Wildfire Simulations for California's Fourth State Climate Assessment

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UC Merced

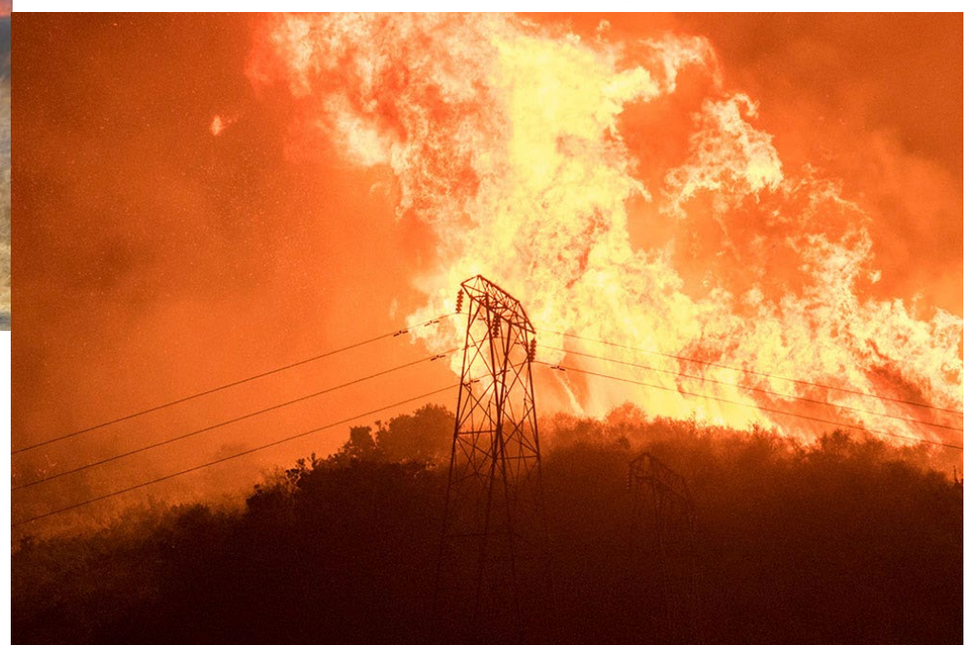
Fires respond to climate everywhere, because climate controls fuel amount and flammability

Sierra Nevada

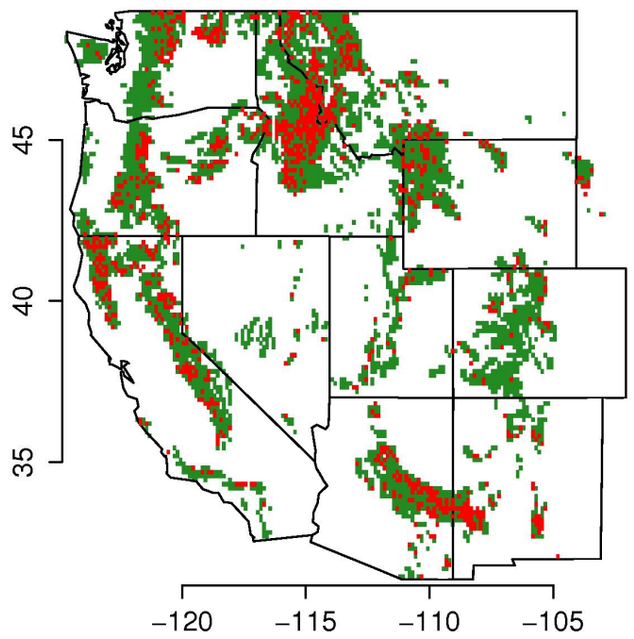
Foothills

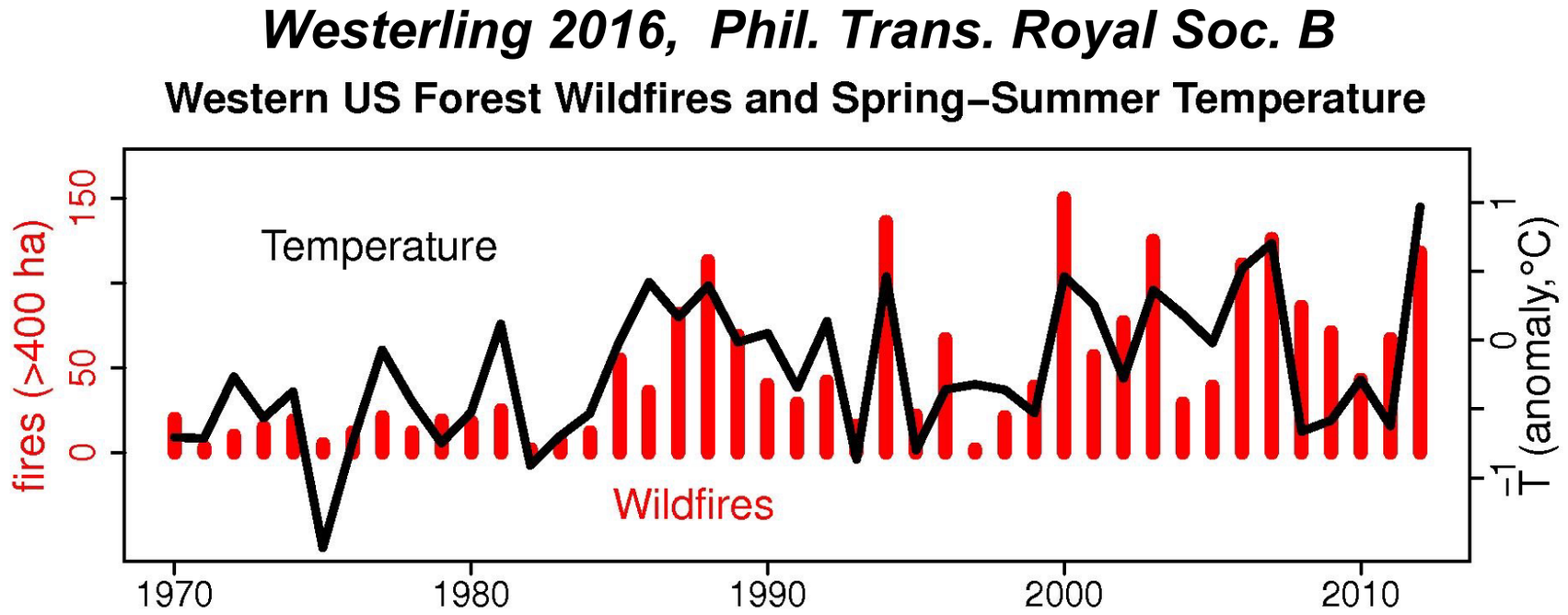
Grass

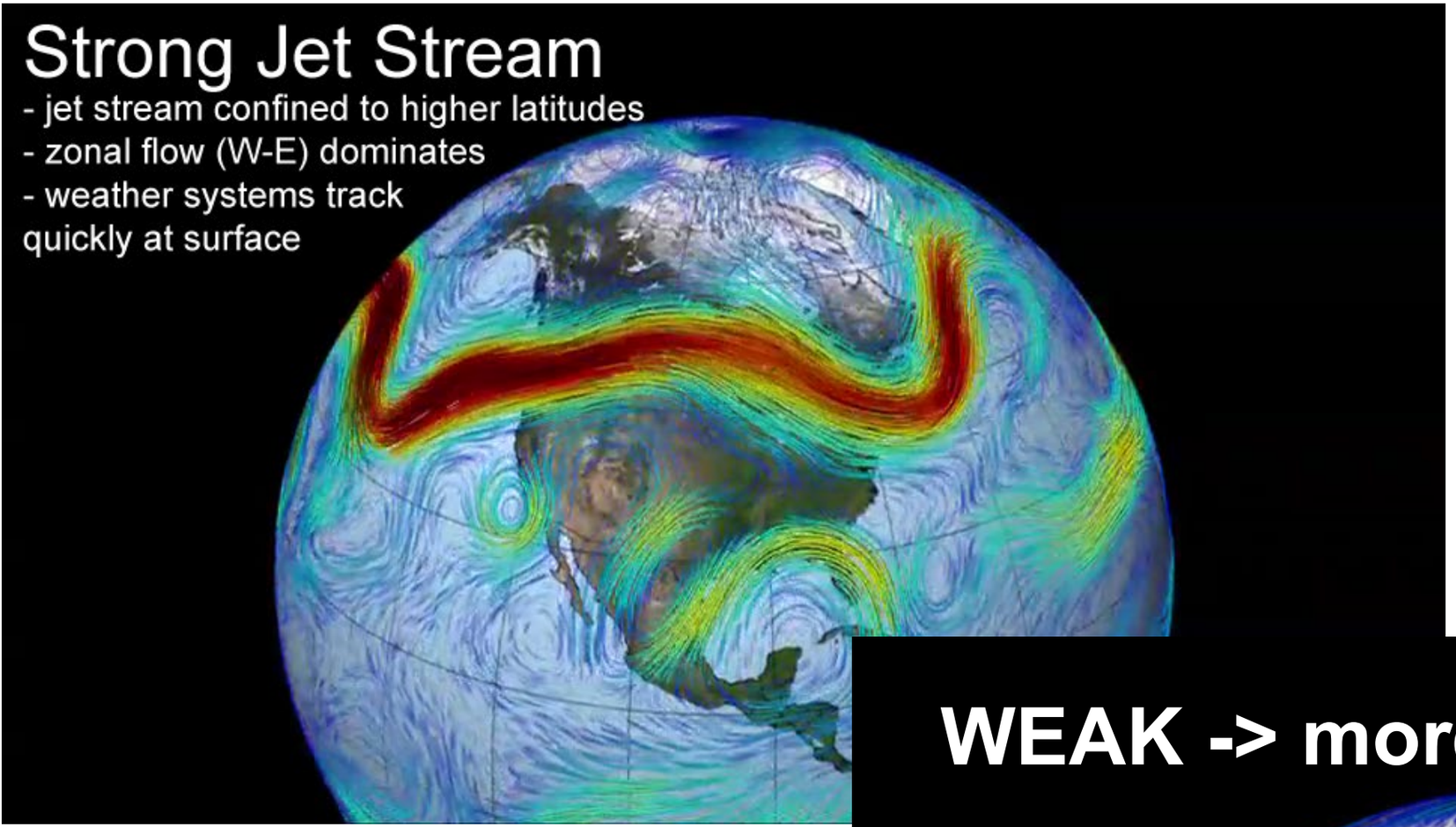
Coastal Chaparral



Temperatures (and Forest Fires) are increasing



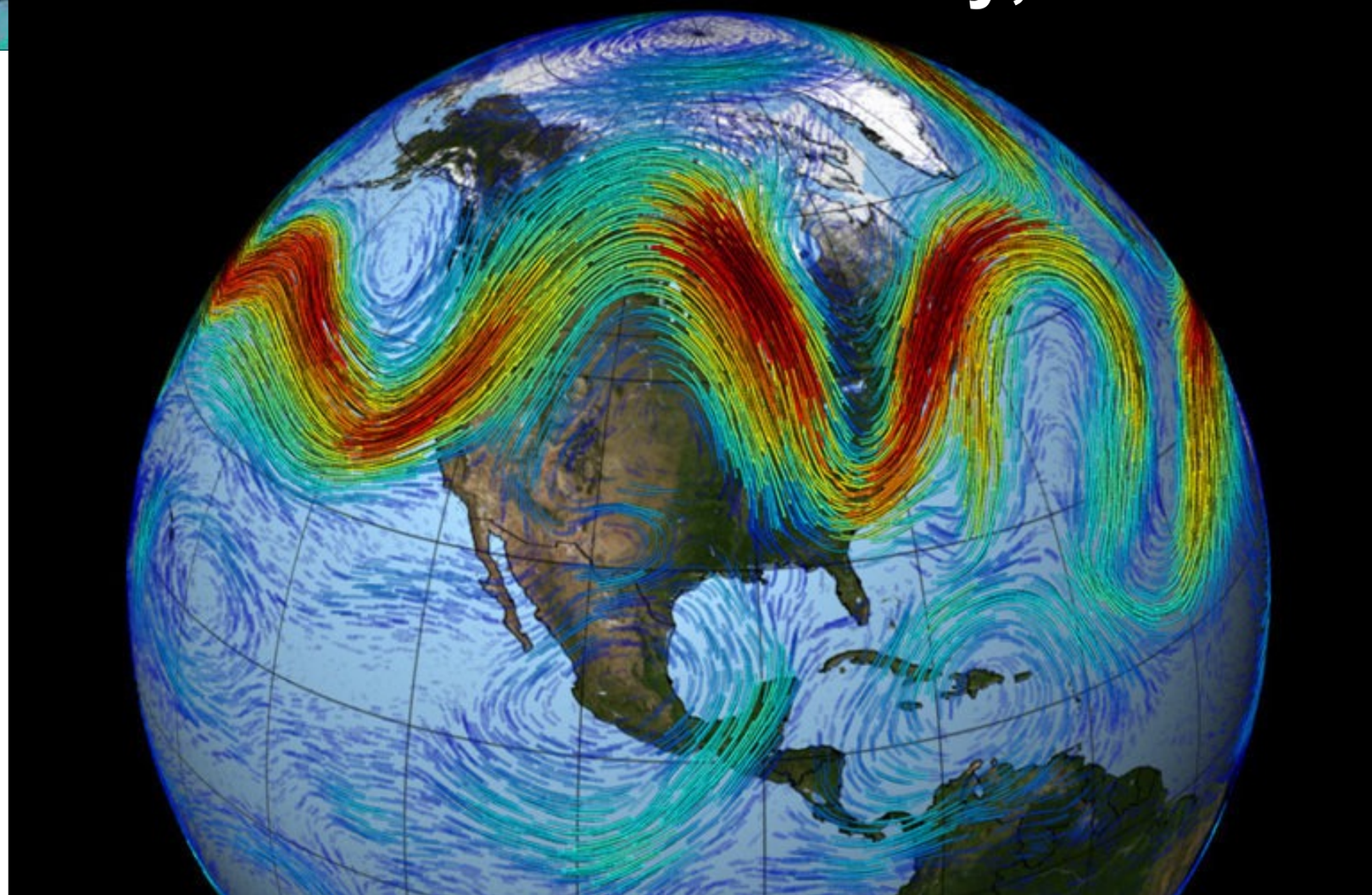




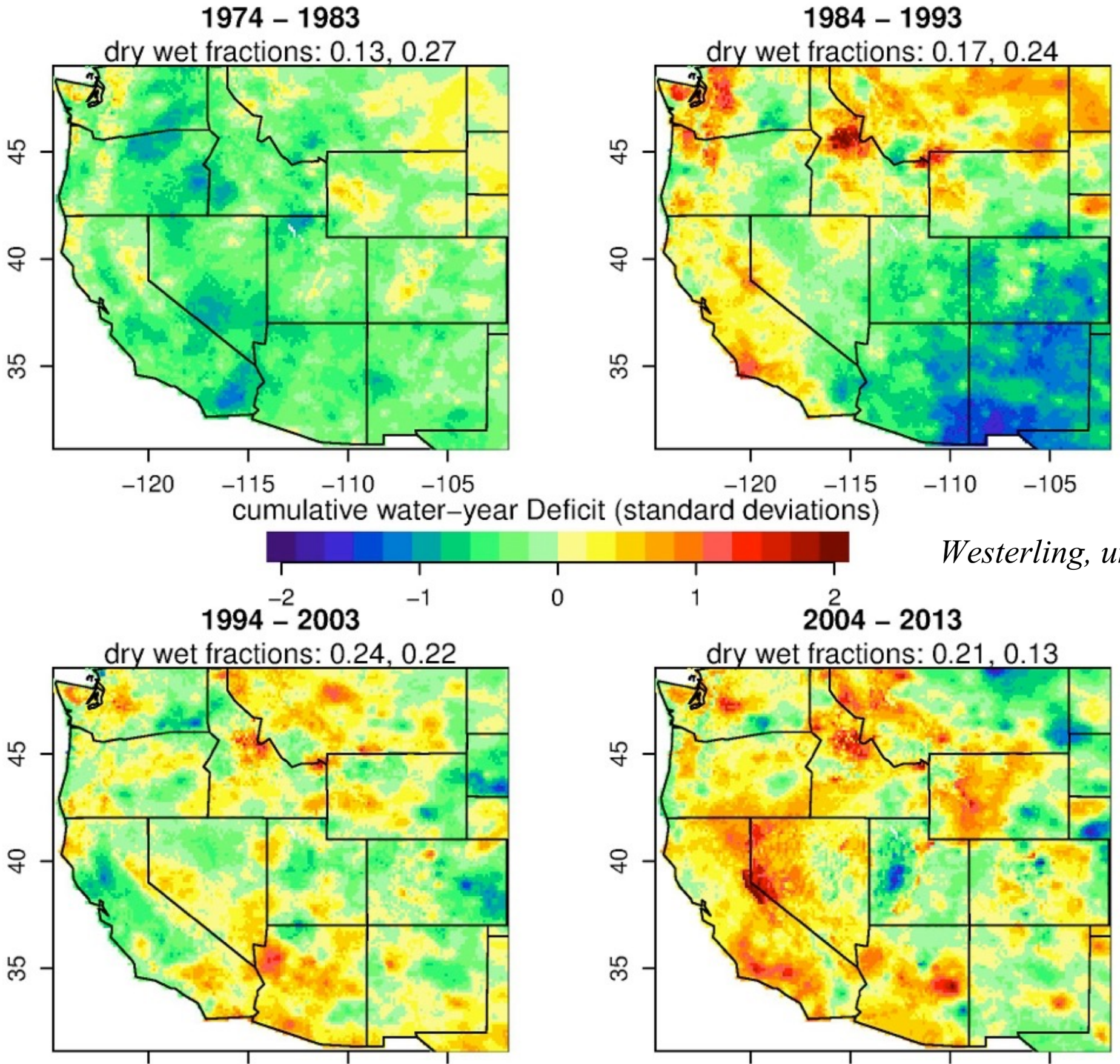
Precipitation is becoming more variable…

as the pole warms faster than the equator, the jet stream slows and weather patters become more persistent

