Supplemental Material for:

Prescribed burns as a tool to mitigate future wildfire smoke exposure: Lessons for states and rural environmental justice communities

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Introduction

- Text S1 describes how we weight $PM_{2.5}$ by population, and Text S2 presents GEOS-Chem's ability to model $PM_{2.5}$ and smoke from wildfires.
- Figures S1-S10 are referenced results found in the main manuscript.
- Table S1 is referenced in the manuscript and deals with the total fire burned area compared to the number of prescribed fires in Northern California over the course of 2018 to 2020

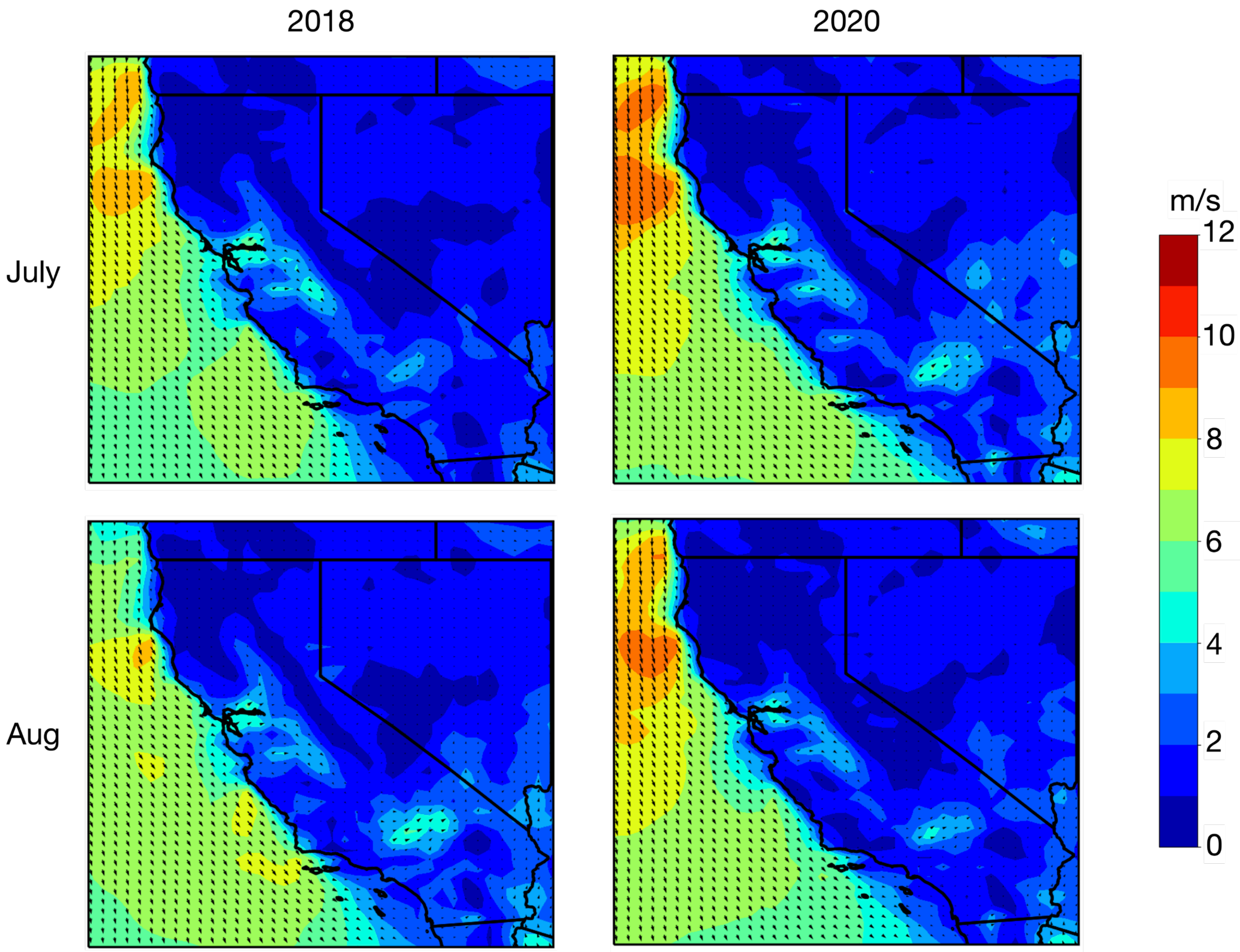
Text S1. **Population weighted $PM_{2.5}$ defintion.**

The following explanation has been adapted from the supplement in Koplitz et al., (2015).

Population weighting of the mean receptor concentrations are carried out by first weighting the smoke $PM_{2.5}$ concentrations of each grid cell within a receptor region by its fractional population of that region. We then calculate the average concentration across these grid cells. The resulting sensitivities – i.e., the fractional contribution of each source grid cell to smoke exposure at each receptor downwind – are applied to the GFED4 biomass burning emissions of primary OC + BC, yielding a gridded estimate of the monthly mean smoke-related $PM_{2.5}$ exposure that results from those emissions. The fractional contributions to exposure from each source grid cell are then summed together to estimate the total population-weighted exposure at the receptor."

Text S2. **GEOS-Chem's ability to represent surface $PM_{2.5}$.**

We use version v8-02-01 of the GEOS-Chem model, which includes many of the same transport and deposition parametrizations as the current generation of the model (v14). Similar GEOS-Chem versions to the one we use here have undergone extensive validation of total and wildfire-specific $PM_{2.5}$ over the United States on a variety of timescales, including daily (Heald et al., 2006; Kim et al., 2015; Liu et al., 2017; Park et al., 2006) and seasonal (Spracklen et al., 2009). Zhang et al. (2014) focused on ozone but included validation of daily mean wildfire $PM_{2.5}$ in GEOS-Chem. Simulated wildfire $PM_{2.5}$ from other regions has also been evaluated on a daily timescale (Shen et al., 2014; Wang et al., 2011). These studies generally find that wildfire-specific $PM_{2.5}$ has a lower mean and median values compared to $PM_{2.5}$ from non-fire sources, but higher extreme values. GEOS-Chem, like many air pollution models, tends to underestimate surface $PM_{2.5}$ concentrations for the most extreme fires but generally captures the bulk statistical behavior of wildfire $PM_{2.5}$ (Liu et al., 2017).


