USFS Cooperative Agreement: *Modeling Potential Fire Impacts with Landscape Vegetation Scenarios and Changing Climate for the Sierra Nevada and Other Areas in the Western U.S.*

Final Report: Changing fire, fuels and climate in the Sierra Nevada

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Executive Summary

Annual wildfire burned area in federally managed Sierra Nevada forests[1] has increased by more than 10,000 ha per decade since the early 1970s. At the same time, recent years have seen some extremely large fires compared to the historical record, with significant areas of moderate to high severity fire (e.g., McNally 2002, Rim 2013, King 2014 fires).

Changes to fuels and fire regimes due to fire suppression and land use, as well as warming temperatures and the occurrence of drought, are thought to be significant factors contributing to increased risks of large, severe fires in Sierra Nevada forests.

Over 70% of the vegetated area in our Sierra Nevada study region is classified as having altered fuels and fire regimes (FRCC 2 & 3,), while ***average annual temperature in the Sierra Nevada has been above the long term mean for all but four years in the past two decades***.[2]

As our climate is expected to continue warming for decades to come, we explored fuels management scenarios as the primary tools available to modify risks of large, severe wildfires (Table 1, Figure 1).

We developed experimental statistical models of fire occurrence, fire size, and high severity burned area, to explore the interaction between climate and altered fuels conditions (see main text). These models were applied to historical climate conditions, a sample of future climate projections, and to both current fuels conditions (as represented by area classified in FRCC 2 & 3) and a range of scenarios for fuels treatments. Emissions from wildfires were estimated using LANDFIRE vegetation characteristics and emissions factors calculated using the Fire Inventory from the National Center for Atmospheric Research (www.landfire.gov, Wiedinmyer et al 2011, Hurteau et al 2014).

Our models project that average ***annual burned area in the Sierra Nevada will more than double by mid-century*** (Table 2 & 3). Annual burned area in the southern Sierra Nevada is also projected to nearly double by mid-century (Table 5). Similarly, ***particulate and other pollution emissions from Southern Sierra Nevada wildfires is projected to more than double***, even if future fire severity does not change (Tables 4, 6 & 7, Figure 4 - 5).

Fuels treatment scenarios significantly reduced simulated future burned area and emissions below untreated projections. For example, treating 100% of altered fuels in areas considered for treatment limited simulated burned area

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[1] Including USFS, NPS and BIA managed fires in the study area, 1970 – 2014 (2013 & 2014 fire statistics preliminary). Fire history data compiled from records obtained from fam.nwcg.gov/fam-web/kcfast/html/ocmenu.htm (for Forest Service fire history) and annual Fire CDRoms (for BIA and NPS; alternatively, see http://fam.nwcg.gov/fam-web/weatherfirecd/fire_files.htm).

[2] Using gridded climate data obtained from the National Hydrologic Prediction System at the University of Washington compiled using the station index method for 1915 - 2014. (Wood and Lettenmaier 2006).

for the Southern Sierra Nevada at mid-century to approximately a 13% increase over the 1961-1990 average (Table 5). While such high rates of fuels treatments are not likely to be feasible, even a 15% treatment scenario reduced future burned area and particulate emissions in the Southern Sierra by approximately 14% and 20%, respectively (Tables 5 & 6).

High severity burned area appeared to be even more sensitive to both climate and fuels treatments than total burned area. A sensitivity analysis indicated that in areas where the fraction of highly altered fuels is high, ***successfully restoring fuels to prehistoric conditions could more than compensate for expected climate change effects on fire severity by mid-century.***

Statistical experiments indicated that treating smaller areas than addressed by the fuels restoration scenarios might still potentially yield significant reductions in burned area, high severity burned area, and total particulate emissions (Tables 8 & 9).

Table 1. Treatment scenarios represent areas that were randomly assigned for treatment based on several criteria. First, the areas were classified as having a vegetation and fuel condition outside of the natural range of variability, Fire Regime Condition Class (FRCC) 2 and 3, using the LANDFIRE (www.landfire.gov) data. Second, assignments were prioritized in landscapes where historically fires occurred most frequently including the ponderosa and Jeffrey pine, mixed conifer, pinyon-juniper, and white fir vegetation types. Third, assignments were prioritized in accessible areas based upon North et al. 2015. There were no assumptions made on what type of restoration treatment would result in the change. It was assumed that the changes could result from one or a combination of mechanical treatment, prescribed fire, or managed wildfire.

Treatment Scenario	Proportion modeled as changed from FRCC 2 or 3 to FRCC 1 out of the total landscape considered for treatment* (see Figure 1)	Distribution of Modeled Changes
no treatment baseline	0 percent	
adm15	15 percent	Across entire landscape (federally managed areas)
adm30	30 percent	
adm60	60 percent	
adm100	100 percent	
bio15	15 percent	Within large watersheds with highest concentration of wide-ranging species: Greater sage-grouse, marten, fisher, goshawk, California spotted owl
bio30	30 percent	
bio60	60 percent	
bio100	100 percent	

*The total area considered for treatment differed for the Admin versus the Bio treatment scenarios, with Admin scenarios considering a larger area for potential treatment. Consequently, the actual area treated in each Admin scenario is far larger than the area treated in the Bio scenario with the same corresponding fraction (e.g., the 100% Bio scenario and the 30% Admin scenario treat similar areas) (see Figure 1).

Table 2: Mean annual burned area for simulations using a GFDL A2 climate projection and various treatment scenarios – **All** Sierra Nevada forests and parks

GFDL A2 climate scenario wildfire simulations	Mean annual burned area – **untreated** scenarios, Sierra Nevada (entire federal area) (ha)	Mean annual burned area – **conservation** (bio15, bio30, bio 60, bio100) treatment scenarios, Sierra Nevada (entire federal area) (ha)	Mean annual burned area – **administrative area** (adm15, adm 30, adm60, adm100) treatment scenarios, Sierra Nevada (entire federal area) (ha)
Historic simulation 1961-90	16942		
midCen simulation 2035-64	33419		
15%*		30960	28599
30%*		29543	25886
60%*		27784	21605
100%*		26214	18680

*caution: for each percentage treatment (15%, 30%, etc.), substantially more hectares are treated under the administrative treatment scenarios than under the conservation treatment scenarios. Over the entire Sierra Nevada region considered, the 100% conservation treatment is approximately equivalent in treated hectares to the 30% administrative area treatment.

Table 3: Mean truncated* annual burned area for simulations using a GFDL A2 climate projection and various treatment scenarios – **All** Sierra Nevada forests and parks

GFDL A2 climate scenario wildfire simulations	Mean annual burned area – **truncated* untreated** scenarios, Sierra Nevada (entire federal area) (ha)	Mean annual burned area – **truncated* conservation** (bio15, bio30, bio 60, bio100) treatment scenarios, Sierra Nevada (entire federal area) (ha)	Mean annual burned area – **truncated* administrative area** (adm15, adm 30, adm60, adm100) treatment scenarios, Sierra Nevada (entire federal area) (ha)
Historic simulation 1961-90	16942		
midCen simulation 2035-64	33077		
15%**		30617	28371
30%**		29256	25669
60%		27509	21519
100%		25992	18623

*area burned simulations are truncated by month and grid cell not to exceed historic observed large fire sizes (Rim Fire).
**caution: for each percentage treatment (15%, 30%, etc.), substantially more hectares are treated under the administrative treatment scenarios than under the conservation treatment scenarios. Over the entire Sierra Nevada region considered, the 100% conservation treatment is approximately equivalent in treated hectares to the 30% administrative area treatment.

Table 4: Mean truncated* annual total particulate matter emissions for simulations using a GFDL A2 climate projection and various treatment scenarios – **All** Sierra Nevada forests and parks*** - **High Severity**/High biomass Emissions scenario

GFDL A2 climate scenario wildfire simulations	Mean annual TPM emissions – **truncated* untreated** scenarios, Sierra Nevada (entire federal area***) (Mg)	Mean annual TPM emissions – **truncated* conservation** (bio15, bio30, bio 60, bio100) treatment scenarios, Sierra Nevada (entire federal area***) (Mg)	Mean annual TPM emissions – **truncated* administrative area** (adm15, adm 30, adm60, adm100) treatment scenarios, Sierra Nevada (entire federal area***) (Mg)
Historic simulation 1961-90	21137		
midCen simulation 2035-64	41052		
15%**		37475	34571
30%**		35630	31237
60%**		33197	26038
100%**		31143	22521

*area burned simulations are truncated by month and grid cell not to exceed historic observed large fire sizes (Rim Fire).

**caution: for each percentage treatment (15%, 30%, etc.), substantially more hectares are treated under the administrative treatment scenarios than under the conservation treatment scenarios. Over the entire Sierra Nevada region considered, the 100% conservation treatment is approximately equivalent in treated hectares to the 30% administrative area treatment.

***Sierra Nevada grid cells outside of CA excluded…emissions factors have only been estimated within CA.

Table 5: Mean truncated* annual burned area for simulations using a GFDL A2 climate projection and various treatment scenarios – **Southern** Sierra Nevada forests and parks

GFDL A2 climate scenario wildfire simulations	Mean annual burned area – **truncated* untreated** scenarios, S. Sierra Nevada (entire federal area) (ha)	Mean annual burned area – **truncated* conservation** (bio15, bio30, bio 60, bio100) treatment scenarios, S. Sierra Nevada (entire federal area) (ha)	Mean annual burned area – **truncated* administrative area** (adm15, adm 30, adm60, adm100) treatment scenarios, S. Sierra Nevada (entire federal area) (ha)
Historic simulation 1961-90	9753		
midCen simulation 2035-64	19003		
15%**		17961	16532
30%**		17271	15074
60%**		16067	12596
100%**		15164	11085

*area burned simulations are truncated by month and grid cell not to exceed historic observed large fire sizes (Rim Fire).
**caution: for each percentage treatment (15%, 30%, etc.), substantially more hectares are treated under the administrative treatment scenarios than under the conservation treatment scenarios.

Table 6: Mean truncated* annual **total particulate matter** emissions for simulations using a **GFDL A2** climate projection and various treatment scenarios – **Southern** Sierra Nevada forests and parks*** - **High Severity**/High biomass Emissions scenario

GFDL A2 climate scenario wildfire simulations	Mean annual TPM emissions – **truncated* untreated** scenarios, S. Sierra Nevada (entire federal area***) (Mg)	Mean annual TPM emissions – **truncated* conservation** (bio15, bio30, bio 60, bio100) treatment scenarios, S. Sierra Nevada (entire federal area***) (Mg)	Mean annual TPM emissions – **truncated* administrative area** (adm15, adm 30, adm60, adm100) treatment scenarios, S. Sierra Nevada (entire federal area***) (Mg)
Historic simulation 1961-90	11790		
midCen simulation 2035-64	22742		
15%**		21167	19435
30%**		20241	17638
60%**		18540	14568
100%**		17412	12823

*area burned simulations are truncated by month and grid cell not to exceed historic observed large fire sizes (Rim Fire).