WEAK -> more variability, stalled

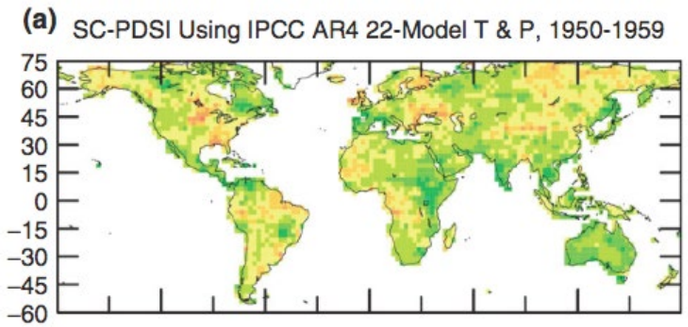


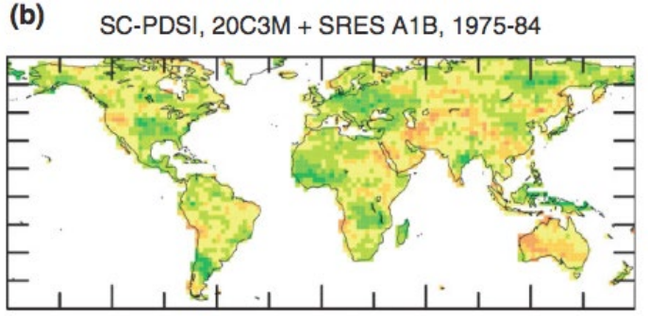
Our region is becoming drier overall

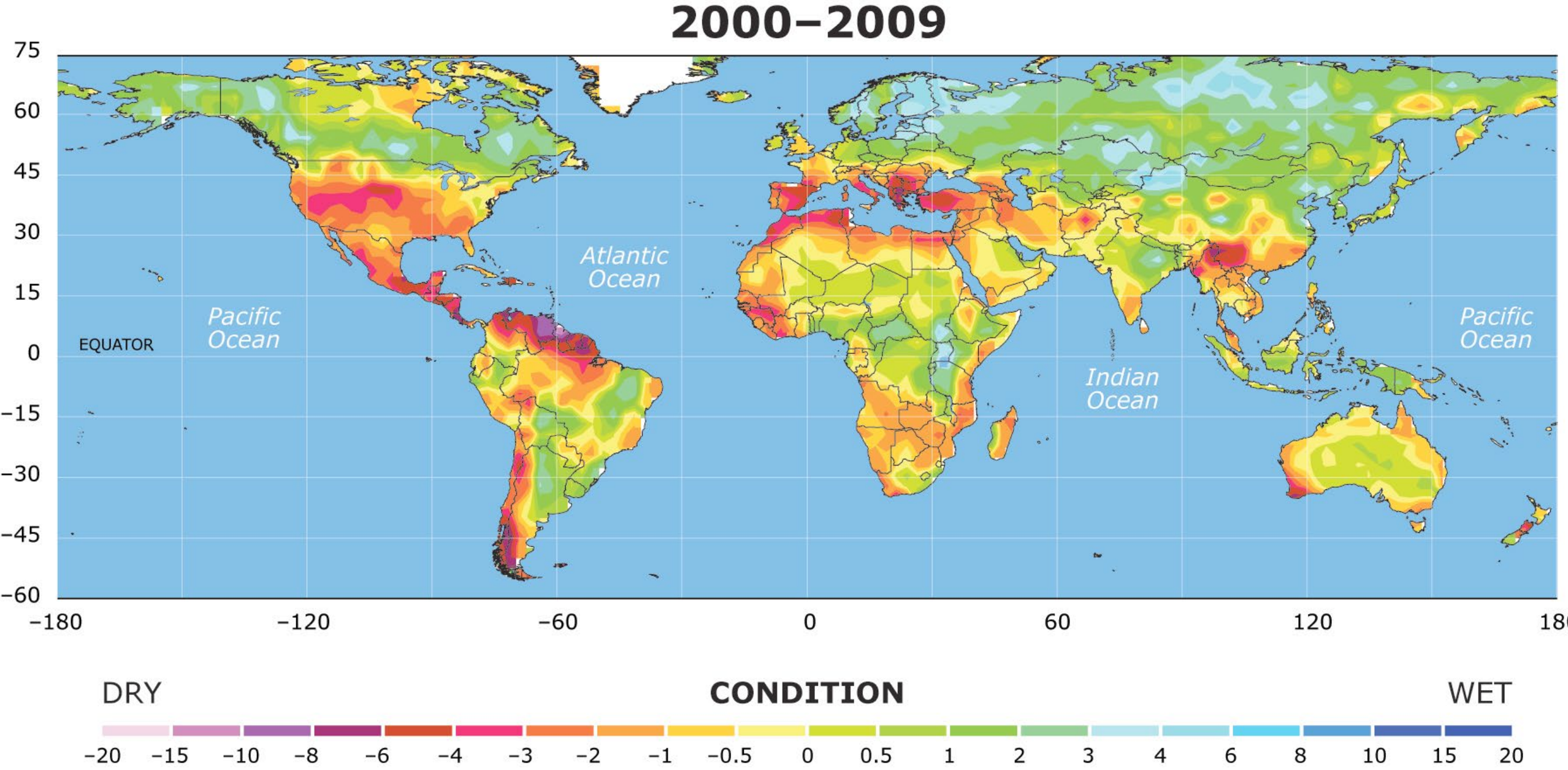


Westerling, unpublished data

Drying is projected to continue



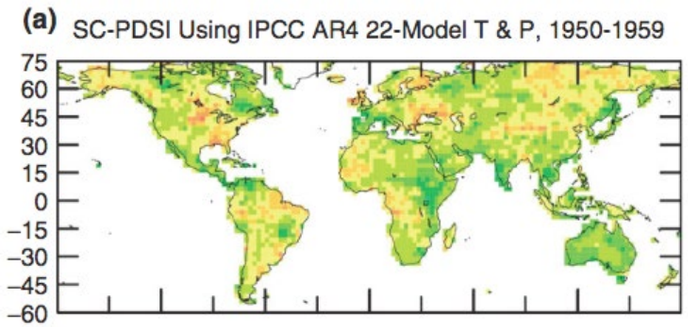


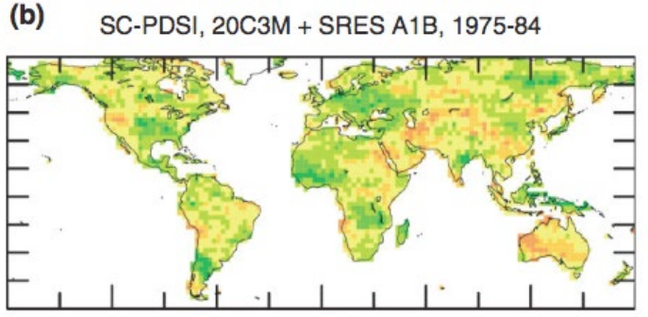


Drought index of -4 or lower is an extreme drought

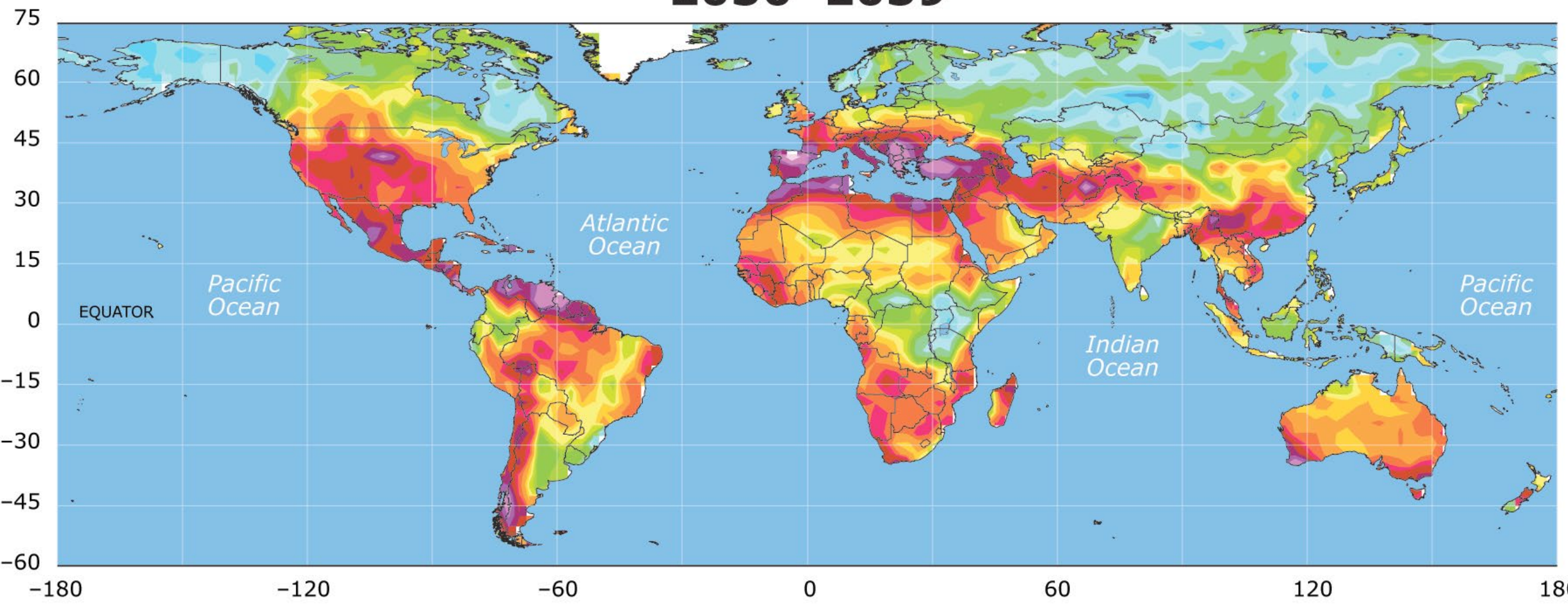
Dai 2010: *Drought under global warming: a review,* National Center for Atmospheric Research

Drying is projected to continue





2030–2039



Drought index of -4 or lower is an extreme drought

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California wildfire activities (1984-2016)

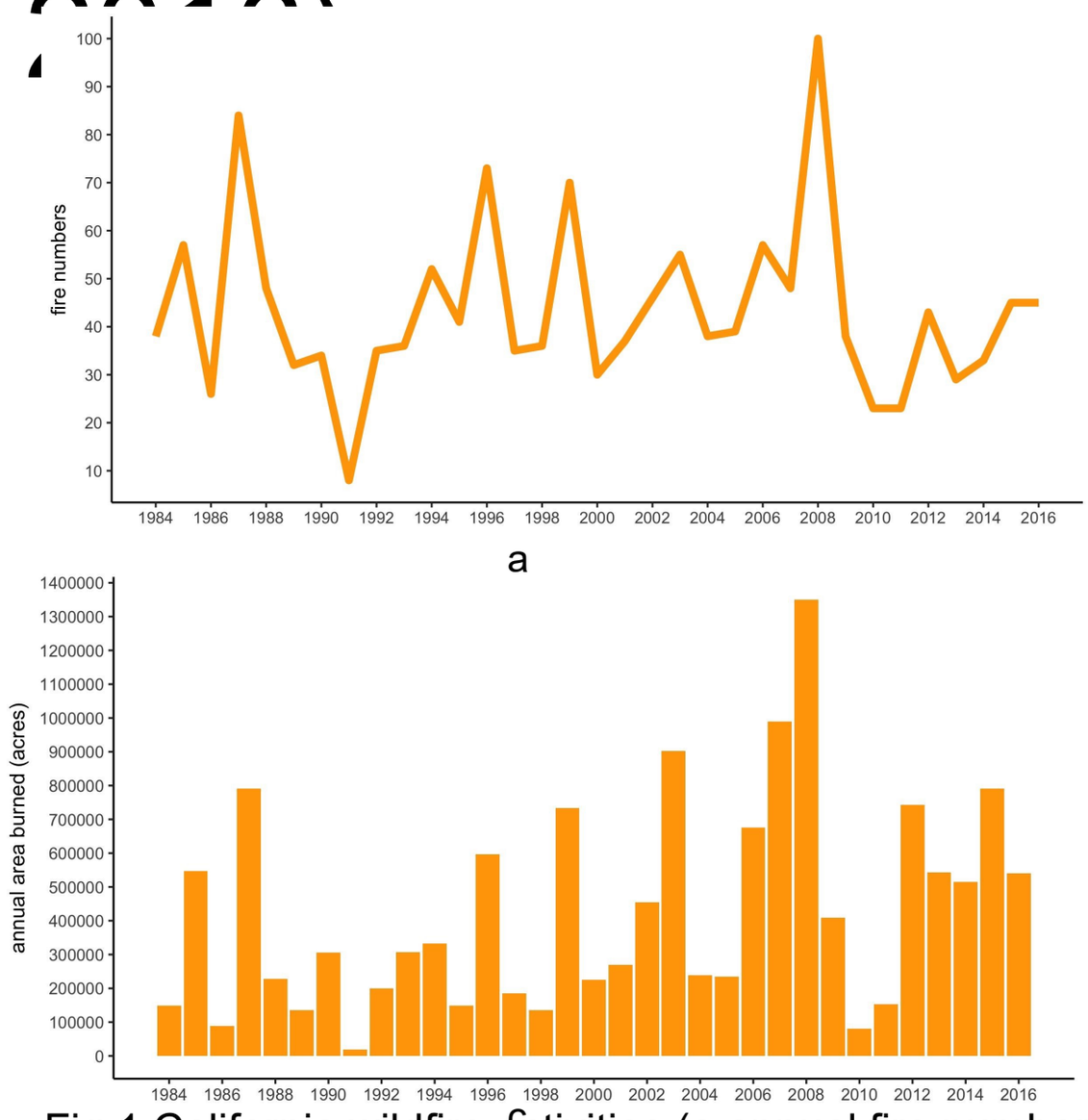
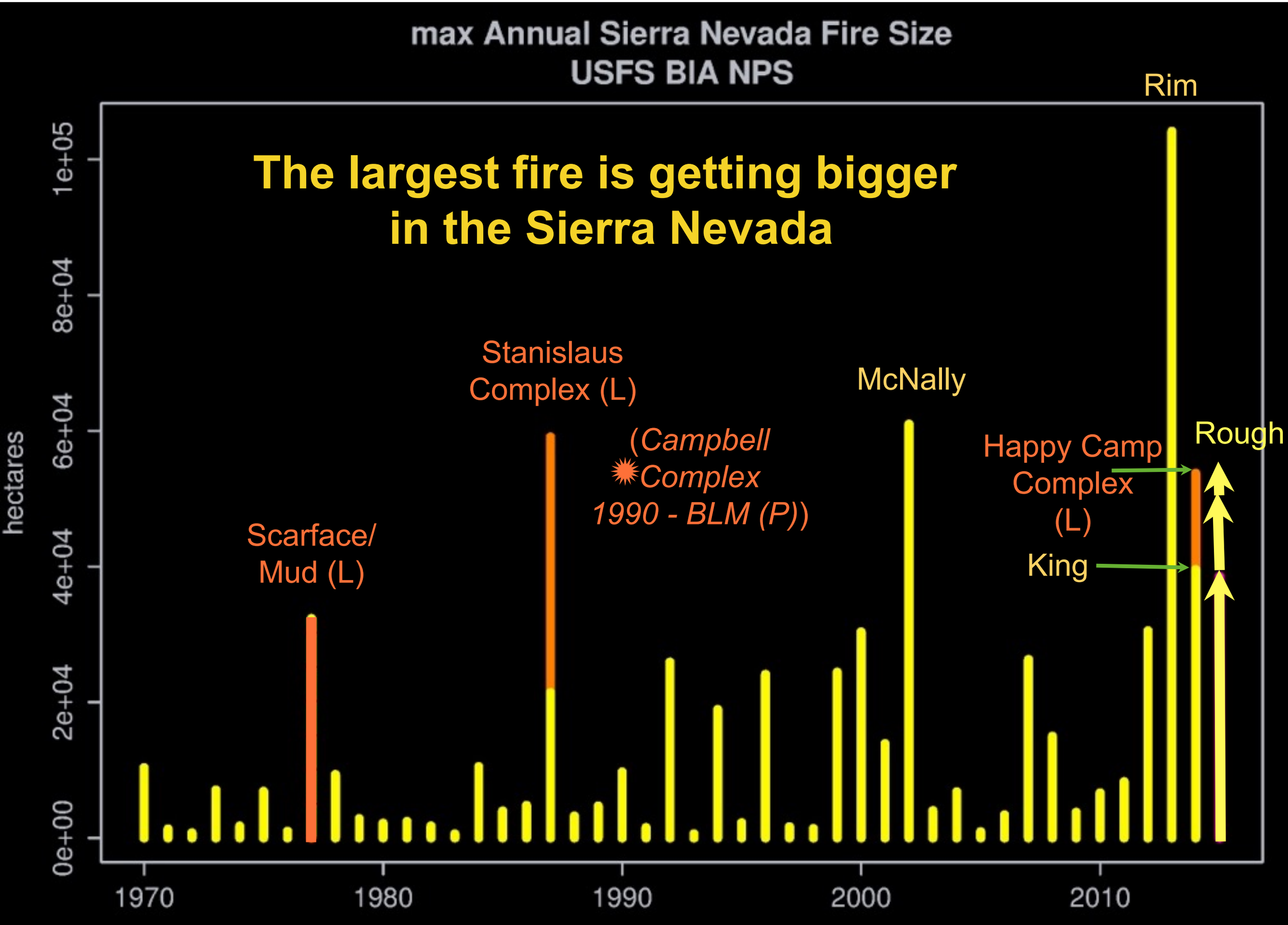
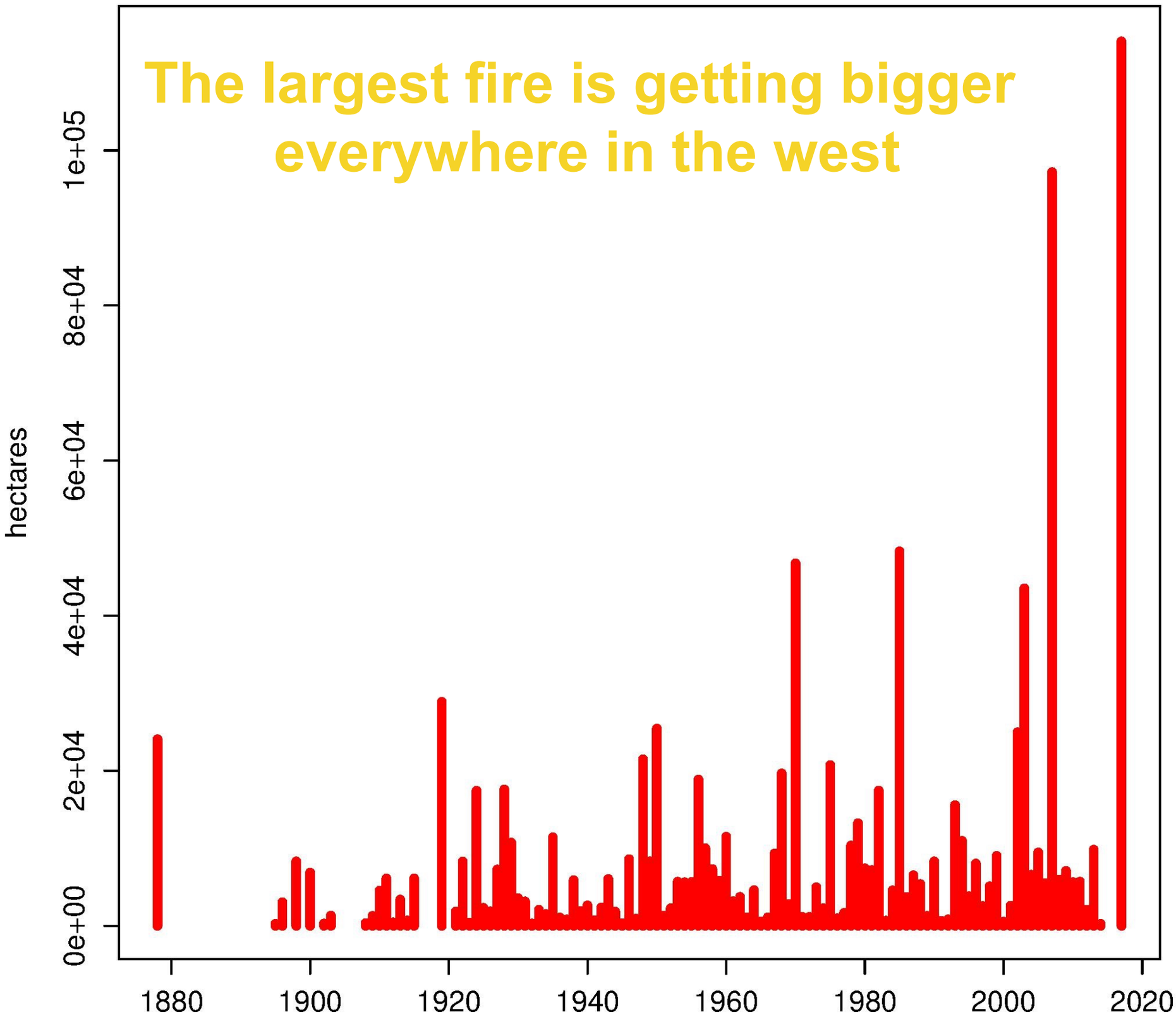


Fig.1 California wildfire activities (a:annual fire numbers; b:fire size of annual largest wildfires; c:annual area burned; d:fire severity trends)