2018
2020
July
Aug
m/s
12
10
8
6
4
2
0

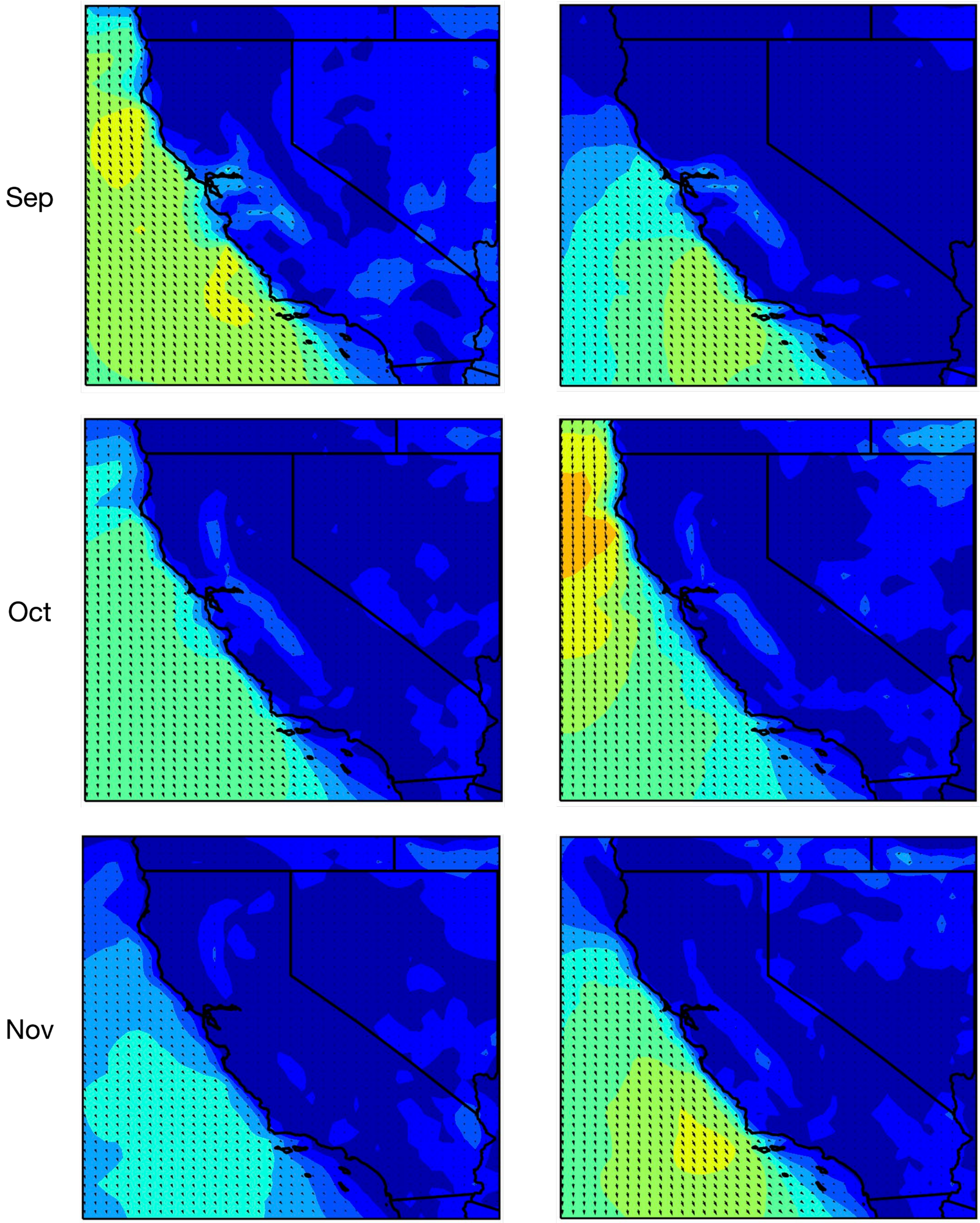


Figure S1. Monthly-mean composite 10-m wind speeds (colored contours) and direction (black arrows) from GEOS-FP for each month in the 2018 and 2020 fire seasons centered on California.