**caution: for each percentage treatment (15%, 30%, etc.), substantially more hectares are treated under the administrative treatment scenarios than under the conservation treatment scenarios. Over the entire Sierra Nevada region considered, the 100% conservation treatment is approximately equivalent in treated hectares to the 30% administrative area treatment.

***Sierra Nevada grid cells outside of CA excluded…emissions factors have only been estimated within CA.

Introduction

In this study we consider the effects of climate, fuels characteristics and topography on large (> 200 ha) fire occurrence, number, size and emissions of particulate pollution. We also present a preliminary analysis of experimental high severity burned area models. We use probabilistic statistical models, including a logistic regression for binomial fire occurrence, a Poisson lognormal distribution for fire number, and generalized Pareto distributions for the logarithm of fire size and the logarithm of high severity burned area per fire. We draw large numbers of random simulations from each distribution to characterize the range of potential outcomes for multiple scenarios. Scenarios considered include both three future climate scenarios for mid-century, and nine fuels treatment scenarios provided by our USFS Pacific Southwest Region partners (Table 1, Figure 1). These were hypothetical scenarios and not meant to portray any specific management plans of the USFS, but rather to inform their future planning. They include considerations other than fire trends, such as wildlife habitat requirements and budgetary constraints.

The results presented here are primarily for the GFDL A2 climate scenario, as well as some results from the CNRM and CCSM A2 climate scenario (differences between fire simulations for the selected climate scenarios were small compared to the effects of fuels treatments; the GFDL climate model yielded mid-century increases in fire activity between the CNRM and CCSM models). Burned area and particulate emissions throughout the Sierra Nevada approximately double by mid-century without fuels treatments (Tables 2 - 6, Figures 2, 4 & 5). Fuels treatments significantly reduced simulated burned area, high severity burned area and emissions, with the greatest potential for reductions in drier vegetation types (Tables 2 - 6, Figures 2 - 7).

Summary of Results: Burned Area and Particulate Emissions

We estimate that burned area in the Sierra Nevada more than doubles by the middle of the 21st Century under the GFDL A2 climate scenario (Table 2). The same result is obtained for the CNRM A2 climate scenario (not shown). Because we cannot be certain that statistical relationships between climate, fuels characteristics and wildfire will be the same for climates outside of our historical reference, we also considered results for truncated statistical fire models, where fires larger than the largest historic reference fire (the Rim fire) were not allowed to occur. In these models, mean annual burned area can still increase, as the conditions favorable to large fires cover larger portions of the Sierra Nevada for longer time periods, even while individual fires are constrained to the historic maximum. Under these truncated scenarios, Sierra Nevada-wide annual burned area still doubles (Table 3, Figure 2). Similarly, total particulate matter (TPM) emissions from wildfire also approximately double by mid-century (Table 4).

Fuels treatments considered here significantly reduced both simulated burned area and simulated TPM emissions. In the largest reduction simulated here, the adm100 treatment reduces burned area 44% from what we simulate for mid-century under the GFDL climate scenario if no fuels treatments were undertaken (Table 3). In this scenario, mean annual burned area increases from 16,942 ha in 1961-90 to 18,623 ha in 2035-64, whereas without treatment it is simulated to increase to 33,077 ha per year. Treating this fraction of the landscape (100% of areas with FRCC 2 or 3 reduced to FRCC 1) is likely to be challenging however. Even modest treatment scenarios reduced burned area (Table 3, Figure 3) and emissions (Table 4, Figure 5).

Southern Sierra Nevada burned area and emissions similarly increased by over 100% by mid-century, with fuels treatments significantly reducing burned area and total particulate matter (Table 5, Table 6). While the adm100 fuels treatment eliminates most of the climate-induced increase in TPM emissions, even the adm30 treatment (30% of areas with FRCC 2 or 3 reduced to FRCC 1) reduces emissions by 22% from what we simulate at mid-century for the no-treatment case. The bio100 fuels treatment scenario treats a similar fraction of the landscape as the adm30 treatment (Figure 1), and also reduces emissions by over 22% (Table 6, Figure 8).

Note that treatment scenarios that treat less than 100% of the altered fuels were not explicitly optimized to maximize emissions reductions. It is possible that a different spatial footprint of treatments might result in greater emissions reductions for the same total area treated. We explored this scenario approach by ranking each grid cell from highest to lowest projected change in emissions without treatment, and then graphed the cumulative effects of incrementally treating fuels in each grid cell under the 15% and 100% scenarios (Figures 4 & 5). Treating 100% of altered fuels in 24% of grid cells limited the emissions increase to 50% above the 1961-90 baseline, when assuming high severity fires occurred in fuel types with mixed severity in both the historic baseline period and at mid-century (Figure 4). Treating 100% of fuels in 65% of grid cells kept emissions from increasing above the historic baseline, even with substantial climate change by mid-century (Figure 4).

Figure 5 shows mid-century emissions as a fraction of the historic 1961-90 baseline versus total area treated, assuming locations with the highest potential increases in emissions are treated first, and that historic emissions in mixed severity fuels types were for moderate severity fires. For example, treating 30% of the area with altered fuels approximately limits emissions increases to about 50%.

All of these treatment scenarios assume that fuels treatments are similarly effective in returning fuels to FRCC 1 conditions, regardless of whether they treat areas that are accessible for mechanical treatment or not. The results presented here represent theoretical best case outcomes, based on observed statistical relationships between recent fire activity, climate, topography and fuels conditions as represented by FRCC.

The largest absolute increases in southern Sierra Nevada TPM emissions occur in Foothill, Montane Dry, Sagebrush – PJ, and Upper Montane vegetation types, although percentage increases in Montane Mesic and Subalpine – Alpine vegetation are similar (Table 7). Significant reductions in emissions relative to the mid-century no-treatment case are modeled under all of the fuels treatment scenarios, with the drier vegetation types tending to show the largest absolute and relative decreases (Table 7). Similarly, when considering conditional large fire size alone (and not the contributions to burned area from changes in large fire occurrence and number), fuels treatment scenarios tended to have the greatest impact in drier vegetation types, while climate effects dominated in cooler, wetter vegetation types (Figure 9, supplemental Tables A1-A10).

There may be some potential for the prevalence of altered fuels (FRCC 2 & 3 occurrence) to be correlated with vegetation type, so that the effects of these factors on fire may be confounding. That is, if FRCC 2 and 3 are likely to occur in some fuel types but not in others, it may be difficult to separate out the effects of fuel conditions and vegetation type on fire activity. To begin to address this issue, we estimated response functions for burned area and emissions dependent on the fraction of grid cell vegetation in each type and the fraction of each grid cell in FRCC 2 & 3 combined using model simulations for the historic reference period (1961-90) (Figures 10 & 11). The fraction in Subalpine – Alpine vegetation did not influence burned area, the effects of Montane Dry and Sagebrush – PJ fraction on burned area were very weak, and fractions in Upper Montane and Montane Mesic tended to reduce burned area (Figure 10). Conversely, FRCC tended to influence burned area significantly in all vegetation types (Figure 10). Similarly, FRCC tended to significantly affect TPM emissions in every vegetation type, although the shape and intensity of the relationships differed somewhat from those for area burned, due to spatial heterogeneity in biomass (Figure 11).

Note that the use of a high biomass/high severity emissions scenario tends to smooth out the effects of mixed severity fire regimes, which would be expected to be sensitive to changes in FRCC. Using scenarios based on the historic mid-range estimates for mixed severity fire regimes might produce somewhat different results.

Large Fire Size and Severity

Our statistical modeling methodology combines a binomial fire presence/absence model, a Poisson lognormal fire number model, and generalized Pareto distributions of total fire size and high severity burned area to simulate fire activity as a function of climate, fuels and topography. The generalized Pareto size distributions can be analyzed on their own as well as in conjunction with the other model elements to consider how different scenarios affect the distribution of possible fire sizes, conditional on a large (> 200 ha) fire having occurred. This approach allows us to examine what happens to the probability of fires becoming very large once they have ignited and passed a minimum size threshold (200 ha). Fire size distributions have heavy right tails, such that the probability of very large events is significant, and it is these extreme events that drive much of the impacts from wildfire.

We used our conditional fire size models to consider what happens to the likelihood of very large (> 1,000 ha and > 10,000 ha) fires as well as the average fire size under different climate and fuels management scenarios (supplemental tables A1-A10). Average fire size increases by 13% to 20% by mid-century with climate change in the absence of fuels treatments (Figure 12, supplemental Tables A1-A10). However, fuels treatment scenarios dramatically reduced simulated mid-century mean fire sizes, in some cases more than compensating for the effects of climate change (Figure 12, supplemental Tables A1-A10). The probability of fires exceeding 1,000 ha increased between 5% and 10%, and the probability of fires exceeding 10,000 ha increased between 23% and 52% (Figure 13, supplemental Tables A1-A10). Again, fuels restoration scenarios significantly reduced or even reversed these climate-driven increases in extreme fire sizes. For example, without fuels restoration, the GFDL mid-century climate scenario increased the conditional probability of large fires exceeding 10,000 ha by 30%, while the adm15 fuels restoration scenario limited that increase to just 20%. The adm100 fuels restoration scenario resulted in an 8% reduction in the conditional probability of > 10,000 ha fires compared to the 1961-90 baseline, even with GFDL mid-century climate change.

Sensitivity Analysis: conditional fire size and high severity burned area size in the vicinity of three large historic fires.

To better understand tradeoffs between changing climate and the effects of fuels on fire size and on high severity burned area, we subjected our large fire size model and high severity burned area model to sensitivity analyses for three locations centered on the McNally, Rim and King fires. For each fire, we compared the drought conditions at the time of the historic fire ignition to conditions one standard deviation drier—an extreme condition not projected to occur even with substantial warming by mid century. We interacted these two climate scenarios with both recent fuels conditions at each site and an extreme treatment scenario where all vegetation was restored to pre-suppression conditions (FRCC 1).

