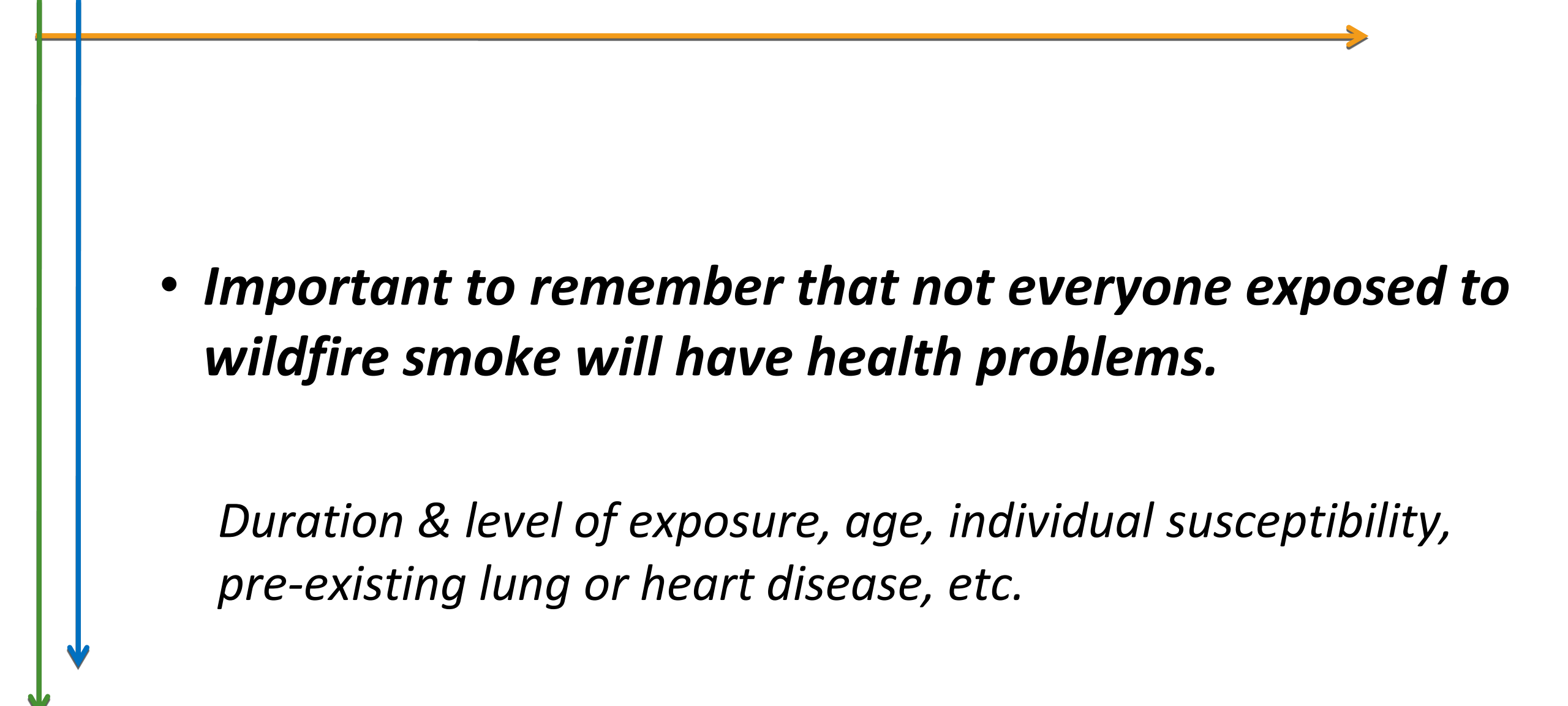
[headwaterseconomics.org/wildfire/homes-risk/northern-california-homes-and-cost-of-wildfires](http://headwaterseconomics.org/wildfire/homes-risk/northern-california-homes-and-cost-of-wildfires)



# Wildfires increasing ambient air pollution

Wildfires  
contributed 20%  
of the particulate  
matter in  
ambient air  
pollution, 2012

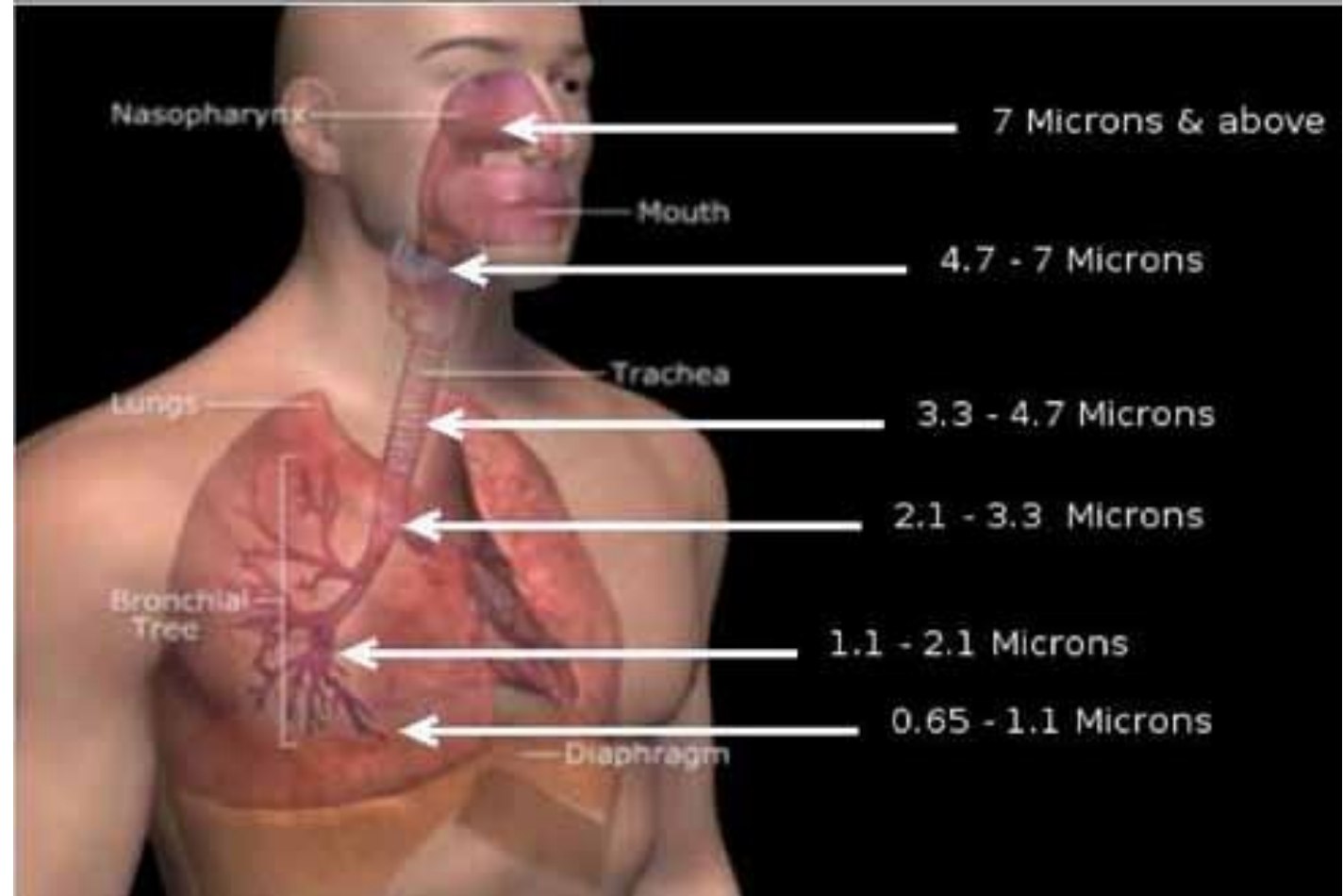


- 
- ***Important to remember that not everyone exposed to wildfire smoke will have health problems.***

*Duration & level of exposure, age, individual susceptibility, pre-existing lung or heart disease, etc.*

# Wildfire particulate matter

- Penetrates deeply into the alveolar region of the lung
- Damage to cilia
- Loss of epithelial cells
- Crosses into the bloodstream



Wegesser TC et al, California wildfires of 2008: coarse and fine particulate matter toxicity. Environ Health Perspect., 2009;117:893-7



## Health effects known or suspected to be caused by wildfire smoke

- Eye irritation
- Sore throat
- Wheeze, cough, difficulty breathing
- Asthma & COPD exacerbations
- Bronchitis & pneumonia
- Cardiovascular outcomes
- Adverse birth outcomes
- All-cause mortality



# Fine Particulate Matter, PM<sub>2.5</sub>



## Urban Sources

Known adverse respiratory and cardiovascular effects



## Wildfire PM<sub>2.5</sub>

Known adverse respiratory

*Inconclusive cardiovascular*



# Pathophysiology

PM<sub>2.5</sub> in lungs

**Autonomic system  
activation**



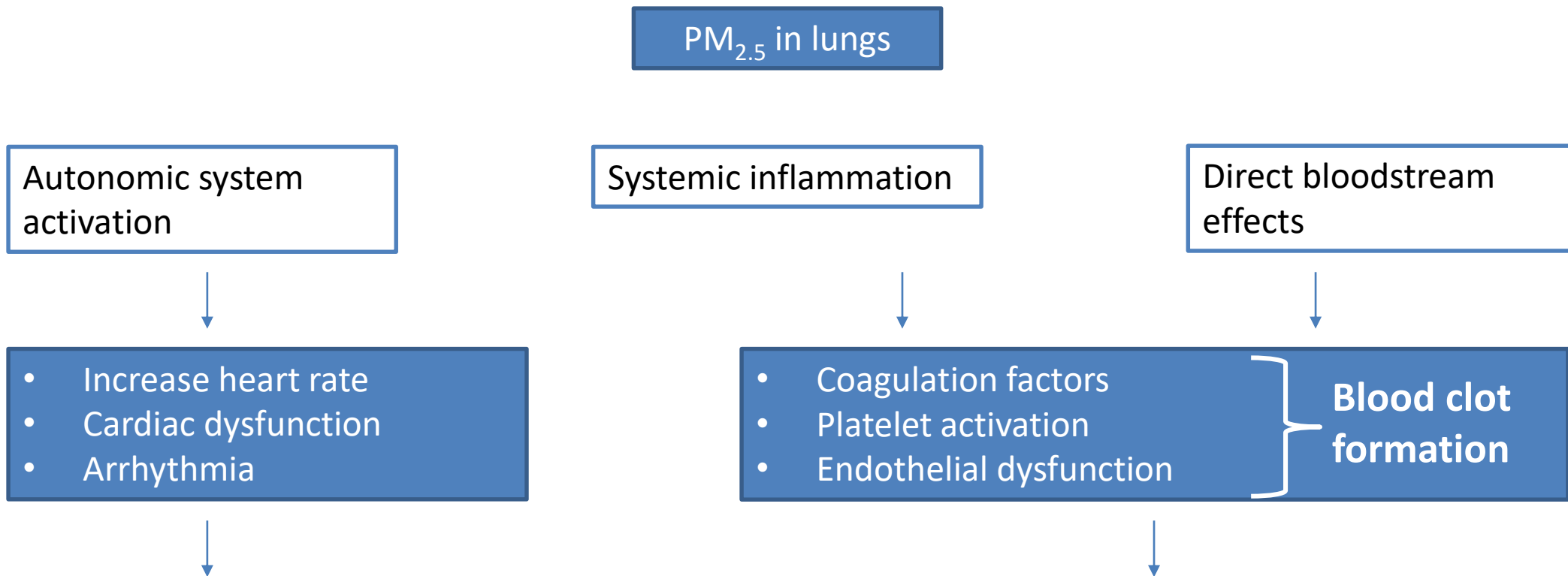
**Systemic  
inflammation**



**Direct bloodstream  
effects**



# Pathophysiology





# Pathophysiology

PM<sub>2.5</sub> in lungs

Autonomic system activation

- Increase heart rate
- Cardiac dysfunction
- Arrhythmia

Clinical outcomes include:

- *Heart failure*
- *Cardiac arrest*
- *Stroke*

Systemic inflammation

- Coagulation factors
- Platelet activation
- Endothelial dysfunction

Blood clot formation

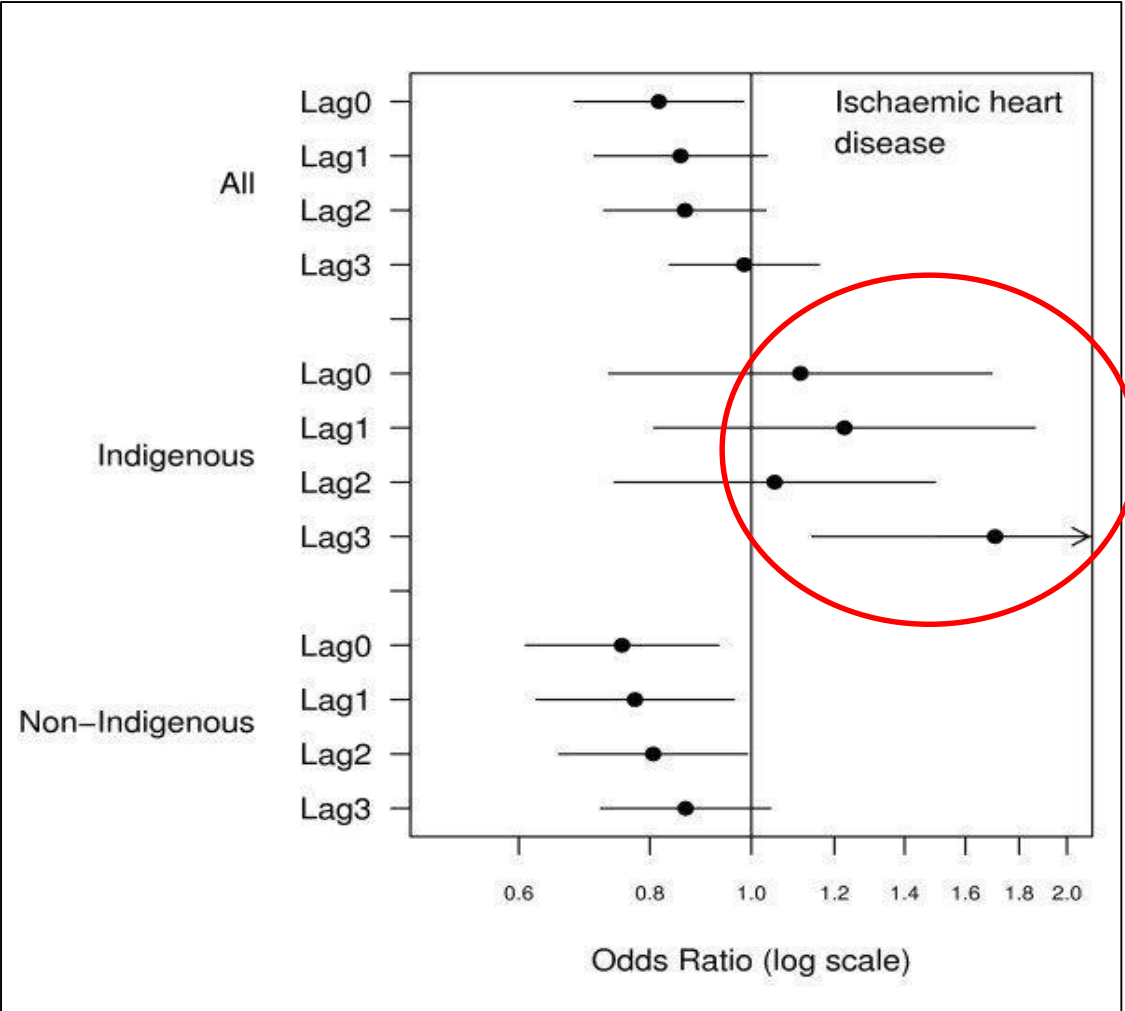
Clinical outcomes include:

- *Coronary artery disease*
- *Pulmonary embolism (Blood clot in lung)*
- *Stroke*

Direct bloodstream effects

# Vulnerability Matters: Indigenous vs. Non-indigenous Populations, Australia

## Ischemic Heart Disease, hospital admissions



Adjusted OR, 95% CI, Per 10 $\mu$ g/m<sup>3</sup> increase in PM10

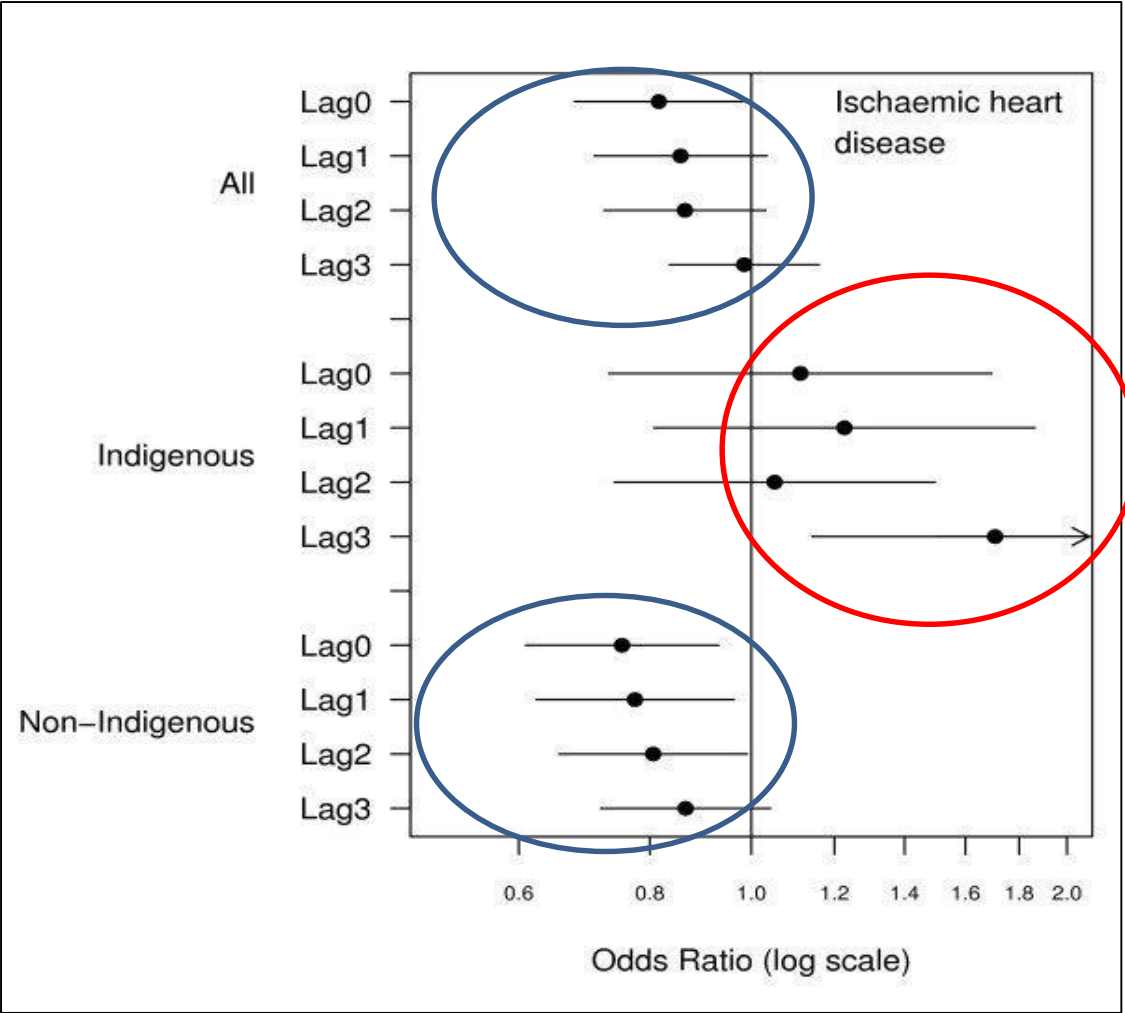
[Johnston FH](#), [Bailie RS](#), [Pilotto LS](#), [Hanigan IC](#). Ambient biomass smoke and cardio-respiratory hospital admissions in Darwin, Australia. [BMC Public Health](#). 2007 Sep 13;7:240.





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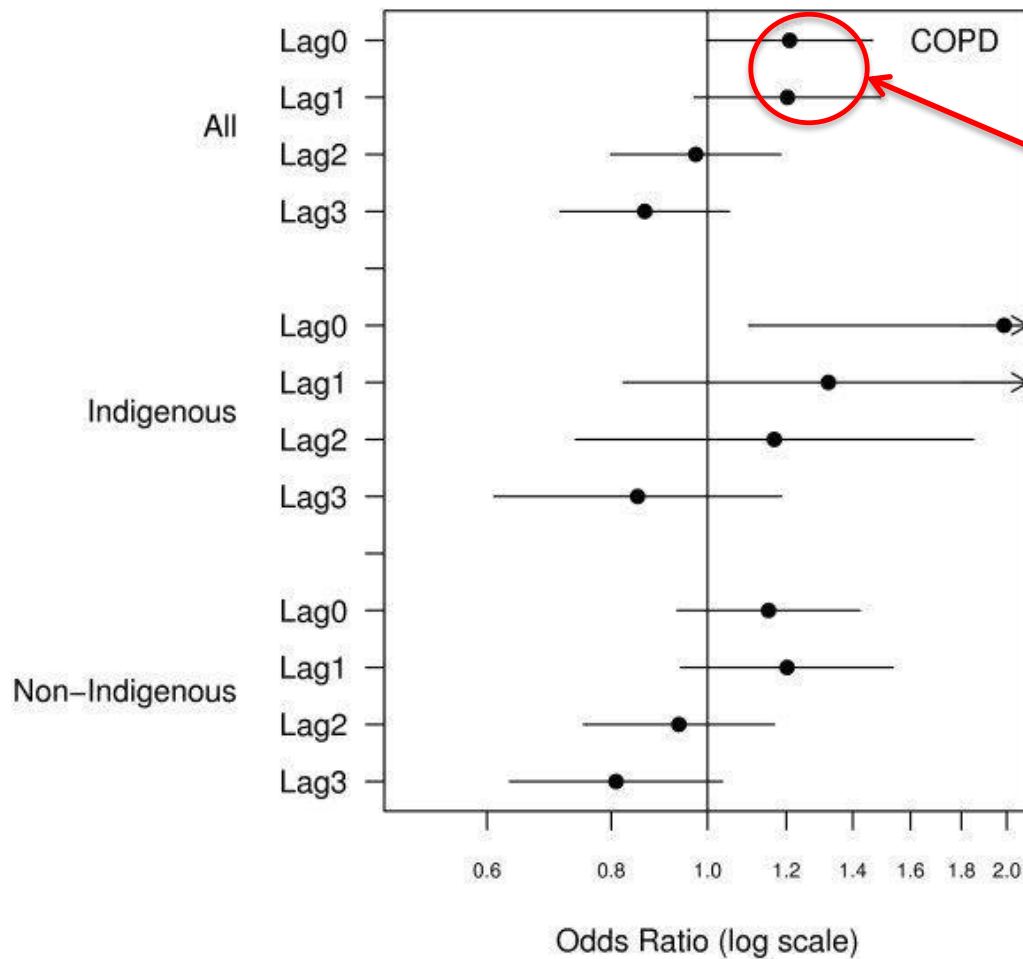
[Johnston FH](#), [Bailie RS](#), [Pilotto LS](#), [Hanigan IC](#). Ambient biomass smoke and cardio-respiratory hospital admissions in Darwin, Australia. [BMC Public Health](#). 2007 Sep 13;7:240.



# Vulnerable Populations: Indigenous vs. Non-indigenous

## COPD Hospital admissions Australia

Adjusted Odds Ratios,  
95% Confidence Interval,  
per 10 $\mu$ g/m<sup>3</sup> increase in  
PM10



General  
population:  
~20%  
increase in  
COPD

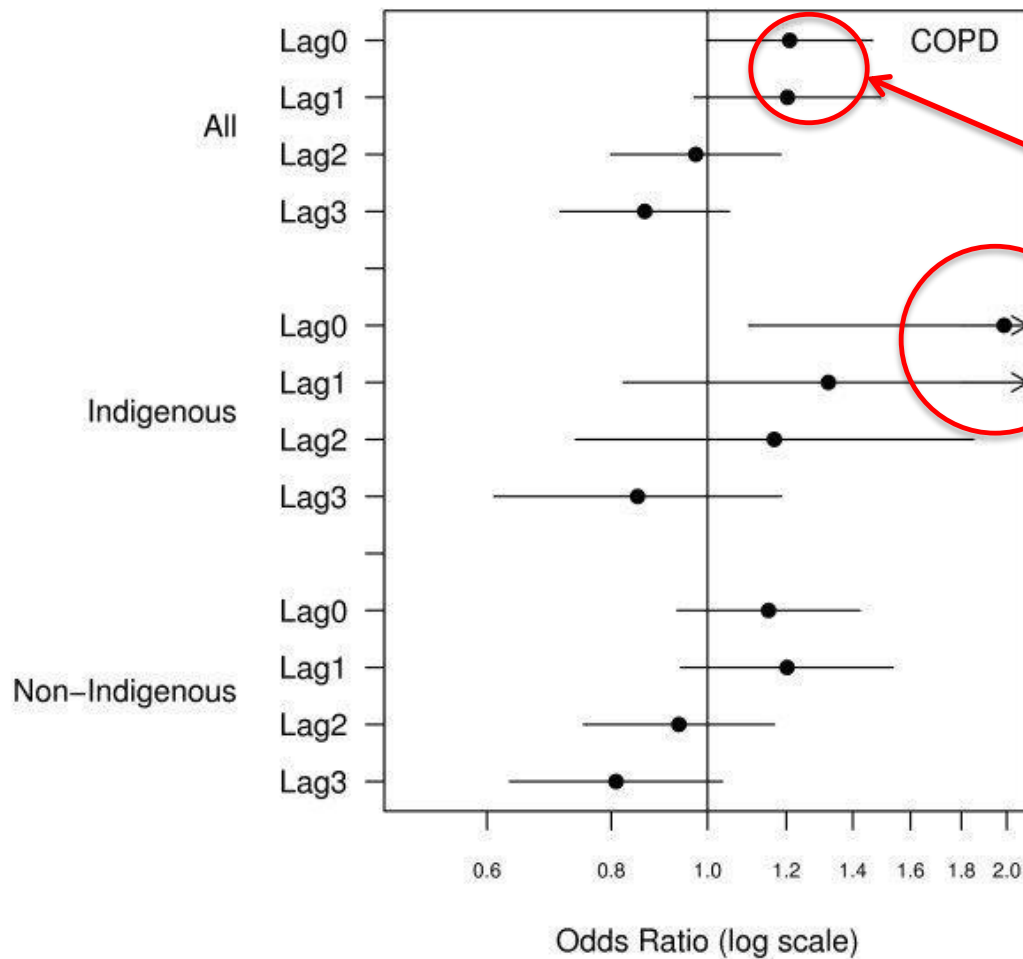
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PM10



General population:  
~20%  
increase in  
COPD

Indigenous population:  
~ 2 times  
more  
COPD  
(log scale)

[Johnston FH](#), [Baillie RS](#), [Pilotto LS](#), [Hanigan IC](#).

Ambient biomass smoke and cardio-respiratory hospital admissions in Darwin, Australia. [BMC Public Health](#). 2007 Sep 13;7:240.