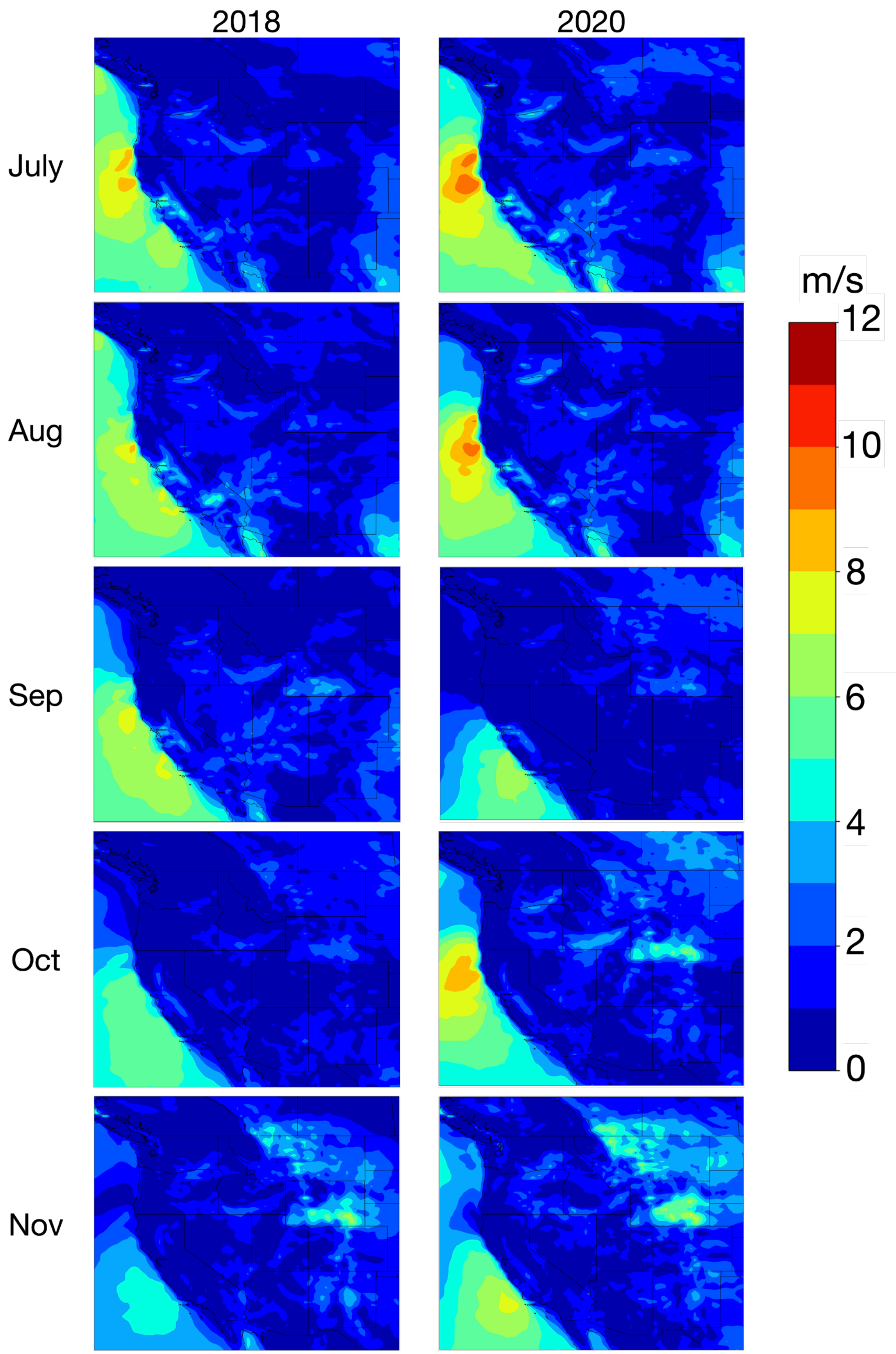


Figure S2. Monthly-mean composite 10-m wind speeds (colored contours) from GEOS-FP for each month in the 2018 and 2020 fire seasons.

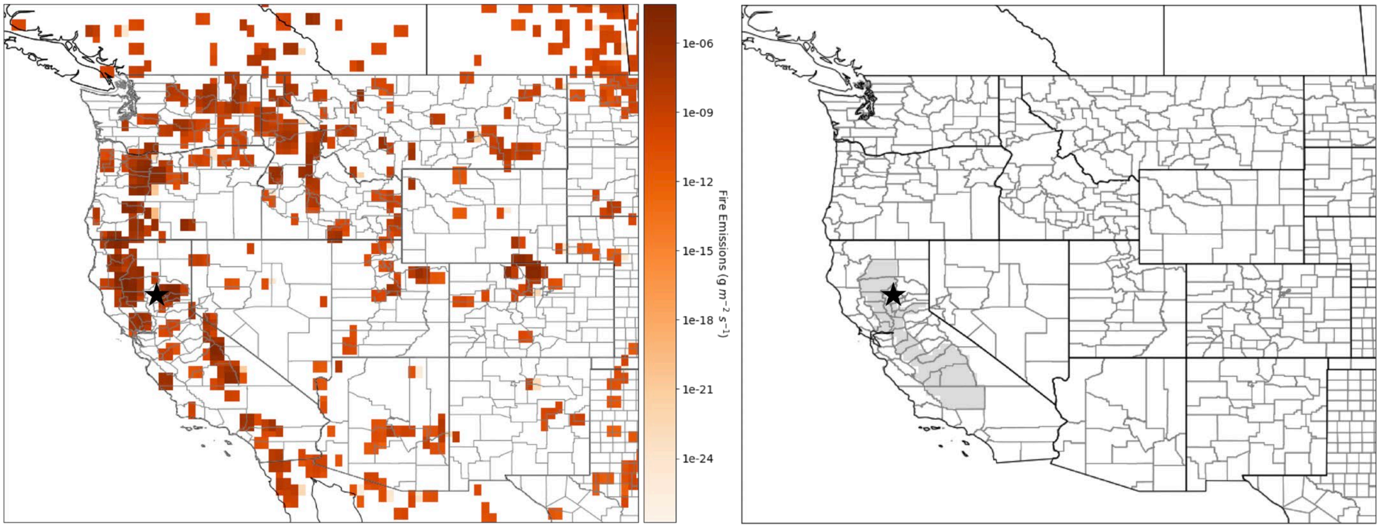


Figure S3. November 2018 GFED fire emissions (left) and the Central Valley, California receptor (right). Most of the Camp Fire (star icon) emissions in California are concentrated in or near the Central Valley.