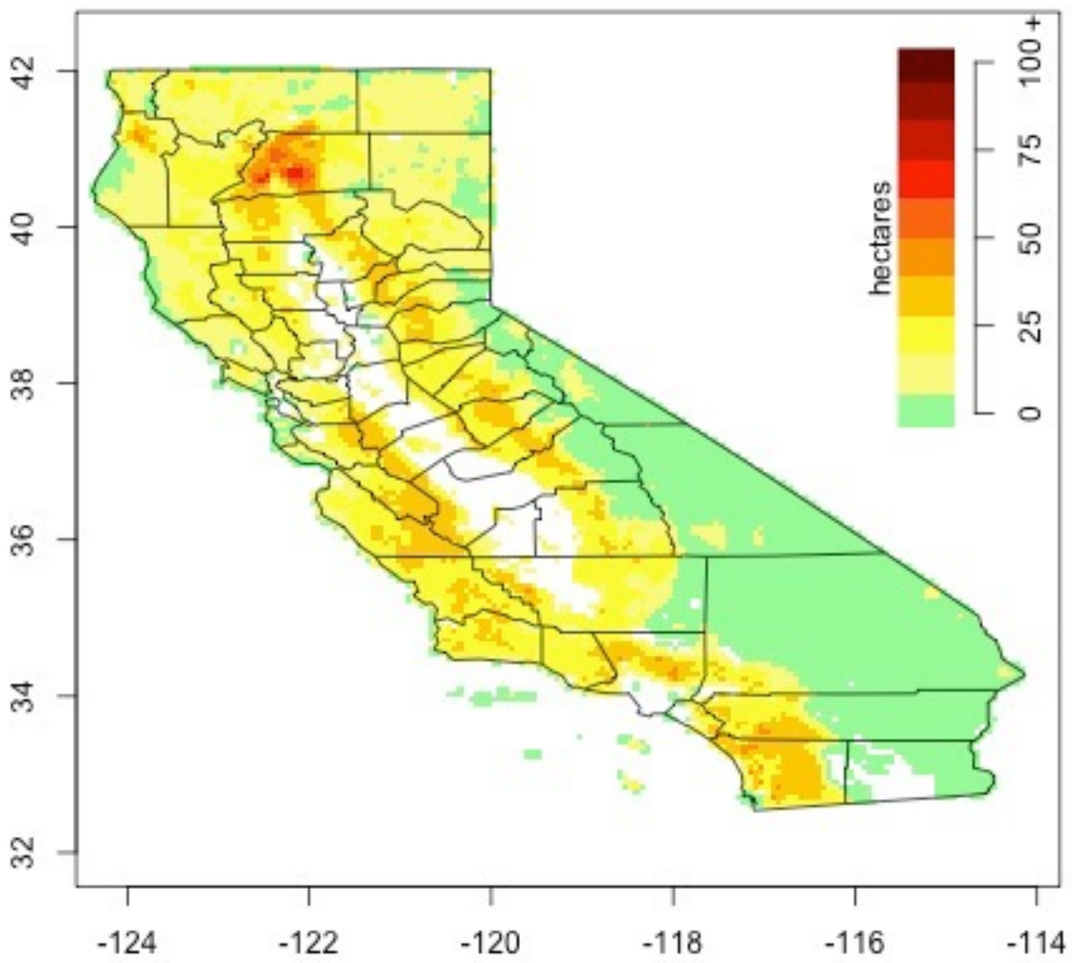

max Annual Sierra Nevada Fire Size
USFS BIA NPS
The largest fire is getting bigger
in the Sierra Nevada
hectares
0e+00
2e+04
4e+04
6e+04
8e+04
1e+05
1970
1980
1990
2000
2010
Rim
Stanislaus
Complex (L)
(Campbell
Complex
1990 - BLM (P))
McNally
Happy Camp
Complex
(L)
Rough
King
Scarface/
Mud (L)

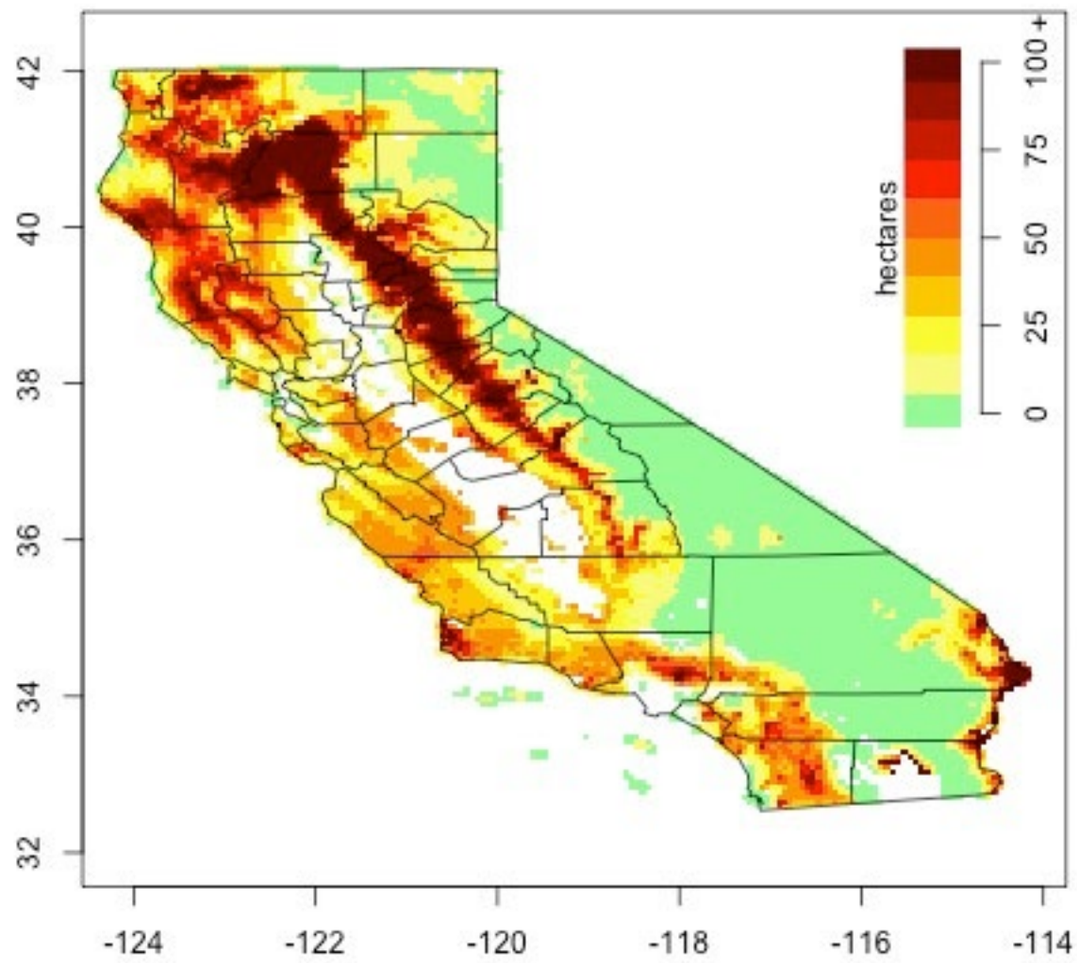
Maximum Recorded Fire Size: South Coast (CalFire/County Protection Responsibility

The largest fire is getting bigger everywhere in the west



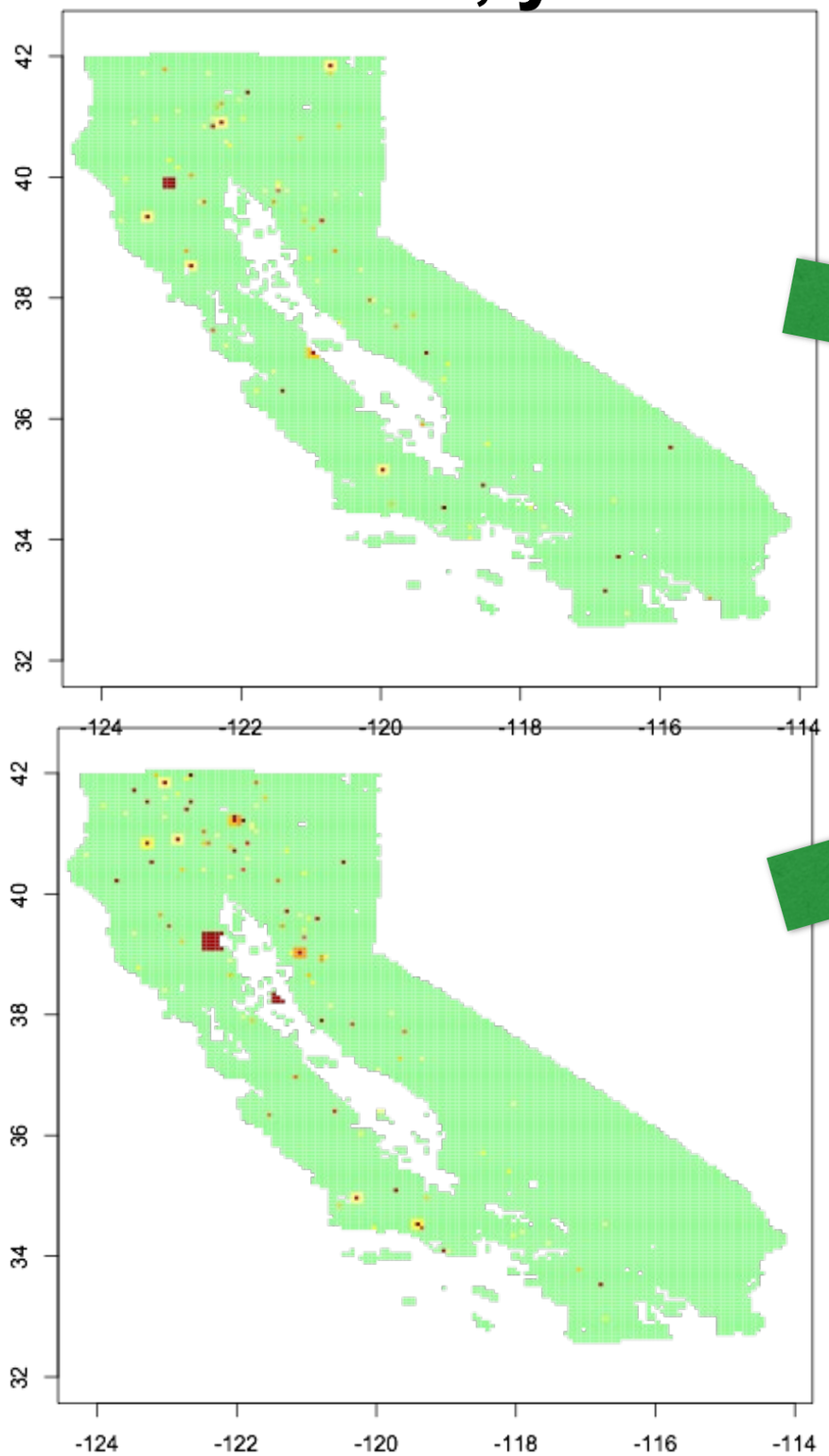
Cumulate over time, scenario(s) to obtain mean, compound distribution



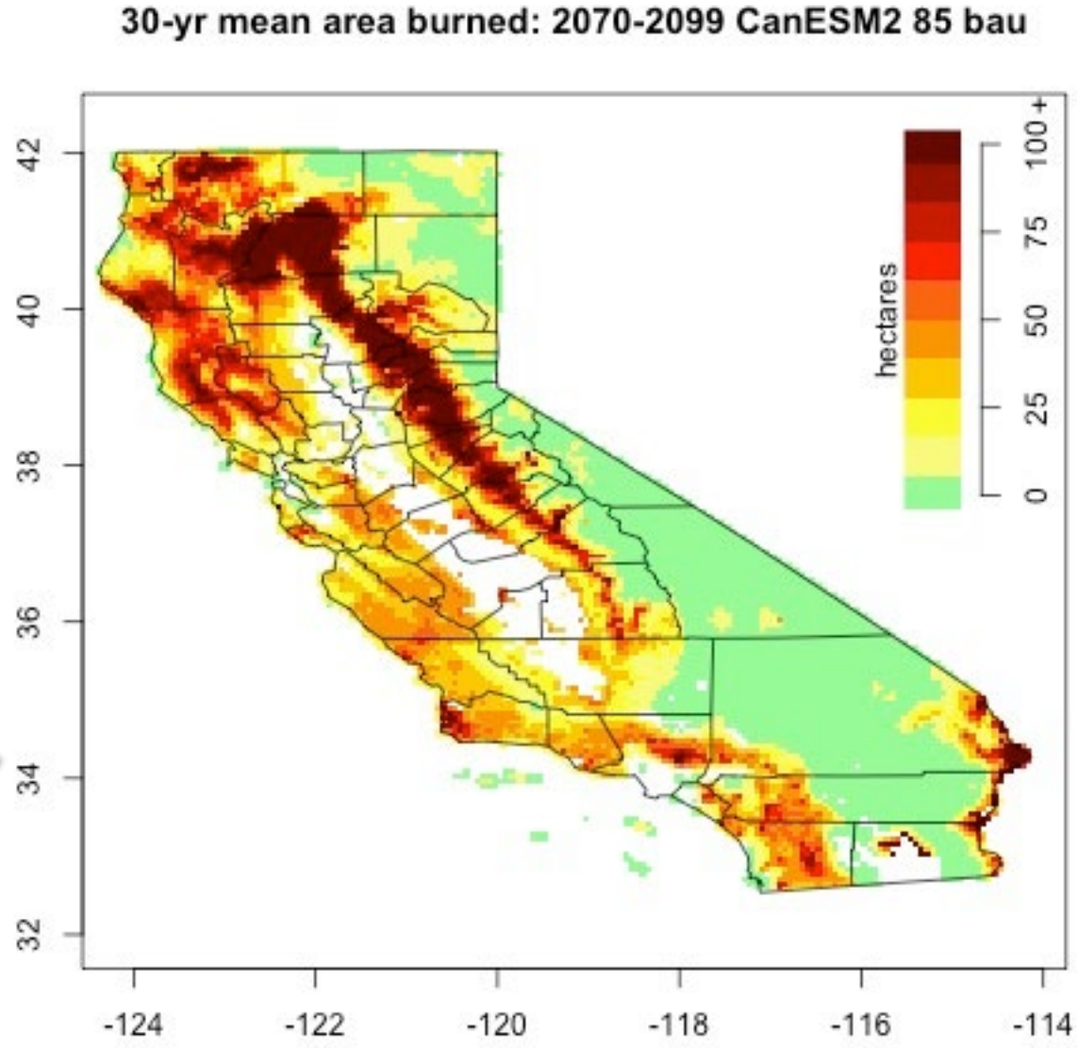


Westerling *(2018)*
Wildfire simulations for the Fourth California Climate Assessment: projecting changes in extreme wildfire events with a warming climate.

Annualized, allocated simulations multiple realizations per scenario, year



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



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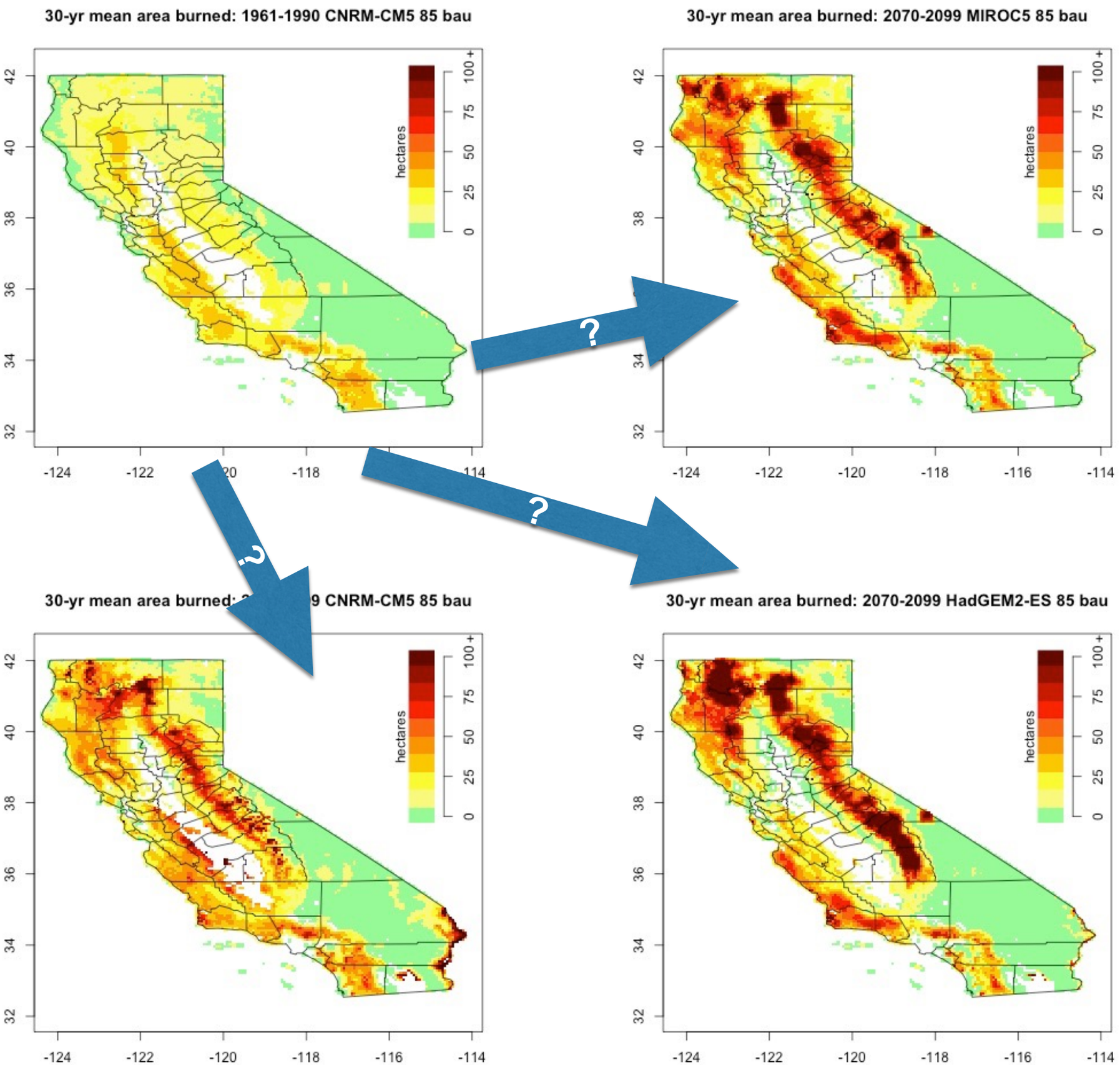
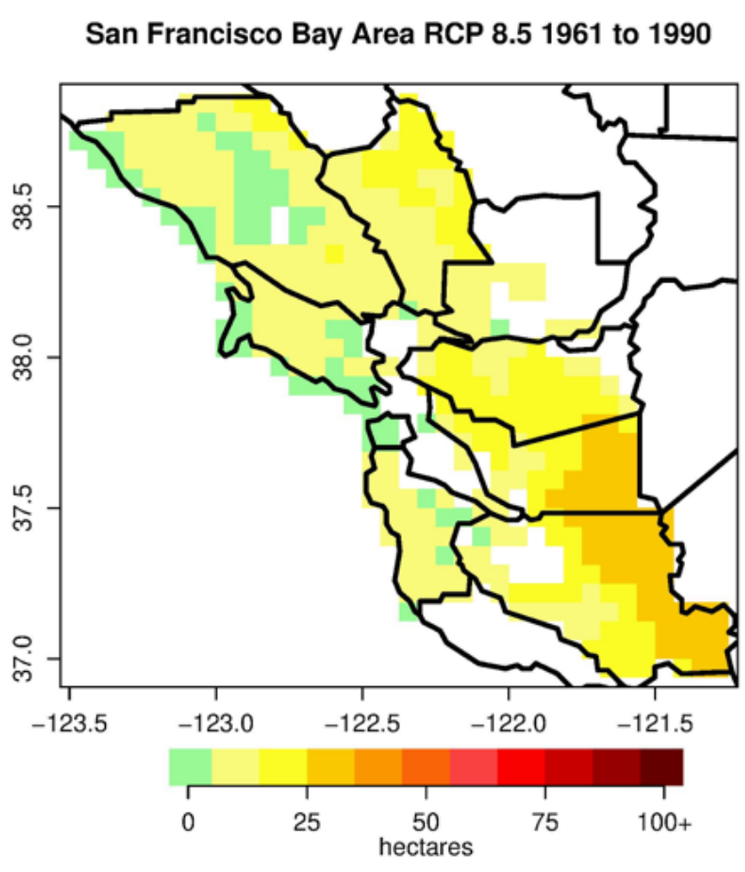
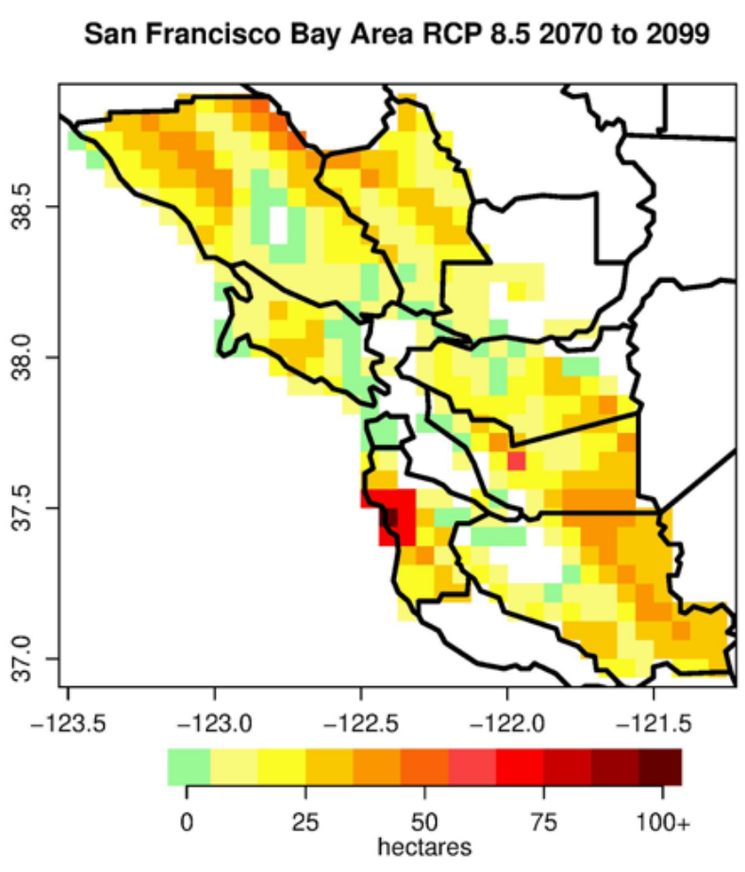
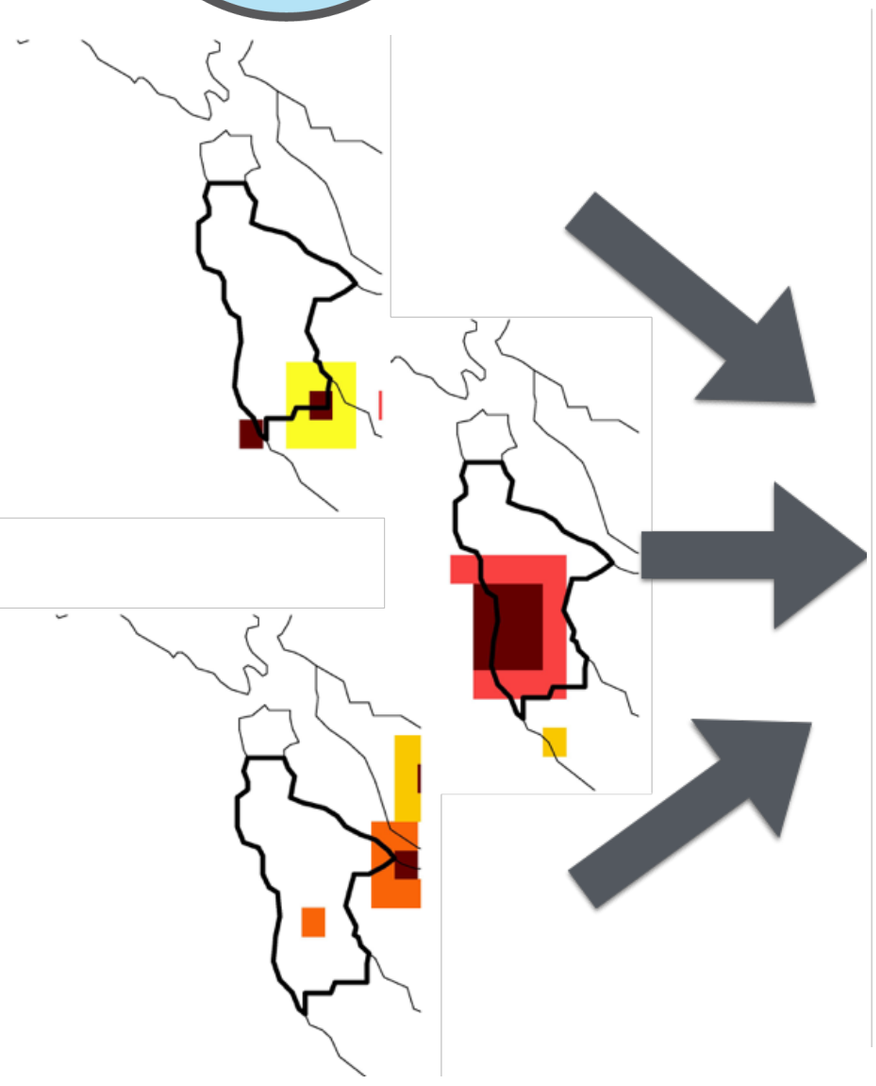