# Natural disasters → Psychological impacts

## ***WILDFIRES***

- **Spain:** ↑ anti-anxiety RX use in months following wildfires
- **Greece:** depression, paranoia, psychopathology
- **Los Angeles fire victims:** sleep disturbances, nightmares

## Sensitive populations

- Young and old
- Pre-existing conditions
  - Lung disease
  - Heart disease
  - Diabetes
- Pregnant women
- Outdoor workers





# Wildfire Susceptible Populations NHANES 2007-2010

Susceptible category	N	Percent (95% CI)
None	7135	73.0 (71.4, 74.6)
Respiratory only	642	6.4 (5.5, 7.2)
Cardiovascular only	319	2.6 (2.3, 2.9)
>65 years only	1713	10.9 (10.1, 11.8)
Respiratory and cardiovascular	136	1.0 (0.7, 1.3)
Respiratory and >65 years	220	1.6 (1.3, 1.8)
Cardiovascular and >65 years	608	3.8 (3.3, 4.3)
All three groups	125	0.7 (0.5, 0.9)

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*27% fall into  
at least one  
susceptible  
group*



# San Diego 2007 Wildfire Research Study:

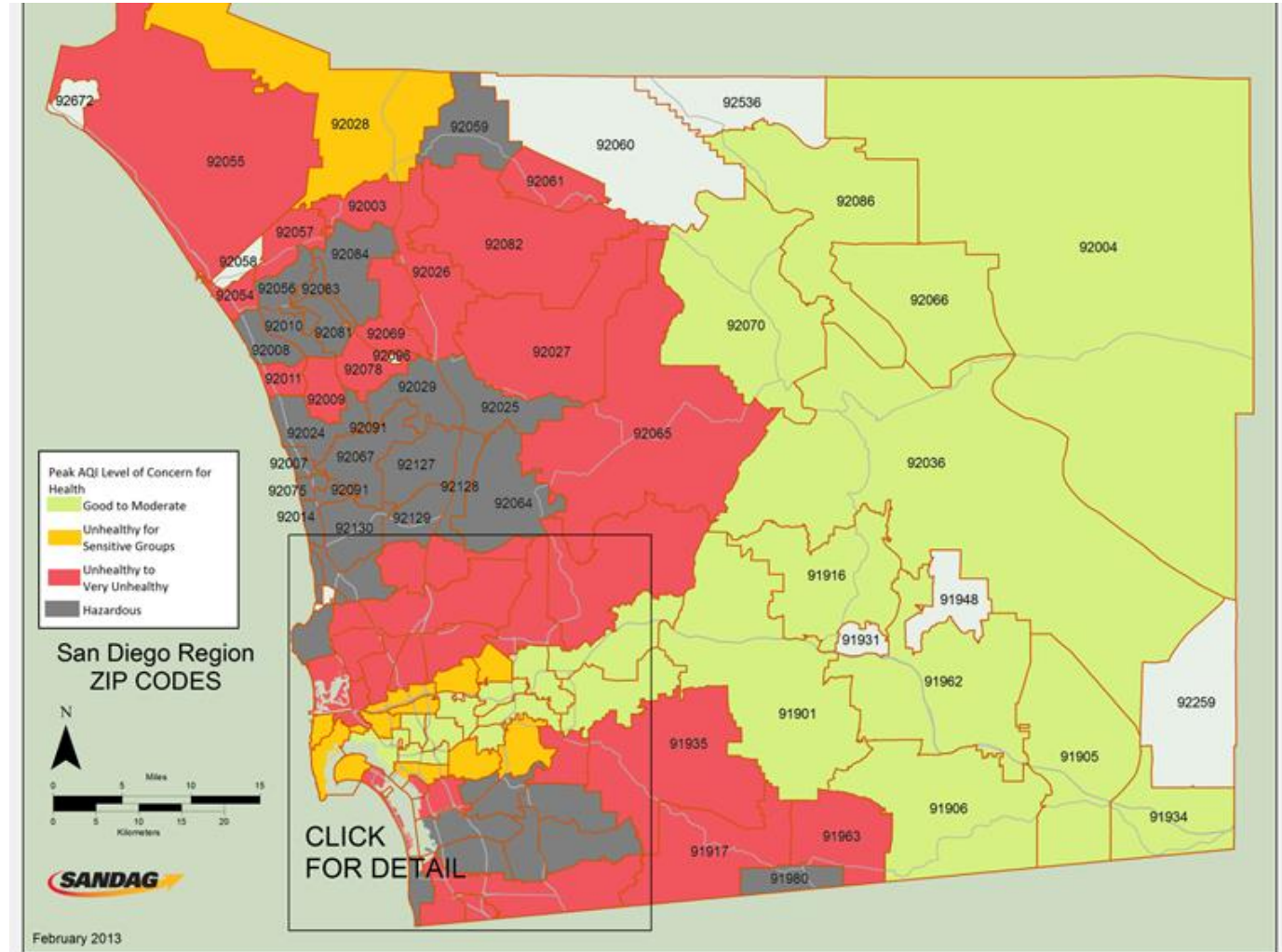
Collaboration with San Diego County, Michigan Tech Research Institute

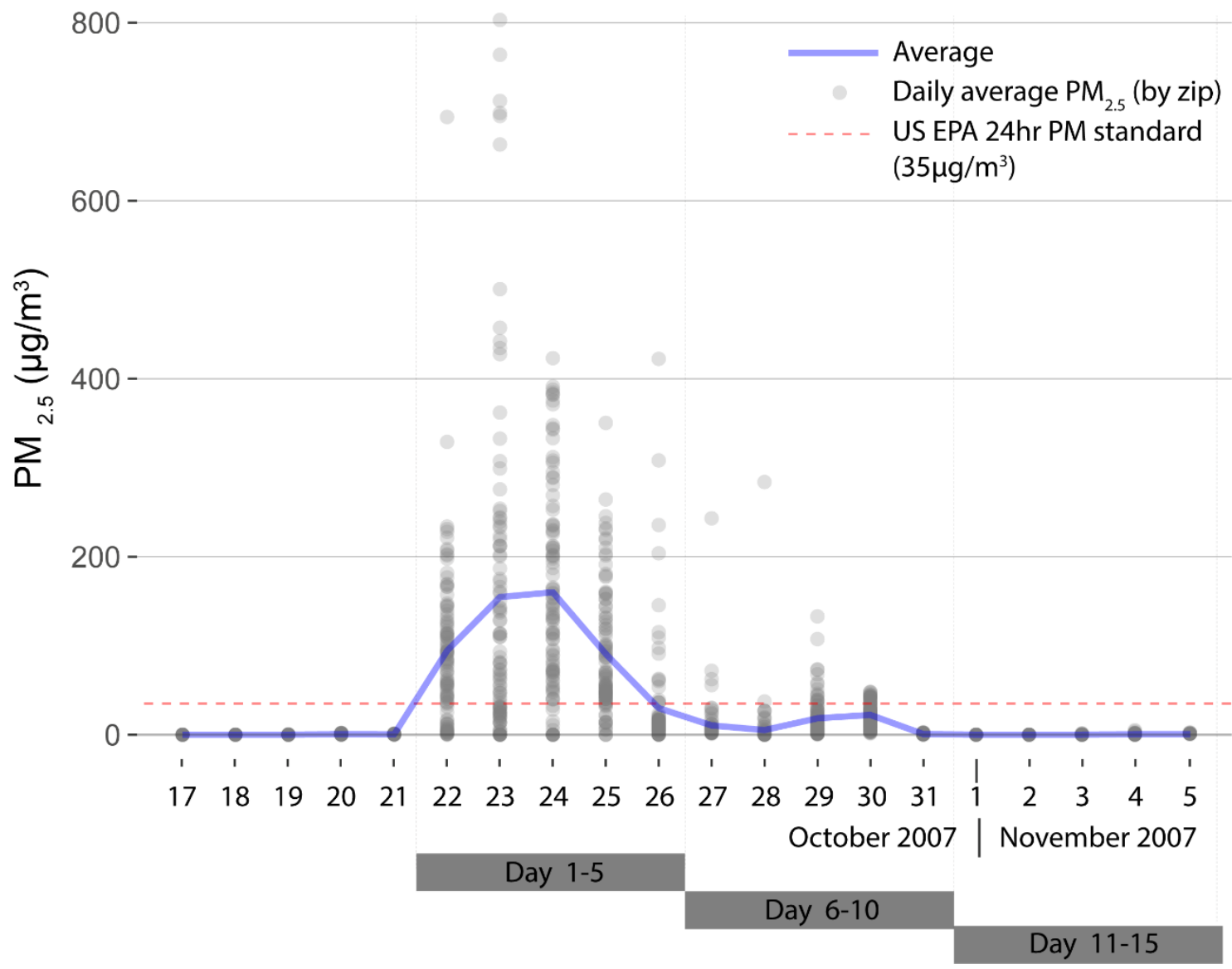
## California

- 9,000 separate wildfires
- >1,000,000 acres burned

## San Diego

- Medi-Cal population
- San Diego firestorm
  - 500,000 evacuated
  - Multiple school & road closings