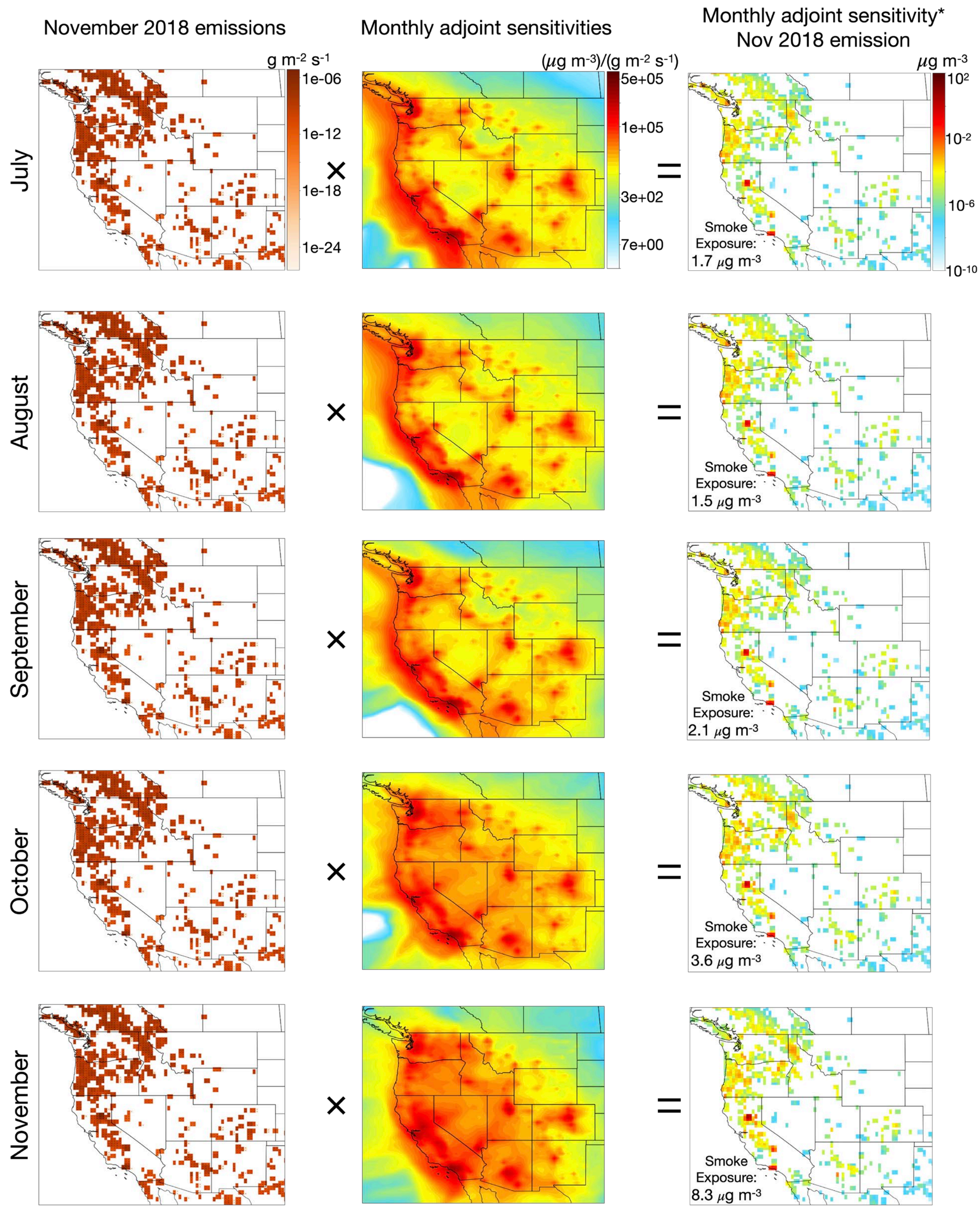


Figure S4. Maximum smoke exposure scenarios for the West using November 2018 fire emissions. To calculate the population weighted $PM_{2.5}$ exposure (right column), the monthly GEOS-Chem adjoint sensitivities [$\mu g\ m^{-3}/g\ m^{-2}\ s^{-1}$] (middle column) of the entire West population-weighted receptor is multiplied by the GFED fire emissions [$g\ m^{-2}\ s^{-1}$] for the month of November 2018 (left column). Shown inset are the population-weighted smoke exposures for the entire western US during each month, with November yielding the highest smoke exposure. Color bars are fixed for each column.