30-yr mean area burned: 1961-1990 CNRM-CM5 85 bau
30-yr mean area burned: 2070-2099 MIROC5 85 bau
30-yr mean area burned: 2070-2099 CNRM-CM5 85 bau
30-yr mean area burned: 2070-2099 HadGEM2-ES 85 bau
hectares
0
25
50
75
100 +
42
40
38
36
34
32
-124
-122
-120
-118
-116
-114
?
?
?

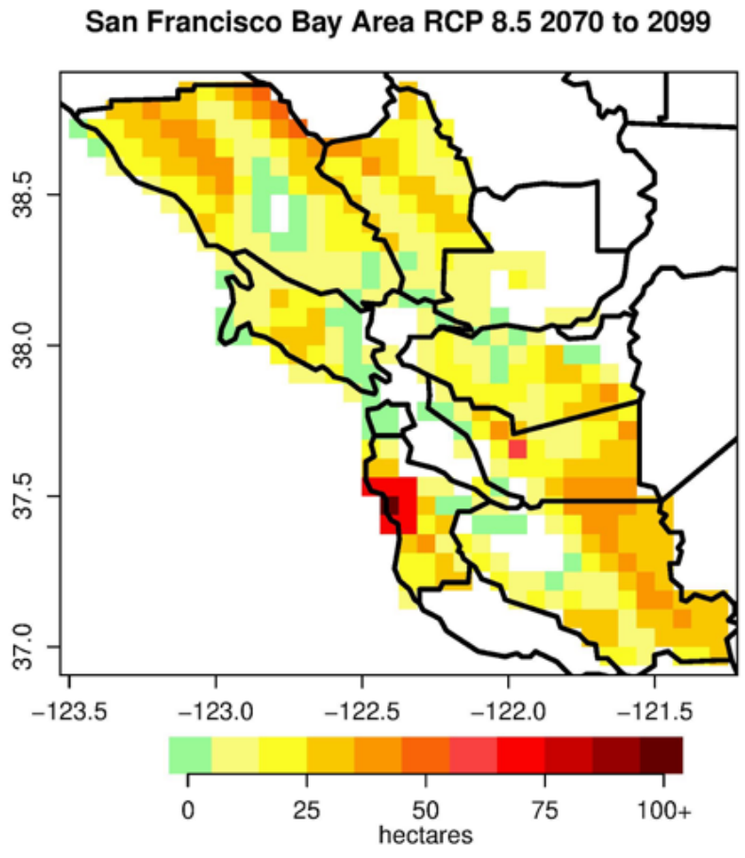
Data that Drives Outcomes
Data to plan for wildfire





Curating fire scenarios

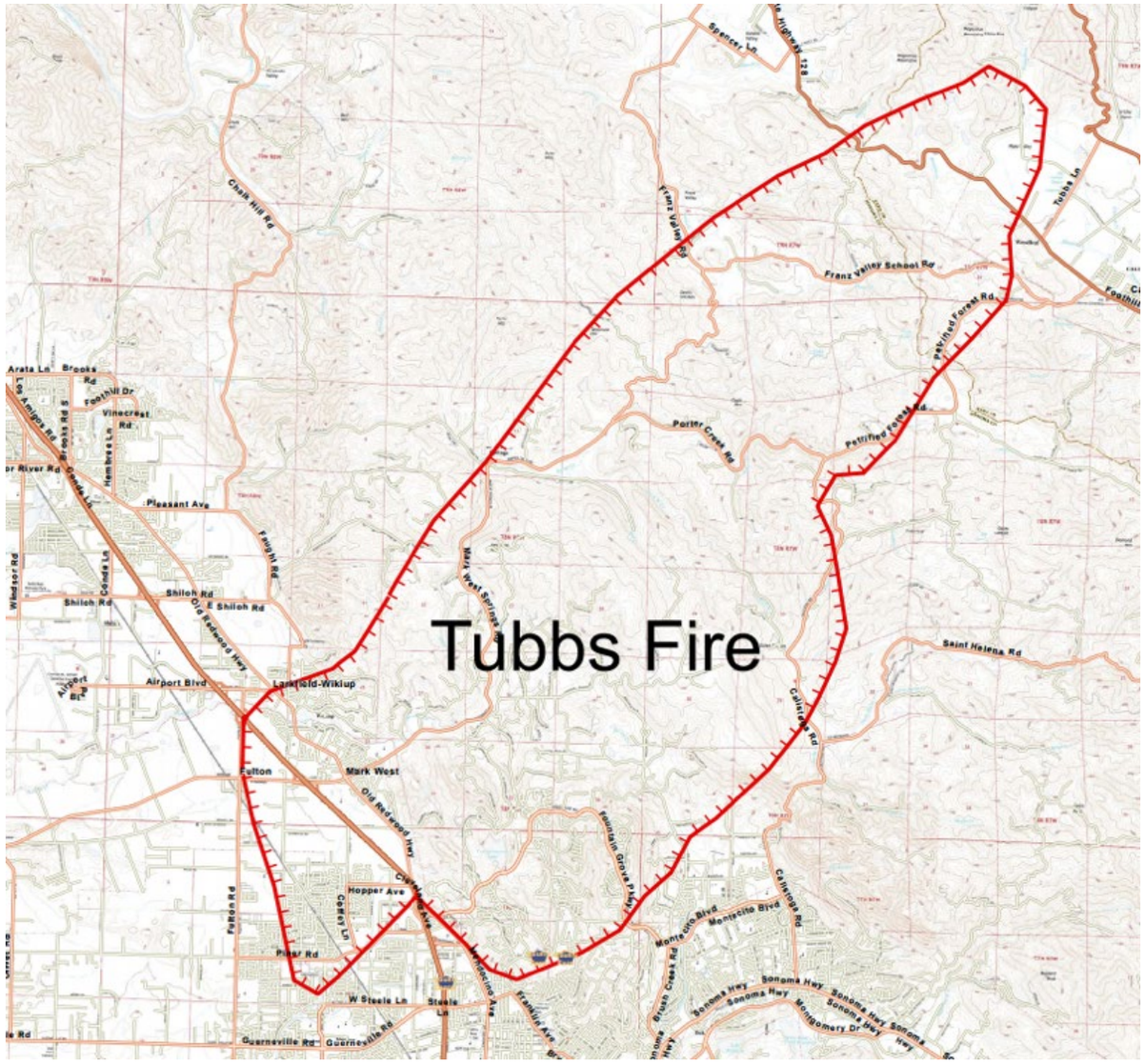


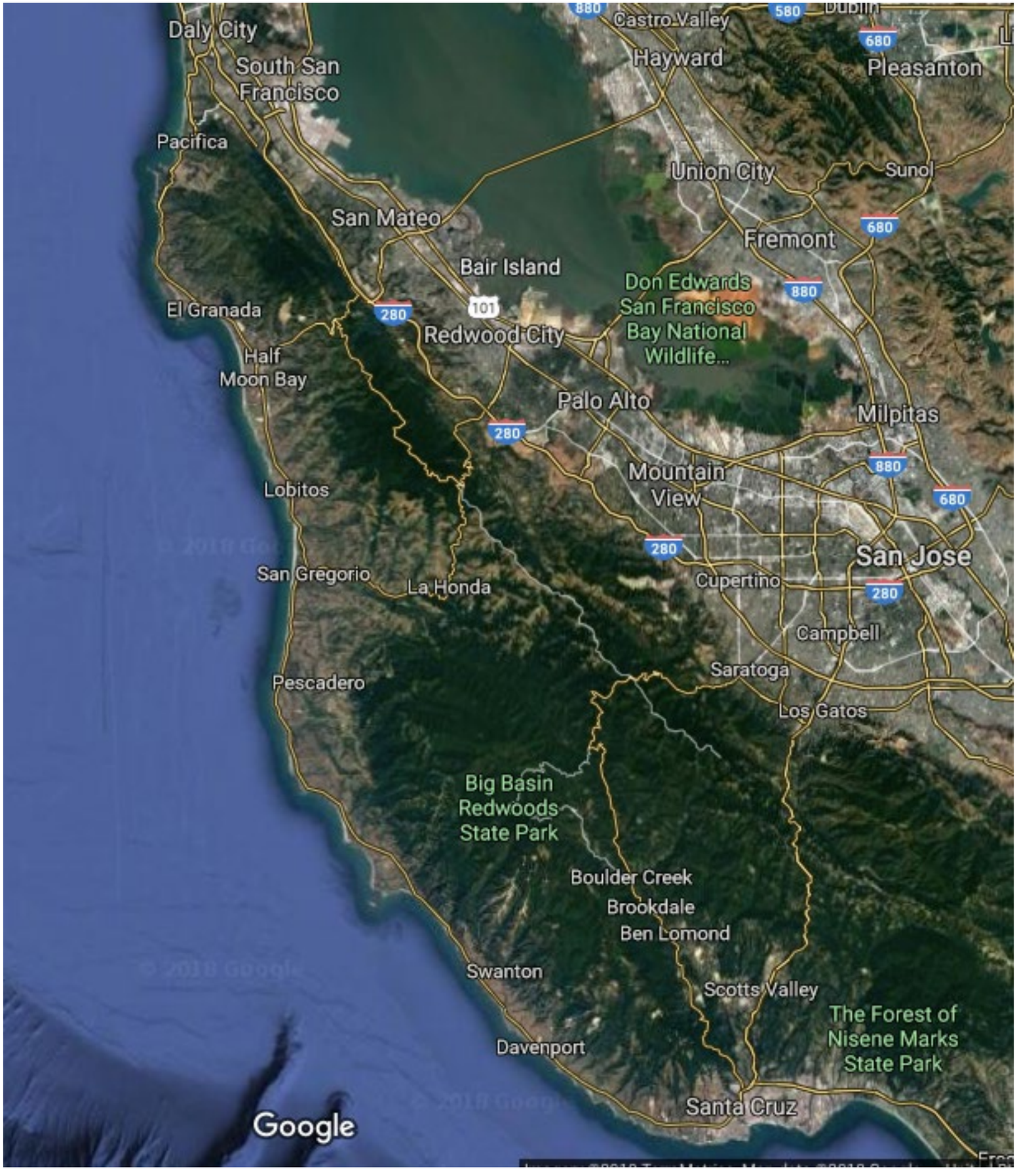


Usable data:

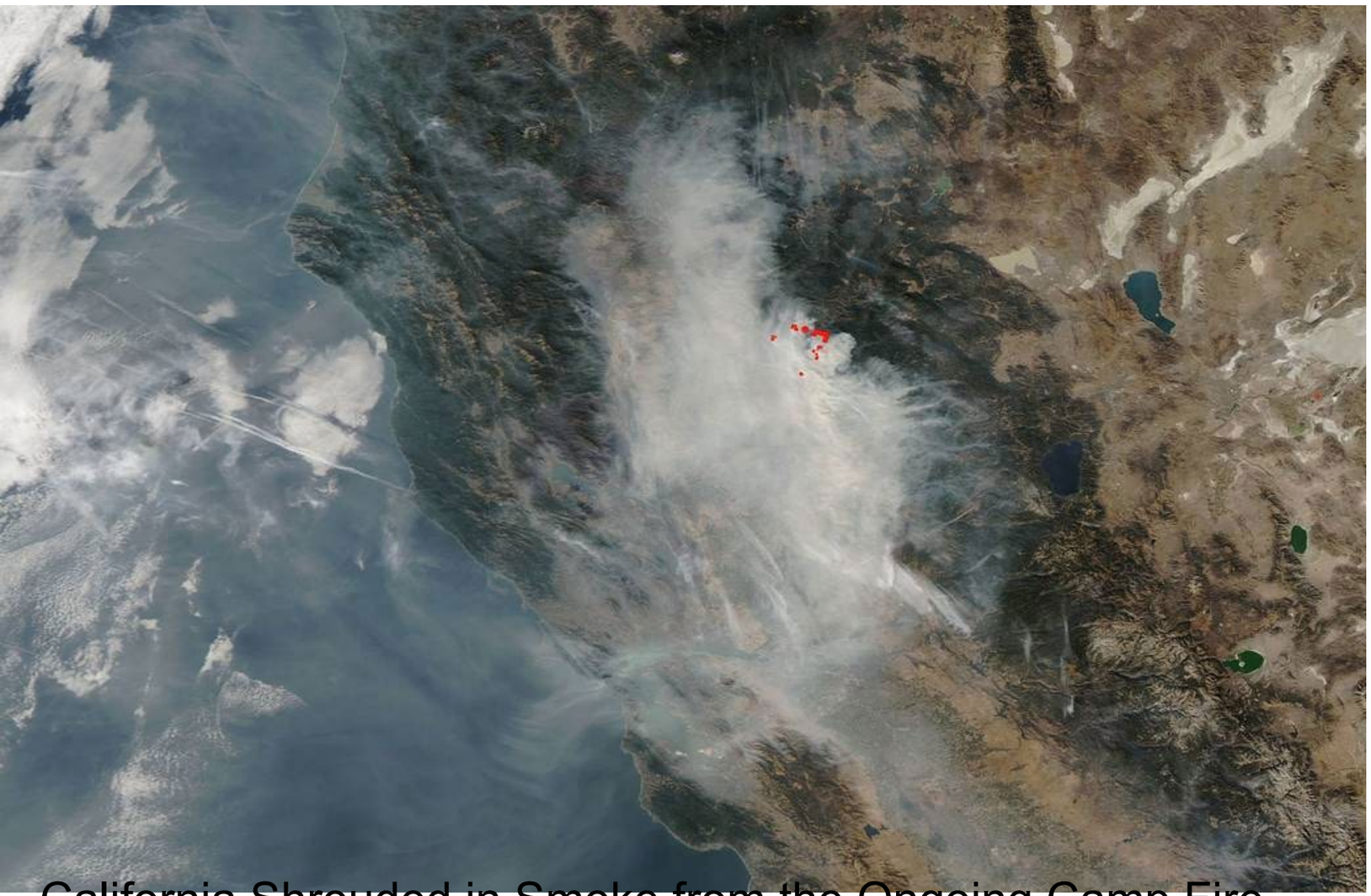
- Planning scenarios
- Context:
  - Climate
  - Region

Translating into realistic fire perimeters




Daly City
South San Francisco
Pacifica
Castro Valley
Hayward
Pleasanton
Union City
Sunol
San Mateo
Fremont
Bair Island
Don Edwards San Francisco Bay National Wildlife...
El Granada
Redwood City
Half Moon Bay
Palo Alto
Milpitas
Mountain View
Lobitos
San Gregorio
La Honda
Cupertino
San Jose
Campbell
Saratoga
Pescadero
Los Gatos
Big Basin Redwoods State Park
Boulder Creek
Brookdale
Ben Lomond
Swanton
Scotts Valley
The Forest of Nisene Marks State Park
Davenport
Santa Cruz
Google

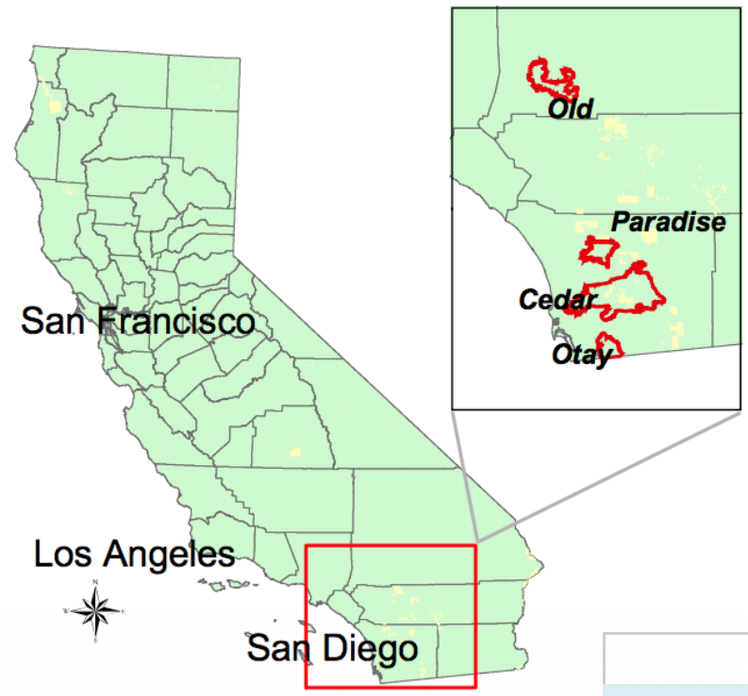
Wildfire smoke

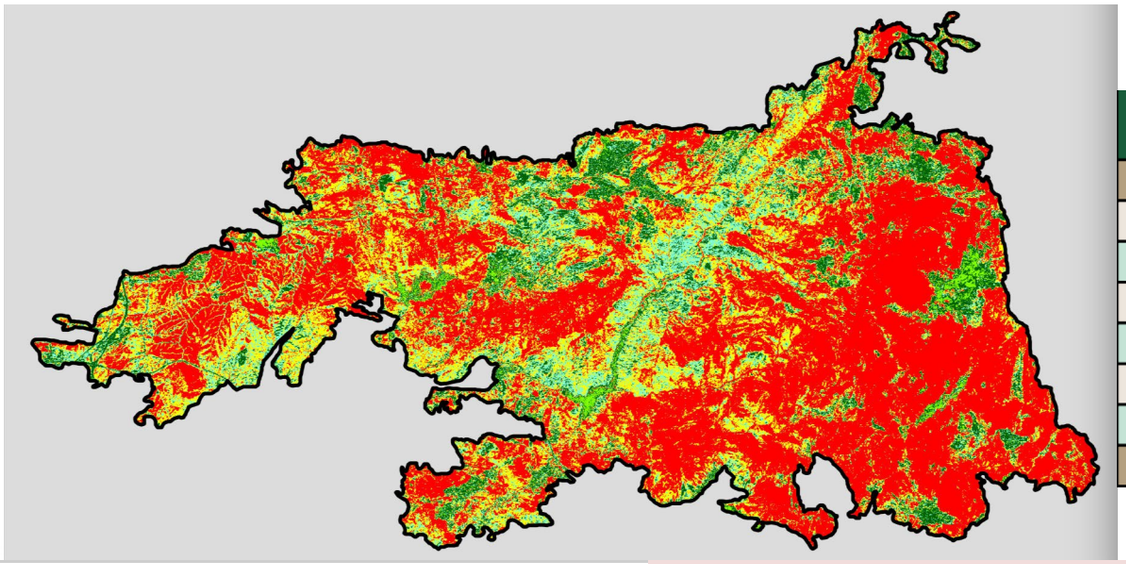


California Shrouded in Smoke from the Ongoing Camp Fire
source: https://www.nasa.gov/image-feature/goddard/2018/california-shrouded-in-smoke-from-the-ongoing-camp-fire