The result: Both burned area and high severity burned area size distribution models were highly sensitive to fuels treatments in these locations. In fact, if restoring 100% of the altered fuels to prehistoric conditions (FRCC1) were feasible, future total fire size distributions would produce smaller extreme fires and lower average burned area per fire than simulated for recent historical conditions (1961-90), even with the extreme drought increase used in this analysis—where we used an increase in drought conditions that exceeds even what is projected for the end of the 21st Century (Figure 6). In other words, large fire sizes may be relatively more sensitive to fuels treatments than they are to climate changes projected for mid century.

Experimental high severity burned area distributions were more sensitive than total burned area distributions to both extreme climate and 100% fuels treatment scenarios (Figure 7). While high severity burned area was more sensitive to climate than was total burned area, with 100% fuels treatment simulated high severity burned area was similar to or lower than what was simulated for conditions at the time of the fires, even using an unrealistically extreme drought scenario (Figure 7).

For example, at the Rim fire location, fully restoring fuels reduced high severity burned area in large fires under extreme drought conditions by over 40% below the simulations using conditions at the time of the Rim fire, and over 70% below average high severity burned area simulated for untreated fuels with extreme drought conditions.[3] The higher the fraction of the vegetated area in FRCC 2 & 3 at the time of the historic fire, the greater the reduction in future high severity burned area from fuels treatments.

Given the difficulty of treating a large fraction of altered fuels in the Sierra Nevada, we conducted another set of experiments with fire size and severity models for the Rim fire location. Prior to the fire, nearly 99% of the fuels in the grid cell where the Rim fire originated were classified as either FRCC 2 or 3. We considered experiments where 1%, 5%, 10% and 15% of the vegetated area there were treated to restore FRCC 1 conditions, conducting 100,000 simulations in each case. Because the functional forms of the extreme fire size and high severity fire size models relate the logarithm of area (total burned or high severity burned) to climate and fuels conditions, a small change in the area in FRCC 2 or 3 can produce a significant change in fire size and high severity burned area (Table 8).

Table 8. Effects of partial fuels treatments in the Rim fire vicinity on average fire size and high severity burned area implied by Generalized Pareto Distributions fit to the logarithm of burned area and high severity burned area.

Rim Fire vicinity fuels treatment experiment	**Change in average fire size, conditional on a fire >200 ha occurring**	**Change in average high severity burned area, conditional on a fire with >200 ha high severity burned area occurring**
1% treatment	-7%	-8%
5% treatment	-16%	-18%
10% treatment	-21%	-23%
15% treatment	-24%	-27%

Because these are “heavy-tailed” distributions, the effect of fuels treatments on extreme fire sizes and high severity burned extent is greater than on the average burned or high severity burned areas. For example, the reduction in both burned area and high severity burned area for fires with total burned area or high severity area in the top 10% of the distribution is over 20% for a 5% fuels restoration scenario (Table 9).

[3] Severity models discussed here are experimental, and results should be understood to be preliminary.

Table 9. Effects of partial fuels treatments in the Rim fire vicinity on average of top 10 percent of fire size and high severity burned area implied by Generalized Pareto Distributions fit to the logarithm of burned area and high severity burned area.

Rim Fire vicinity fuels treatment experiment	Change in average size of top 10% of fires, conditional on a fire >200 ha occurring	Change in average high severity burned area of top 10% of high severity fires, conditional on a fire with >200 ha high severity burned area occurring
1% treatment	-9%	-9%
5% treatment	-20%	-21%
10% treatment	-26%	-28%
15% treatment	-30%	-33%

Southern Sierra Nevada Transects: examining projected changes and historic conditions across elevation transects.

In order to depict some of the variability in fire simulations and related conditions, we extracted data for three transects running roughly west to east across the Southern Sierra through Mariposa county, Stansilaus National Forest and Yosemite National Park (Mariposa Transect, Figure 16); through Sierra and Inyo National Forests (Sierra-Inyo NF Transect, Figure 17); and through the southeast edge of the Sequoia National forest south of Sequoia-Kings Canyon National Park (Sequoia NF transect, Figure 18). In each case, the greatest absolute increase in burned area and particulate emissions generally coincides with the where peak area burned and peak emissions have occurred historically, in dry Montane forests. The elevation of the greatest increase in burned area increases with decreasing latitude (i.e., higher elevations further south). While the percentage area with altered fuels (FRCC 2 & 3) varies along each transect, in most cases a majority of the fuels are highly departed from prehistoric conditions due to fire suppression and land use changes. The largest increases in burned area and emissions occur in areas under federal management.

Data and Data Methodology

Fire. Fire histories for National Park Service (NPS) and Bureau of Indian Affairs (BIA) lands were obtained from the US Department of Interior (2012 Fire CDROM, online) and for US Forest Service (USFS) lands from the US Department of Agriculture (http://fam.nwcg.gov/fam-web/kcfast/ mnmenu.htm) and used to update and extend Westerling et al.'s (2006) fire history. Westerling et al. (2006) assembled a fire history for western US forest areas managed by NPS and USFS, including fires >400 ha reported to burn in forest areas through 2003 and classified as "suppression" or "action" fires. We used the same methodology here to create a comprehensive history of fires >200 ha reported burning in all vegetation types by NPS, USFS, and BIA through 2012. Additionally, data on the 2013 Rim Fire was obtained from http://inciweb.nwcg.gov for use in preparing related figures. Fires classified as suppression or action fires were retained to create a database for estimating Poisson lognormal and generalized Pareto distributions (GPD) and aggregated to monthly gridded presence/absence data for estimating logistic regression models. For severity modeling, we used the high severity burned area from classified dNRB imagery from the Monitoring Trends in Burn Severity (MTBS) database (Eidenshink et al 2007, http://www.mtbs.gov). The thresholded dNBR images are classified into the following categories: unburned to low severity, low severity, moderate severity, high severity, increased greenness, nodata/non-processing mask.

Landsurface Characteristics. Gridded topographic information derived from the GTOPO30 Global 30 Arc Second (~1 km) Elevation Data Set (elevation, slope, aspect) and coarse vegetation types using the University of Maryland vegetation classification scheme were accessed online from the North American Land Data Assimilation System (LDAS) (http://ldas.gsfc.nasa.gov) (Mitchell et al 2004). Additional coarse vegetation type categories (Foothill, Sagebrush-PJ, Montane Dry, Montane Mesic, Upper Montane, Subalpine-Alpine) were obtained from USFS Pacific Southwest Region partners.

Fuels restoration scenarios. Eight fuels treatment scenarios and an historic reference fuels scenario were obtained from USFS Pacific Southwest Region partners. Scenarios were expressed in terms of fire regime condition class (FRCC) on a fine grid. For the modeling results reported here, scenarios were rescaled to a 1/8 degree lat/lon grid in ArcGIS and expressed as fractions of the vegetated landscape in fire regime condition classes 1, 2 and 3. The eight fuels treatment scenarios (adm15, adm30, adm60 adm100, bio15, bio30, bio60, bio100) prioritized treatments only by mechanical availability and departure of fuels from reference conditions. A summary of the methodology as provided by USFS Region 5 partners is provided in the box below. Scenarios in every case equated fuels restoration with converting a fraction of the total area of fuels in FRCC 2 and FRCC 3 combined to FRCC 1. FRCC 2 and 3 were combined because statistical models relating fire size to FRCC do not distinguish between FRCC 2 and 3 (Westerling, unpublished results).

Climatic and hydrologic data. Gridded daily climate data (temperature, precipitation, and wind speed) derived from historical (1916– 2013) station observations were obtained from the University of Washington National Hydrologic Prediction System (NHPS) (http://www.hydro.washington.edu/forecast/westwide/). Gridded daily climate data derived from observations at a subset of stations using the index station method (Wood and Lettenmaier 2006) for 1961–2005 were obtained from the University of Washington National Hydrologic Prediction System (NHPS) (http://www.hydro.washington.edu/forecast/westwide/). The NHPS data do not incorporate all of the potentially available station data but are updated monthly using observations at a subset of stations using the index station method (Wood and Lettenmaier 2006), providing an up-to-date time series adequate for use in model validation, and use stations with high-quality records.

Simulated future daily temperature and precipitation values were obtained directly from modeling groups contributing to the World Climate Research Program (WCRP)'s Coupled Model Intercomparison Project phase 3 (CMIP3) multimodel dataset for three GCM runs—National Center for Atmospheric Research (NCAR) CCSM 3.0 run 5, Centre National de Recherches Météorologiques (CNRM) CM 3.0 run 1, and Geophysical Fluid Dynamics Laboratory (GFDL) CM 2.1 run 1—forced with the SRES A2 emissions pathway (IPCC 200) (see http://www-pcmdi.llnl.gov/ for GCM scenario metadata). Similarly, 20th century simulations ("20C3M")—NCAR CCSM 3.0 run 5, CNRM CM 3.0 run 1, and GFDL CM 2.1 run 2—were obtained directly and downscaled to the grid to provide simulations for the historic period. NCAR CCSM3.0 daily data were accessed via the Earth System Grid (http://www.earthsystemgrid.org) with assistance from Gary Bates (NCAR). Daily CNRM CM3.0 data were obtained via special permission granted to Scripps Institution of Oceanography (SIO) from CNRM. GFDL CM2.1 data were obtained from the GFDL ftp server nomads with permission granted to SIO by Tom Delworth at GFDL. GCM simulations were downscaled to the LDAS grid using the Bias Corrected Constructed Analogs method (Maurer et al 2010). Wind speed data for 1950–1999 were accessed online from the National Centers for Environmental Prediction Reanalysis project (http://www.esrl.noaa.gov/psd/data/reanalysis/) and used to calculate a monthly wind speed climatology interpolated to the LDAS grid.

We used daily climate data from global climate model projections, LDAS (historical) vegetation and topography, and climatological winds to force the Variable Infiltration Capacity (VIC) hydrologic model at a daily time step in water balance mode, resulting in a suite of gridded hydroclimatic variables, including actual evapotranspiration (AET), relative humidity, soil moisture, and snow water equivalent (Liang et al 1994). Similarly, we obtained historical VIC model simulations from the NHPS. Because VIC does not output readily usable potential evapotranspiration (PET), PET was estimated for historical and projected climates using the Penman–Montieth equation with the same forcing and output data and used to calculate moisture deficit ($D = PET - AET$) (Westerling et al 2006, Penman 1948, Monteith 1965). All variables were aggregated to monthly average or cumulative values, as appropriate.

Using these predicted hydroclimatic variables, we created a monthly historical record for each grid cell ($n = 667$ cells) of number of fires >200 ha, fire presence (i.e., 1 if number of fires >0, 0 otherwise), and area burned; along with historic temperature, precipitation, and simulated hydrologic variables; topographic variables such as mean and SD of elevation, slope, and aspect; and fraction of the landscape in fire regime condition classes 1, 2 and 3.

