Appendix for “Wildfire particulate matter in Shasta County, California and respiratory and circulatory emergency department visits and mortality, 2013–2018”

eTable 1: Valley and Mountain Zip Code Tabulation Areas.

Mountain ZCTA codes			Valley ZCTA codes		
Total population: 23,835[a]			**Total population: 166,632[a]**		
ZCTA	**City**	**Population**	**ZCTA**	**City**	**Population**
96008	Bella Vista	1,328	96001	Redding	34,571
96011	Big Bend PO Box	162	96002	Redding	33,901
96013	Burney	4,810	96003	Redding	44,475
96016	Cassel	375	96007	Anderson	23,106
96017	Castella	152	96019	Shasta Lake	10,111
96025	Castle Crags	1,957	96022	Cottonwood	16,442
96028	Fall River Mills	1,359	96049	Redding PO Box	87
96033	French Gulch	500	96073	Palo Cedro	3,939
96040	Hat Creek	178	96079	Shasta Lake PO Box	-
96047	Igo	851	96089	Shasta Lake PO Box	-
96051	Lakehead	1,351	96099	Redding PO Box	-
96056	Mcarthur	1,572			
96059	North of Manton	599			
96062	Milville	1,007			
96065	Montgomery Creek	359			
96069	Oak Run	828			
96070	Obrien PO Box[a]	-			
96071	Old Station	49			
96076	Plantina	200			
96084	Round Mountain	458			
96087	Shasta PO Box	589			
96088	Shingletown	4,419			
96095	Whiskeytown PO Box	1,328			
96096	Whitmore	732			
960XX		-			

ZCTA, Zip Code Tabulation Area

[a] Total population from the 2014-2018 American Community Survey

eMethods 1: Approach to estimate wildfire-specific $PM_{2.5}$

We first modelled daily total $PM_{2.5}$ mass concentrations at the ZIP code-level for the area and study period of interest as described elsewhere.[1] We then used a 4-stage approach to estimate $PM_{2.5}$ attributable to wildfires smoke as described in Aguilera et al.[2]:

Step 1: Identify ZIP code days exposed to smoke plumes intersecting each NOAA Hazard Mapping Systems (HMS) smoke plume with ZIP code polygons (if intersected, smoke exposed zip code day = 1)
Step 2: Replace smoke-exposed ZIP code day = 1 by missing
Step 3: Impute non-smoke $PM_{2.5}$ for exposed ZIP code-days using cubic spline interpolation. We only imputed non-smoke $PM_{2.5}$ for ZIP code-days where $PM_{2.5}$ data was originally available, i.e., we did not impute missing values in the original dataset. Cubic spline interpolation was implemented by means of the imputeTS R package. This step provided estimates of ambient $PM_{2.5}$ unrelated to wildfire smoke.
Step 4: Subtract imputed non-smoke $PM_{2.5}$ from the original $PM_{2.5}$ data to obtain ZIP code daily $PM_{2.5}$ attributable to smoke.

We used available smoke plume datasets from NOAA's HMS (to identify ZIP code days exposed to wildfire smoke). HMS uses visible satellite imagery and trained satellite analyst skills to estimate the spatial extent of smoke, though it cannot discern whether a given plume is at ground level (where $PM_{2.5}$ samples are taken for monitoring) or higher in the atmosphere. The HMS smoke products represent the spatial extent of daily smoke plumes.[1] A simple smoke binary variable was created by intersecting ZIP code polygons with smoke polygons, which was then used as an indication of daily exposure to wildfire smoke $PM_{2.5}$. In other words, a value of 1 was assigned to a ZIP code on a given day if its boundaries were within a smoke plume polygon from the HMS dataset.