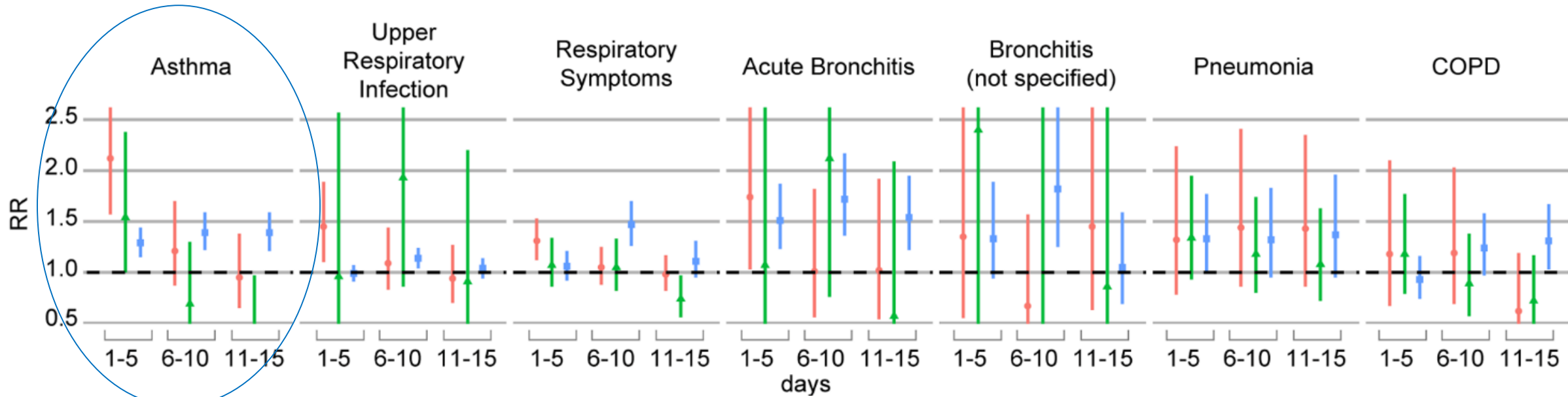


# Daily PM<sub>2.5</sub>



# San Diego County during 2007 fire period

## Respiratory visits

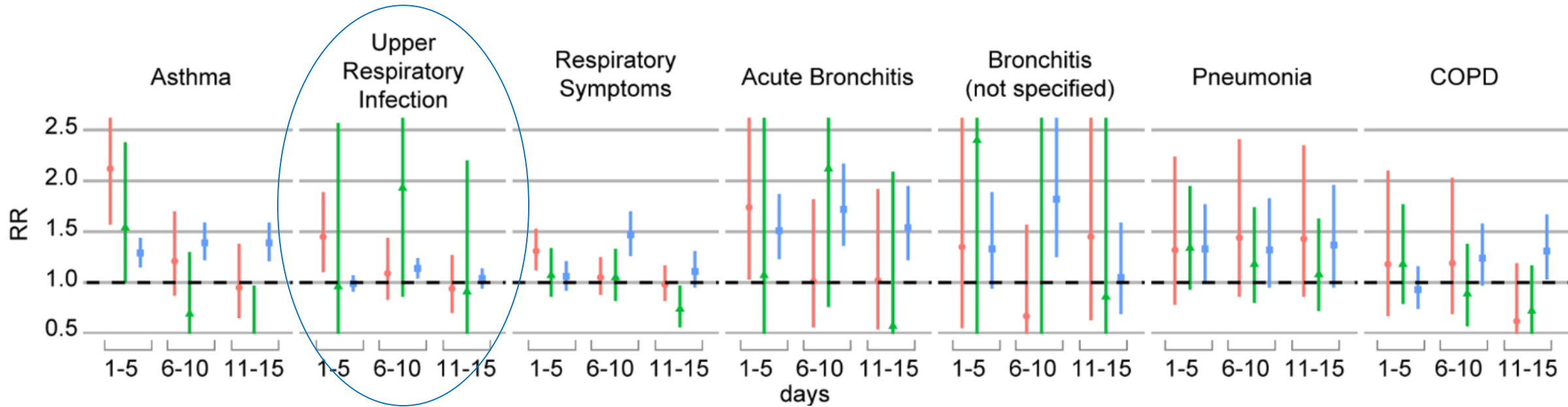


Visit Type

- Emergency Presentations
- Inpatient Hospitalizations
- Outpatient Visits



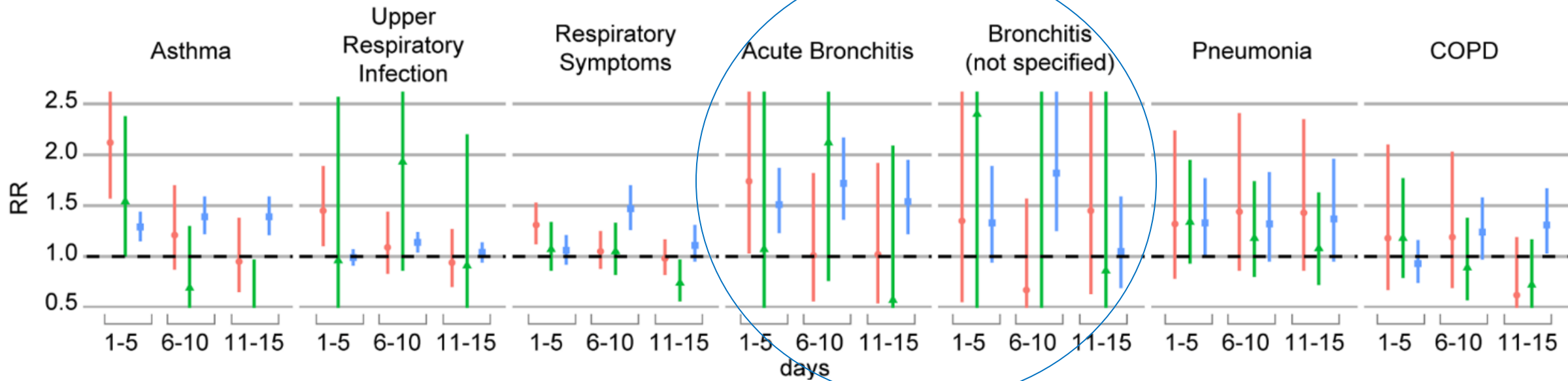
# Respiratory visits



### Visit Type

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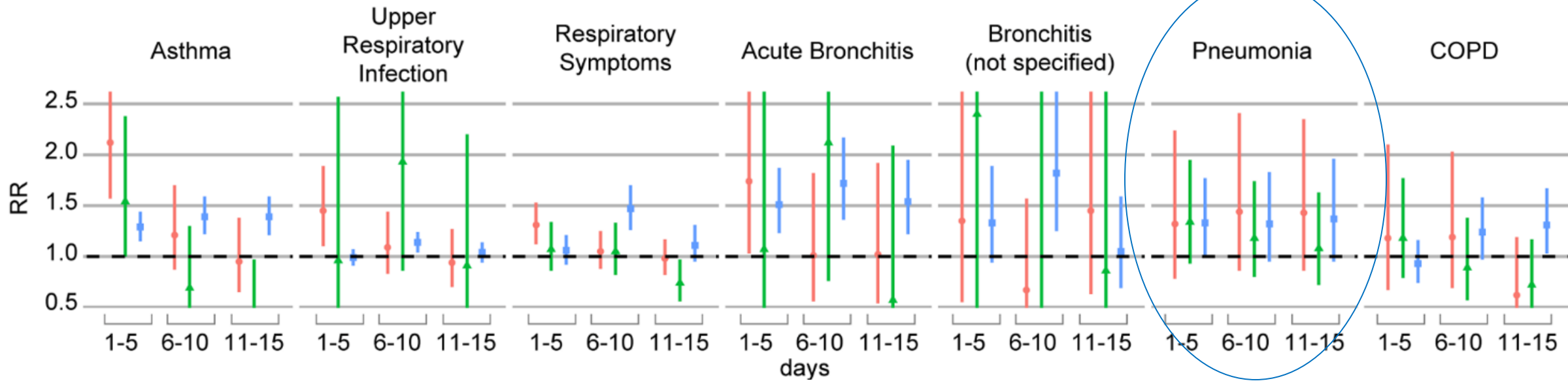
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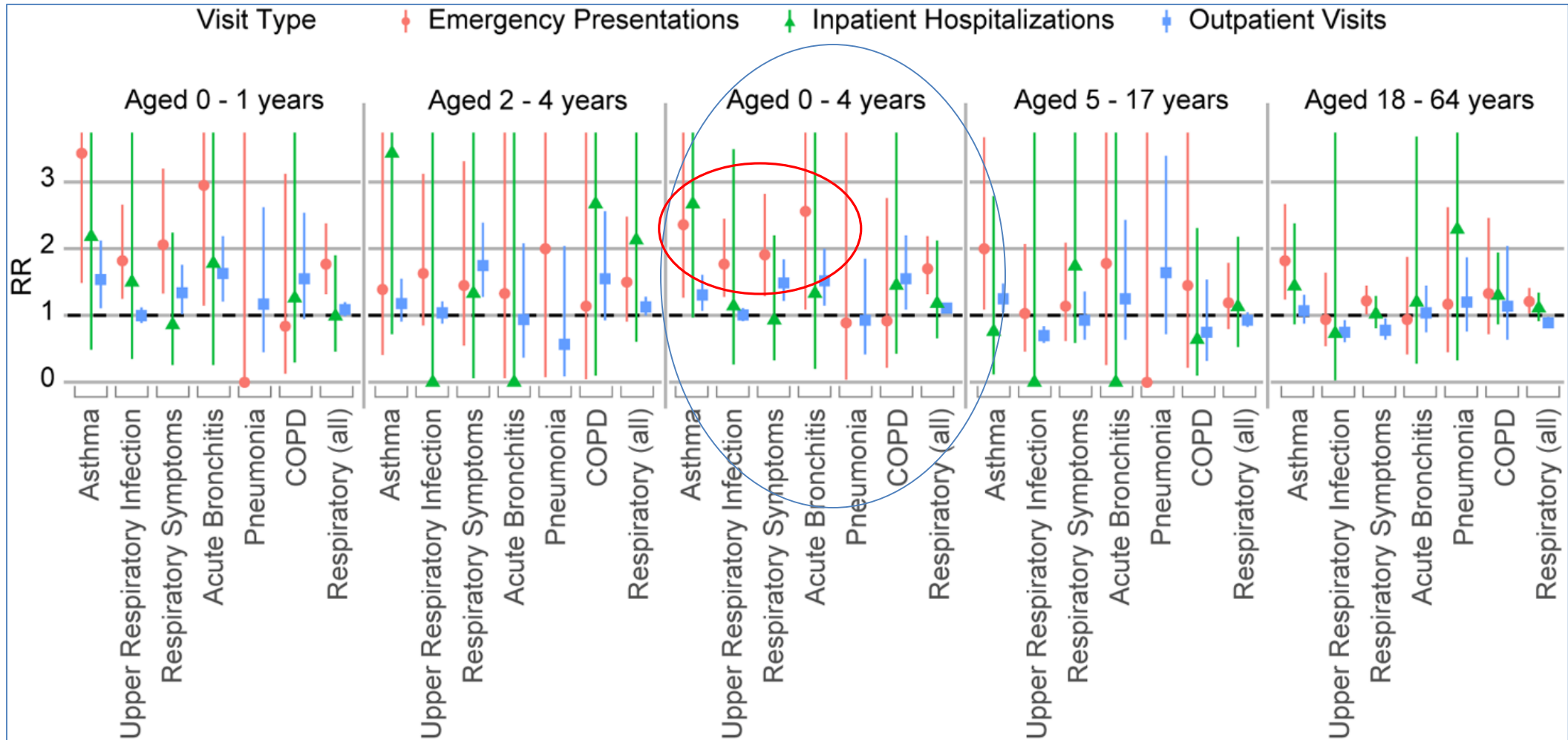


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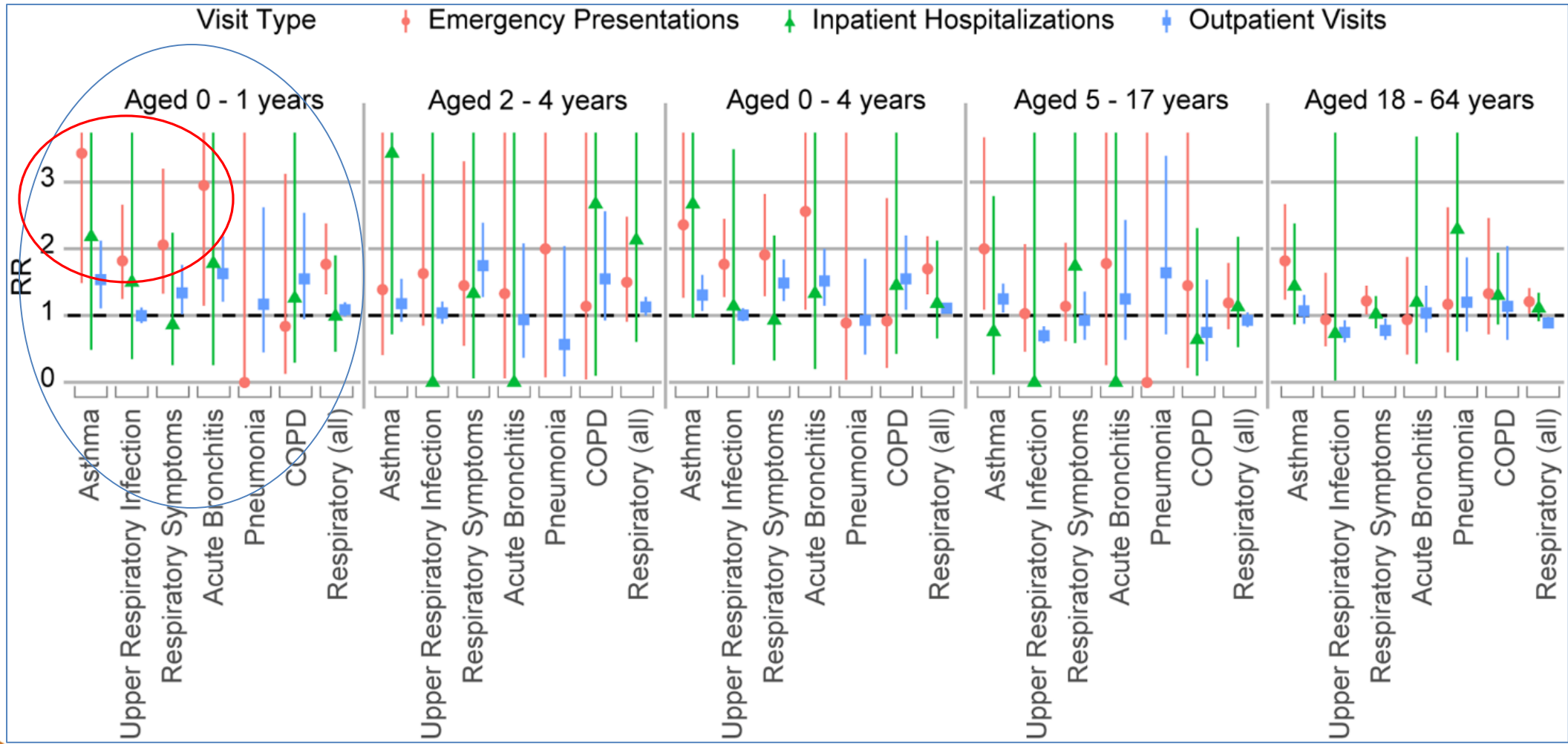
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# Respiratory visits, by age group



# Respiratory visits, by age group



## Air Quality Index (AQI)

### Odds Ratios (ORs), conditional logistic regression of respiratory emergency department visits

AQI categories PM <sub>2.5</sub> (µg/ m <sup>3</sup> )	OR (95% CI) Same day	OR (95% CI) 1-day lag	OR (95% CI) 2-day lag
Good (0 -12)			
Moderate (12.1 - 35.4)			
Unhealthy for Sensitive Groups (35.5 - 55.4)			
Unhealthy (55.5 - 150.4)			
Very unhealthy (150.5 - 250.4)			
Hazardous (≥ 250.5)			
Temperature			
Relative humidity			
AIC			



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Good (0 -12)	Reference	Reference	Reference
