The impact of climate variability and anthropogenic forcing on wildfire over the western US

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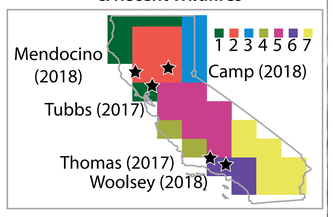
Abstract

Recent California fires have caused unprecedented damage to humans and natural habitat. Anthropogenic warming of the atmosphere has increased the likelihood of droughts and fires in California, and in other regions globally. We explore fire occurrence under different anthropogenic forcing scenarios in order to understand human caused impact on fire risk. Using a large ensemble of climate simulations under historic and future anthropogenic forcing, accompanied by simulations of the climate with fixed aerosols, fixed greenhouse gases, fixed land use change, and fixed biomass burning, we can disentangle the impacts of different human activities on the variability and trends in fire occurrence. We also investigate the mechanisms through which anthropogenic forcing influences fire risk. This has implications for the adaptation and mitigation of future fire risk in the Western United States.

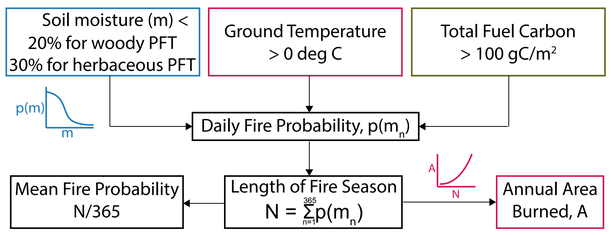
Methods

We use data from the CESM Large Ensemble (CESM-LE) simulations, as well as accompanying large ensemble single forcing (all but one) simulations. The fire module in the CLM4.0 land model is used to simulate fires in these simulations. We use the CA Climate Divisions to explore regional variations within California.

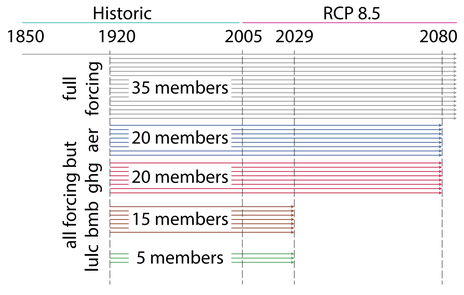
CA Climate Divisions & Recent Wildfires



CLM4.0 Fire module



Single Forcing Large Ensemble Runs



Effect of Forcing Calculation

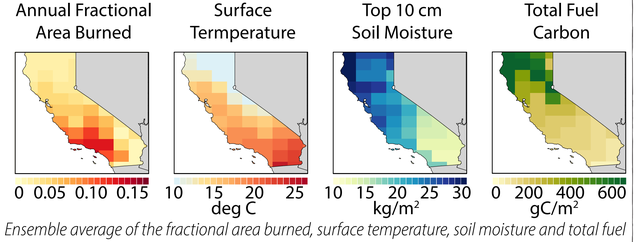
$X_{all,n}$ = X simulated by all forcing ensemble member n

$X_{xsf,n}$ = X simulated by all but SF forcing ensemble n

$X_{sf\_eff,n}$ = effect of SF on X for ensemble member n

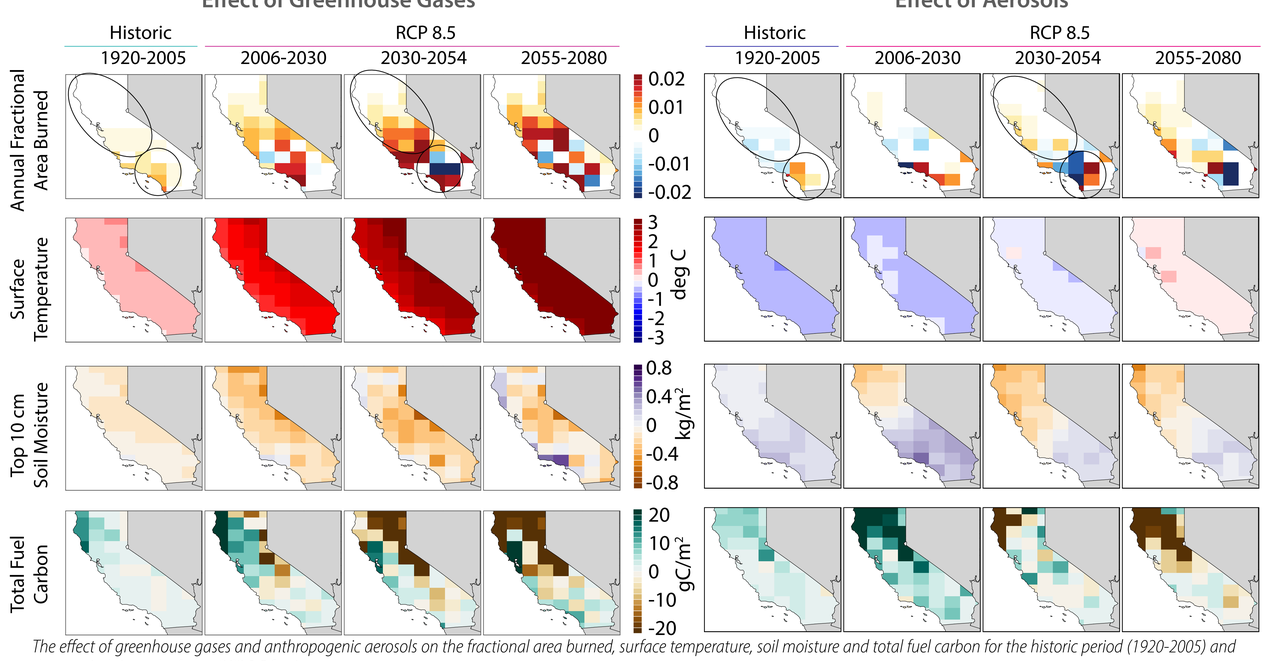
$$X_{sf\_eff,n} = X_{all,n} - \overline{X}_{xsf}$$