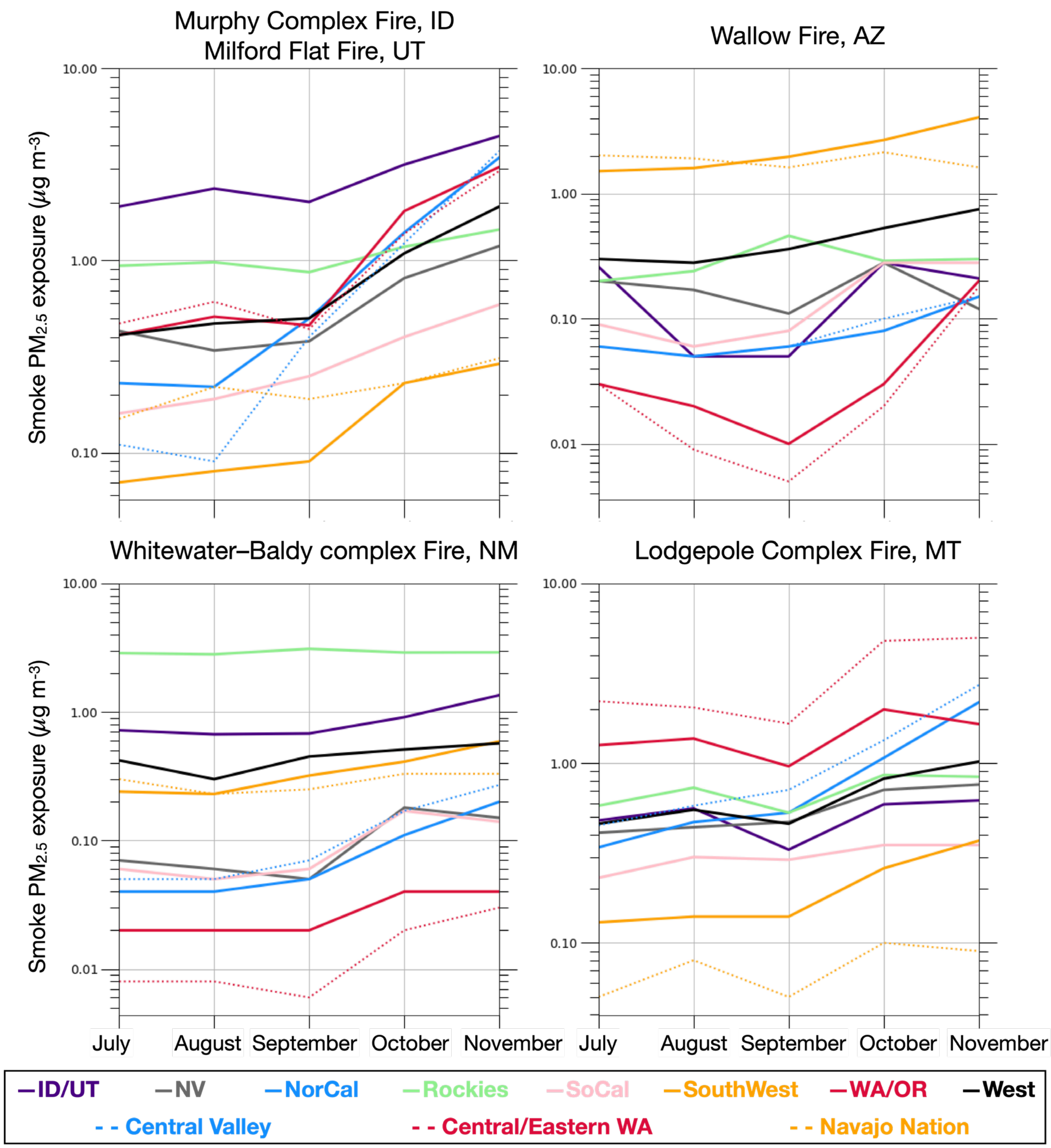


Figure S5. Population-weighted smoke $PM_{2.5}$ exposure for states and rural environmental justice communities in the West for select high fire case studies using 2018 adjoint sensitivities. The concentrations of smoke $PM_{2.5}$ are plotted on a log scale with the minor axis tick marks delineating the intervals between decades. The plots show emissions from a specific fire event in which monthly mean fire emissions are multiplied by their paired monthly adjoint sensitivity. The rural environmental justice communities are represented by dashed lines with the same color as the state receptor that is closest to them spatially. The black line ("West") represents population-weighted smoke exposure across the entire western United States. All smoke exposure values in the figure are found in the Supporting Information.

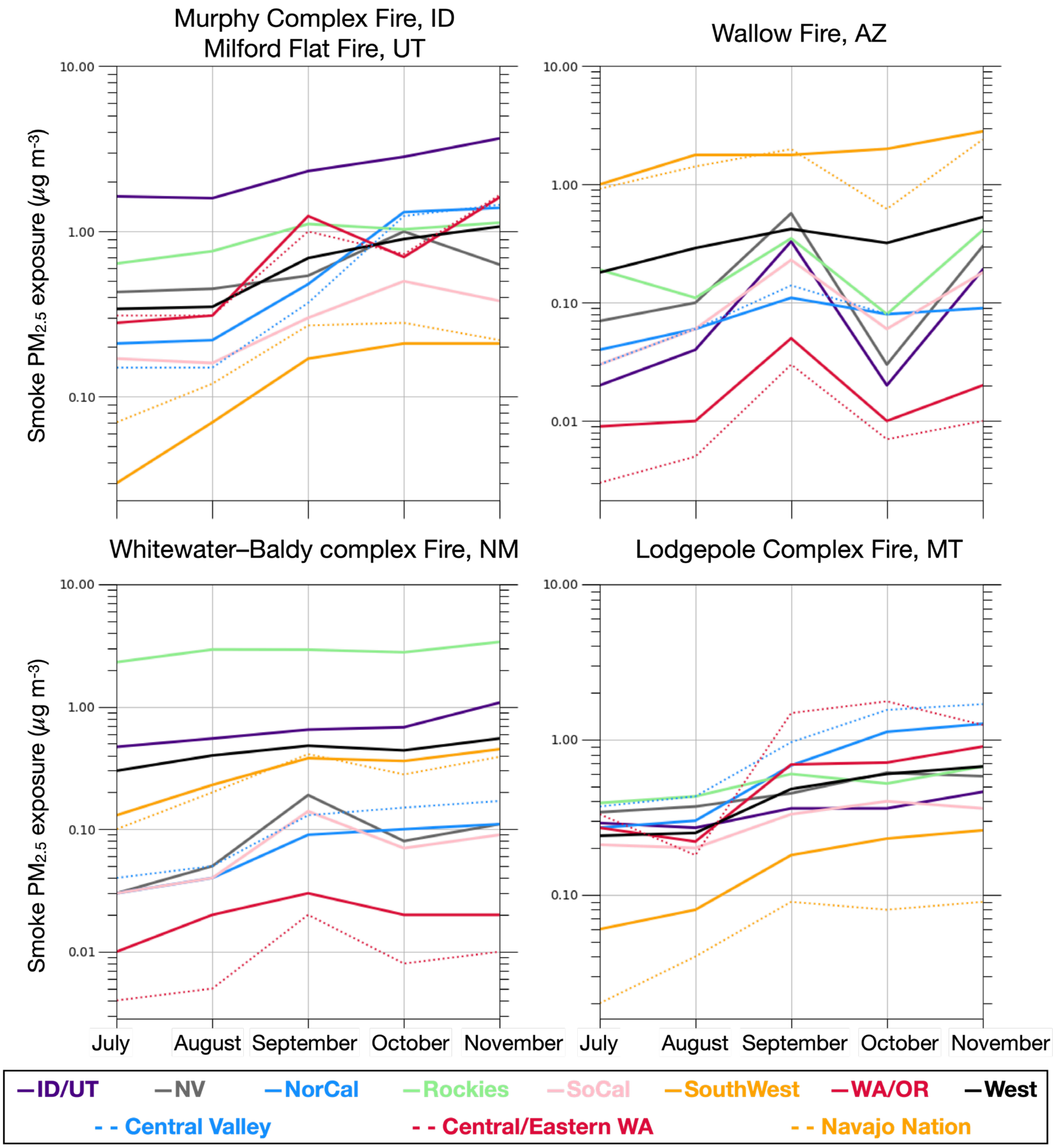


Figure S6. Population-weighted smoke $PM_{2.5}$ exposure for states and rural environmental justice communities in the West for select high fire case studies using 2020 adjoint sensitivities. The concentrations of smoke $PM_{2.5}$ are plotted on a log scale with the minor axis tick marks delineating the intervals between decades. The plots show emissions from a specific fire event in which monthly mean fire emissions are multiplied by their paired monthly adjoint sensitivity. The rural environmental justice communities are represented by dashed lines with the color of the state receptor that is closest to them in space. All smoke exposure values in the figure are found in the Supporting Information. the state receptor that is closest to them in space. The black line ("West") represents population-weighted smoke exposure across the entire western United States. All smoke exposure values in the figure are found in the Supporting Information.