Moderate (12.1 - 35.4)	1.20 (0.91-1.59)	1.11 (0.84-1.47)	0.80 (0.59-1.08)
Unhealthy for Sensitive Groups (35.5 - 55.4)	1.43 (0.96-2.13)	1.73 (1.18-2.53)*	1.51 (1.00-2.28)*
Unhealthy (55.5 - 150.4)	1.27 (0.97-1.67)	1.79 (1.30-2.23)*	1.50 (1.13-1.98)*
Very unhealthy (150.5 - 250.4)	1.68 (1.00-2.83)	1.58 (0.93-2.68)	1.87 (1.07-3.27)*
Hazardous (≥ 250.5)	<b>2.41 (1.39-4.18)*</b>	1.28 (0.70-2.36)	1.74 (1.00-3.03)*
Temperature	1.00 (0.99-1.01)	1.00 (0.99-1.01)	1.00 (0.99-1.00)
Relative humidity	1.01 (1.00-1.01)*	1.01 (1.00-1.01)*	1.01 (1.00-1.01)*
AIC	5233.2	5228.9	5231.8

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Relative humidity	1.01 (1.00-1.01)*	1.01 (1.00-1.01)*	1.01 (1.00-1.01)*
AIC	5233.2	5228.9	5231.8

# CARDIOVASCULAR EFFECTS & WILDFIRE SMOKE

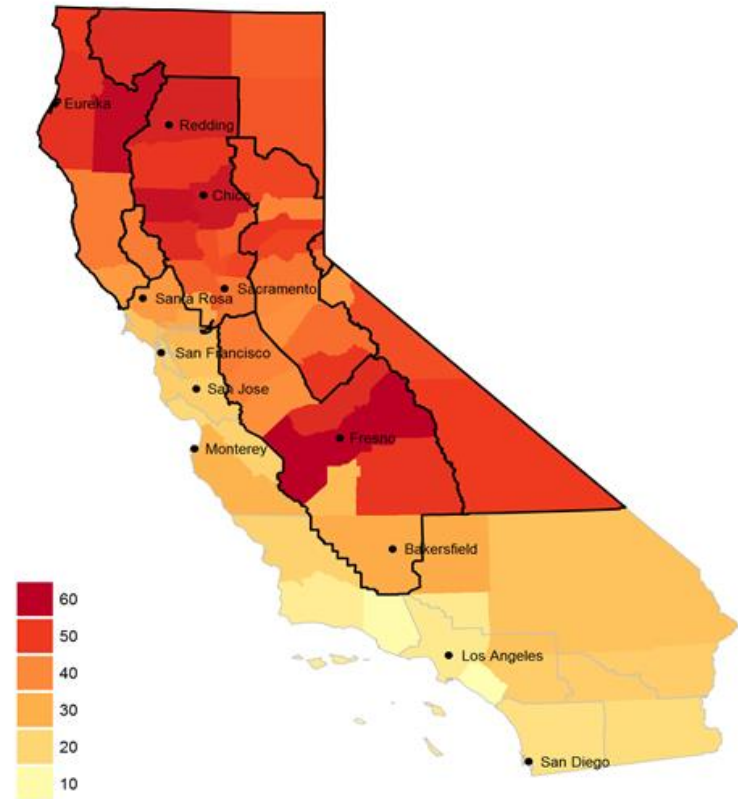
## 2015 WILDFIRES

CDPH Collaborative Research

Number of Smoky Days per County:

May 1 through September 30, 2015

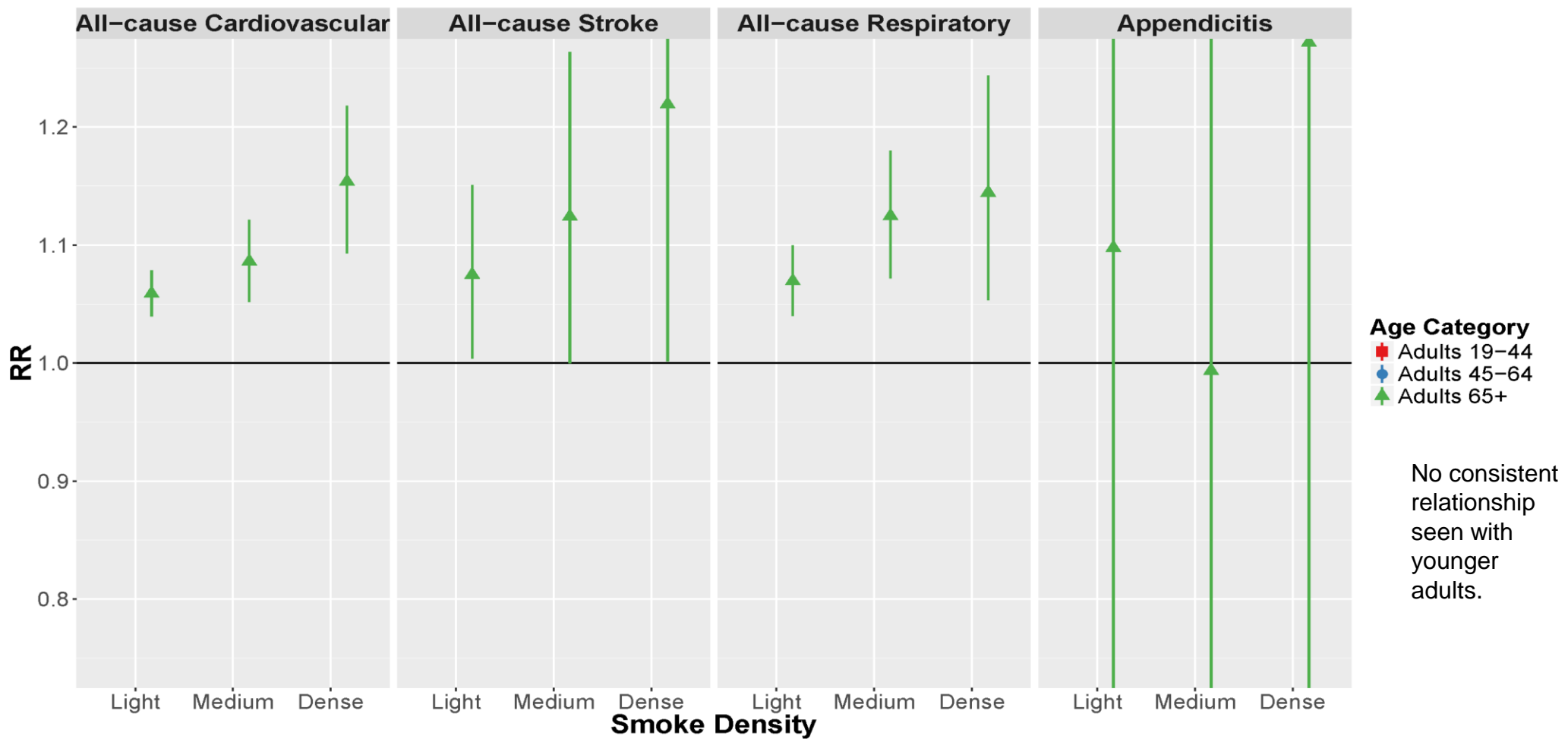
[Wettstein ZS](#)<sup>1</sup>, [Hoshiko S](#)<sup>2</sup>, [Fahimi J](#)<sup>3</sup>, [Harrison RJ](#)<sup>4,5</sup>, [Cascio WE](#)<sup>6</sup>, [Rappold AG](#)<sup>7</sup>. [J Am Heart Assoc. Cardiovascular and Cerebrovascular Emergency Department Visits Associated With Wildfire Smoke Exposure in California in 2015. 2018 Apr 11;7\(8\).](#)