Historic 1920-2005 Ensemble Average Full Forcing



Ensemble average of the fractional area burned, surface temperature, soil moisture and total fuel carbon for the historic period (1920-2005) from the full forcing simulations.

Impact of Anthropogenic Forcing on Fire Area Burned



The effect of greenhouse gases and anthropogenic aerosols on the fractional area burned, surface temperature, soil moisture and total fuel carbon for the historic period (1920-2005) and three periods in under future RCP 8.5 forcing.

Many areas experience an increase in the area burned due to **greenhouse gas forcing** in historic and future periods.

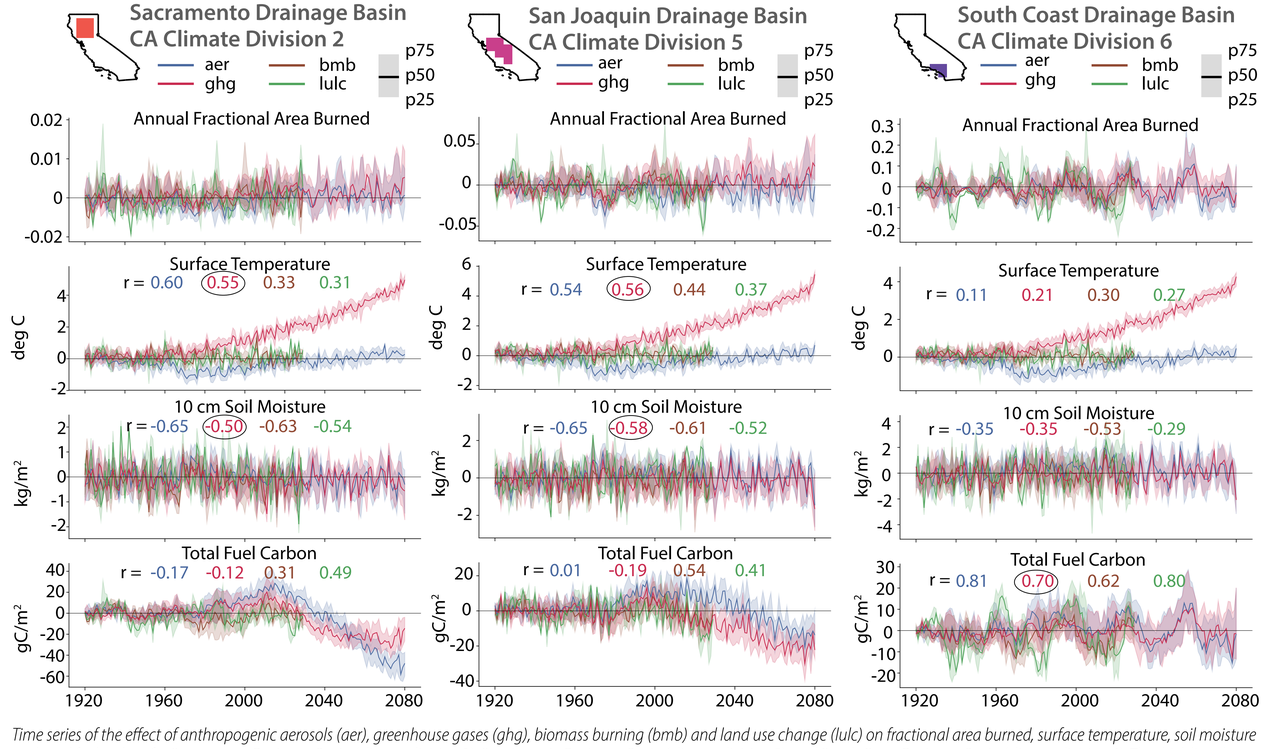
Increases in area burned are correlated with warmer temperatures and drier soils in the Sacramento and San Joaquin Drainage basins.