Modeling Methodology

Predicting fire occurrence. Fire occurrence on the LDAS grid was predicted using a logistic regression model with NHPS climate data and hydrologic data, GTOPO topographic data from LDAS, and historic reference FRCC from our USFS Region 5 partners. The model was specified as:

$$\mathbf{Logit}(P) = \log(P/(1-P)) = \beta \times (\mathbf{bs}(md0n) + md00n + md01n + tmax + \mathbf{p}(prec) + elevsd + aspect + frcc23 + lm)$$

where **bs**(md0n) is a basis spline function of current month standardized moisture deficit, md00n and md01n are cumulative current and prior water year standardized moisture deficit, tmax is current month maximum temperature, **p**(prec) is a 3rd order polynomial of current month precipitation, elevsd is the standard deviation of elevation, aspect is transformed as cos(pi/2+aspect*pi/180), frcc23 is a transformation of the fraction of the grid cell in FRCC 2 and 3 as log((frcc2+frcc3 + .001)/(1 – frcc2 –frcc3 + .001)), and lm is the fraction of the grid cell managed by BIA, USFS and NPS transformed as log((bia + usfs + nps +.001)/(1 – bia – usfs – nps +.001)).

To estimate **logit**(P) for the regression described above, we used the glm() function in the stats package in the R statistical computing and graphics environment (http://www.r-project.org) to estimate a generalized linear model with binomial error terms, where the predictand was 1 when a fire was observed and 0 otherwise. Candidate model specifications were compared using Akaike information criterion (AIC) statistics calculated by glm(). The AIC measures statistical models' goodness of fit while accounting for differ- ences in model complexity and is not affected by spatial auto-correlation in the variables (Burnham and Anderson 2002).

Predicting number of fires. To determine the number of fires given fire occurrence, we fit Poisson lognormal distributions to fire numbers observed per grid cell and month. Distributions were fit to two samples of fire data defined by breakpoints in the logit(P) corresponding to observed occurrence of increased numbers of fires. Results were not highly sensitive to the selection of breakpoints (i.e., the probability of observing larger numbers of fires increased gradually with increasing logit(P)).

Predicting fire size and high severity burned area. To determine fire size and high severity burned area, we used generalized Pareto distributions (GPD) fit to the logarithm of fire size. The GPD is a "points over thresholds" model that allows us to simulate fire size distributions, in our case for fires >200 ha total burned area or total high severity burned area. The choice of a 200-ha threshold when creating our fire history was arbitrary but fit the criteria for a GPD (i.e., for samples defined above a threshold, the sample means are a linear function of the threshold values) (Coles 2001). We fit GPDs to observed Sierra Nevada fire sizes and high severity burned area using the ismev library in R. As when estimating our logistic regression, we used the AIC to compare model specifications for GPD scale and shape parameters (using our suite of climatic, hydrologic, and topographic variables). A parsimonious model with standardized current month moisture deficit (md0n), standard deviation of elevation (elevsd), and the fraction of vegetation in FRCC 2 and 3 combined (frcc23) as predictors for the scale parameter and a stationary shape parameter was best for total area burned. The best fit model for high severity burned area used standardized current month moisture deficit and the interaction between the fraction of vegetation in FRCC 2 and 3 and the long term average cumulative monthly moisture deficit for each location. Statistical models tested did not distinguish between FRCC 2 and FRCC 3. The QQ diagnostic plots for these GPD models indicate that the high severity burned area model underestimates the largest high severity burned area observed, while the total fire size GPD model is a better fit at the extremes (Figures 15).

Because the sample of large fires for the Sierra Nevada study area contains relatively few large fires in chaparral, the fire size distribution parameters mostly reflect climate-fire relationships for other fuels types, and fire sizes may be consequently over-predicted in this drier vegetation type. However, fire sizes and simulated total burned area in chaparral is still low compared to what is modeled in other vegetation types. We would need to model fires over a larger area, and/or with a longer time series, to better fit models to the underrepresented fire regime types.

Simulating conditional fire size distributions. To simulate conditional fire size distributions, 1000 random draws were taken for each grid cell and month from the GPD with the scale parameter calculated using md0n and frcc23 from the appropriate climate and fuels treatment scenarios, and elevsd for each grid cell. The density function in the R stats library was then used to calculate smoothed probability density curves.

Simulating area burned. To simulate area burned for each scenario, we take 1000 random draws for each grid cell and month from the binomial distribution using the rbinom function in R, where the probability of fire occurrence is derived from the equation for the logit(P) as above, with climate and FRCC values derived from the appropriate scenario for 30 year samples. This corresponds to 240,120,000 simulations for each scenario examined. For each fire occurrence thus simulated (i.e., every time a binomial draw of ‘1’ is obtained), we then take a random draw from the corresponding Poisson lognormal distribution to simulate the number of fires at that location and time. For each of these simulated fires, we then take a random draw from the appropriate GPD to simulate burned area for each fire. Because some fires that ignite in a given grid cell can exceed the area of burnable vegetation in that grid cell, annual burned areas in excess of that burnable vegetated area were assumed to be evenly apportioned across the surrounding grid cells. Mean annual values for each grid cell are then obtained by summing over 12 months and then averaging over 30,000 simulated years (30 years x 1000 simulations). As burned area increases over time, our models would need to be adjusted to account for area burned fires in years immediately prior. However, because annual burned area merely doubles by mid-century, the effects of not accounting for prior years' fires in the current model is assumed to be negligible. Work in progress sponsored by USDA AFRI incorporates both prior year fires' influence on vegetation, as well as changing climatic influences on recruitment and productivity.

Simulating total particulate emissions. To simulate total particulate emissions (TPM), for each scenario considered we take annual simulated burned area in each grid cell and multiply it by emissions factors calculated by Hurteau et al (2014) using their "high severity case" that concentrated burned areas in the fuels with the highest biomass in a grid cell and assumed mixed severity fire regimes burned at high severity. Hurteau et al.'s description of their methodology for generating emissions factors is reproduced in the box below.

Parsing results by vegetation types. Because each coarse 1/8-degree lat/lon grid cell contains a variety of vegetation types, we followed to approaches to produce results aggregated by vegetation type. Annual means and changes in annual means given by vegetation types in the tables are weighted sums, where the fraction of each grid cell in a given vegetation type is used to weight burned area and emissions from that cell. For the fire size distributions in Figure 9, only grid cells with a majority of their area in a given vegetation type were used, with no weighting.

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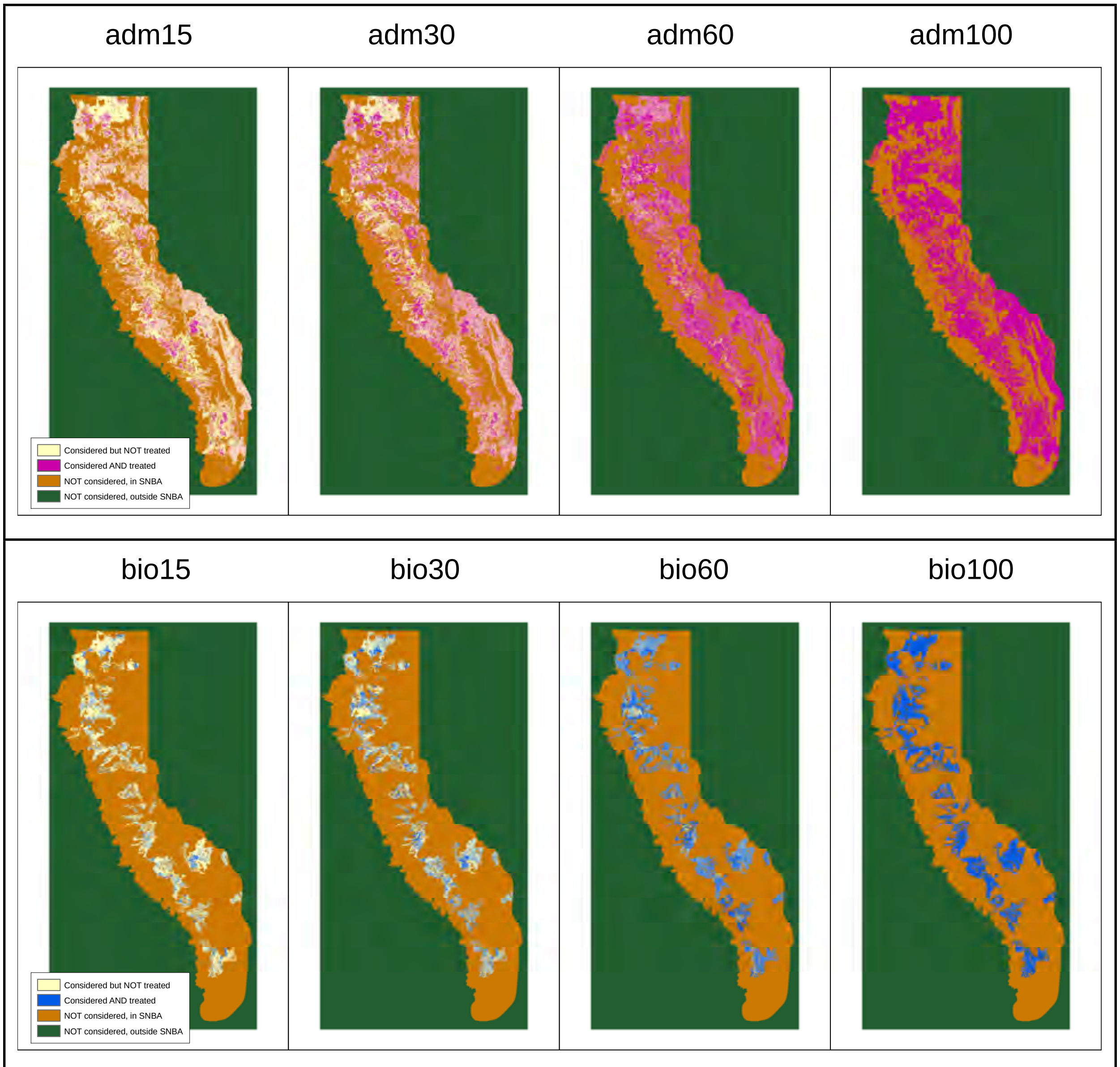


Figure 1: Administrative (*top*) and conservation (or "bio"; *bottom*) 15%, 30%, 60% and 100% fuels restoration scenarios.