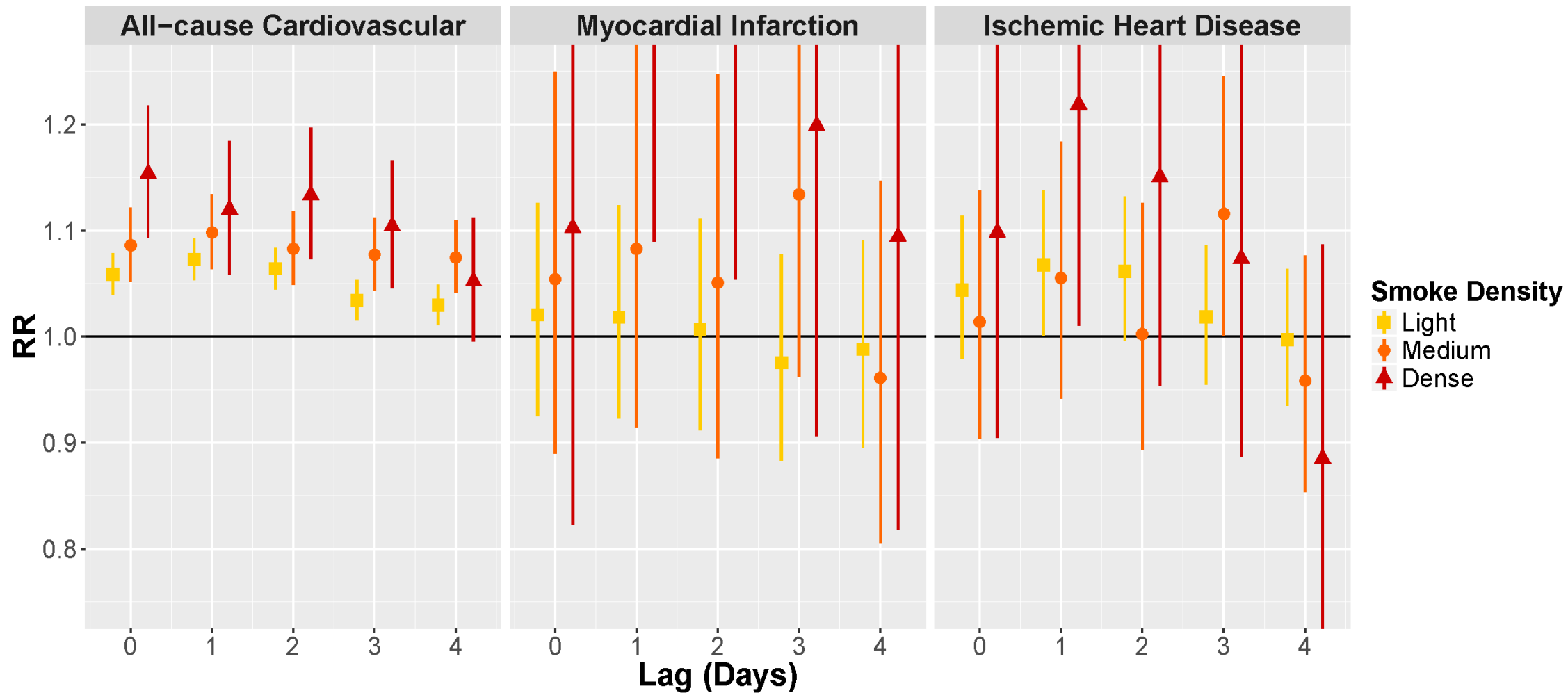


# Cardiovascular and other ER visits

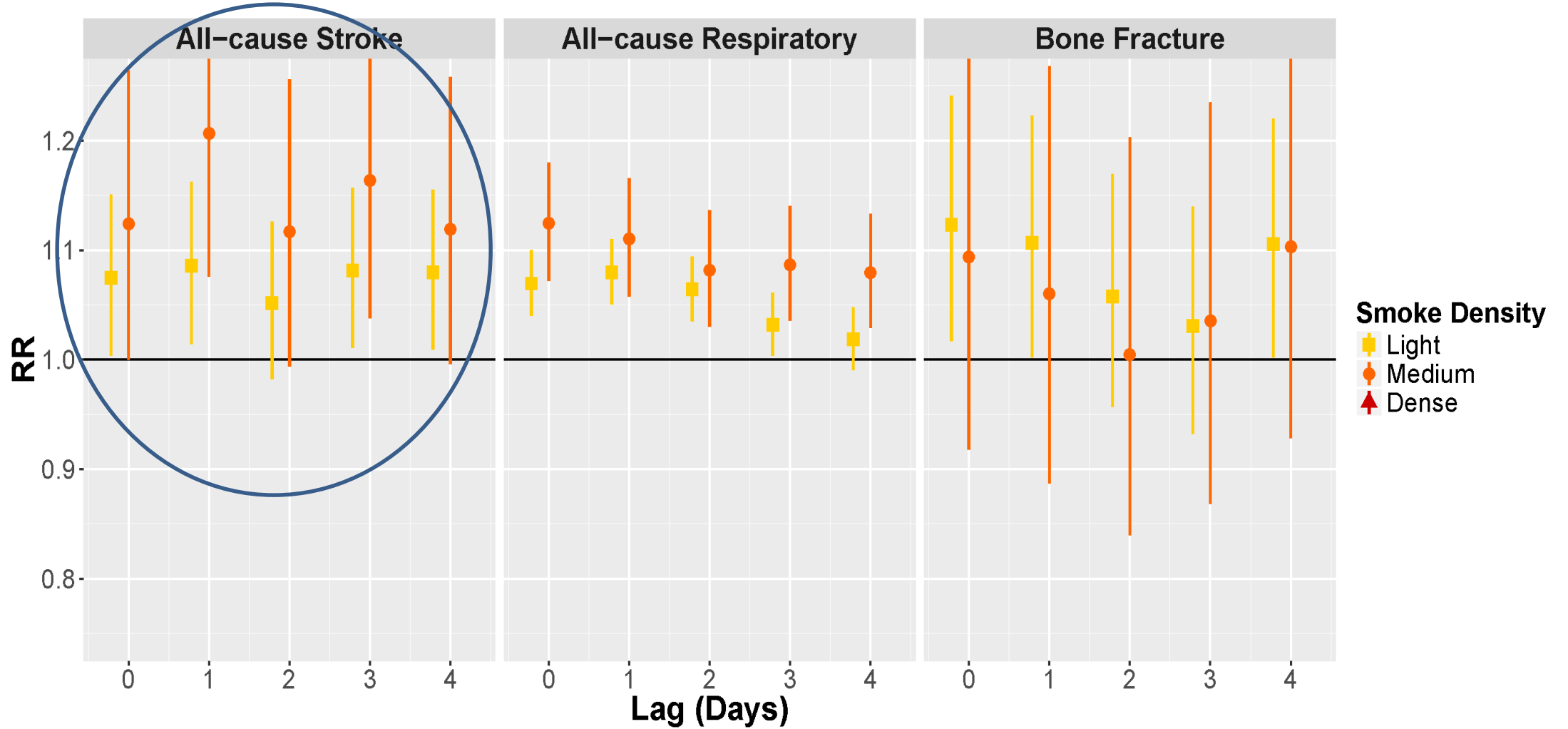
↑ Risks from light, medium and dense smoke -- Adults 65+



**Adults 65 Years and Older**  
**Relative Risk (95% CI) – Lags 0 to 4 Days**

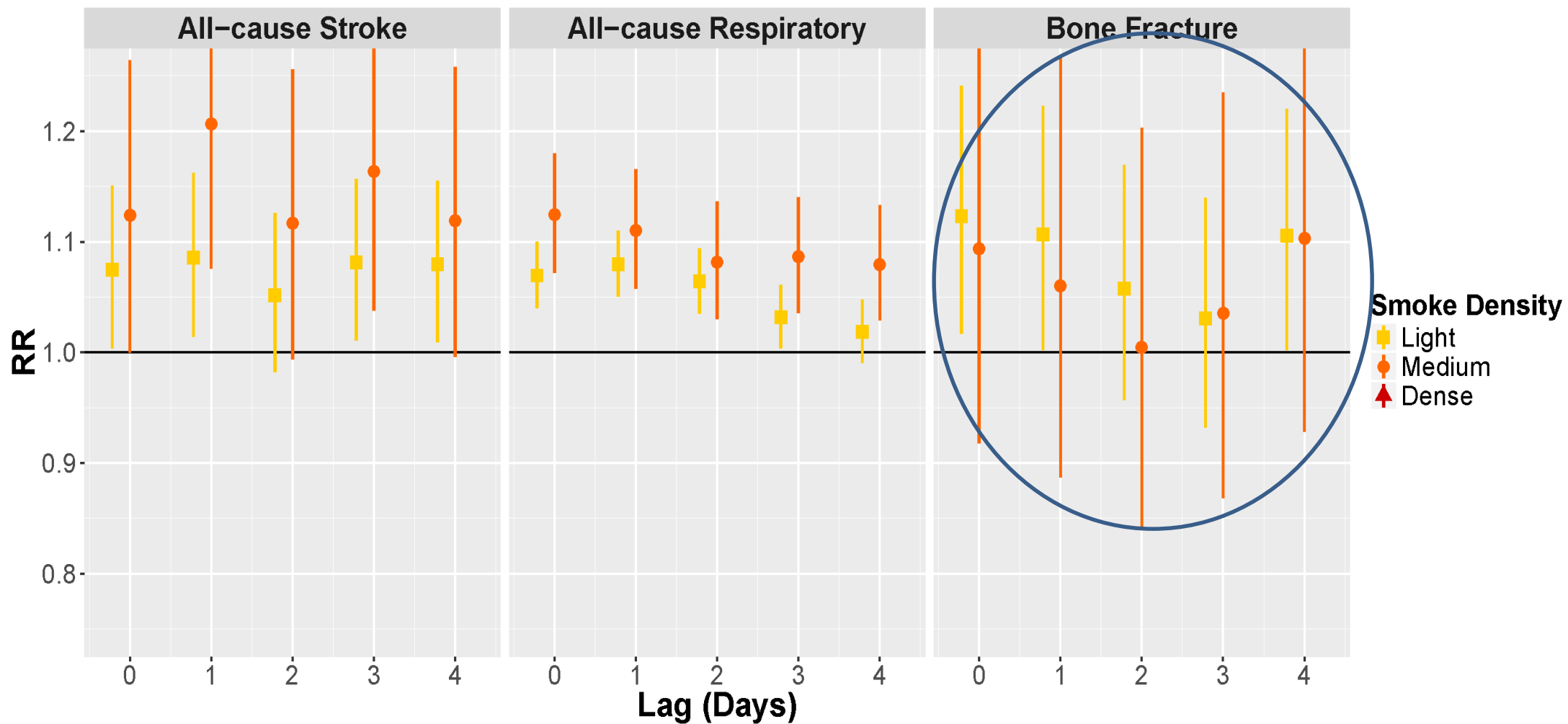


**Adults 65 Years and Older**  
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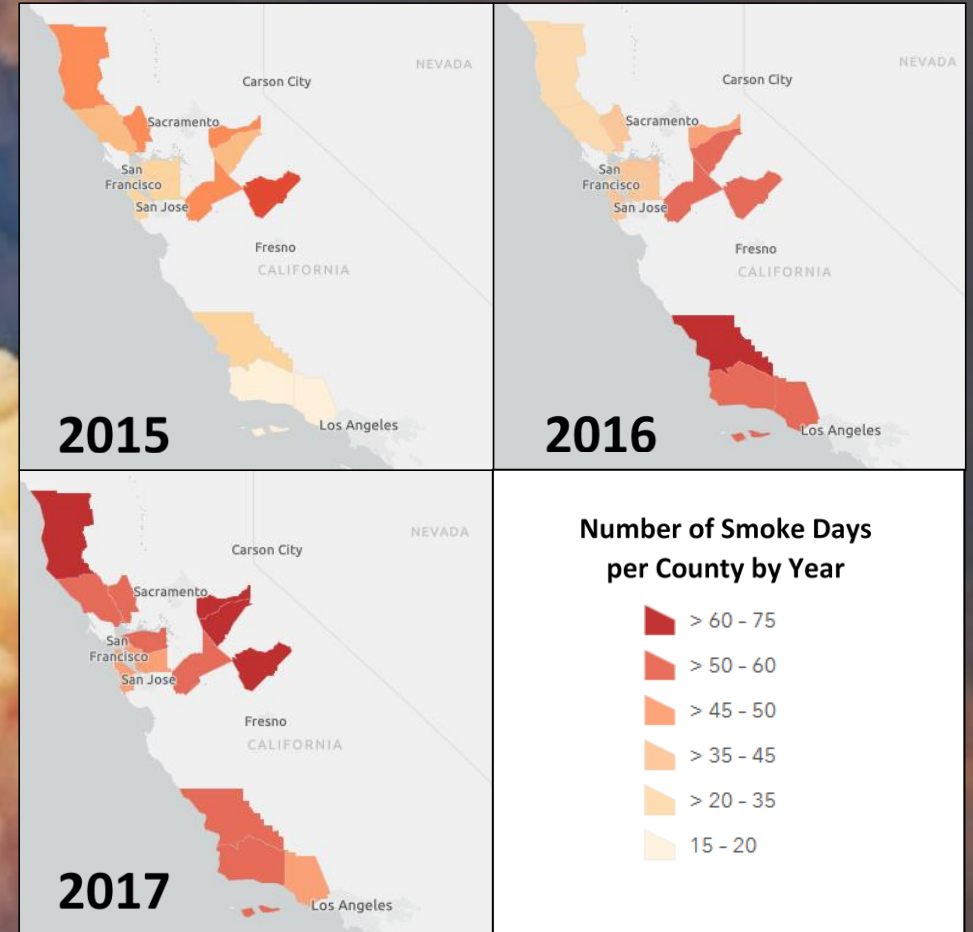


**Adults 65 Years and Older**  
**Relative Risk (95% CI) – Lags 0 to 4 Days**



# Research Question

In California in 2015 - 2017, were wildfire smoke exposures associated with risk of out-of-hospital cardiac arrests?