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)

Emission calculation example: Cedar fire 2003





Acreage of Burn Severity	
Burn Severity	**Acres**
Unburned to Low	29,711
Low	32,619
Moderate	63,840
High	138,437
Increased Greenness	3,744
Non-Processing Area Mask*	3
Total	**268,353**

location	lat16	32.96875
	lon16	-116.71875
vegetation Fractior	grass	0.485075
	shrub	0.000175
	forests <5500	0.07175
	forests >7500	0
	forests 5500-750(	0.002125
	foests in total	0.073875

emissions (Gg)	CO2	1176.39472
	CO	64.5646935
	CH4	3.28328011
	NMOC	28.3615202
	SO2	0.35670756
	NH3	0.60343537
	NO	0.47175641
	NO2	0.94064082
	NOx	1.01335974
	PM2.5	16.7890465

3.PM2.5 and land cover

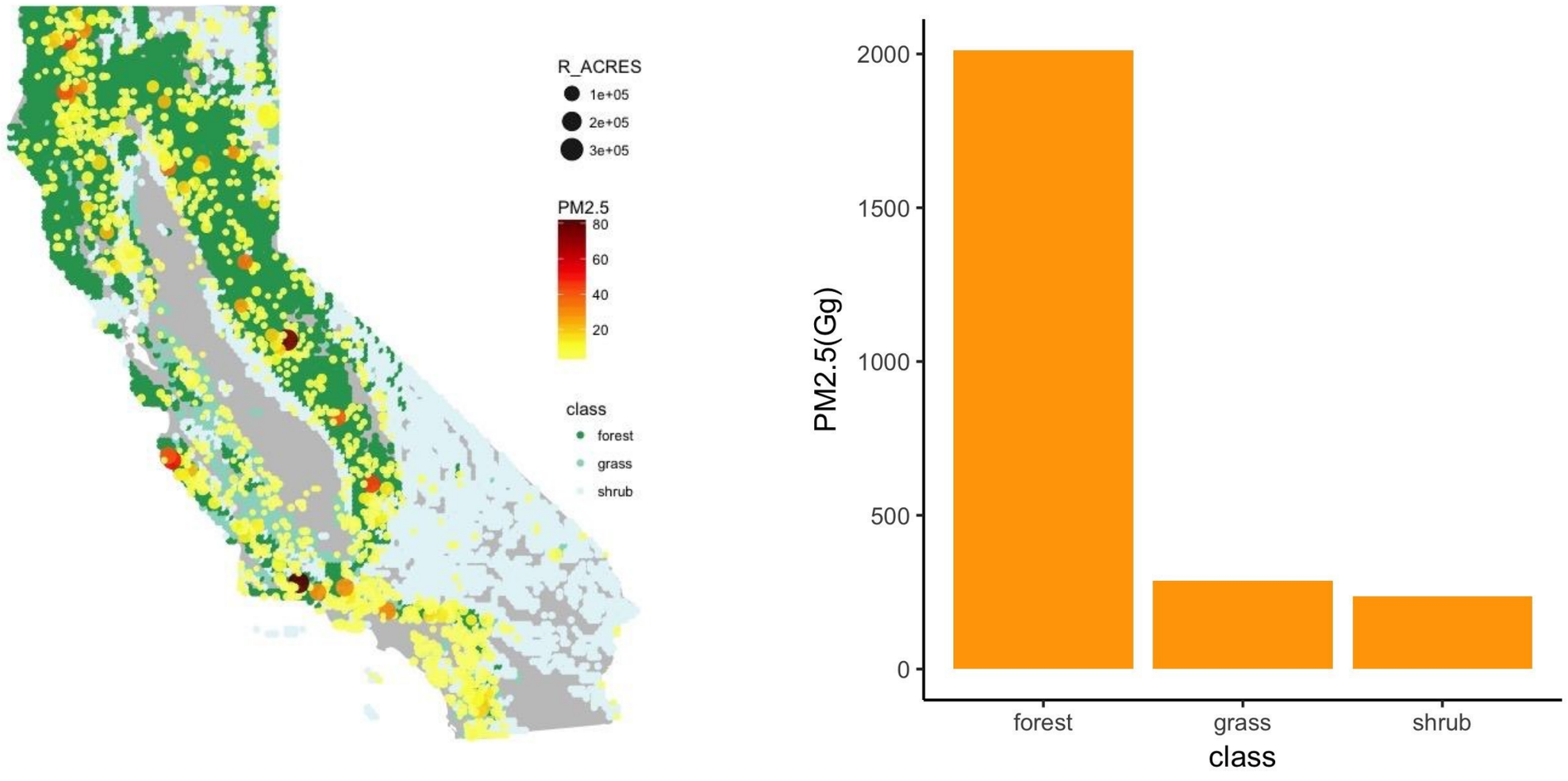


Fig.4 PM2.5 emissions in forest, shrub, and grass land in California (1984-2016) (Gg)

3.Fire severity and land cover

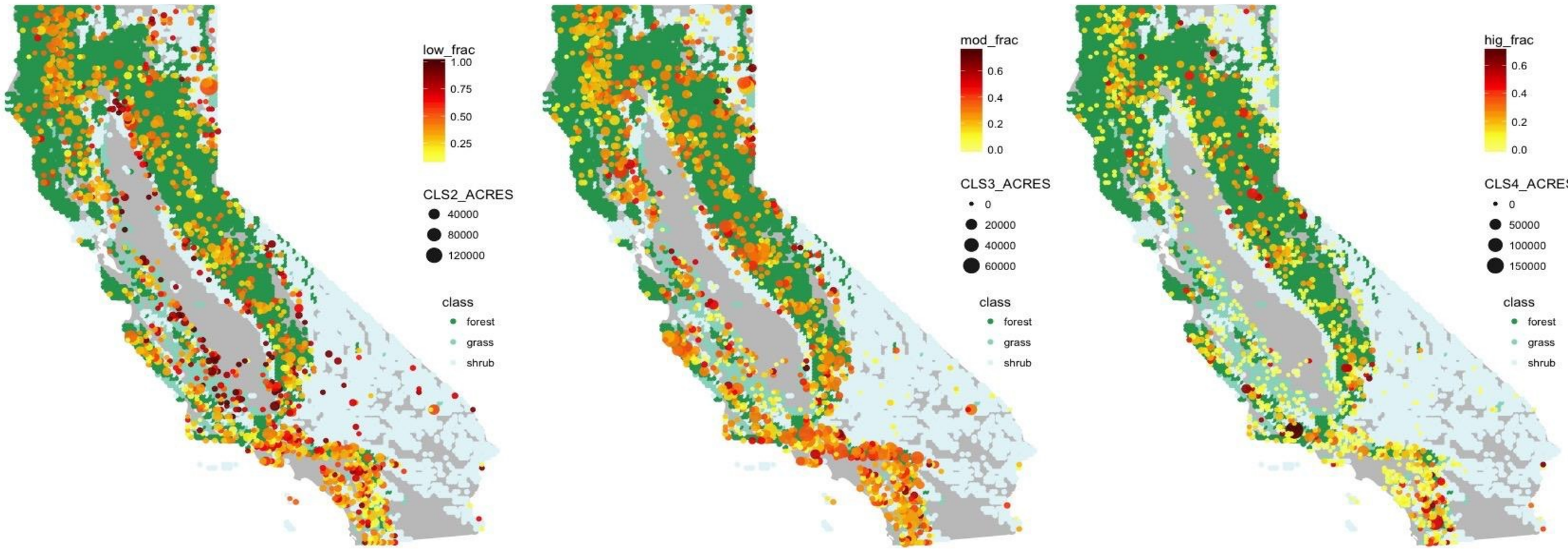


Fig.5 Wildfire severity distribution in forest, shrub, and grassland in California (1984-2016) (Gg) (from left to right: low, moderate, and high severity)

2. PM2.5 emissions from wildfire, annual

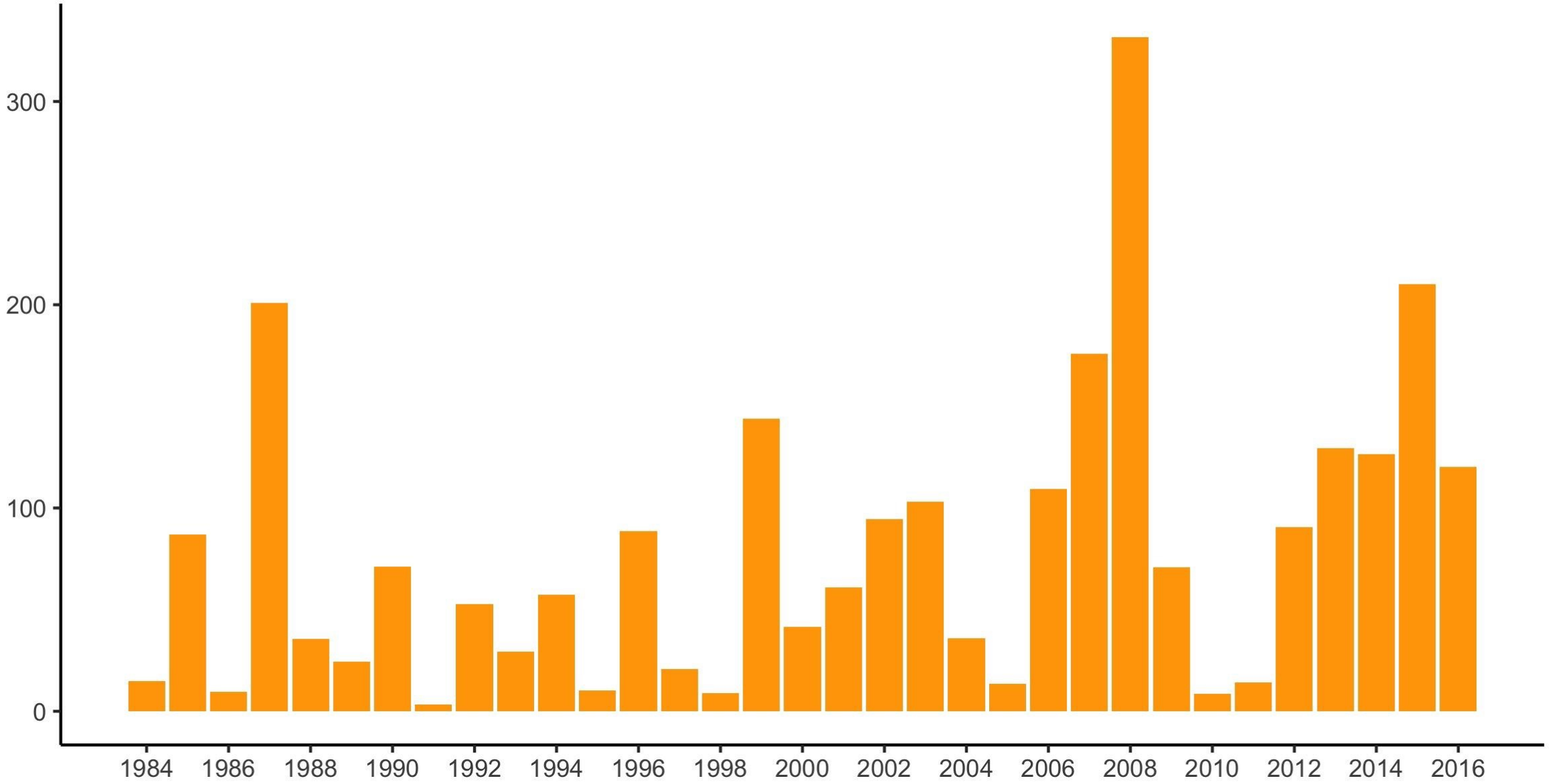
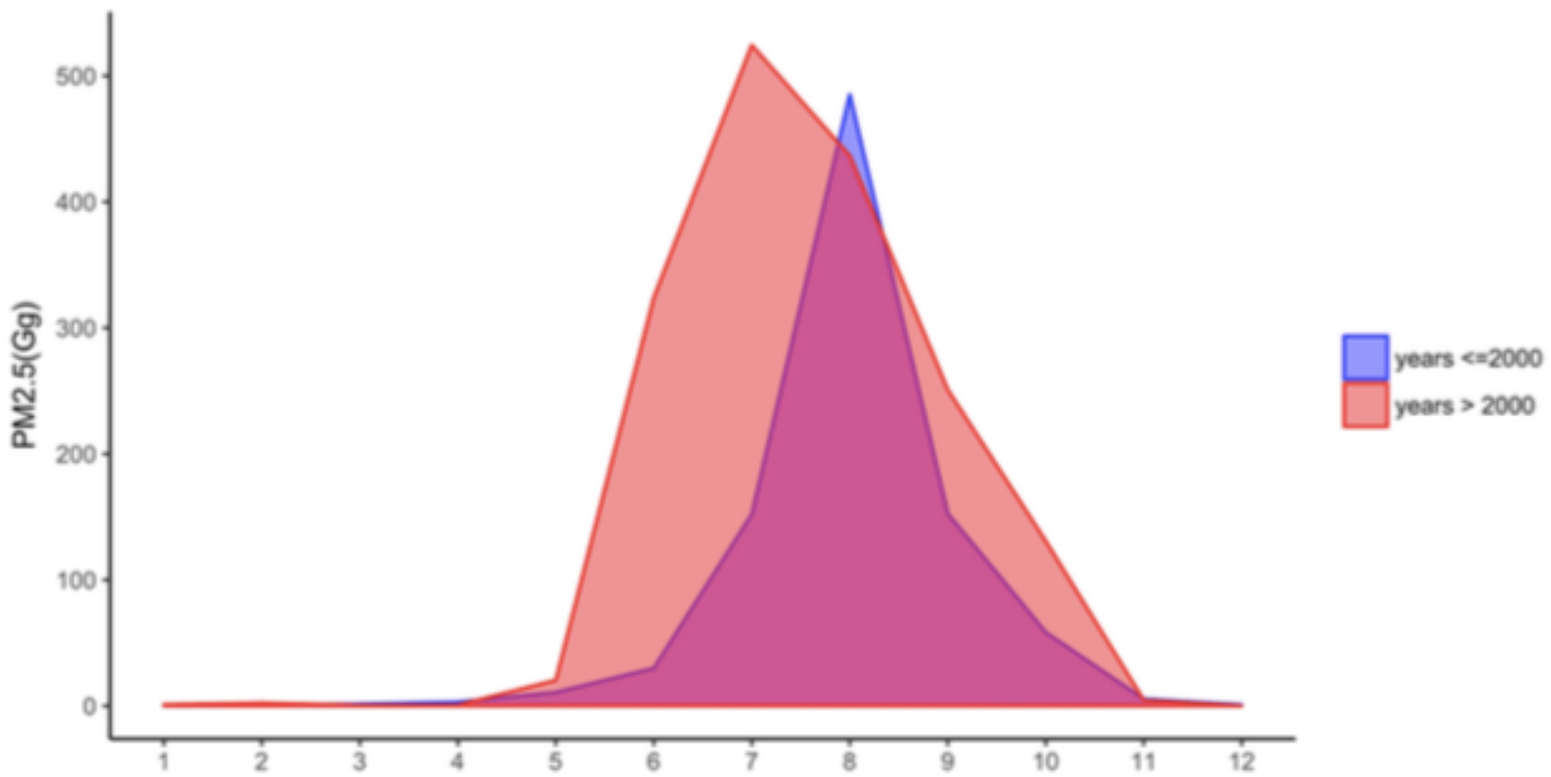
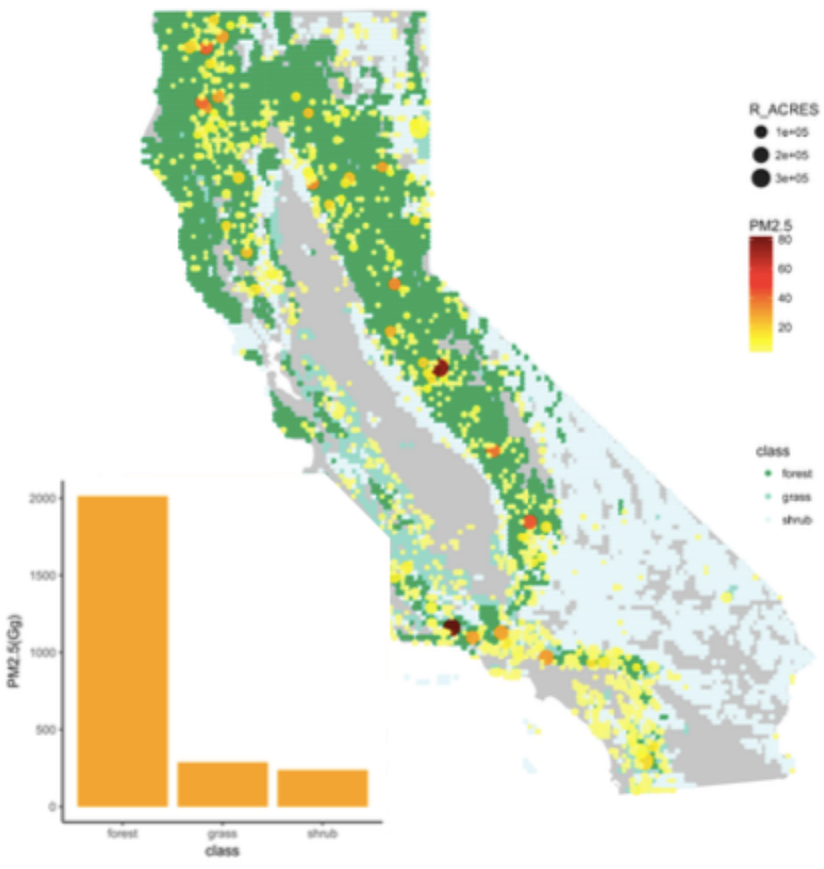


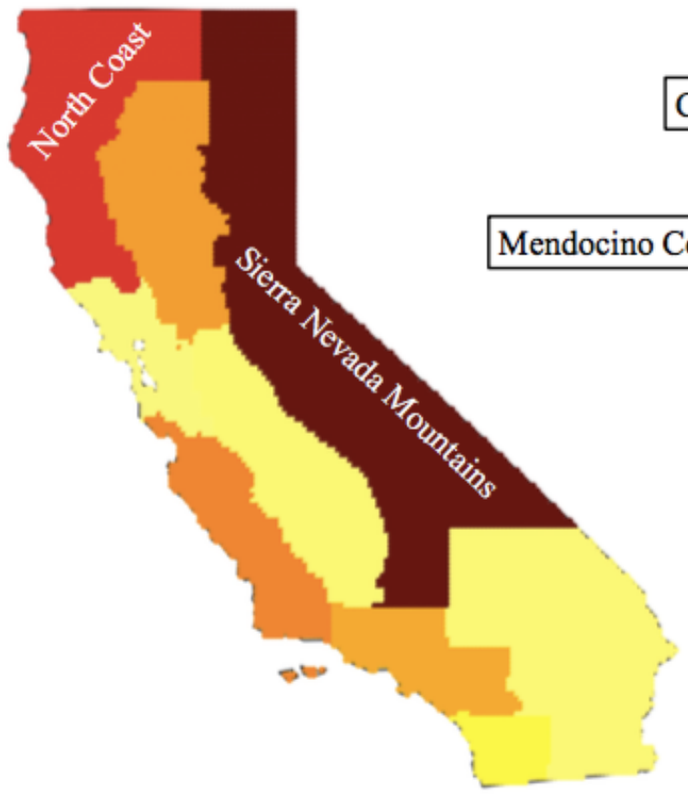
Fig.3 PM2.5 annual emissions aggregated over the state of California, 1984-2016(Gg)