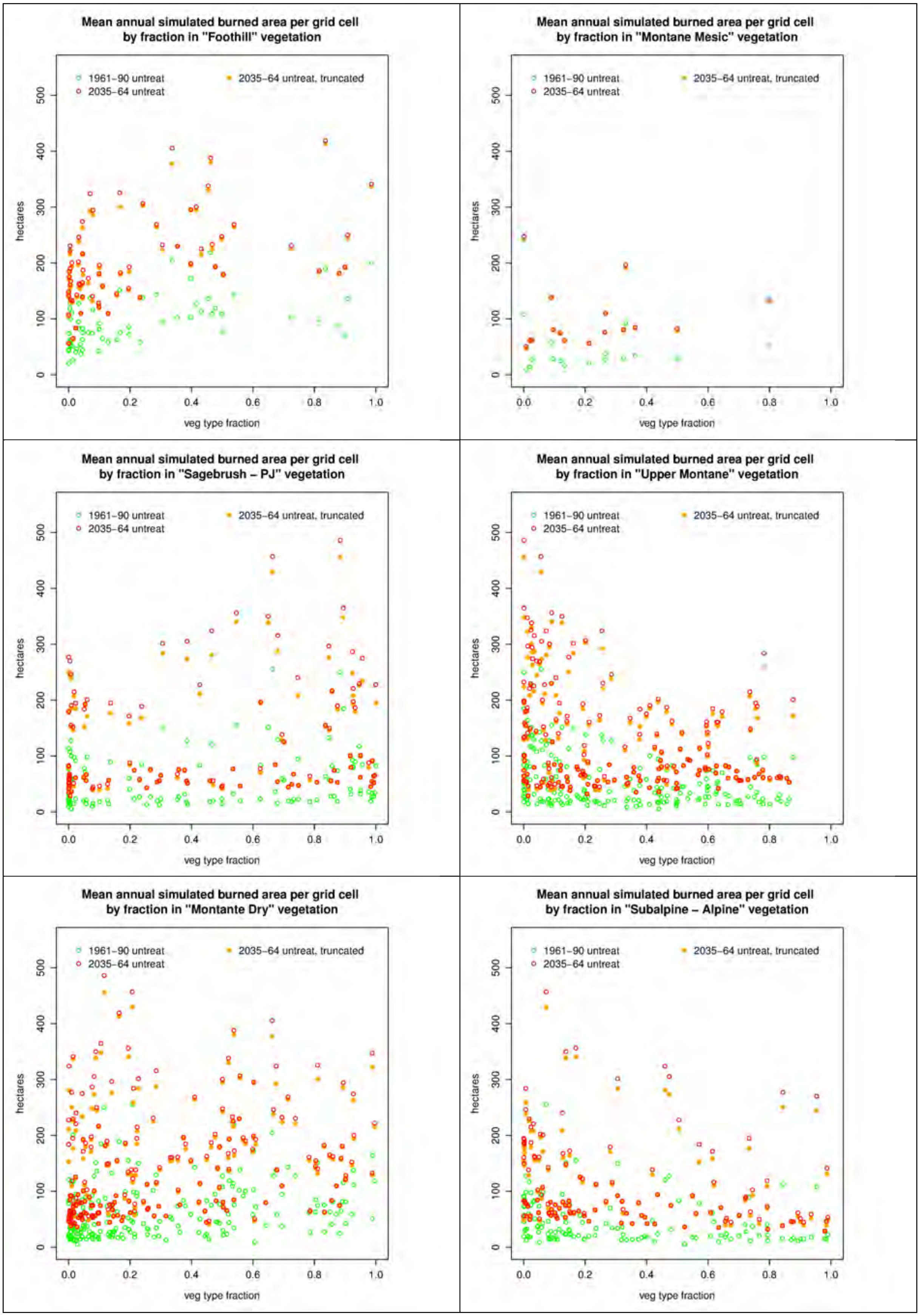


Figure 2. GFDL A2 simulation mean ha burned per grid cell per year vs fraction vegetation type, for historic (1961–90), mid-century (2035–64), and mid-century with fire size truncated to historic observed maximum (Rim Fire) for untreated simulations. Each point is a grid cell with greater than 0% area in the given vegetation type.

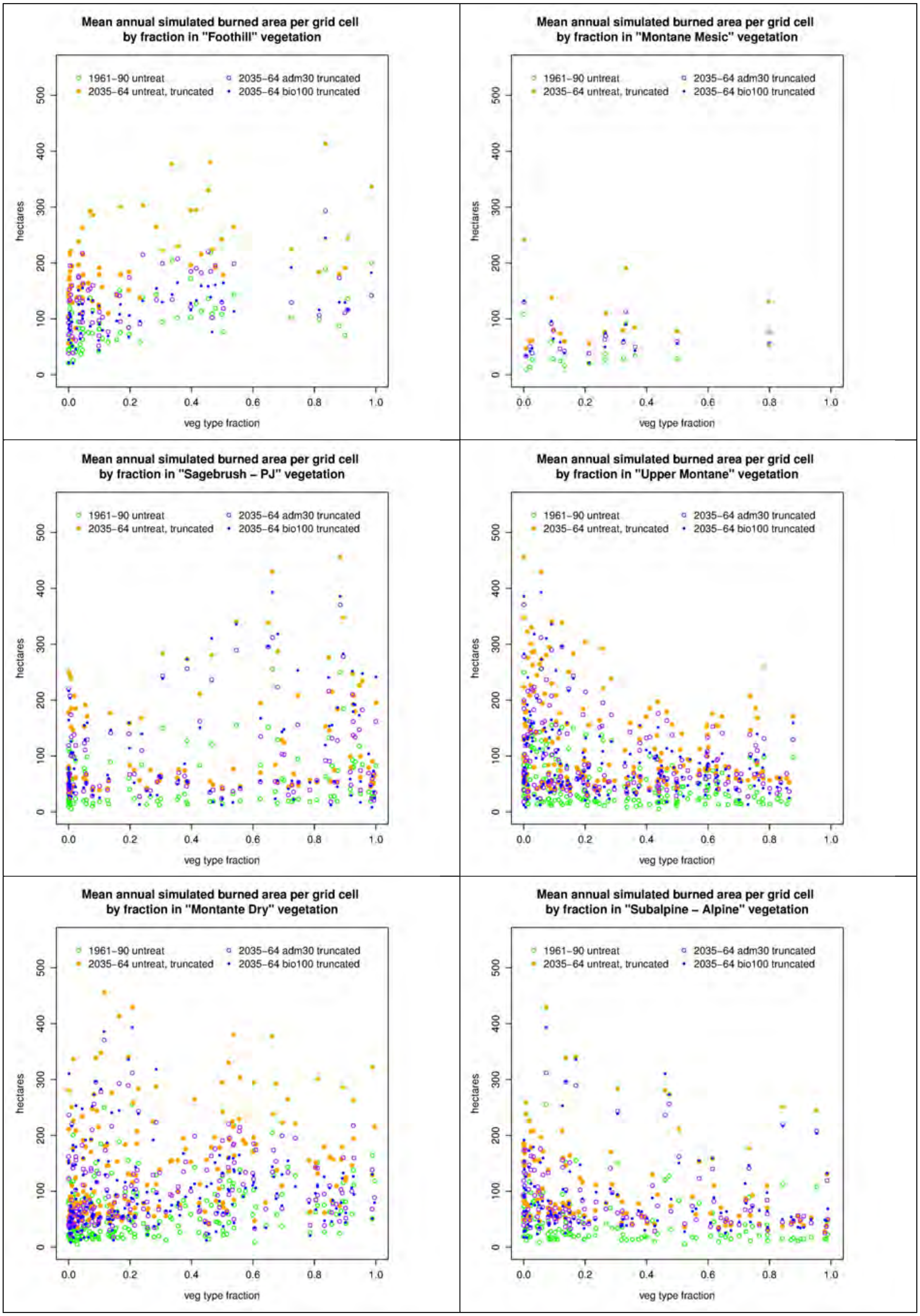


Figure 3. GFDL A2 simulation mean ha burned per grid cell per year vs fraction vegetation type, for historic (1961-90), midcentury (2035-64), and midcentury with fire size truncated to historic observed maximum (Rim Fire) for Bio100 & Adm30 simulations. Each point is a grid cell with greater than 0% area in the given vegetation type.