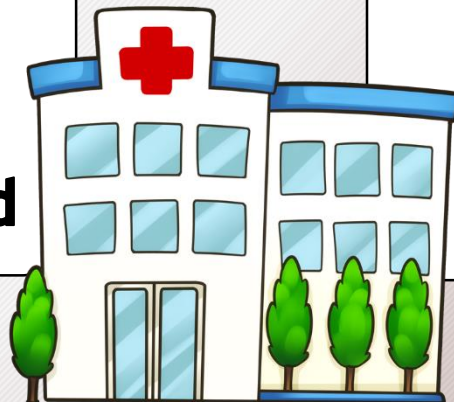


# Out-of-Hospital Cardiac Arrest

- **5,336 cases of OHCA**
  - *Cardiac Arrest Registry to Enhance Survival*
  - 14 California counties, 2015-2017
- Exposure assigned by day and census tract of the OHCA event for lag day 0-3

**~ 30%**

**are hospitalized**



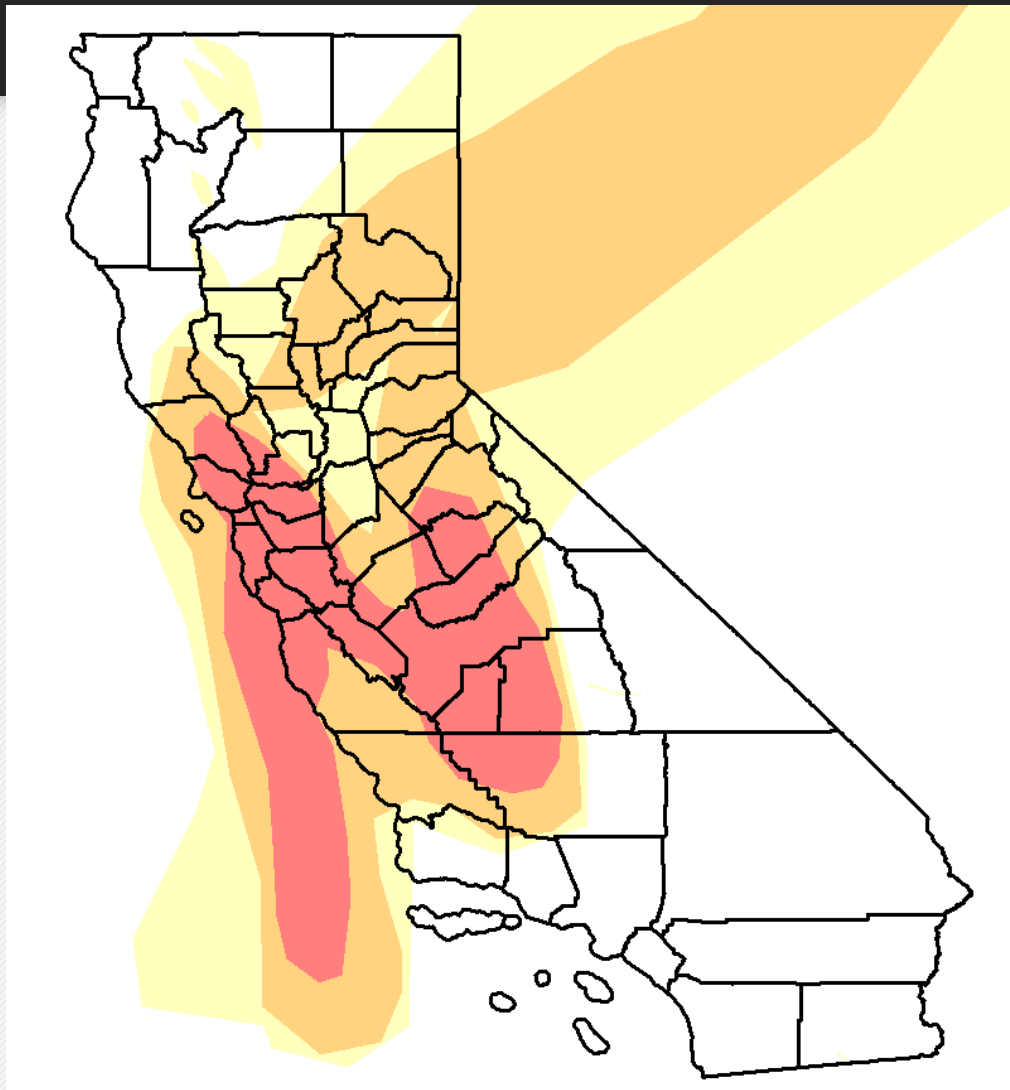
**~ 90%**

**fatal**



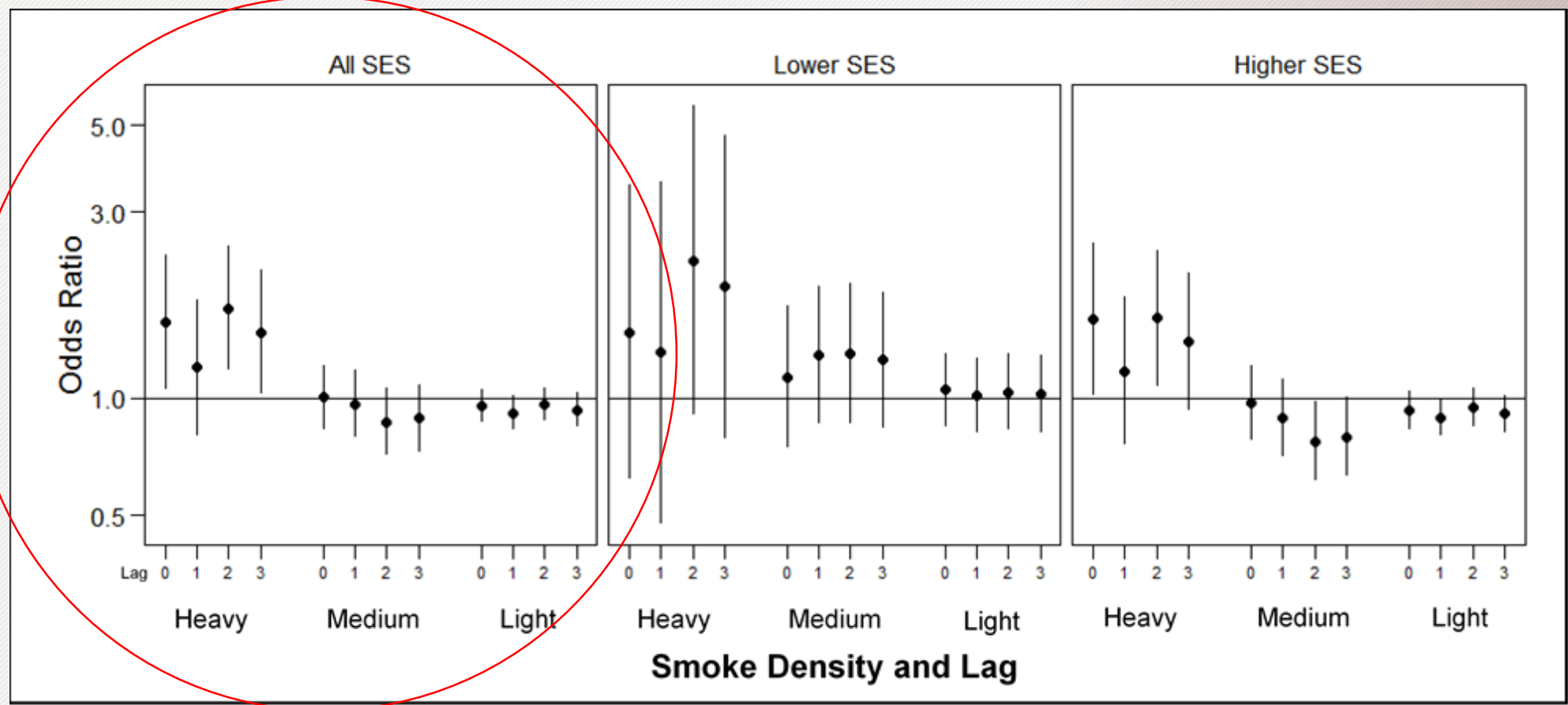


# NOAA HMS Product

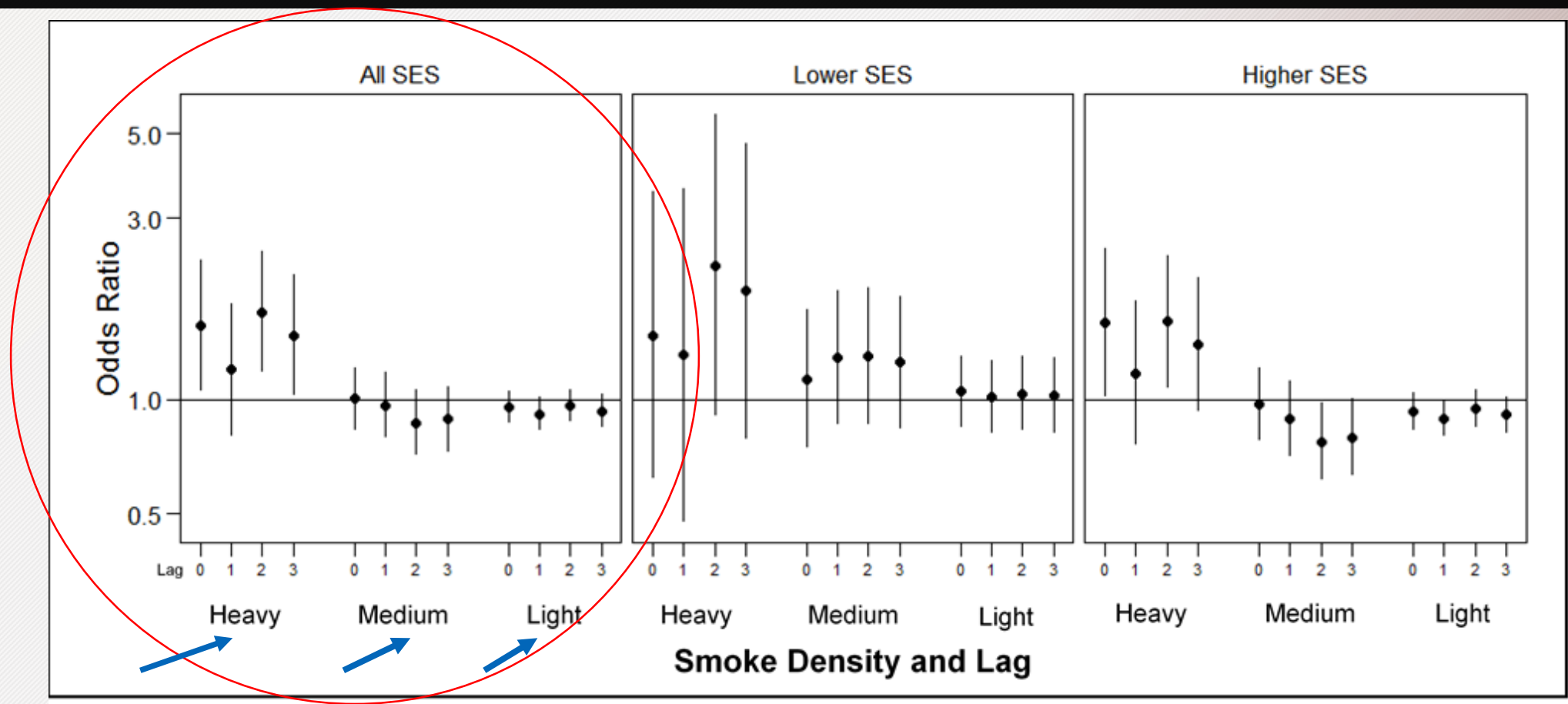




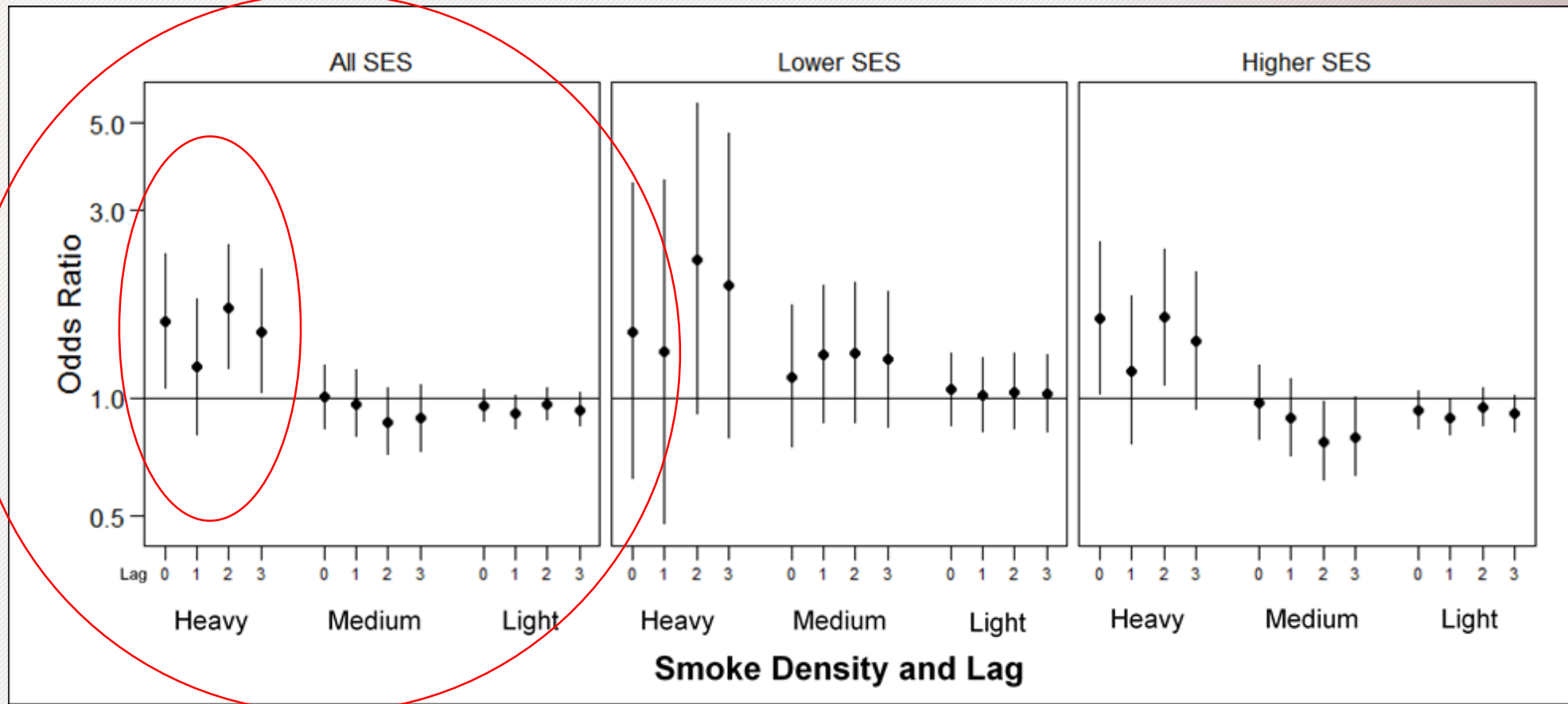
# Odds Ratios for Out-of-Hospital Cardiac Arrest (OHCA)



- Heavy, medium and light smoke
- Lags 0, 1, 2, 3

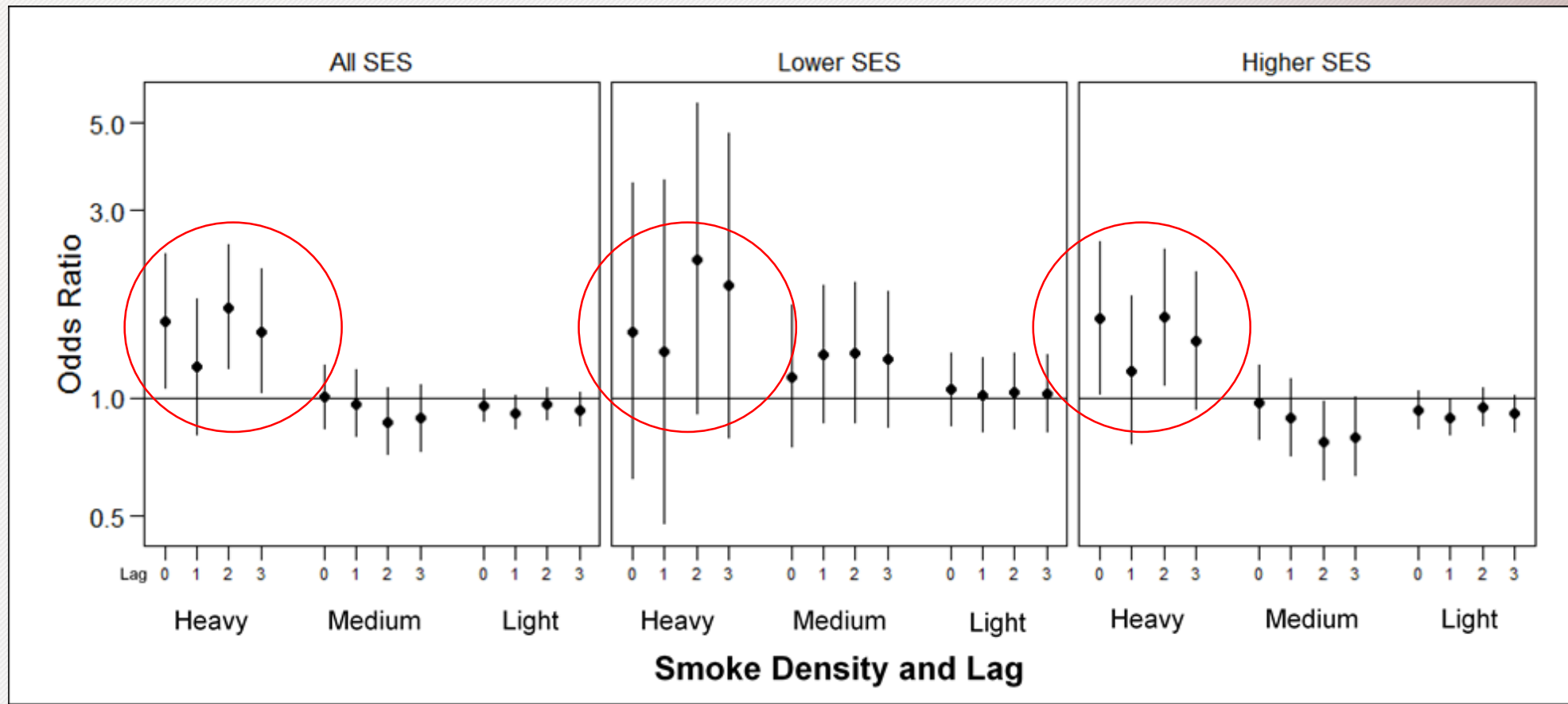


- OHCAs increased with heavy smoke



# Socioeconomic Status

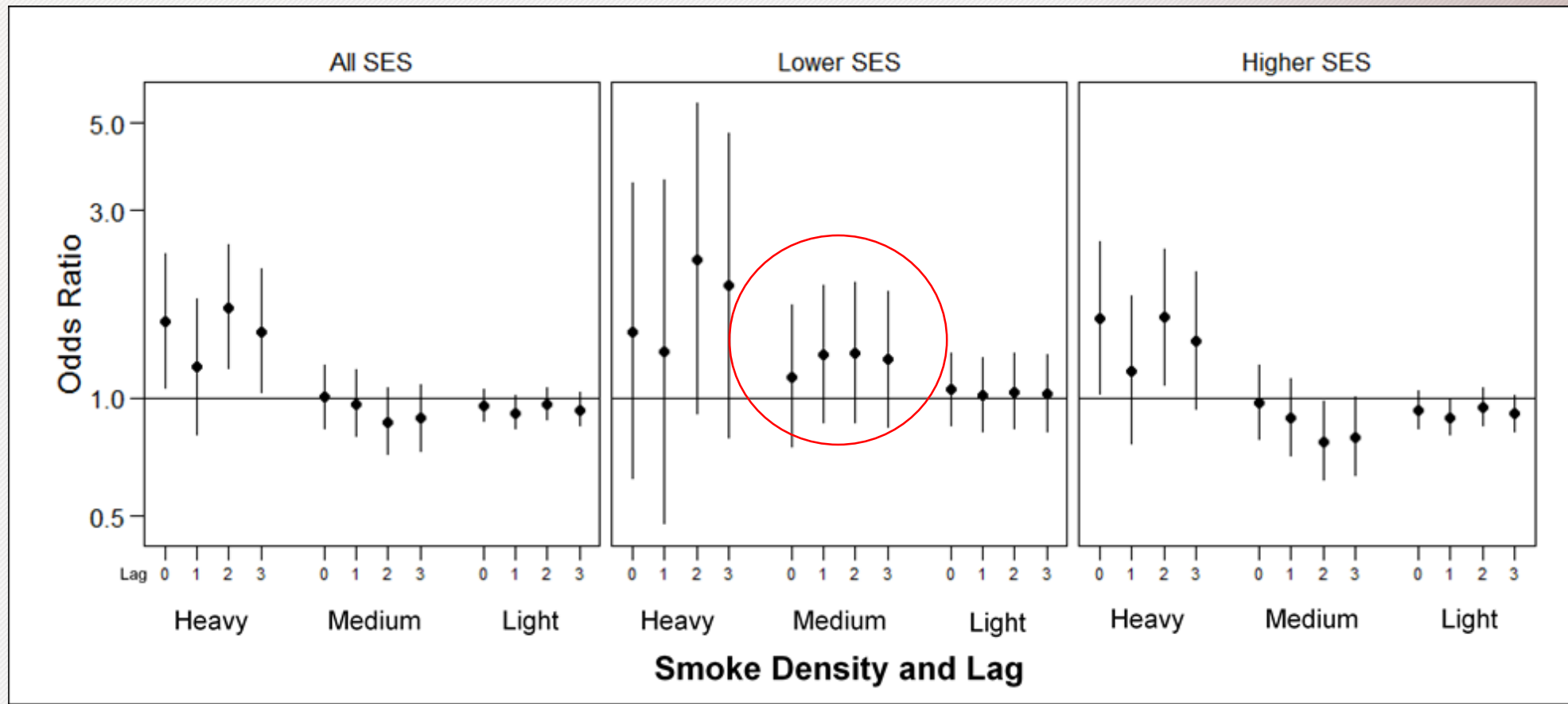
- All groups elevated for heavy smoke
- Effects for same day to 3 days lag
- Fewer low SES (20% v 80% higher SES)