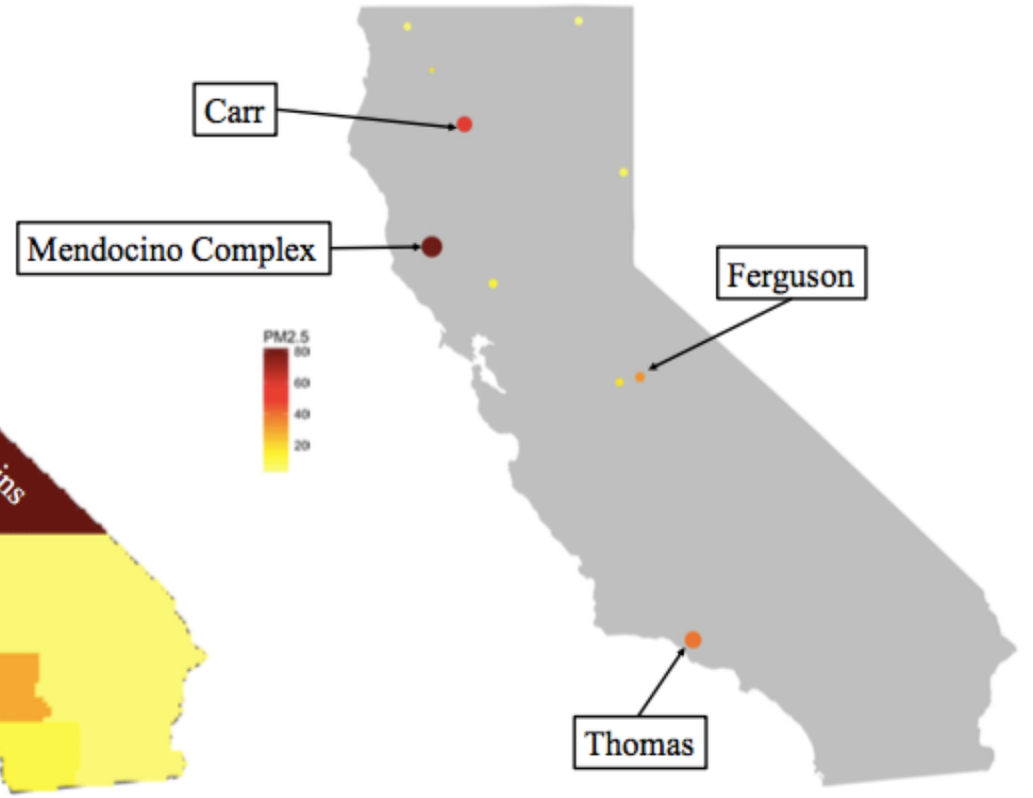
Since the 21st century, there has been an earlier and longer wildfire emission season



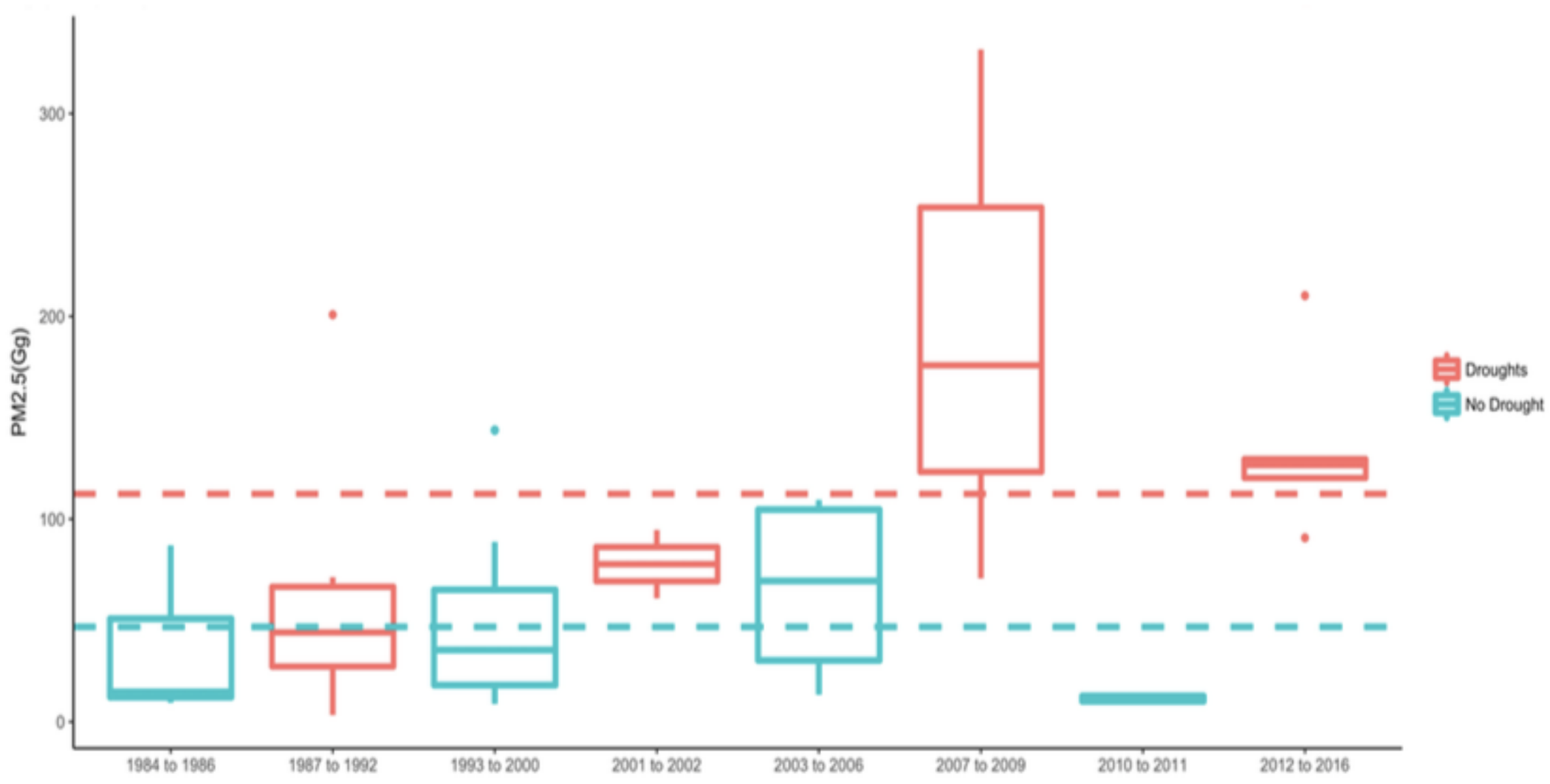
Most of the emissions come from forest burning in Sierra Nevada Mountains and North Coast climate regions





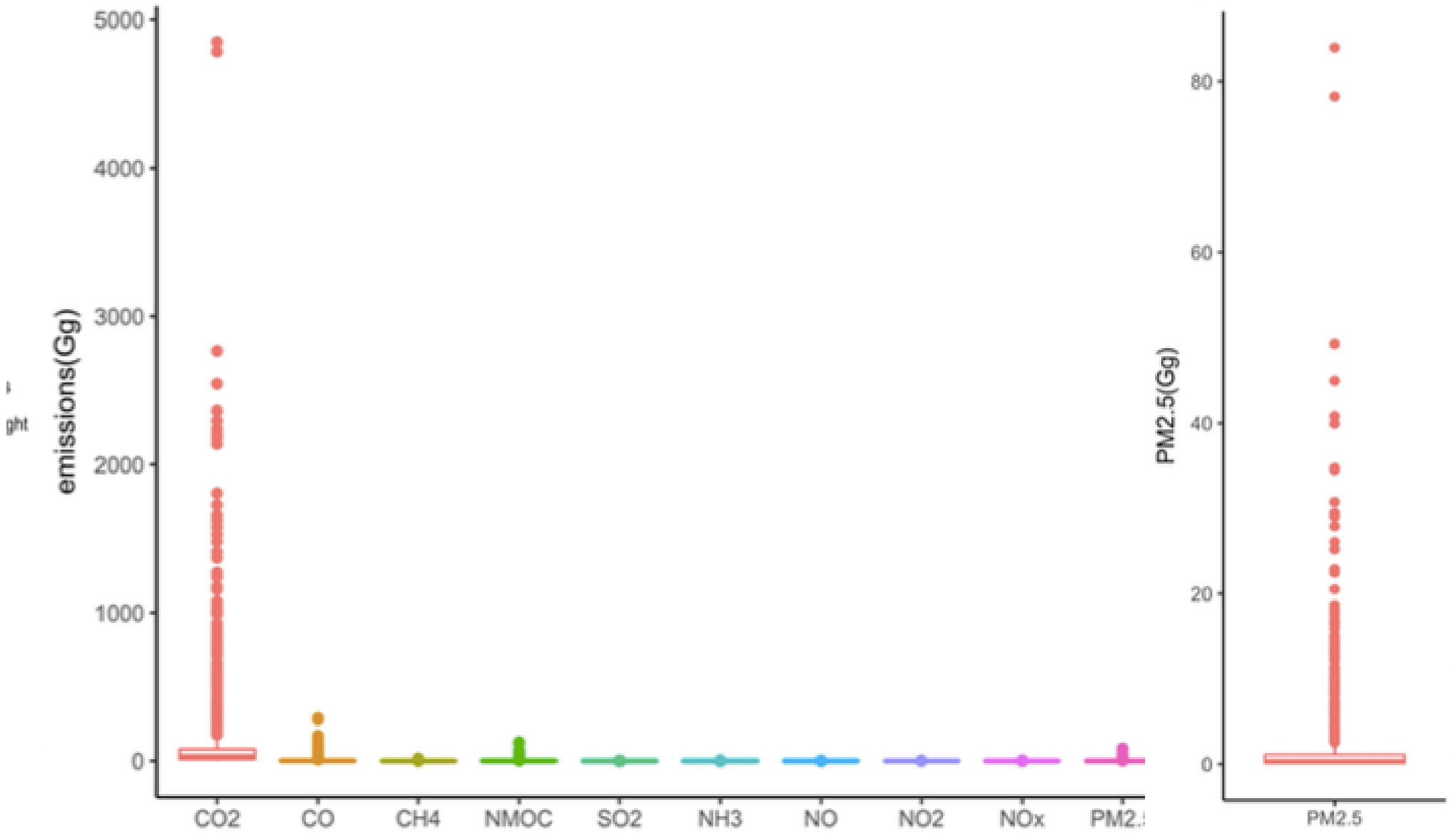


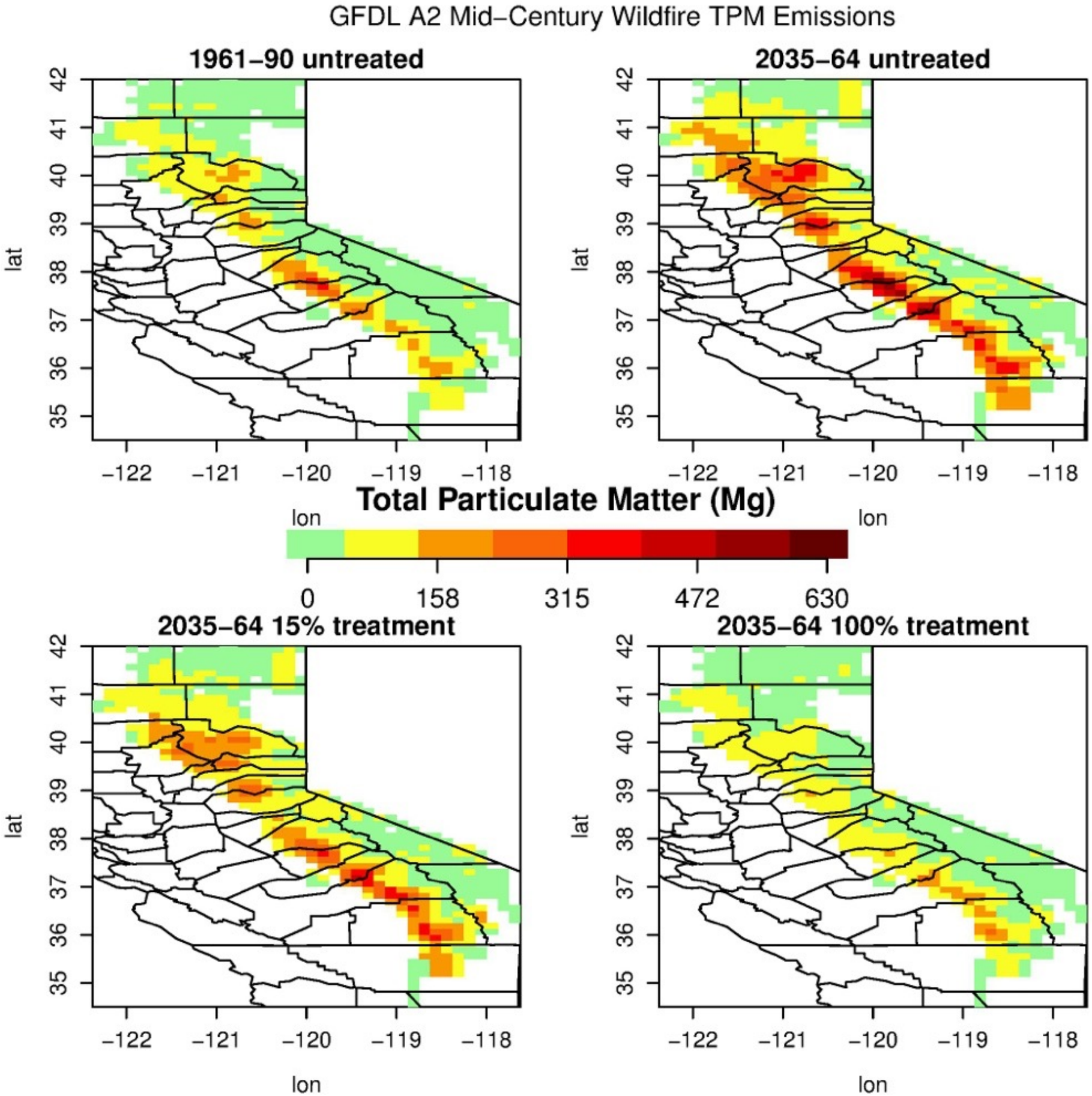
A larger proportion of PM2.5 was produced during drought years



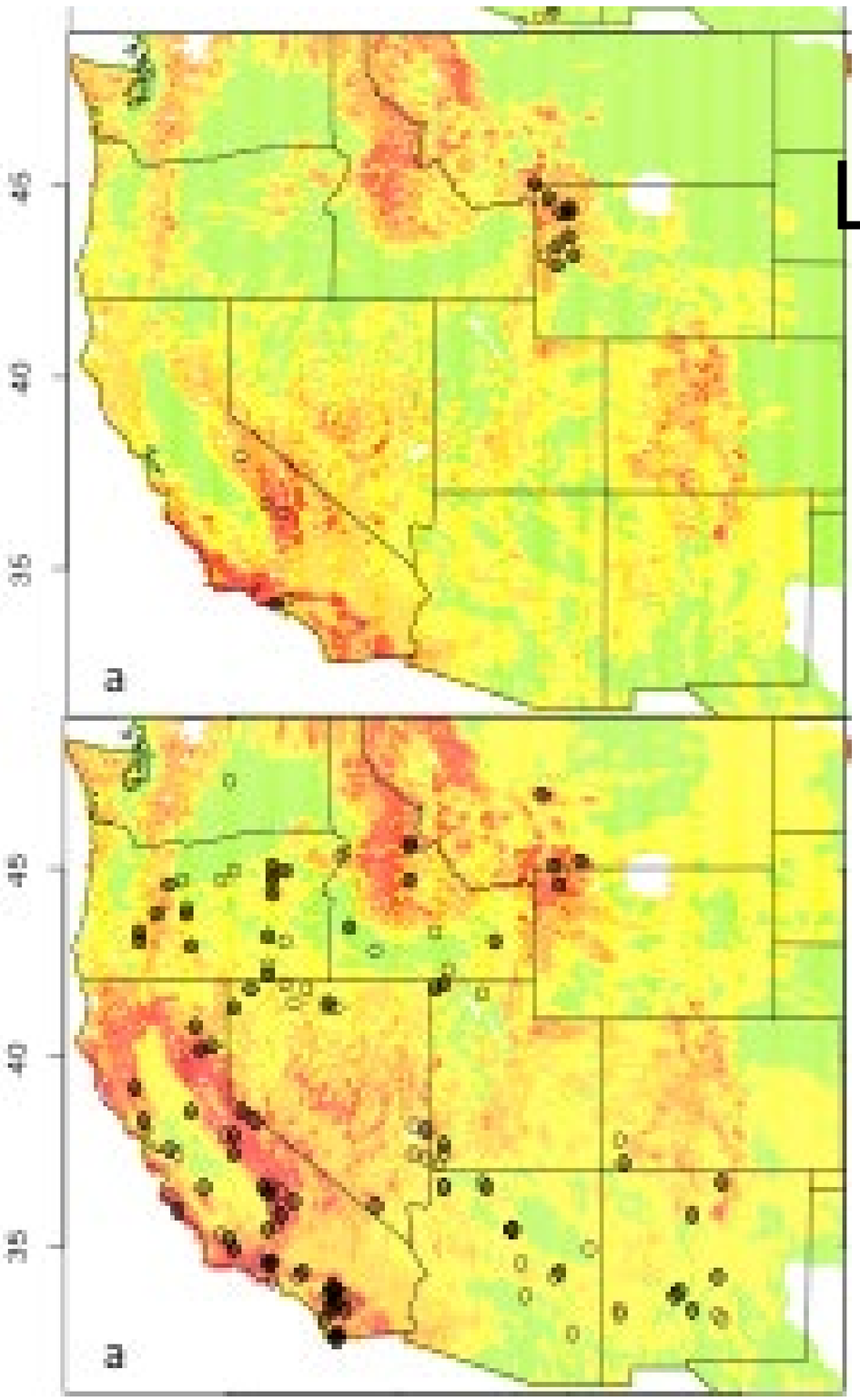
84-86 87-92 93-00 01-02 03-00 07-09 10-11 12-16

A significant amount of PM2.5 was emitted, but CO^2 made up the vast majority of wildfire emissions




GFDL A2 Mid−Century Wildfire TPM Emissions
1961−90 untreated
2035−64 untreated
2035−64 15% treatment
2035−64 100% treatment
lat
lon
42
41
40
39
38
37
36
35
−122
−121
−120
−119
−118
Total Particulate Matter (Mg)
0
158
315
472
630

Probability: high severity fraction in top 25%: Climate influences fire severity, even in the N. Rockies