Some locations in the South Coast Drainage Basin experience decreases in area burned under greenhouse gas RCP 8.5 forcing, where area burned is highly correlated with fuel availability (r = 0.70).

Anthropogenic aerosols have a smaller impact on the fractional area burned than greenhouse gases.

Cooler temperatures and wetter soils decrease the fire area burned in the historic and first future period, counteracting the effect of greenhouse gases.

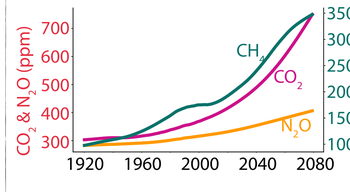
From 2030-2080, aerosols and greenhouse gases both increase area burned in northern California and decrease the area burned in southern California.



Time series of the effect of anthropogenic aerosols (aer), greenhouse gases (ghg), biomass burning (bmb) and land use change (lulc) on fractional area burned, surface temperature, soil moisture and total fuel carbon for Sacramento Drainage Basin (climate division 2), San Joaquin Drainage Basin (climate division 5), and South Coast Drainage Basin (climate division 6). The thick line shows the median value of the ensemble spread, and the shaded area shows the interquartile range of the ensemble spread. The numbers for the 2nd, 3rd, and 4th rows of panels show the Pearson correlation coefficient (r) of the mean fractional area burned time series and the mean time series of the respective variables (surface temperature, soil moisture and fuel carbon) under different forcings. The color of the number matches the color of the forcing times series.

Anthropogenic Forcing in Full Forcing Simulations

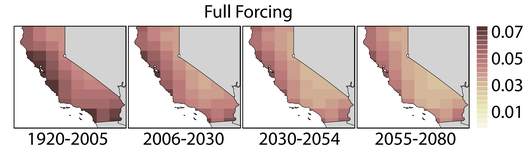
Greenhouse Gases



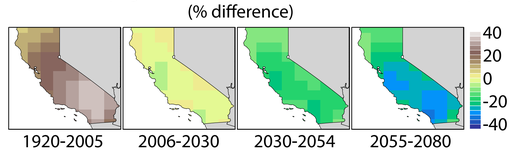
Greenhouse gas concentrations (CO_2, CH_4 and N_2O) used in the full forcing simulations. The all but greenhouse gas forcing runs keep the concentrations constant from 1920 onwards at 1920 values.

Anthropogenic Aerosols

Aerosol Optical Depth
Full Forcing

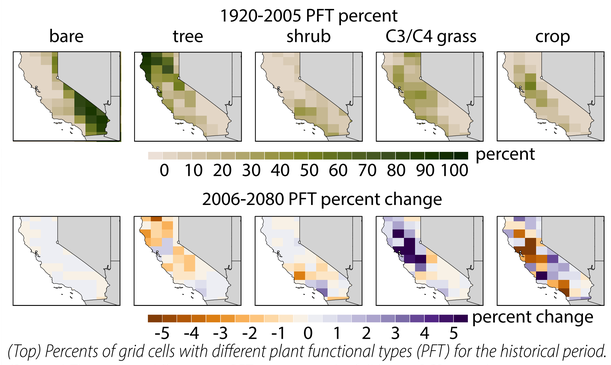


Effect of Anthropogenic Aerosol Forcing on Aerosol Optical Depth
(% difference)



(Top) Aerosol optical depth in the full forcing ensemble for the historic and three RCP future periods. (Bottom) The percent difference in aerosol optical depth due to anthropogenic forcing in the historic and three future periods.

Land Use Change



(Top) Percents of grid cells with different plant functional types (PFT) for the historical period. (Bottom) The percent difference in PFT percents in the full future RCP period.

Main findings

- The variability of fire area burned is driven by temperature and soil moisture in northern and central California, and fuel availability in southern California.
- Aerosol forcing counteracts the effect of greenhouse gases in the historic and early future periods, but plays an additive role to greenhouse gases in later future periods, increasing the area burned.
- Correlations between temperature and soil moisture with area burned remain relatively consistent under different anthropogenic forcings.
- The correlation between fuel carbon and area burned vary under different anthropogenic forcing in some regions.
- Further investigation of the drivers of area burned under different anthropogenic forcing is needed.
- Extending the analysis to other regions will allow us to better understand the drivers of variability in area burned.

Acknowledgments
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