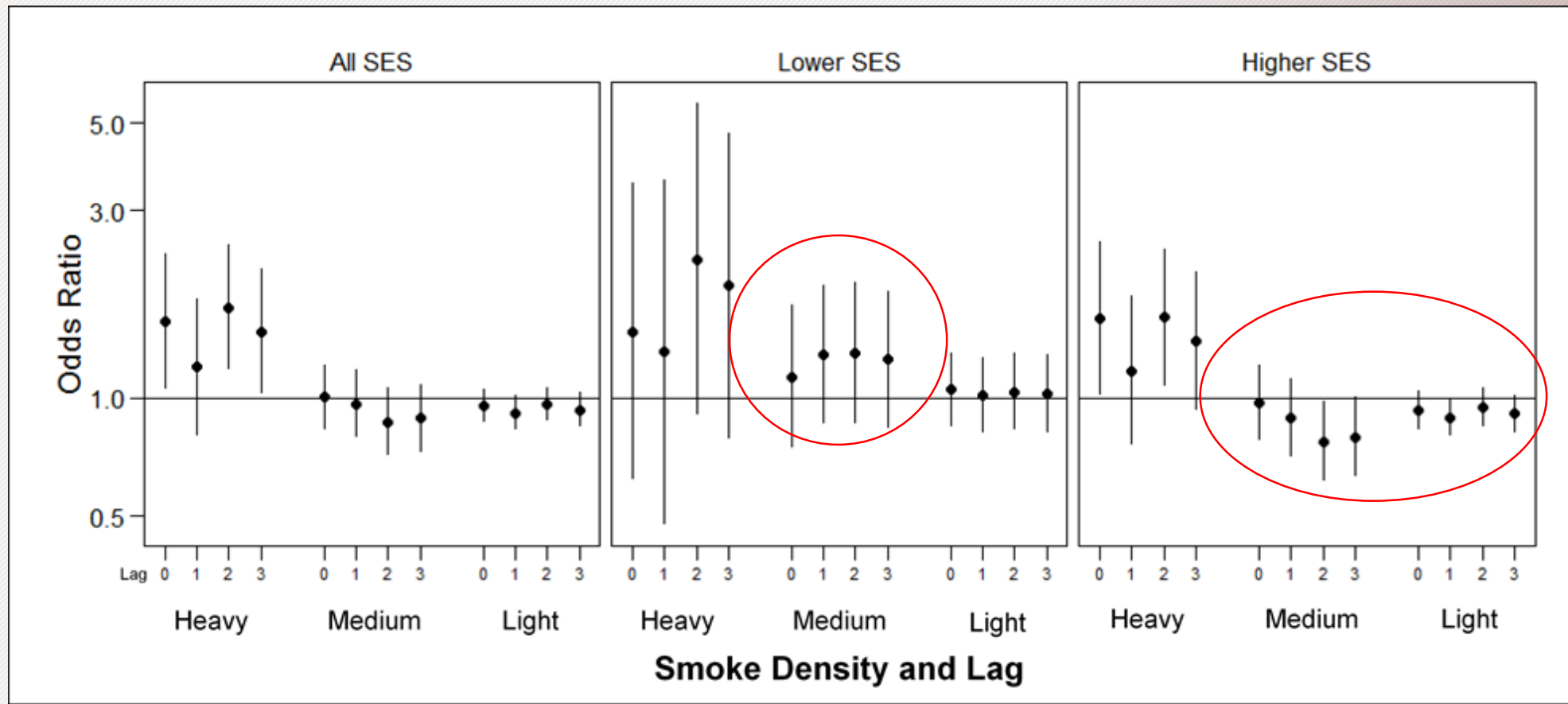
# Socioeconomic Status

- Elevated effects for lower SES at medium smoke



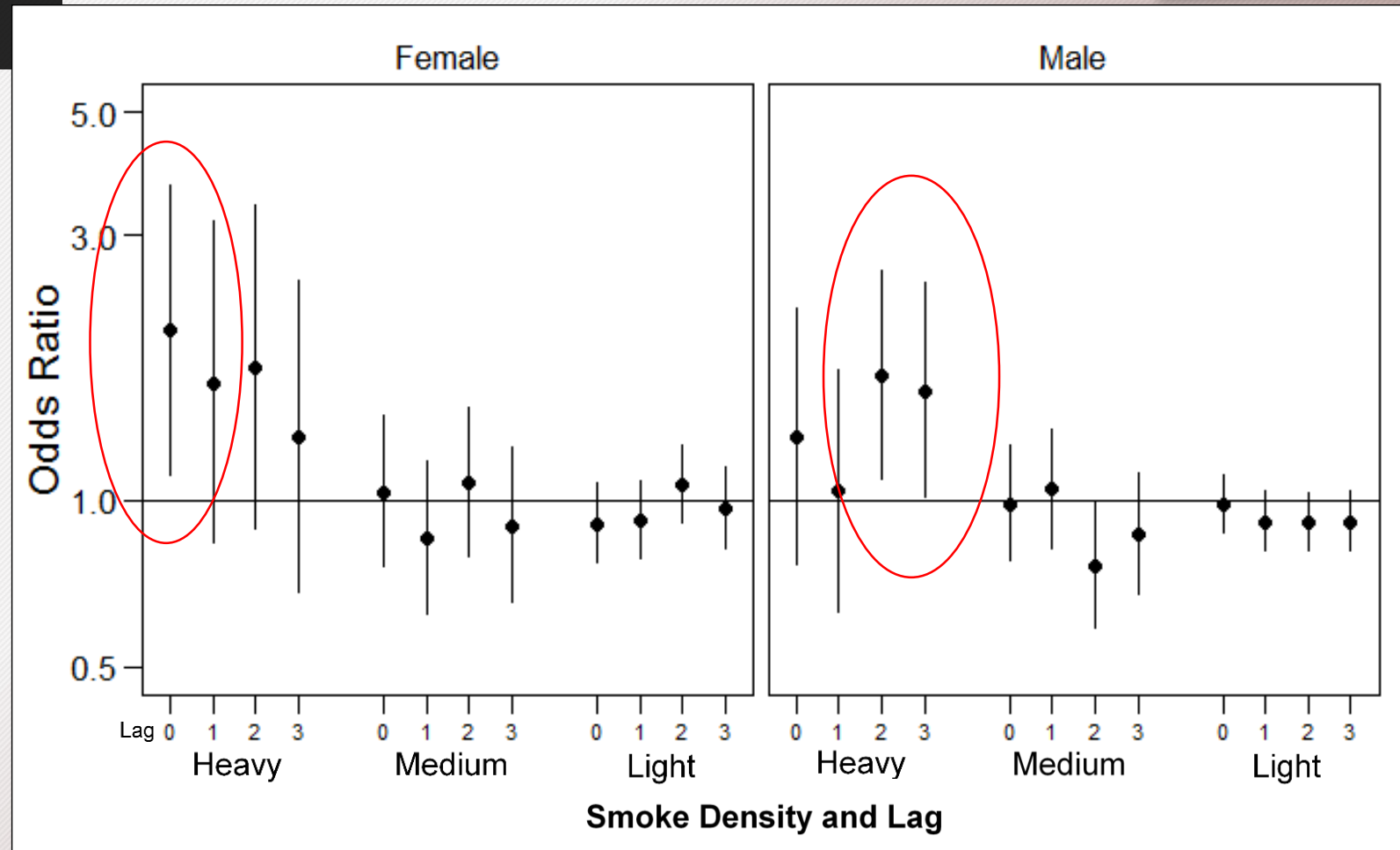
# Socioeconomic Status

- Elevated effects for lower SES at medium smoke
- Deficits for higher SES at medium, light smoke.



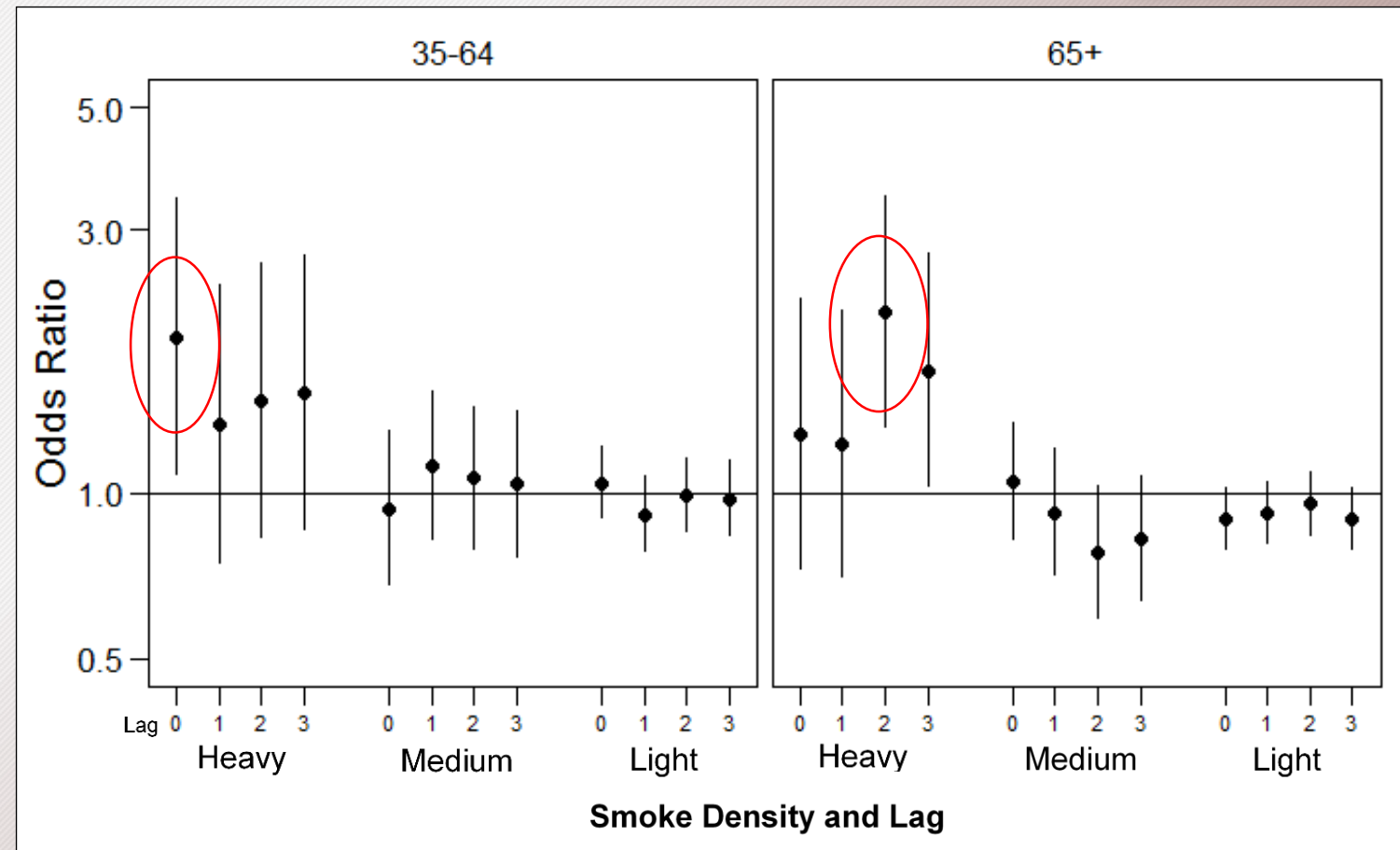
# Sex

- No difference in OR between females and males.



# Age Group

- Different lag effects
  - Younger adults, lag 0
  - Elderly adults, lags 2&3
- Differences not statistically significant.







**Smoke Sense**

## SmokeSense Mobile App:

**A collaborative citizen science research project developed by US EPA**

The California Department of Public Health  
with support from  
the American Lung Association  
collaboration with US EPA



# Resources

## US EPA – AirNow

### Fires and Your Health



Smoke is made up of a complex mixture of gases and fine particles produced when wood and other organic materials burn. The biggest health threat from smoke is from fine particles. These microscopic particles can get into your eyes and respiratory system, where

they can cause health problems such as burning eyes, runny nose,

#### Publications

- Wildfire Smoke, A Guide for Public Health Officials, 2016
- How Smoke from Fires Can Affect Your Health
- Particle Pollution and Your Health
- Other AirNow Publications

Exit AirNow

- Before, During, and After a Wildfire - CDC - Information on emergency preparedness

<https://airnow.gov/index.php/air-quality-and-health/fires-and-your-health>

## US EPA – CME Education

### Particle Pollution and Your Patients' Health

CONTACT US

SHARE



#### Evidence-based Training for Healthcare Professionals

describes the biological mechanisms responsible for the cardiovascular and respiratory health effects associated with particle pollution exposure.

Provides educational tools to help patients understand how particle pollution exposure can affect their health and how they can use the Air Quality Index to protect their health.



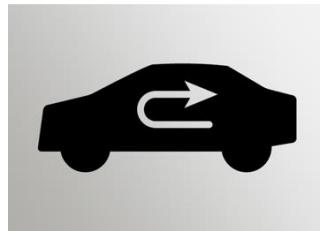
This course is designed for family medicine physicians, internists, pediatricians, occupational and rehabilitation physicians, nurse practitioners, nurses, asthma educators, pulmonary specialists, cardiologists, and other medical

<https://www.epa.gov/pmcourse/continuing-education-particle-pollution-course>

# How to reduce health risk during smoky periods

## DO:

- **Stay indoors**
- Home – close fresh intake for AC. Be aware of heat risk.
- Use a Portable Air Cleaner with HEPA filter to clean the air in rooms
- Car AC – recirculate
- Keep medicine supply and non-perishable food on hand.



## DO NOT:

- Fry or broil foods – adds particles to indoor air
- Use fireplace, gas logs, or gas stove
- Play or exercise outdoors
- Smoke indoors
- Vacuum (can stir up dust)

# Protective measures – Portable Air Filters

- Portable air cleaners with high efficiency filters
  - can reduce indoor particle concentrations by as much as 85%.
  - can be used alone or with enhanced central air filtration.
- *Advance planning!*

**Use the right ones!**  
California Air Resources Board

<https://www.arb.ca.gov/research/indoor/aircleaners/certified.htm>



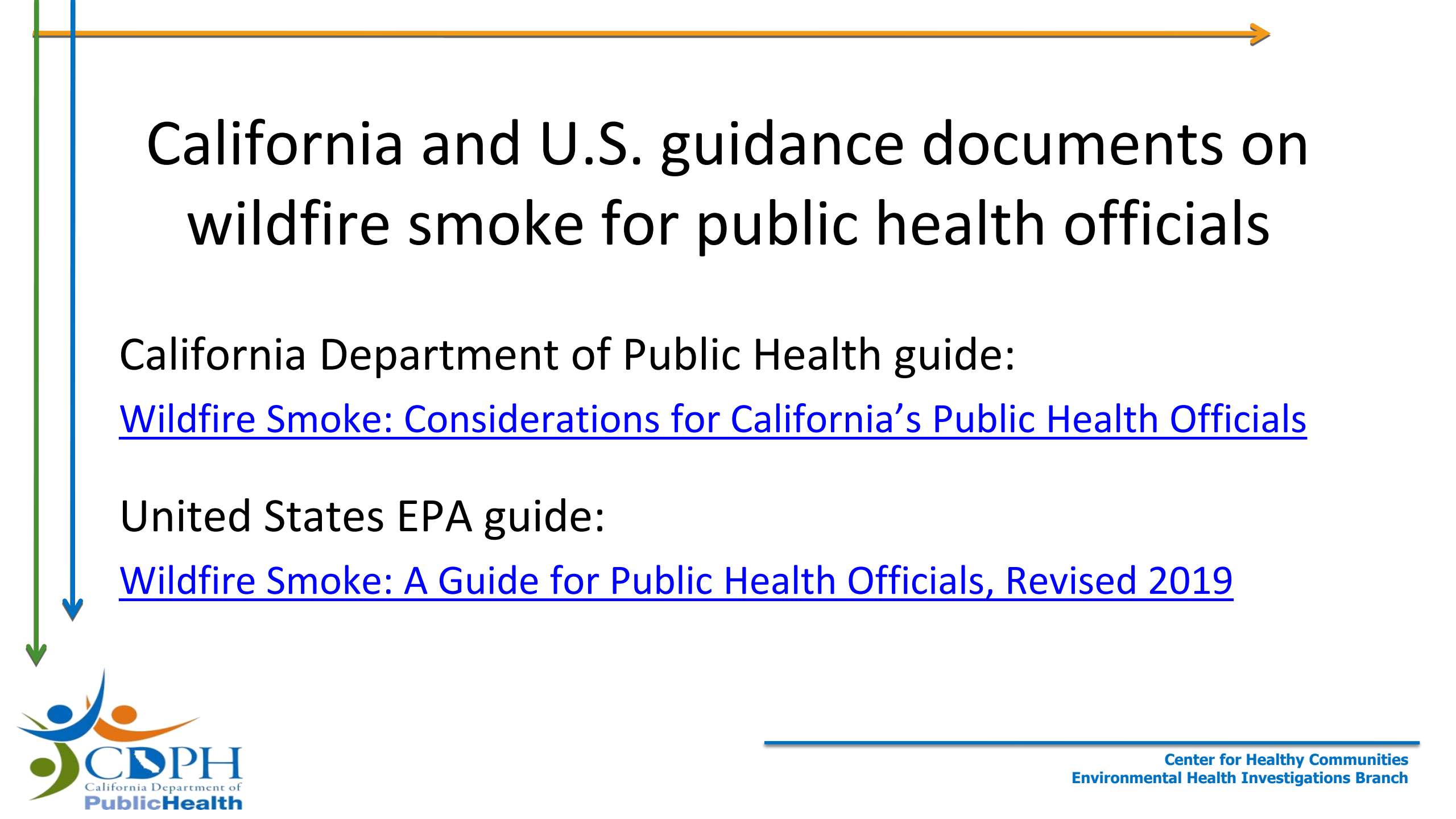
The screenshot shows the California Air Resources Board (ARB) website. At the top, there are logos for CA.GOV and CALIFORNIA AIR RESOURCES BOARD, along with a search bar and navigation links like 'About Our Work', 'Resources', 'Business Assistance', and 'Rules'. The main heading is 'California Certified Air Cleaning Devices', dated 'Saturday, November 4, 2017'. Below the heading, there is a 'LINKS' section with links to 'Reducing Air Pollution - ARB Programs', 'Research Activities', and 'Indoor Air Quality'. The main content area contains the text: 'All portable indoor air cleaning devices sold in California after October 18, 2010 must be certified by the California Board (CARB). To be certified, air cleaners must be tested for electrical safety and ozone emissions, and meet emission concentration limit of 0.050 parts per million. These and other requirements such as specific labeling I'.





## N95 Respirators

- Use NIOSH-certified
- Should fit closely to the face
- Adults who must remain outdoors in unhealthy air for extended periods of time may benefit
- In occupational setting, medical evaluation & fit testing required.
- Members of the public with heart or lung conditions - consult with health care provider.
- Not designed for children, use alternate strategies
- Surgical masks or one-strap paper masks do not protect



# California and U.S. guidance documents on wildfire smoke for public health officials

California Department of Public Health guide:

[Wildfire Smoke: Considerations for California's Public Health Officials](#)

United States EPA guide:

[Wildfire Smoke: A Guide for Public Health Officials, Revised 2019](#)

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***THANK YOU!***

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