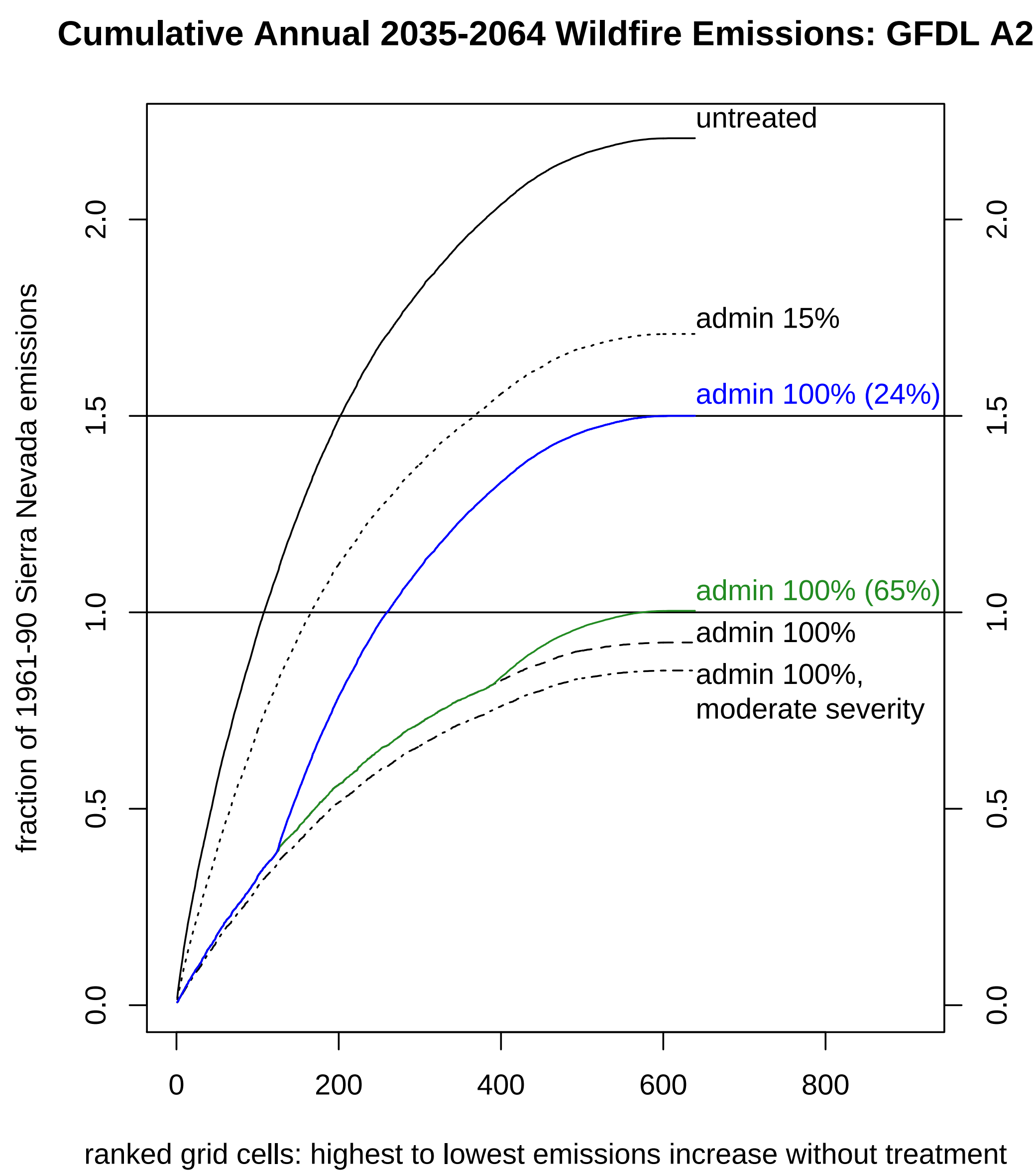


Figure 4. The curves show the cumulative emissions from grid cells ranked from highest (on the left) to lowest (on the right) contribution to emissions increases for six scenarios, represented as the cumulative fraction of 1961-90 emissions. Scenarios show emissions (1) without treatment, (2) with treatment in the admin 15% scenario where approximately 15% of the treatable area of each grid cell is treated, (3) with treatment where the highest emitting 24% of grid cells are given the admin 100% treatment and the remaining 76% of grid cells are untreated, (4) with treatment where the highest emitting 65% of grid cells are given the admin 100% treatment and the remaining 36% of grid cells are untreated, (5) with the full admin 100% treatment, (6) with the full admin 100% treatment but assuming future burn severity in mixed severity fuel types is moderate. Scenarios 1-5 assume that the future severity is high. Scenarios 1-6 assume that the baseline (1961-90) severity for comparison is high.

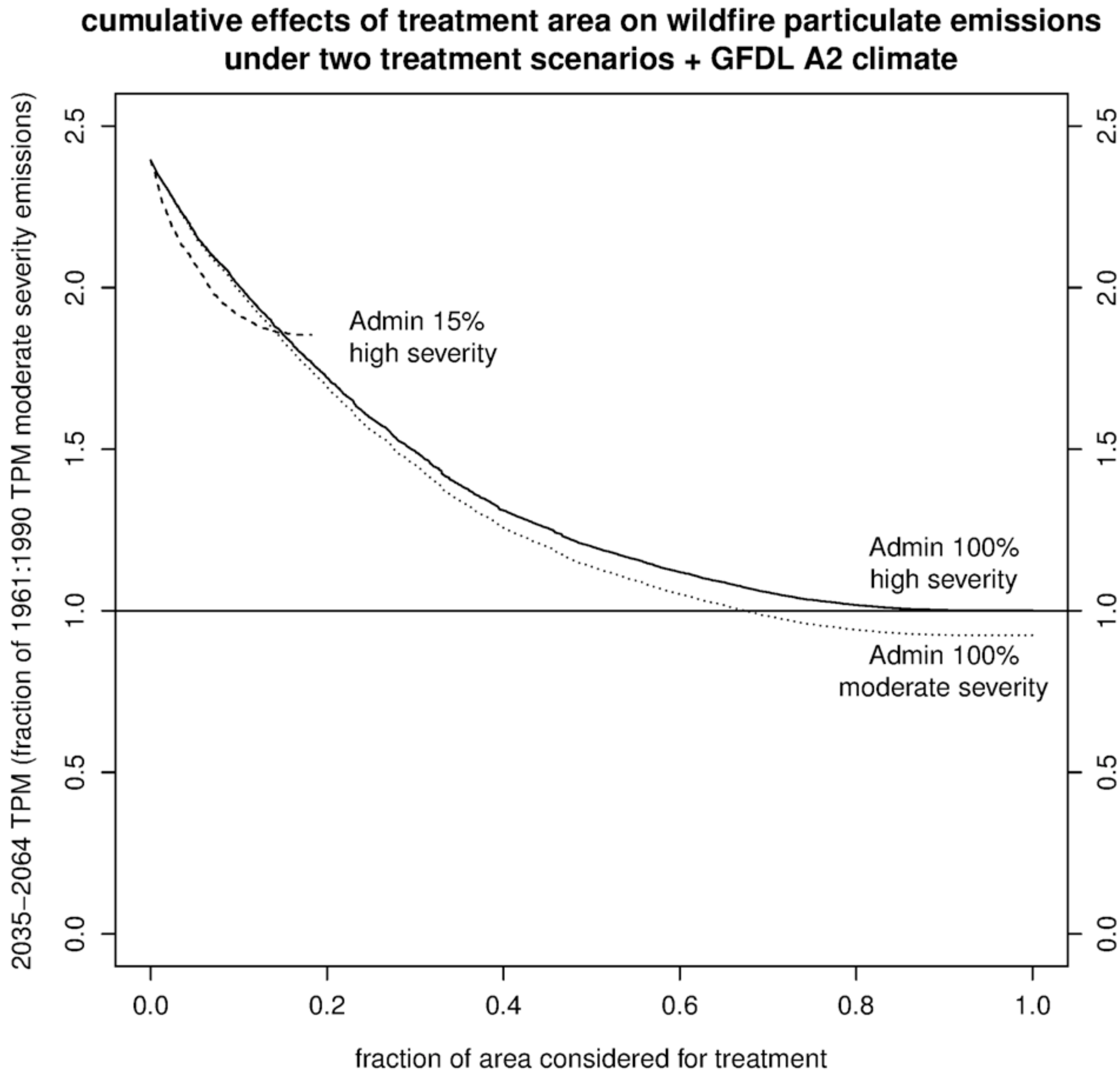
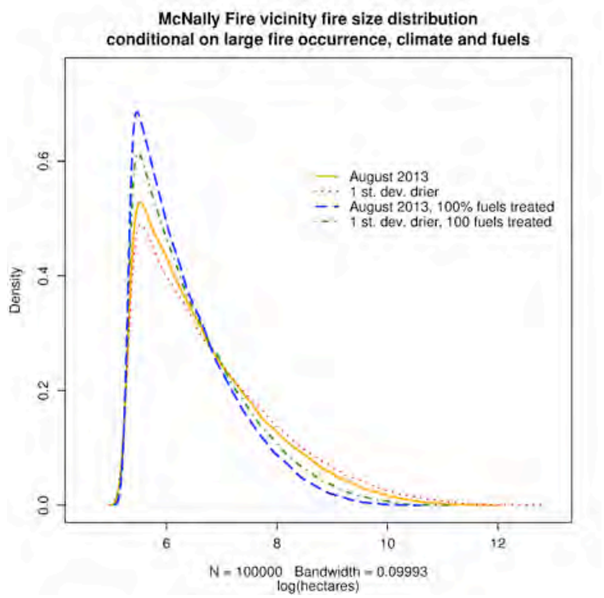
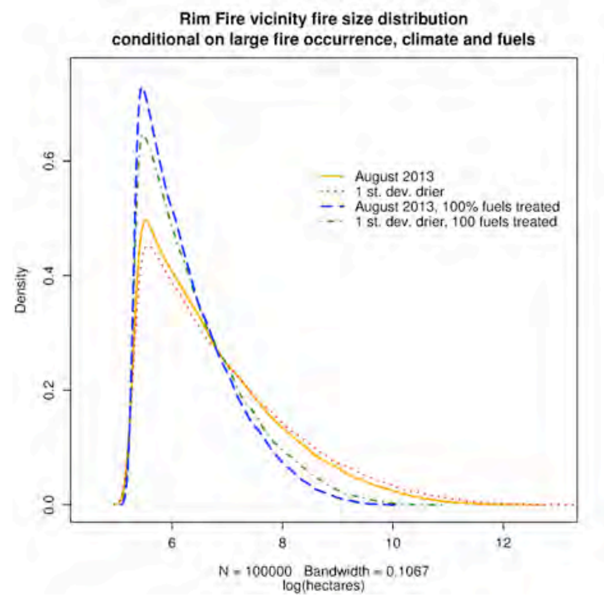


Figure 5. A large number of scenarios were simulated by ranking the Sierra Nevada study area grid cells from highest to lowest increase in emissions (without treatment), and then treating an arbitrary number of grid cells starting with the highest emitting grid cells, under either the 100% treatment per grid cell or 15% treatment per grid cell rules. Each point on the plotted lines shows the total Sierra-wide emissions for one of our scenarios (y axis) versus the net area treated out of the total Sierra-wide area considered for treatment under the original "Admin" scenarios (x-axis), with different assumptions about future average fire severity. The baseline assumes moderate severity in mixed severity fuel types for fires modeled using the 1961-90 reference period climate, for a GFDL A2 climate run. The common left-most point is the scenario where no fuels are treated, the next point on each curve is the scenario where one grid cell is treated, etc.