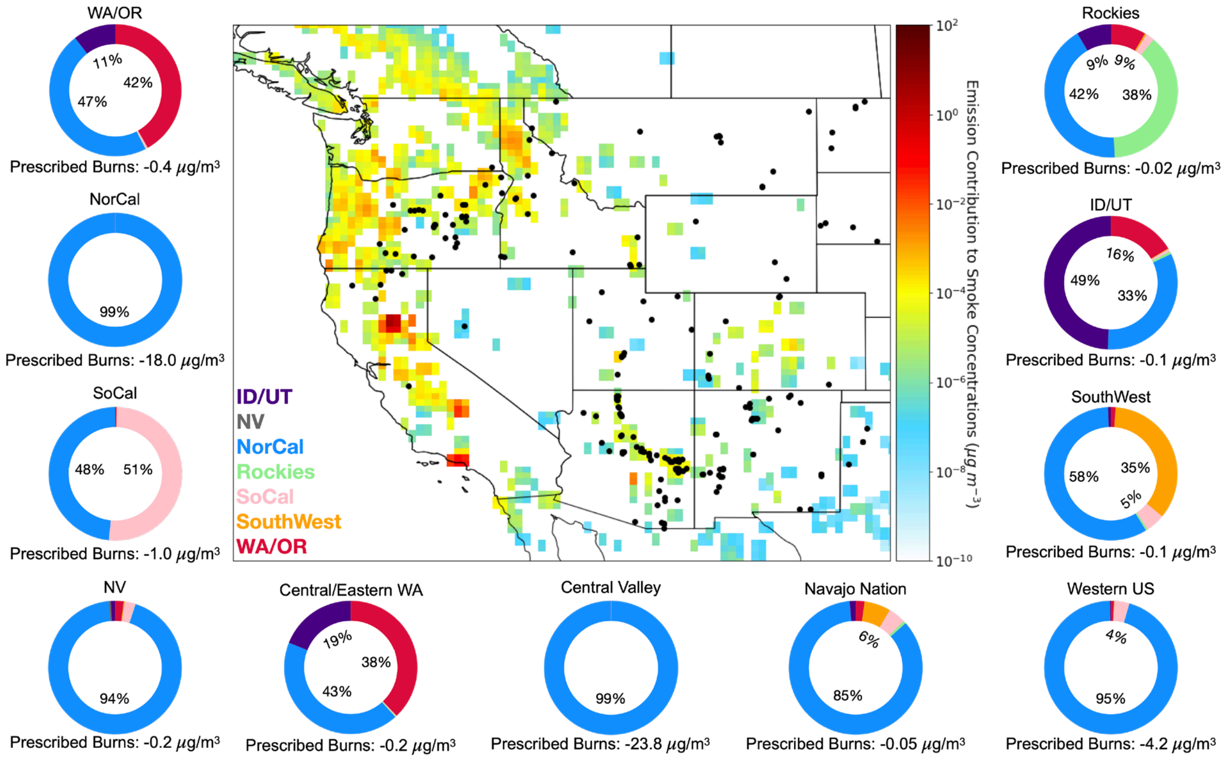


Figure S7. Contributions to population-weighted smoke exposure for the western United States in November 2018 (center panel) and effects of applying prescribed burning interventions in all receptors in the West during this month (pie charts). The center panel shows the locations of MTBS prescribed burn (>1000 acres) during 2015-2020 (black dots, n=190) and the contribution of smoke $PM_{2.5}$ emissions in each grid cell to population-weighted smoke exposure in the West receptor (colors). These contributions are calculated through multiplication of the GEOS-Chem adjoint sensitivities [mg m^{-3}/g m^{-2} s^{-1}] of the West population-weighted receptor by the GFED fire emissions [g m^{-2} s^{-1}] for the month of November 2018. The pie charts in the side panels illustrate the contribution to that smoke reduction from the application of prescribed burns in each receptor, with the values inset indicating the overall reduction of smoke exposure from prescribed burning interventions within that receptor.