Finally, we aggregated wildfire $PM_{2.5}$ and non-wildfire $PM_{2.5}$ concentrations from the ZIP code daily to (1) county-wide weekly and (2) valley ZCTA and mountain ZCTA weekly level for statistical analyses.

eTable 2: Estimated coefficients and 95% confidence intervals for time-series models estimating the association between weekly wildfire $PM_{2.5}$ and the Carr Fire and weekly pulmonary and circulatory emergency department visits and death among residents of valley Zip Code Tabulation Areas in Shasta County, California, 2013–2018 (n = 314 weeks).[a]

Outcome	% change (95% CI)
Respiratory disease-related ED visits[b]	
Wildfire $PM_{2.5}$ binary (≥5.5 $\mu g/m^3$)	
Same week	14.6 (4.2, 24.9)
Lag 1 week	1.7 (-8.3, 11.6)
Lag 2 week	6.5 (-3.6, 16.6)
Carr Fire[c]	27.0 (4.0, 50.0)
Circulatory disease-related ED visits[d]	
Wildfire $PM_{2.5}$ binary (≥5.5 $\mu g/m^3$)	
Same week	2.3 (-9.0, 13.6)
Lag 1 week	3.1 (-8.5, 14.8)
Lag 2 week	-8.1 (-19.3, 3.1)
Carr Fire	1.1 (-14.5, 16.7)
All-cause deaths[d]	
Wildfire $PM_{2.5}$ binary (≥5.5 $\mu g/m^3$)	
Same week	8.1 (-2.0, 18.2)
Lag 1 week	-5.0 (-15.6, 5.6)
Lag 2 week	-1.1 (-11.0, 8.8)
Carr Fire	-5.4 (-17.7, 6.9)
Respiratory disease-related deaths[e]	
Wildfire $PM_{2.5}$ binary (≥5.5 $\mu g/m^3$)	
Same week	8.2 (-25.3, 41.6)
Lag 1 week	5.9 (-29.4, 41.1)
Lag 2 week	-31.5 (-64.4, 1.5)
Carr Fire	4.6 (-31.9, 41.1)
Circulatory disease-related deaths[e]	
Wildfire $PM_{2.5}$ binary (≥5.5 $\mu g/m^3$)	
Same week	-10.2 (-27.4, 7.1)
Lag 1 week	-9.8 (-27.9, 8.4)
Lag 2 week	9.8 (-7.2, 26.8)
Carr Fire[c]	-18.2 (-39.4, 2.9)

[a] The Shasta County Health and Human Services Agency acquired mortality data from the California Integrated Vital Records System and emergency department data from the California Office of Statewide Health Planning and Development.

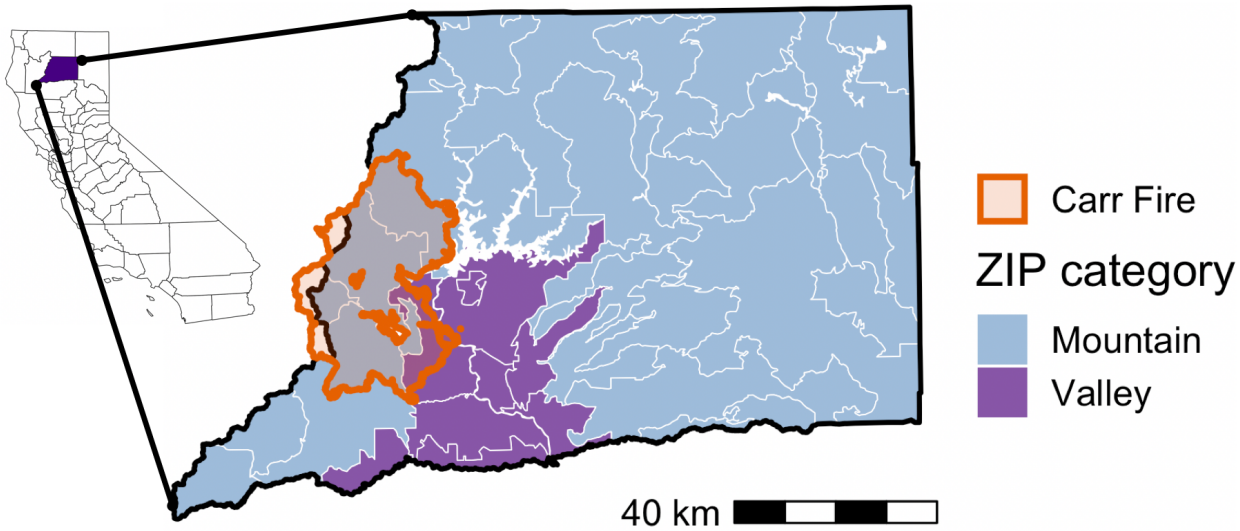
[b] Respiratory ED visits exhibited AR1 and AR2 as well as seasonal AR51 and AR52 autocorrelation.

