Forest Fire Research and Simulations for the Fifth California Climate Assessment: Open Source Next Generation Wildfire Models

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Pyregence - Wildfire Projections Under a Changing Climate
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Greater Yellowstone Temperatures

The graph shows the trend in spring and summer temperatures (°C) from 1950 to 2100. The data indicates a significant increase in temperatures over the years, with fluctuations around a rising trend. The inset map highlights the study area and shows the distribution of fire ignitions.

Westerling et al. 2011 PNAS
After 2050: The coldest year in the future is always hotter than the hottest year in history!
Western US Forest Wildfires and Spring–Summer Temperature

Westerling et al 2006, Science
+ Westerling 2016, Phil. Trans. Royal Soc. B
as the pole warms faster than the equator, the jet stream slows and weather patterns become more persistent

Precipitation is becoming more variable…
California's shifting fire season: area burned

1984–2000
2001–2018
Largest California fires per year

max annual fire size, 1984 – 2019

five largest fires, 2020
Annualized, allocated simulations multiple realizations per scenario, year

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

Westerling (In Review)
Wildfire simulations for the Fourth California Climate Assessment: projecting changes in extreme wildfire events with a warming climate.
"30%" Treatment by Administrative Unit

"100%" Treatment by Conservation Objective

Provided by JoAnn Fites-Kaufman & April Brough USDA Forest Service, Region 5
Average annual area burned composites for RCP 4.5: 0% (left), 54% (mid), and 90% (right) of altered forest fuels treated to restore pre/fire suppression fuel densities for mid/century (top) and end of century (bottom).
Effects of dynamic vegetation on area burned and total C
midcentury burned area, untreated GFDL A2 (ratio of 2035–64 burned area to 1961–90 burned area)

Liang et al., 2017

white fir, Douglas-fir
Incense cedar
Red fir
Subalpine species
Jeffrey pine
Sugar pine
Ponderosa pine
Gray pine
Oaks
Singleleaf pinyon
 Aspen
Forest Management for Spotted Owl Habitat

Jones Keyser Westerling Baldwin Gutiérrez Sawyer Keane Clare Peery 2019
Vulnerability Assessment & Adaptation Planning Support for San Mateo County
Free and open access to the next generation of wildfire risk models for grid resiliency
Research Collaborators
Collaborating across four workgroups

Spatial Informatics Group

WG1
- UCAR
- USF
- EXTREME WEATHER
- Janice Coen

WG2
- Berkeley
- FIRE BEHAVIOR
- Scott Stephens

WG3
- REAX
- ENGINEERING
- FORECAST TOOLS
- Chris Lautenberger

WG4
- UNIVERSITY OF CALIFORNIA
- MERCED
- SCENARIO ANALYSES
- LeRoy Westerling

PRINCIPAL INVESTIGATOR (PI) & PROJECT MANAGER (PM)
NEXT GENERATION WILDFIRE MODELS

Science

Models

Tools

Implement

Impact

FIRE BEHAVIOR

FORECAST TOOLS

ELECTRIC UTILITIES

SAFE, RELIABLE, COST EFFECTIVE AND RESILIENT GRID

EXTREME WEATHER

SCENARIO ANALYSES

5TH CLIMATE CHANGE ASSESSMENT, CA

Science Models Tools Implement Impact
Extreme Weather and Weather Stations

- Analytical approach for optimizing the placement of weather stations
- Pilot Testing of Upper Air Profiler for situational awareness
- Algorithm to identify regional archetypal weather conditions associated with rapid fire growth.
  - Based on analysis of historic fire-weather data
  - 8 weather regions
  - Regional analysis is refined by hyper-local coupled airflow - fire modeling.
  - Finding - days with the most fire growth are associated with two or three extreme weather types.
Fire Behavior

- Predicting heat release rates across the range of fuel structures and environmental conditions found in wildland areas
- New fuel measurement and mapping system
- Map current and projected future fuel conditions in areas of elevated tree mortality
- Develop fire model that includes large fuels (> 3 inches diameter), solid phase combustion, and buoyancy
Near-term Wildfire Forecast System

- Open access and intuitive web-based fire forecast platform
  - Fire Weather Forecast
  - Active Fire Forecast
  - Risk Forecast
- Beta version - https://pyregence.org/forecast
5th Assessment - Long-term Wildfire Projections

Source of Information
- URBAN LAND USE & FOREST MANAGEMENT SCENARIOS
  - CLIMATE
    - Historical
    - Synthetic Projections
    - Downscaled
  - EARTH OBSERVABLES
    - Vegetation
    - Imp. Surface
    - Historic Fire
    - Topography
    - Ignitions
- STAKEHOLDER ATTRIBUTES

Model / Data Inputs
- LANDSCAPE SIMULATION MODELS
  - LANDIS II
  - LUCAS
- VEGETATION PROJECTIONS
- BIOMASS PROJECTIONS

Analysis / Models
- FIRE RISK SIMULATION MODEL (FRSM)

Outputs
- VEG OUTPUTS
  - VEGETATION
  - BIOMASS
  - ABOVE / BELOW GROUND CARBON
- FIRE OUTPUTS
  - FIRE SIZE
  - # OF FIRES
  - FIRE PRESENCE
  - FIRE SEVERITY
  - SMOKE EMISSIONS

Tools or Products
- GRIDDED MAP SURFACES
- CAL ADAPT WEB TOOL
- 5th CLIMATE CHANGE ASSESSMENT
- REPOSITORY & CODE PACKAGES
PM2.5 emissions in forest, shrub, and grass land in California (1984-2016) (Gg)
PM$_{2.5}$ of the largest 15 wildfires contributed 22% percent of total emissions

Fig.3  PM$_{2.5}$ range for each fire (Gg) (left); Map of PM$_{2.5}$ emissions of the largest 10 fires during 1984-2018 (right)
Since the 21st century, there has been an increasing in PM$_{2.5}$ emissions, an earlier and longer wildfire emission season.

Fig. 4  PM$_{2.5}$ annual (left) and monthly (right) trends aggregated over the state of California, monthly data also aggregated for historical 1984-2016(Gg)
Methods - fire severity prediction

(1) Spatial and temporal domain of analysis
- 1/24 latitude/longitude grid
- 1984-2017
- California statewide, 3 sub regions (Sierra Nevada, Northern Coastal California, Southern Coastal California)

Fig.1. Wildfire perimeters and fire start month in California during 1984-2017. Data source: MTBS
(3) Modeling framework

- Random Forest
  - Variable importance
- Generalized Pareto Distribution model (GPD)
  - Total area burned
- Generalized Additive Model
  - Fraction of area burned in 3 severity classes
Fig. 3. Predicted severity fractions versus observed severity fraction distribution and observed mean fraction for each group (line) in California.

"avgTJJA", "avgTMA M", "sum", "cprec"
R-sq.(adj) = 0.476

"firemonthVPD", "fores t", "elevation"
R-sq.(adj) = 0.234

"forest", "cprec", "avgTJJA"
R-sq.(adj) = 0.371
Fig. 6 Vegetation classes in Sierra Nevada (left); Fire severity of wildfires (middle); PM2.5 emissions from each wildfire (right)
Thank You