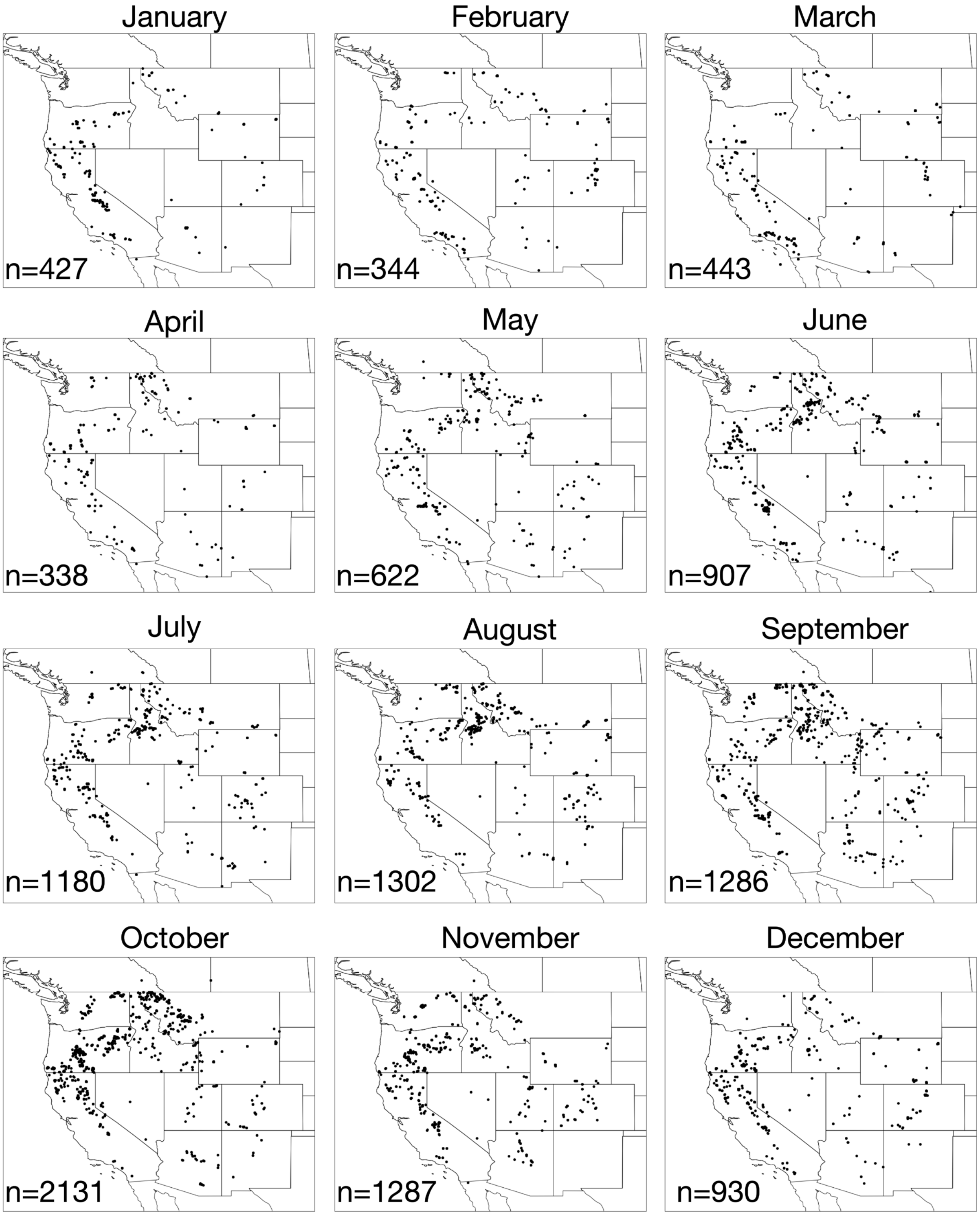


Figure S8. Monthly historical prescribed fires from the NFPORS database over 2019. Black dots indicate the locations of prescribed burns. The inset of each figure reports the total number of prescribed burns during that year given the filtering condition.

