Wildfire Simulations for California’s Fourth State Climate Assessment

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Fires respond to climate everywhere, because climate controls fuel amount and flammability.
Temperatures (and Forest Fires) are increasing

Westerling 2016, *Phil. Trans. Royal Soc. B*
Western US Forest Wildfires and Spring–Summer Temperature

[Map showing forest fires and temperature anomaly over time]
Precipitation is becoming more variable...

as the pole warms faster than the equator, the jet stream slows and weather patterns become more persistent.
Our region is becoming drier overall

Westerling, unpublished data

Cumulative water-year Deficit (standard deviations)

1974 – 1983
dry wet fractions: 0.13, 0.27

1984 – 1993
dry wet fractions: 0.17, 0.24

1994 – 2003
dry wet fractions: 0.24, 0.22

2004 – 2013
dry wet fractions: 0.21, 0.13
Drying is projected to continue

2000–2009

Drought index of -4 or lower is an extreme drought

Dai 2010: *Drought under global warming: a review*, National Center for Atmospheric Research
Drying is projected to continue

2030–2039

Drought index of -4 or lower is an extreme drought

Dai 2010: *Drought under global warming: a review*, National Center for Atmospheric Research
California wildfire activities (1984-2016)

Fig. 1 California wildfire activities (a: annual fire numbers; b: fire size of annual largest wildfires; c: annual area burned; d: fire severity trends)
The largest fire is getting bigger in the Sierra Nevada.
The largest fire is getting bigger everywhere in the west
Cumulate over time, scenario(s) to obtain mean, compound distribution

Westerling (2018)
Wildfire simulations for the Fourth California Climate Assessment: projecting changes in extreme wildfire events with a warming climate.
Annualized, allocated simulations multiple realizations per scenario, year

Cumulate over time, scenario(s) to obtain mean, compound distribution

Westerling (2018)
Wildfire simulations for the Fourth California Climate Assessment: projecting changes in extreme wildfire events with a warming climate.
30-yr mean area burned: 1961-1990 CNRM-CM5 85 bau

30-yr mean area burned: 2070-2099 MIROC5 85 bau

30-yr mean area burned: 2009 CNRM-CM5 85 bau

30-yr mean area burned: 2070-2099 HadGEM2-ES 85 bau
Data that Drives Outcomes
Data to plan for wildfire

San Francisco Bay Area RCP 8.5 1961 to 1990

San Francisco Bay Area RCP 8.5 2070 to 2099
Curating fire scenarios

Usable data:

- Planning scenarios
- Context:
  - Climate
  - Region
Translating into realistic fire perimeters
Wildfire smoke

Smoke is a complex mixture of carbon dioxide, water vapor, carbon monoxide, particulate matter, hydrocarbons and other organic chemicals, nitrogen oxides, and trace minerals. (EPA, 2016)

California Shrouded in Smoke from the Ongoing Camp Fire
Emission calculation example: Cedar fire 2003
3. PM2.5 and land cover

Fig. 4 PM2.5 emissions in forest, shrub, and grass land in California (1984-2016) (Gg)
3. Fire severity and land cover

Fig. 5 Wildfire severity distribution in forest, shrub, and grassland in California (1984-2016) (Gg) (from left to right: low, moderate, and high severity)
2. PM2.5 emissions from wildfire, annual

Fig. 3  PM2.5 annual emissions aggregated over the state of California, 1984-2016 (Gg)
Since the 21st century, there has been an earlier and longer wildfire emission season.
Most of the emissions come from forest burning in Sierra Nevada Mountains and North Coast climate regions.
A larger proportion of PM2.5 was produced during drought years
A significant amount of PM2.5 was emitted, but CO$_2$ made up the vast majority of wildfire emissions.
Probability: high severity fraction in top 25%. Climate influences fire severity, even in the N. Rockies

Empirical study: Over 1984 - 2010
Proportion of Stand Replacing fire increased from 22% to 27% in the Northern Rockies

— Harvey et al 2016
*Landscape Ecology*
High-severity burn extent were greater as climate changes (Crockett & Westerling, 2018)
Fig. 6 Area burned in low, moderate, and high severity and total area burned in forest, shrub, and grassland in California (1984-2016) (Gg)
The 2014 King Fire: occupancy

![Map and graph showing the 2014 King Fire occupancy](image)
Rim Fire Butte Fire

Observed BA90

Predicted BA90 probabilities from Random Forest

Jones, Keyser, Peery, Westerling in preparation
Spatial distribution of mean cumulative change in aboveground carbon over the simulation period under different treatment scenarios.

Values in each grid are averaged across ten replicate simulations of each of the three climate-wildfire scenarios for a given treatment scenario.