Low Fire Year

High Fire Year

Open circles are large fires;

hatched circles are large fires with

high severity fraction >0.1732

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

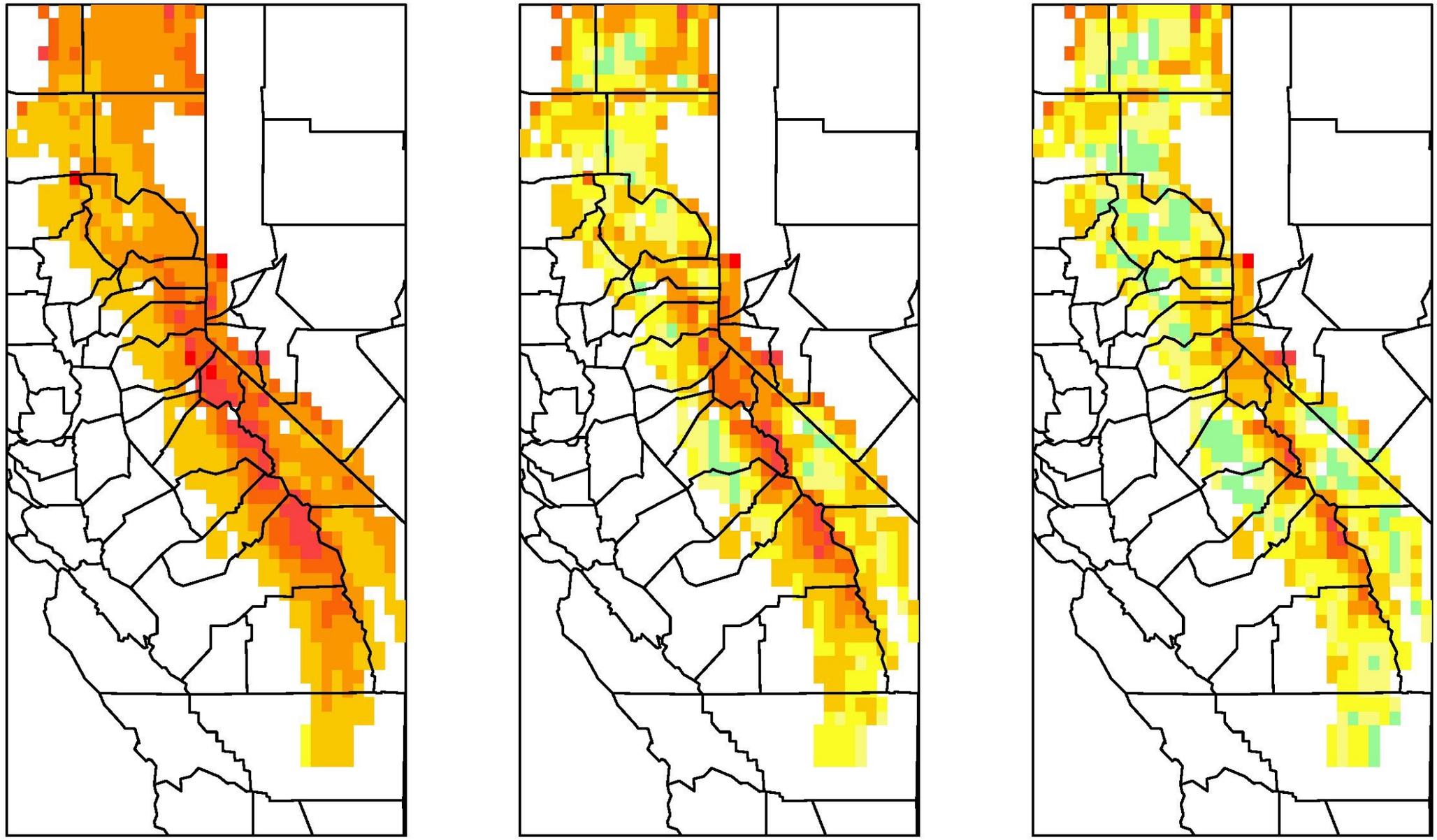
— Harvey et al 2016
Landscape Ecology

percent change in expected BA90 area

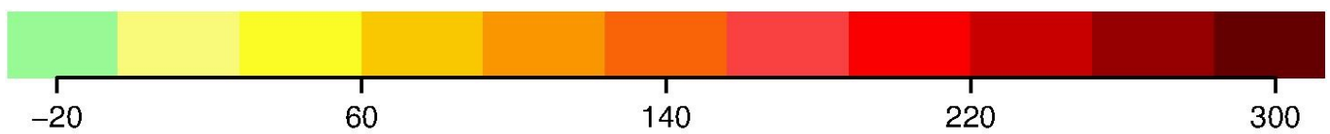
GFDL 2035–64 with no fuels treatment

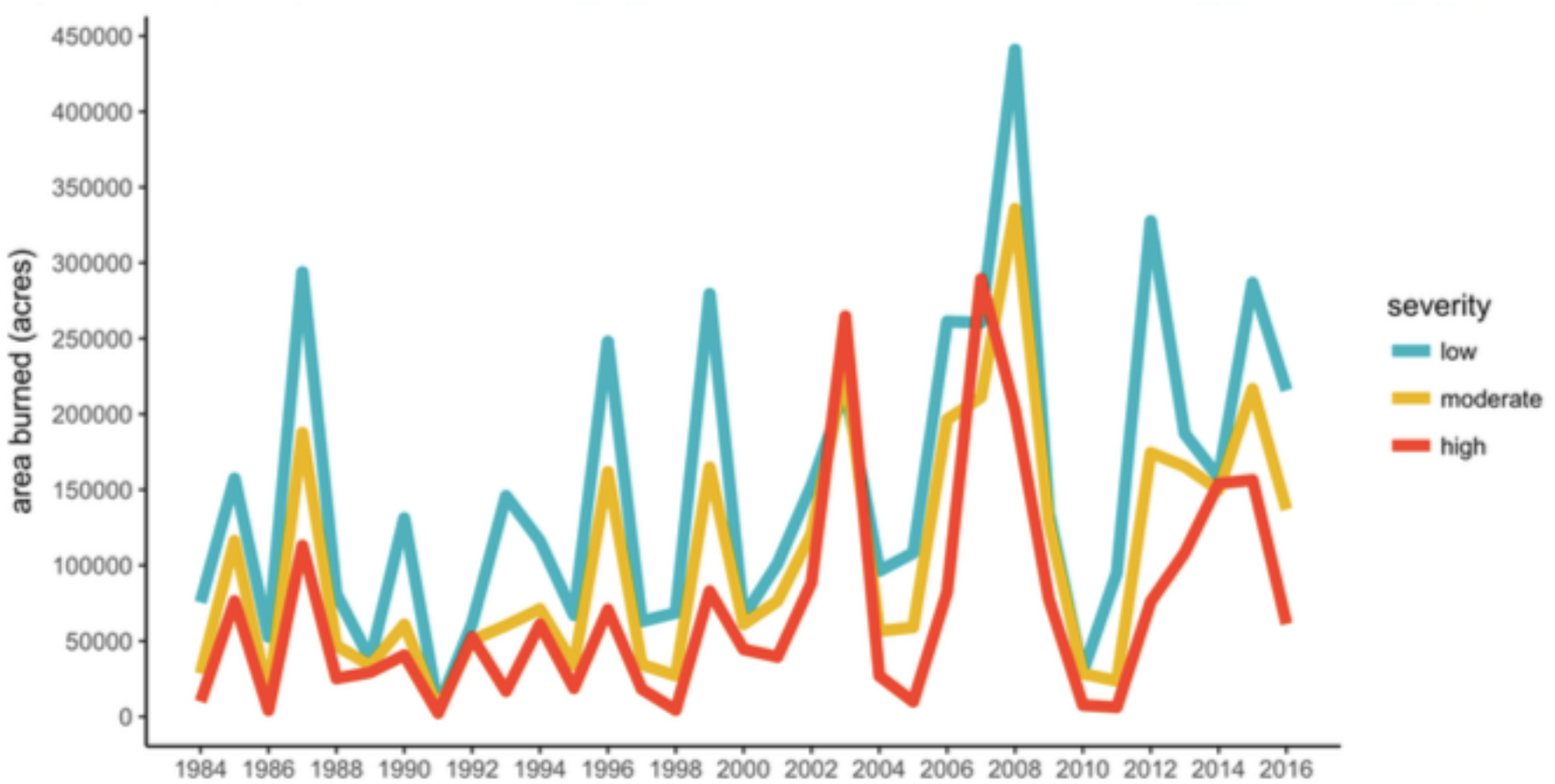
GFDL 2035–64 with admin 30% reduction

GFDL 2035–64 with admin 60% reduction



percentage change





High-severity burn extent were greater as climate changes (Crockett & Westerling, 2018)

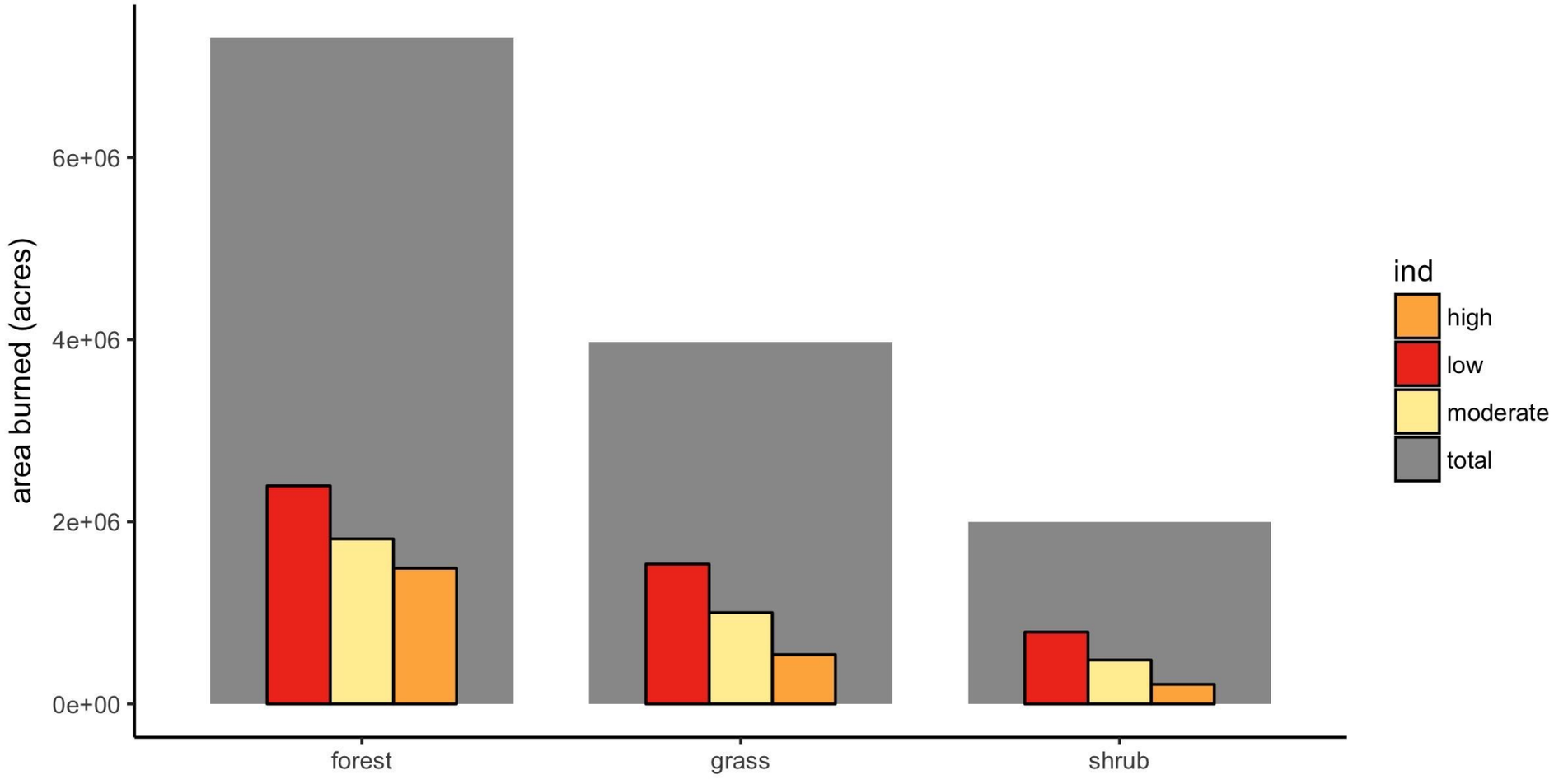
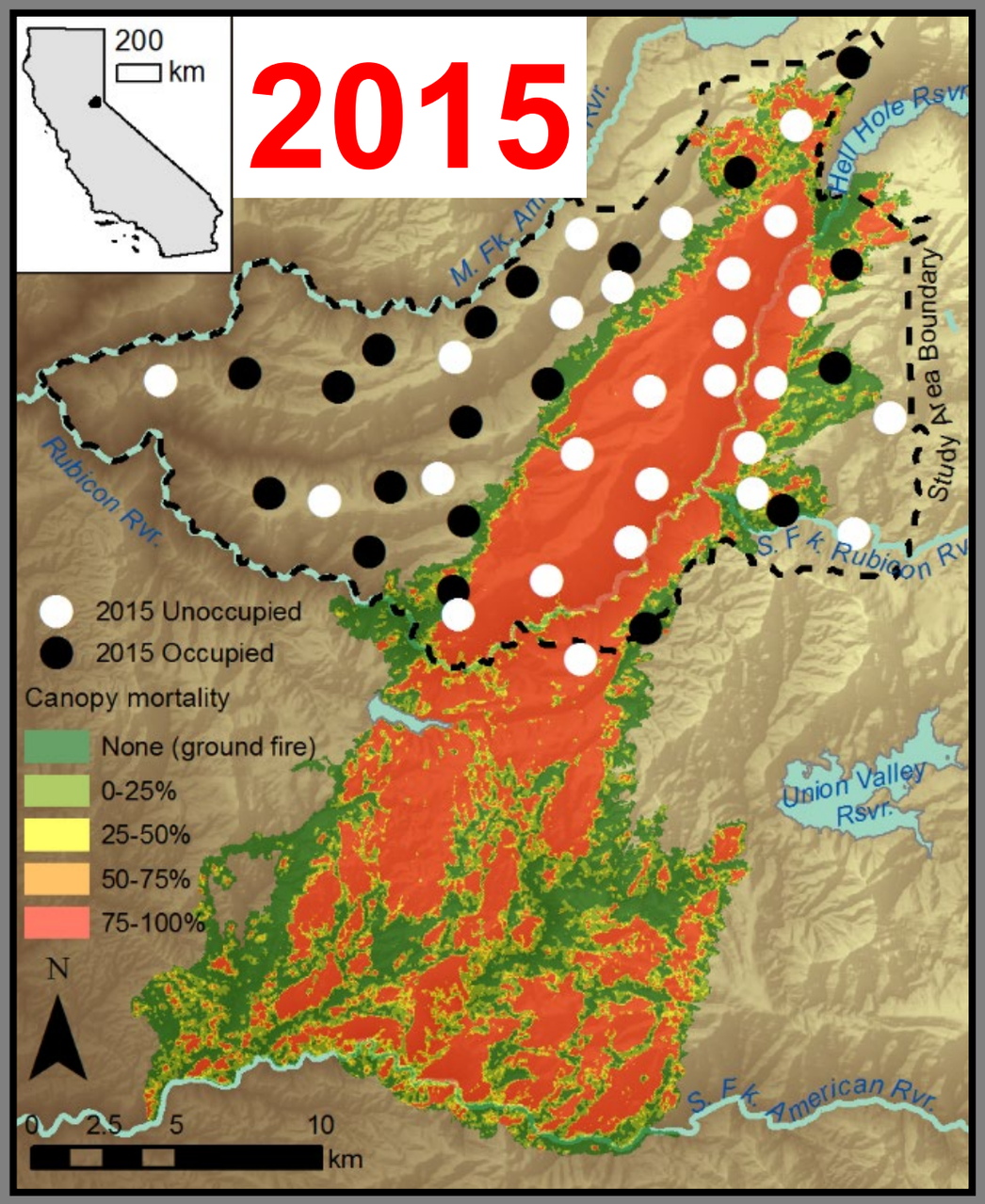
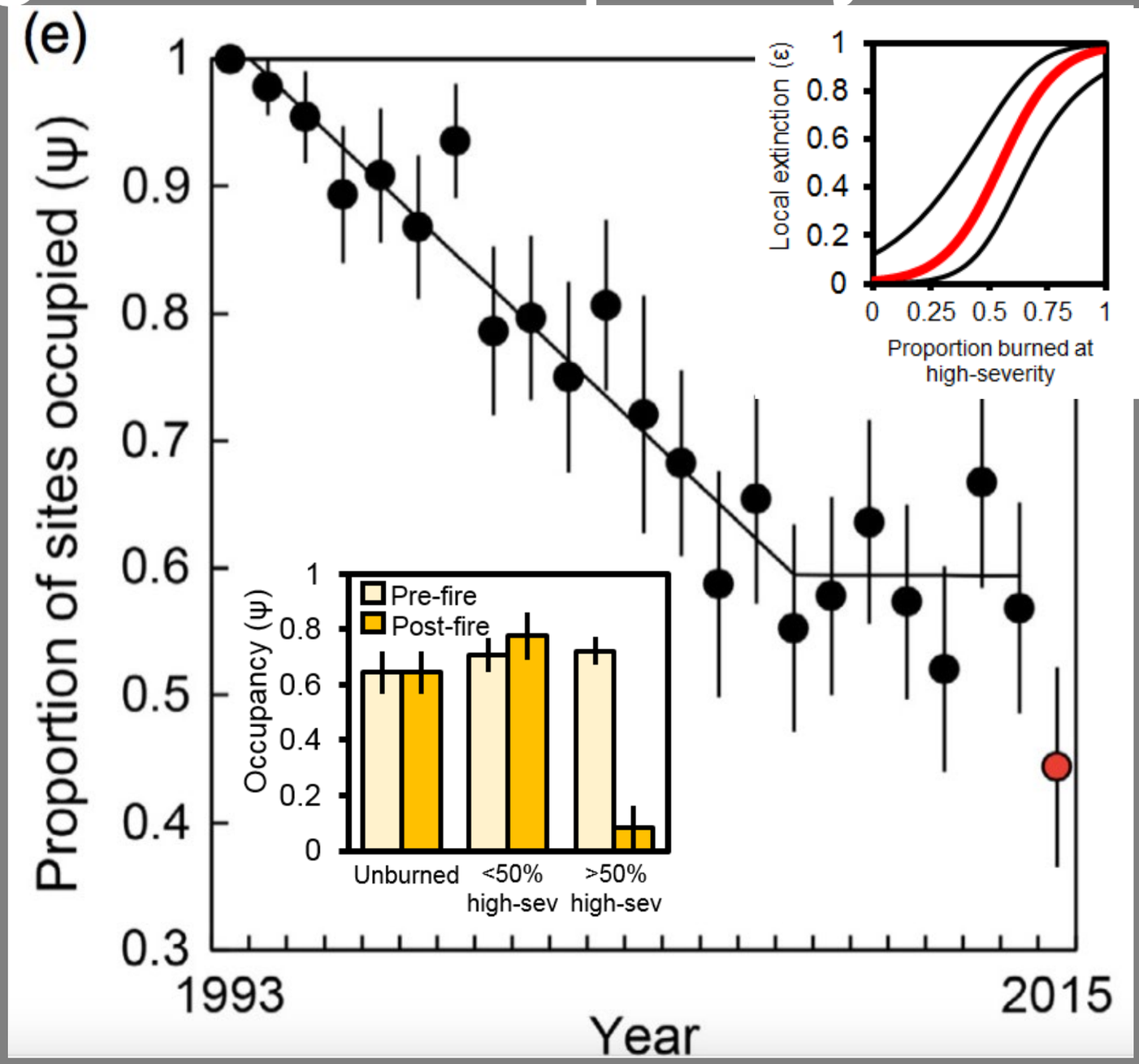
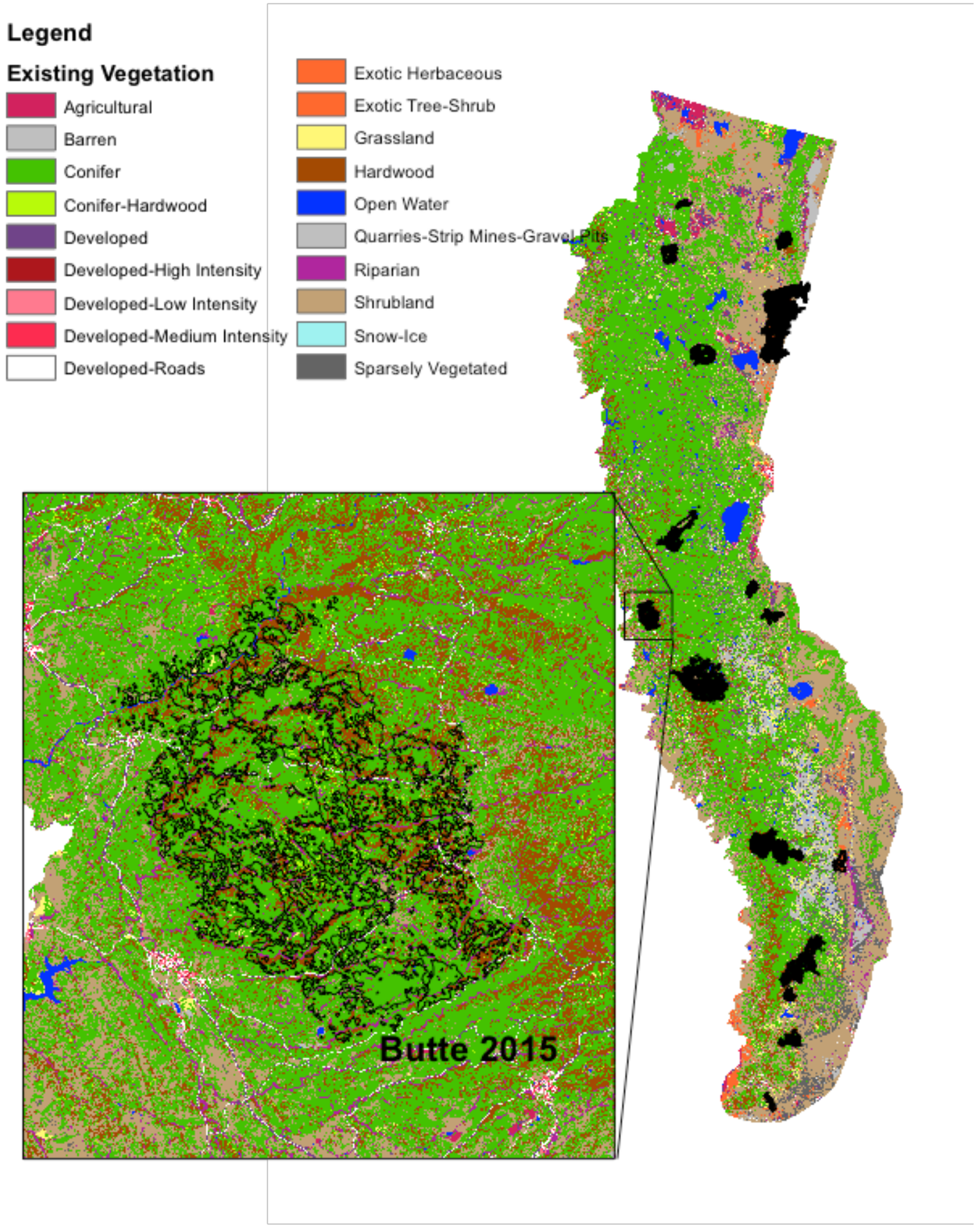