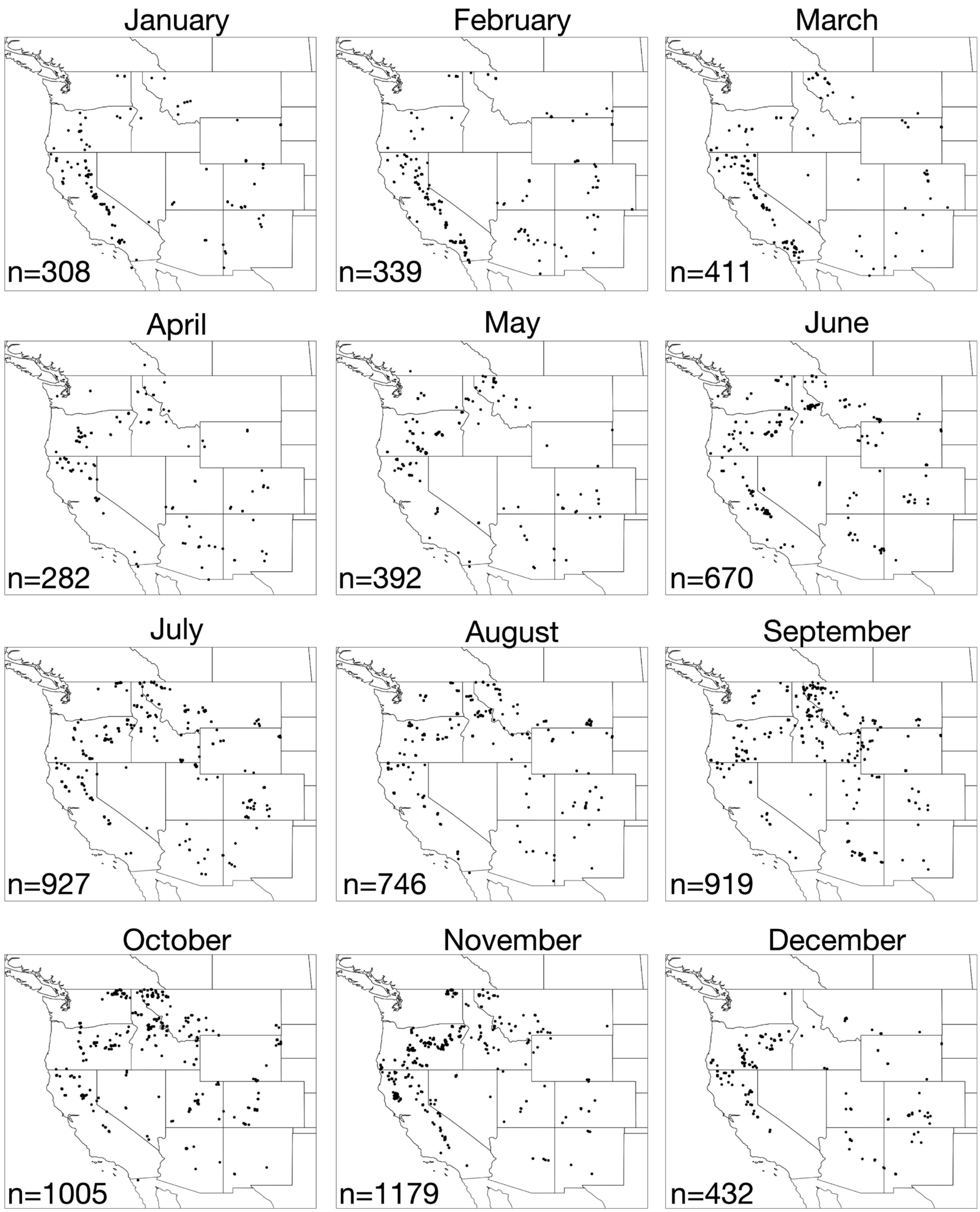


Figure S9. Monthly historical prescribed fires from the NFPORS database over 2020. Black dots indicate the locations of prescribed burns. The inset of each figure reports the total number of prescribed burns during that year given the filtering condition.

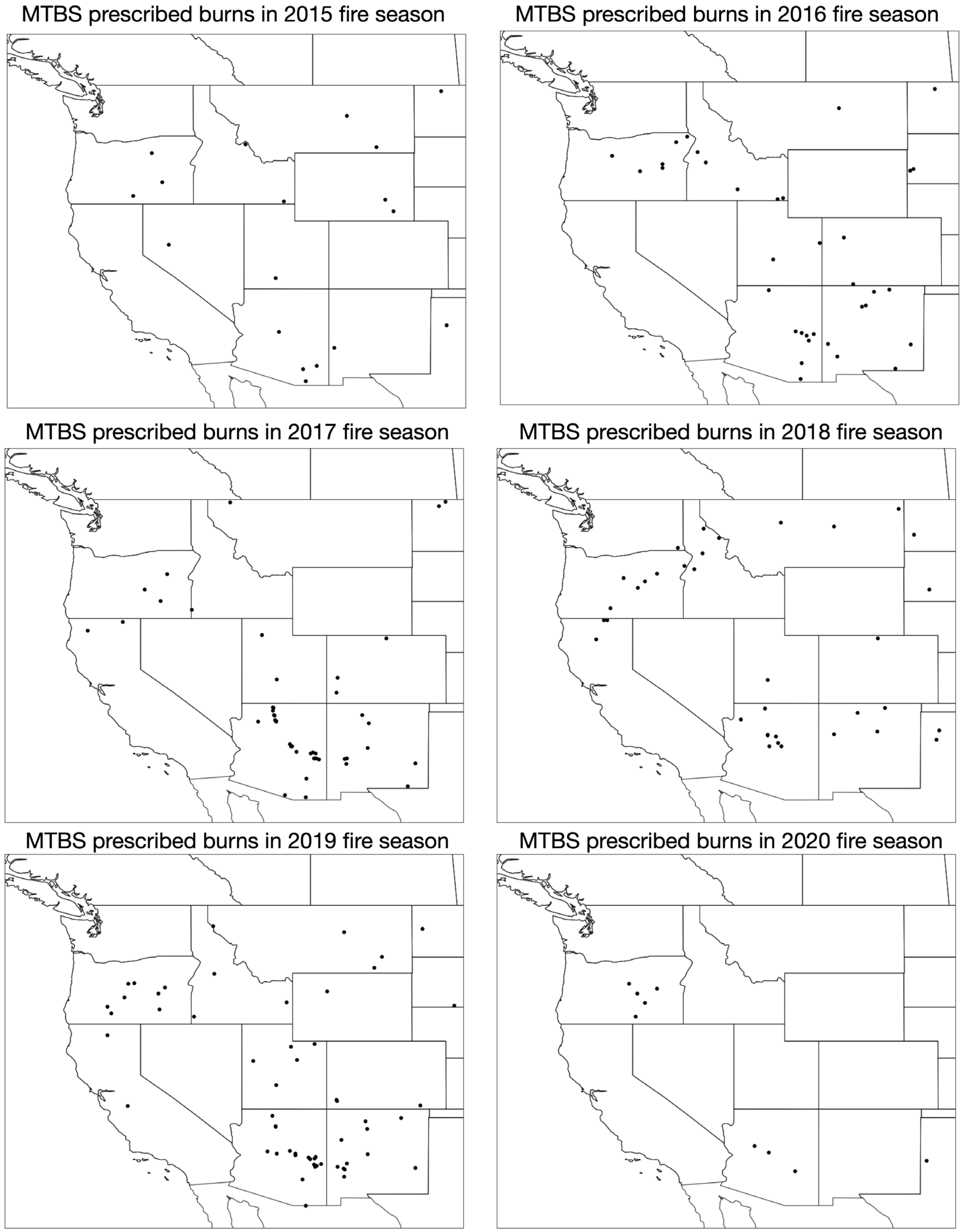


Figure S10. Historical prescribed fires from the MTBS database over 2015-2020. Black dots indicate the locations of prescribed burns in 2015 (n=18), 2016 (n=35), 2017 (n=41), 2018 (n=34), 2019 (n=53), and 2020 (n=9).

Table S1. NFPORS prescribed fire total burned acreage and number of fires over the course of 2018 to 2020 in the NorCal receptor.

	2018	2019	2020
All fires	96,228 acres (2%)[a] 1,992 fires	193,375 acres (4%) 4,112 fires	481,866 acres (11%) 3,493 fires
Fires <10 acres	2,467 acres 516 fires	6,448 acres 1,283 fires	5,438 acres 1,067 fires
Fires <100 acres	45,565 acres 1,781 fires	84,836 acres 3,649 fires	70,620 acres 3,083 fires
Fires <1000 acres	90,152 acres 1,988 fires	179,579 acres 4,104 fires	146,260 acres 3,466 fires

a. Proportion of burned area compared to annual prehistoric burned area in all of California inferred from fire return intervals for different vegetation types (Stephens et al., 2007). Most wildfire area burned occurs in the northern part of the state.