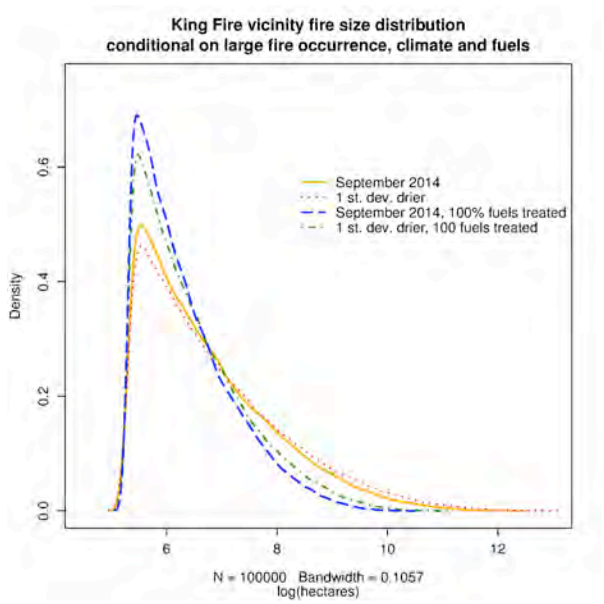
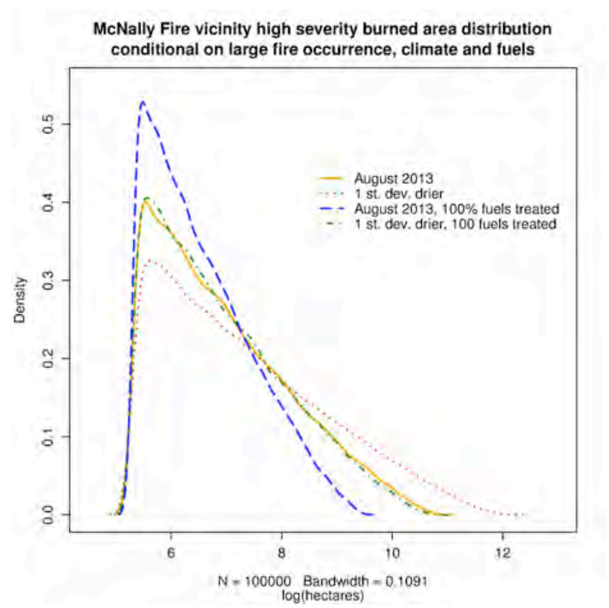
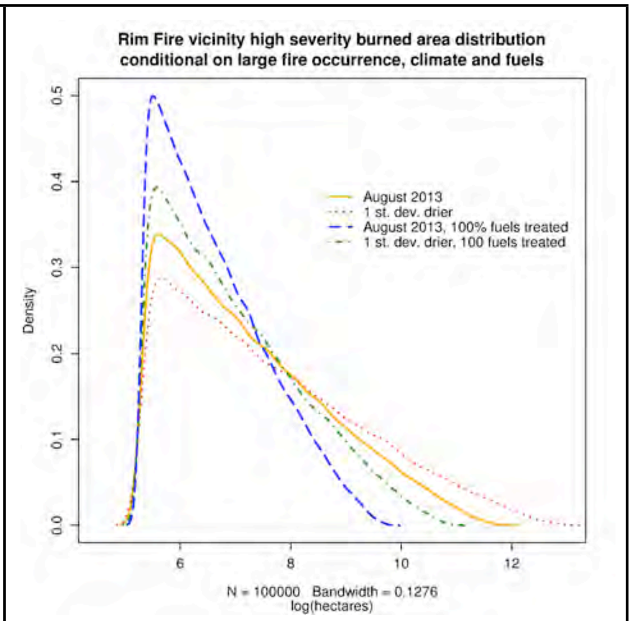


Figure 6. Large fire size distributions conditional on a fire over 200 ha occurring--as well as on climate and fuels conditions--in the vicinity of the McNally (upper left), Rim (upper right) and King (lower left) fire locations. Restoring all fuels to FRCC 1 conditions produces fire size distributions with smaller mean burned areas and lower probabilities of extreme fire sizes.





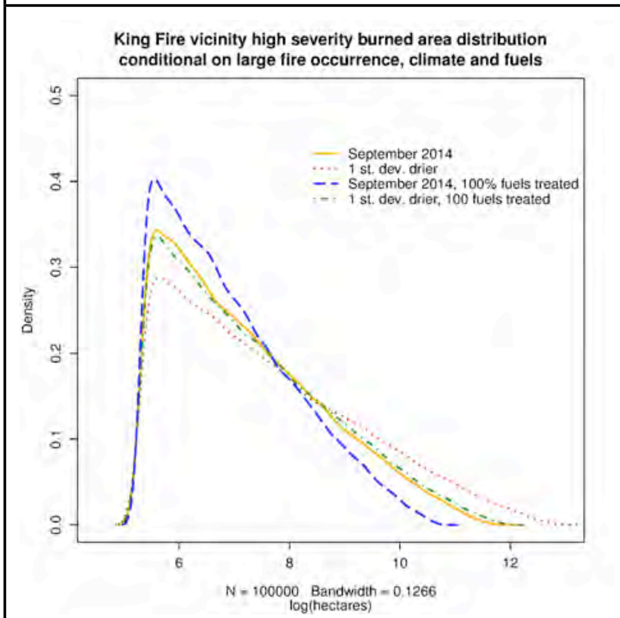


Figure 7. High severity burned area size distributions conditional on a fire with high severity burned area over 200 ha occurring--as well as on climate and fuels conditions--in the vicinity of the McNally (upper left), Rim (upper right) and King (lower left) fire locations. Restoring all fuels to FRCC 1 conditions produces high severity burned area size distributions with smaller mean high severity burned areas and lower probabilities of extremely large high severity burned areas.

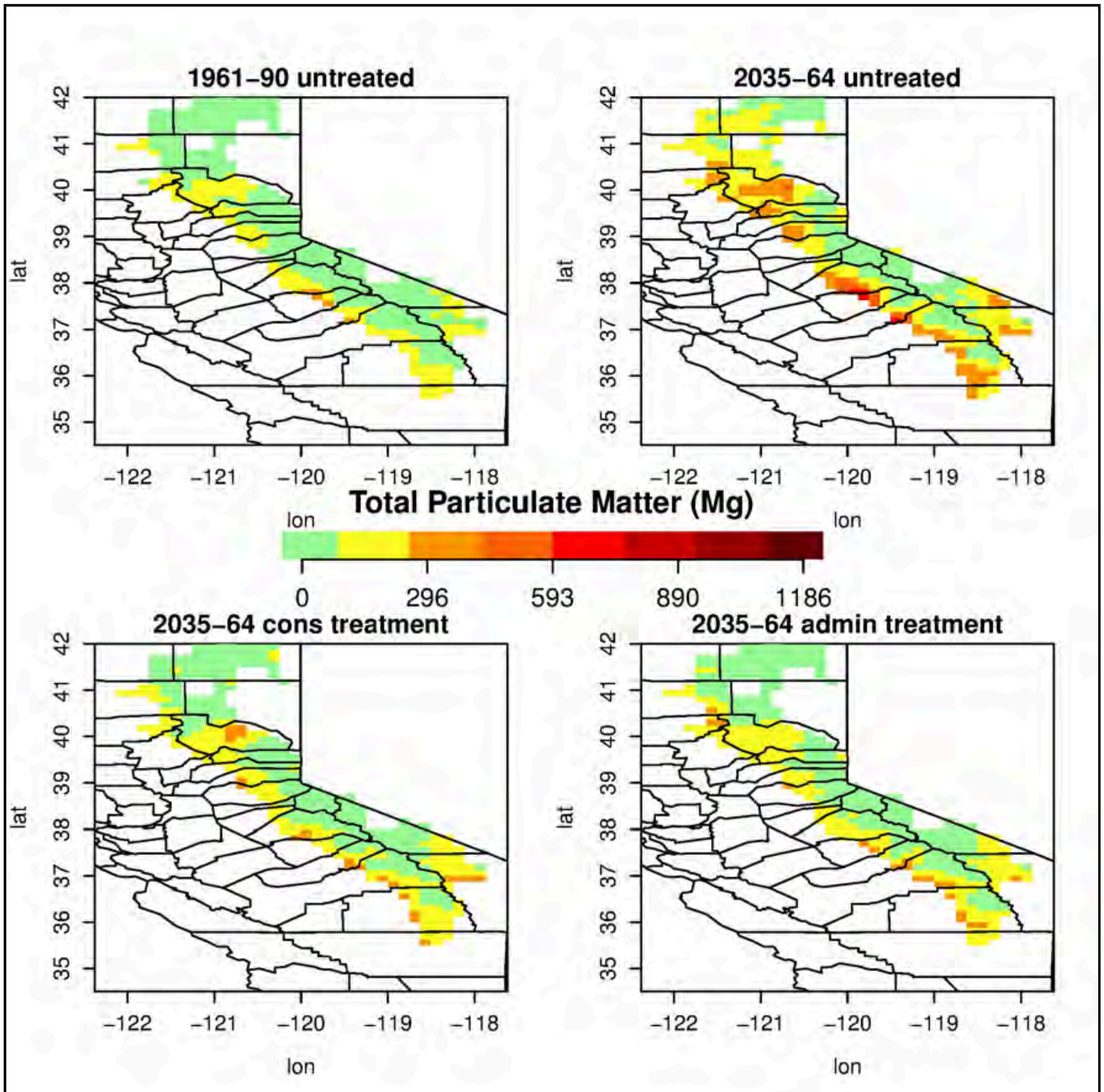


Figure 8: Total Particulate Matter emissions simulated for 1961-90 and 2035-64 without fuels treatments (top left and right) and for 20135-64 with the bio100 and adm30 treatments (bottom left and right), using a CNRM A2 climate simulation.