Fig.6 Area burned in low, moderate, and high severity and total area burned in forest, shrub, and grassland in California (1984-2016) (Gg)

The 2014 King Fire: occupancy





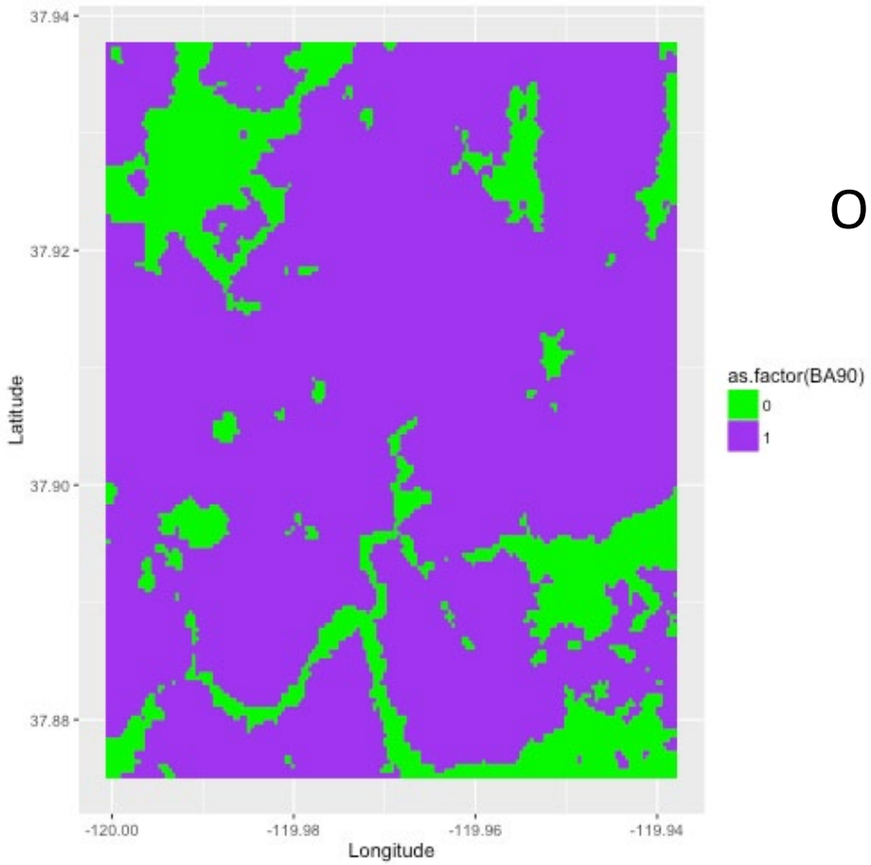

Legend
Existing Vegetation
Agricultural
Barren
Conifer
Conifer-Hardwood
Developed
Developed-High Intensity
Developed-Low Intensity
Developed-Medium Intensity
Developed-Roads
Exotic Herbaceous
Exotic Tree-Shrub
Grassland
Hardwood
Open Water
Quarries-Strip Mines-Gravel Pits
Riparian
Shrubland
Snow-Ice
Sparsely Vegetated
Butte 2015

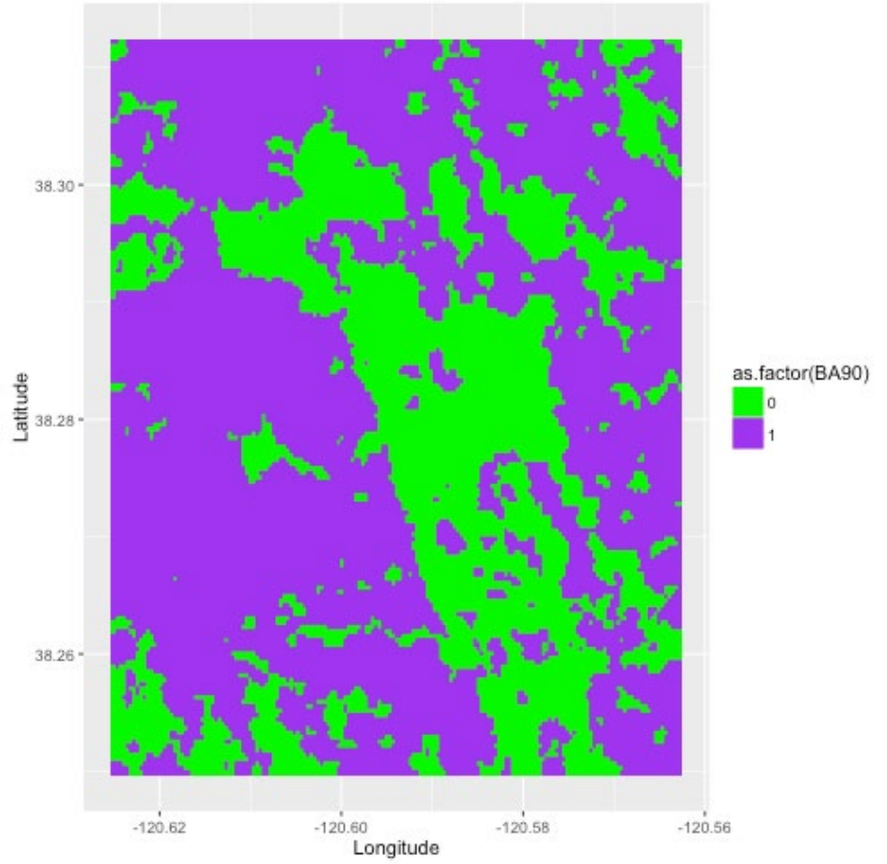
Jones, Keyser, Peery, Westerling in preparation

Rim Fire

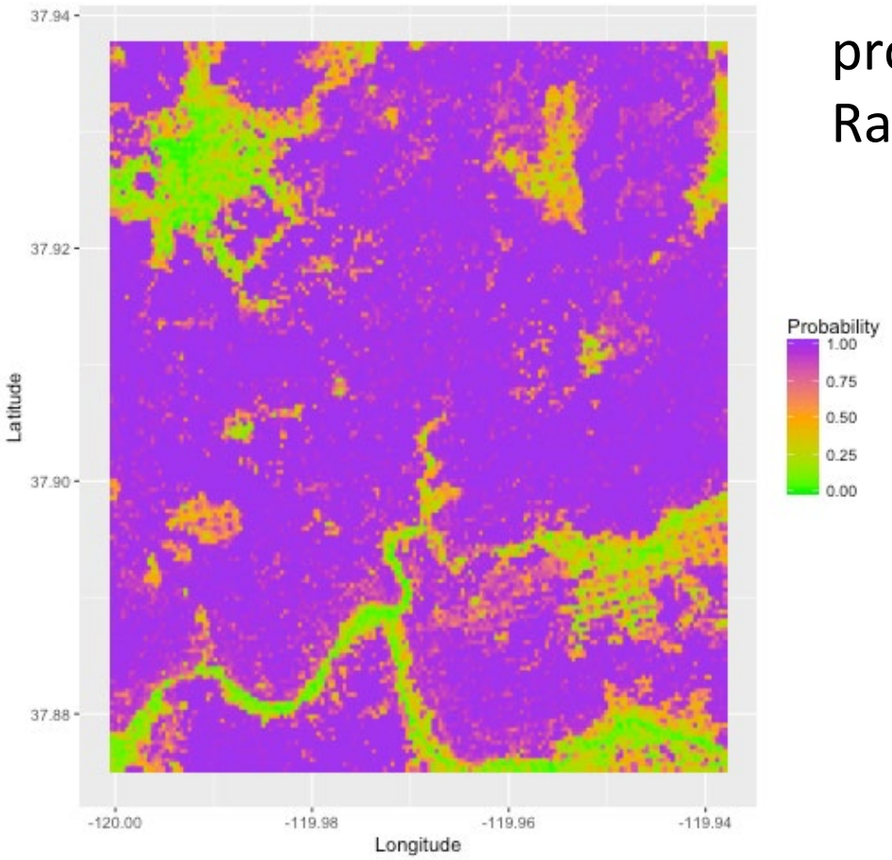
Butte Fire

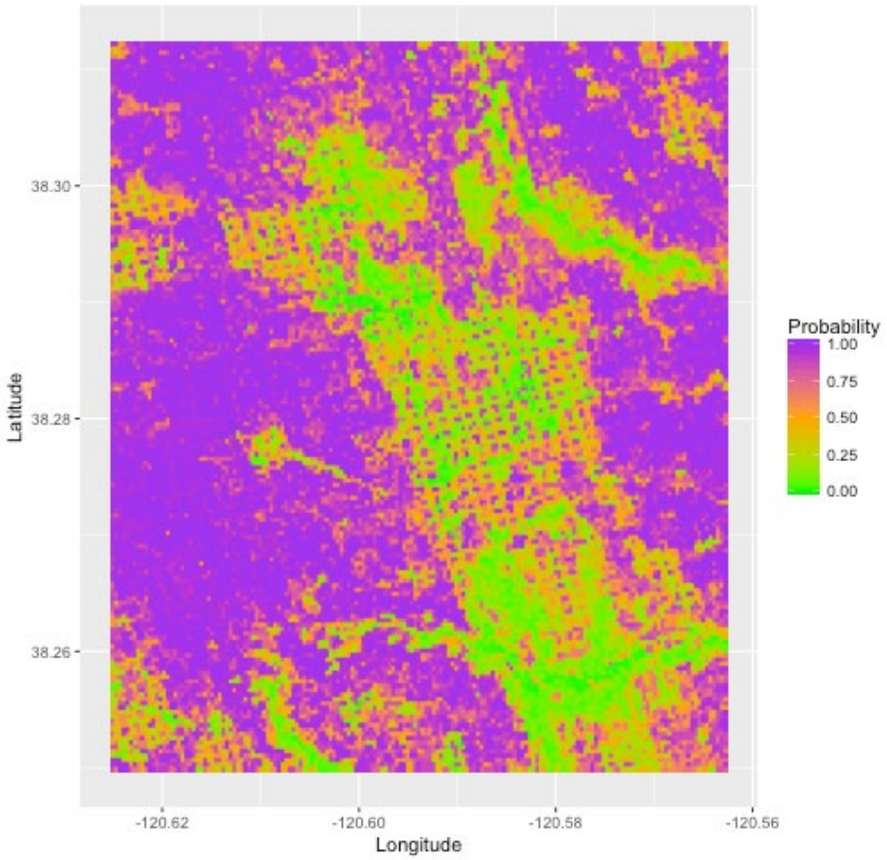
Observed BA90



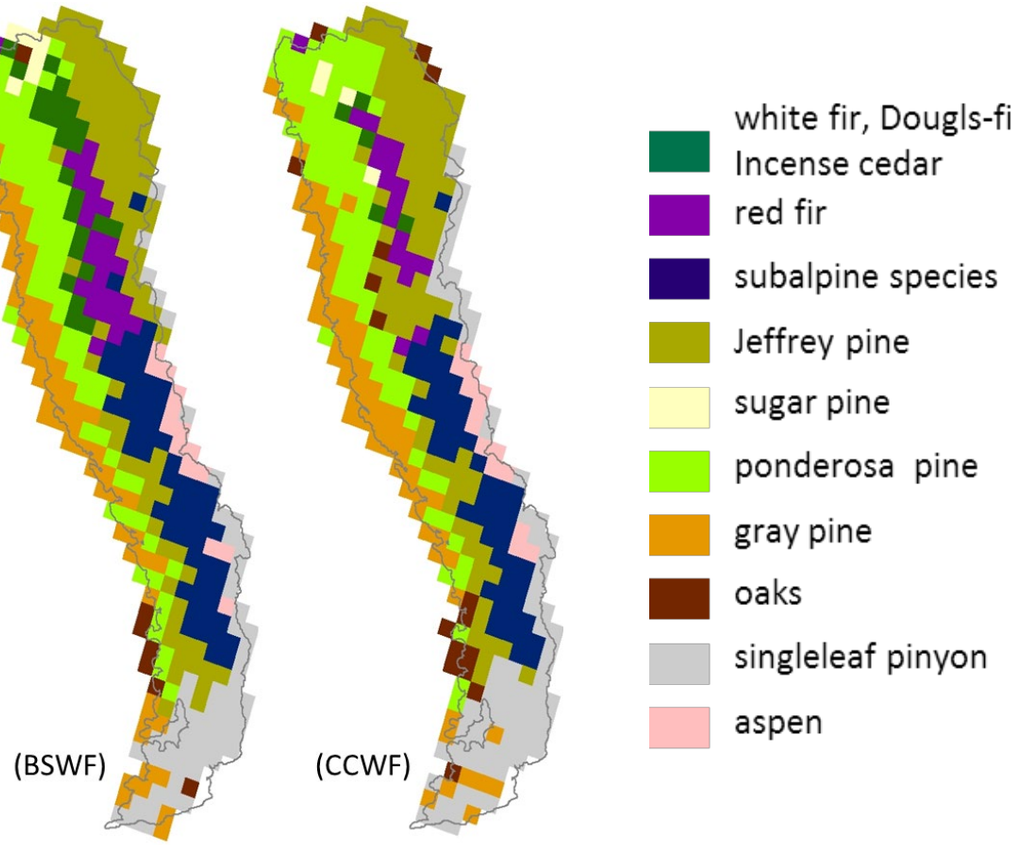


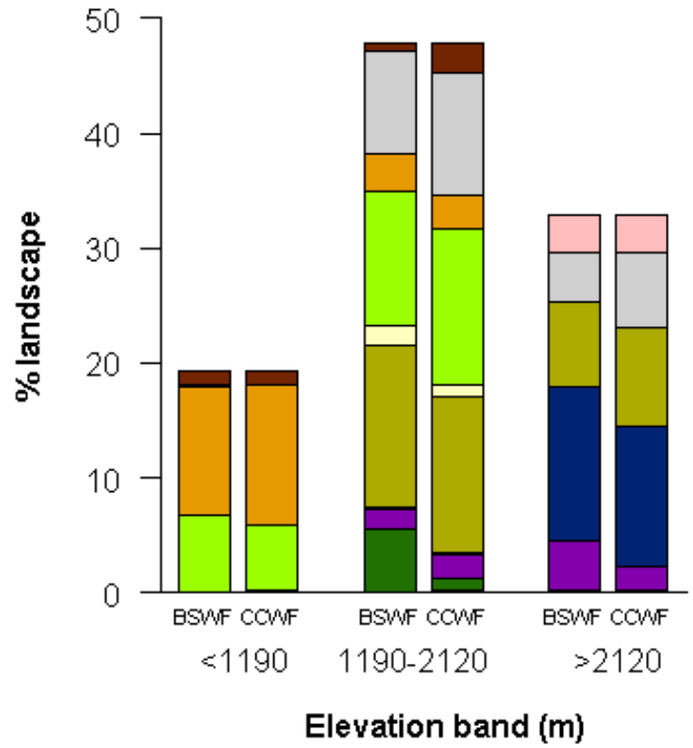
Predicted BA90 probabilities from Random Forest



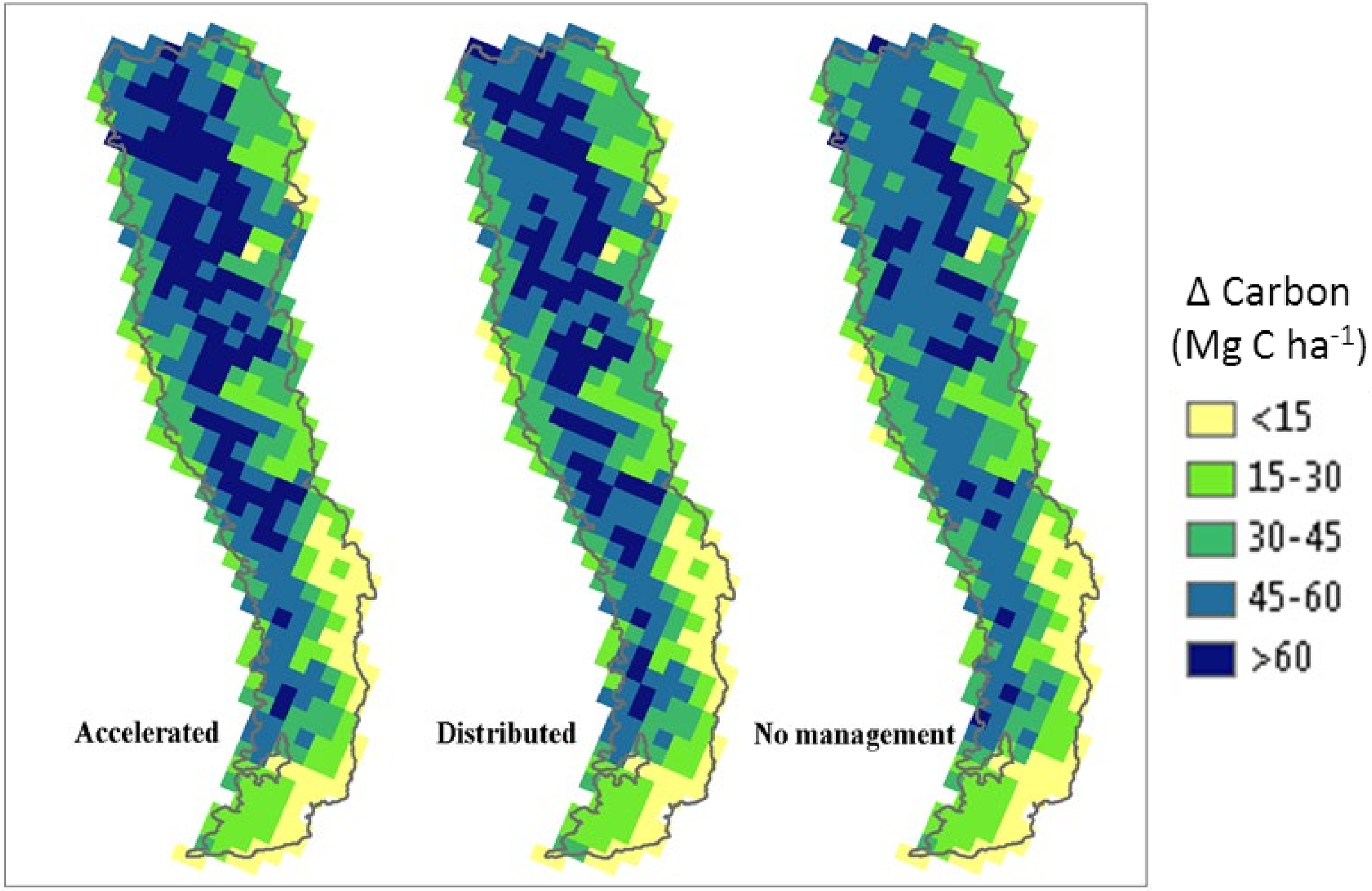


Liang Hurteau & Westerling, 2017 Global Change Biology





Liang Hurteau & Westerling, 2017 Forthcoming



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