[c] The Carr Fire (229,651 acres) ignited on July 23, 2018 and was contained on August 30, 2018, however, high wildfire $PM_{2.5}$ days persisted until the second week of September and we included the weeks between July 23, 2018 to September 9, 2018 in the binary Carr Fire exposure variable. Additionally, though smaller in size, the Hirz Fire (46,150 acres burned) and the Delta Fire (63,311 acres) also burned during this time, contributing to smoke in Shasta County.[3]

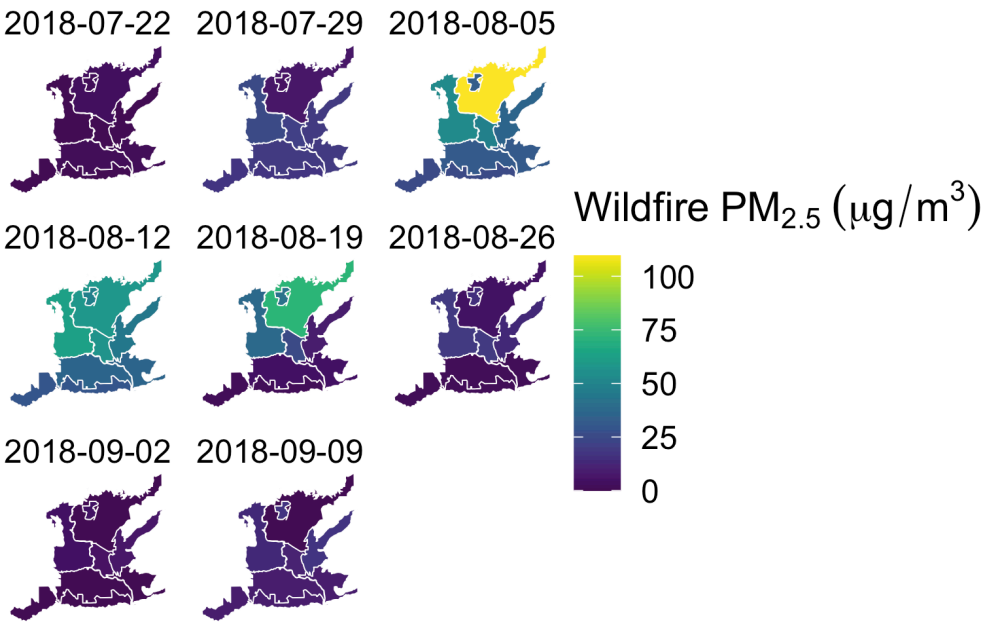
[d] Circulatory ED visits and all-cause deaths exhibited MA1 and AR1 autocorrelation.

[e] Respiratory and circulatory disease-related deaths exhibited no autocorrelation.

eFigure 1: Location and categories of Zip Code Tabulation Areas in Shasta County, California along with the 2018 Carr Fire boundary.



eFigure 2: Weekly average wildfire $PM_{2.5}$ concentration at the ZCTA-level during the 2018 Carr Fire in Shasta County, California valley ZCTAs.



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2. Aguilera R CT, Gershunov A, Benmarhnia T. Wildfire smoke impacts respiratory health more than fine particles from other sources: observational evidence from Southern California. *Nature Comm [In Press].* 2020.
3. The California Department of Forestry and Fire Protection. Cal Fire Incident Information. https://www.fire.ca.gov/. Published 2020. Accessed 16 June 2020.