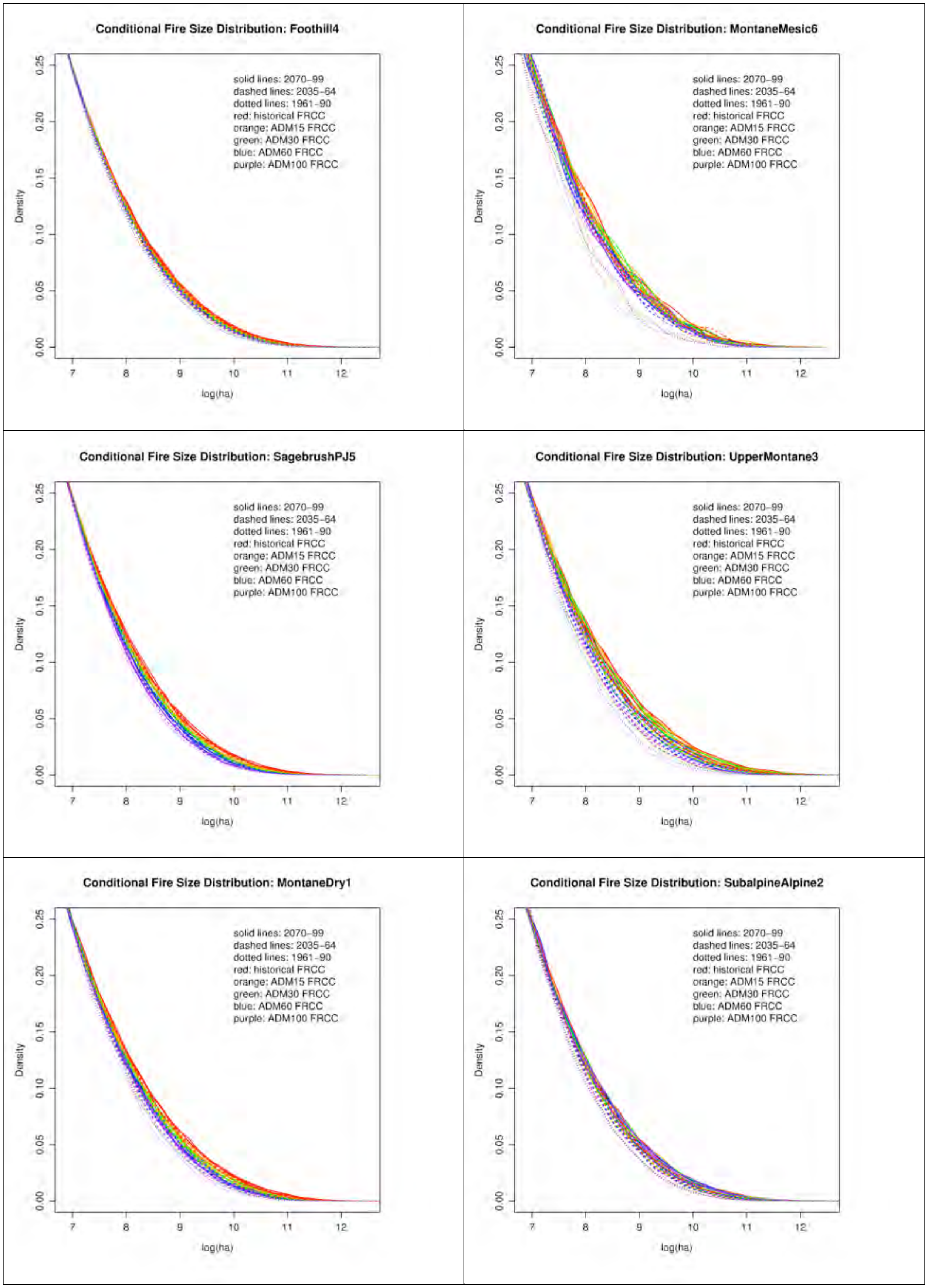


Figure 9. Fire size distributions by vegetation type conditional on a fire > 200 ha being present. Calculated for average conditions simulated for 30 year periods for the CNRM climate model using an A2 global emissions scenario, and administrative unit fuels treatment scenarios.

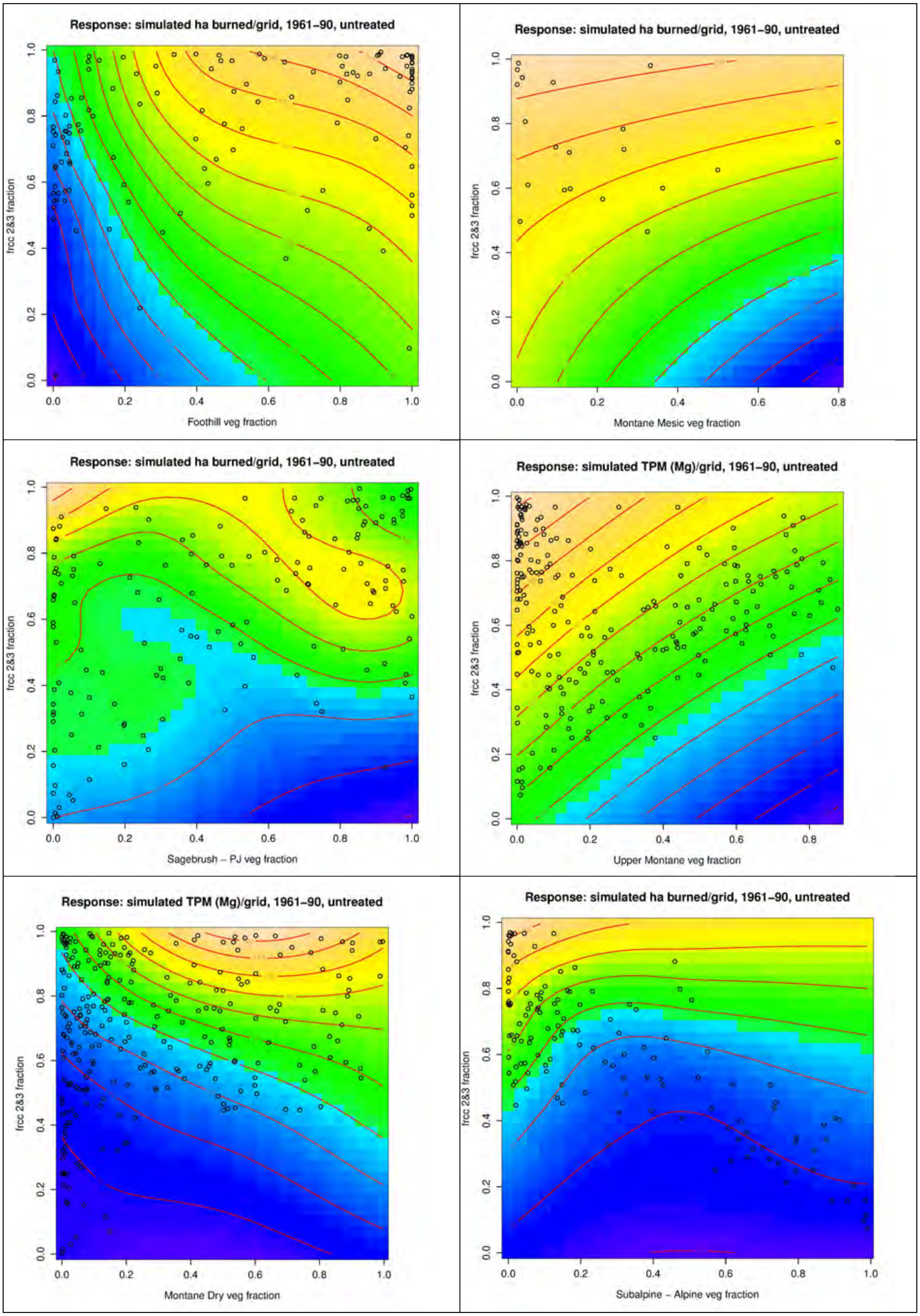


Figure 10. Simulation response (in ha burned per grid cell per year) to fraction in FRCC 2&3 vs fraction vegetation type. Points show sampled grid cells used to calculate response function… contours far from the sample may be unreliable.

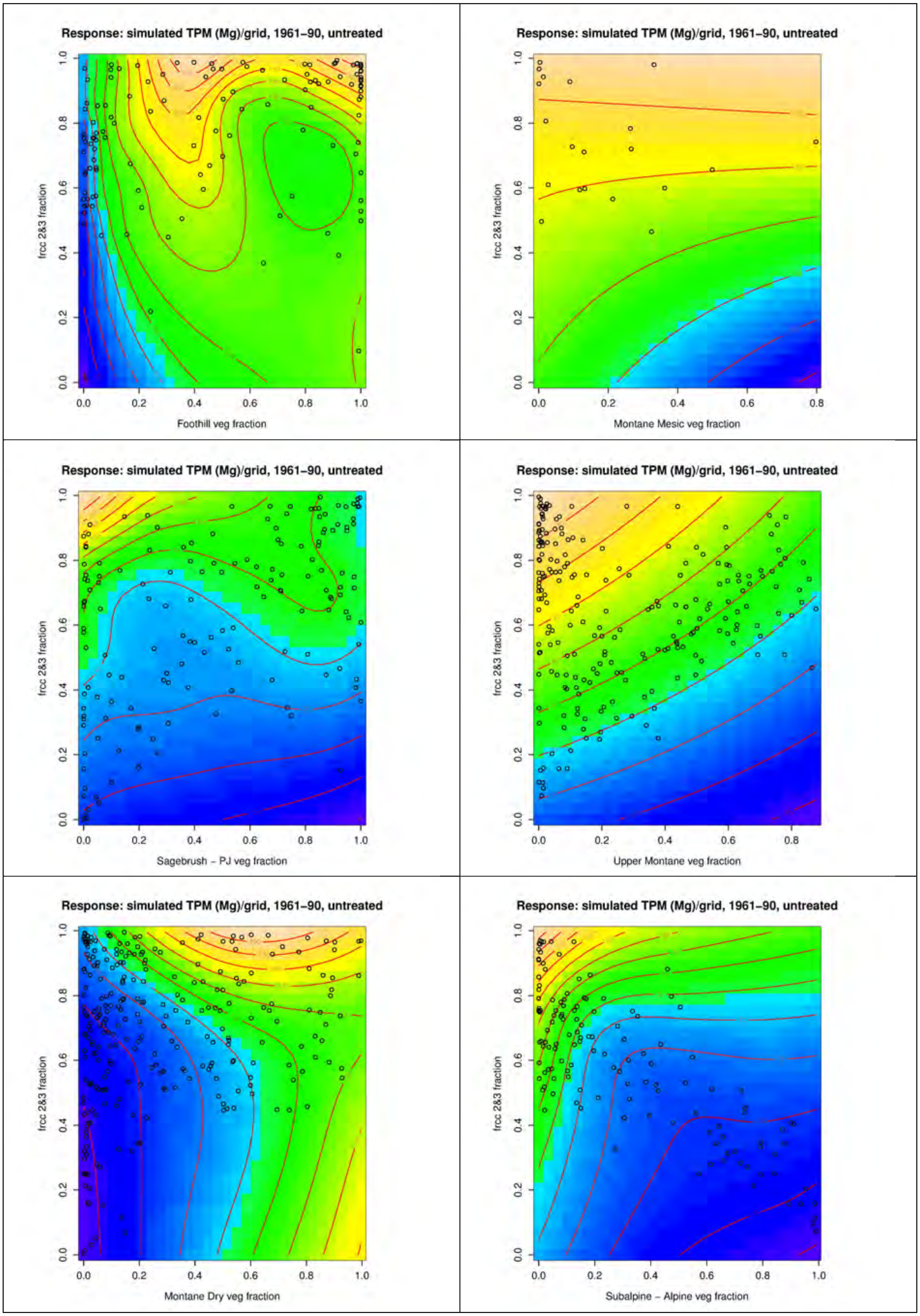


Figure 11. Simulation response (in Mg Total Particulate Matter per grid cell per year) to fraction in FRCC 2&3 vs fraction vegetation type. Points show sampled grid cells used to calculate response function… contours far from the sample may be unreliable.

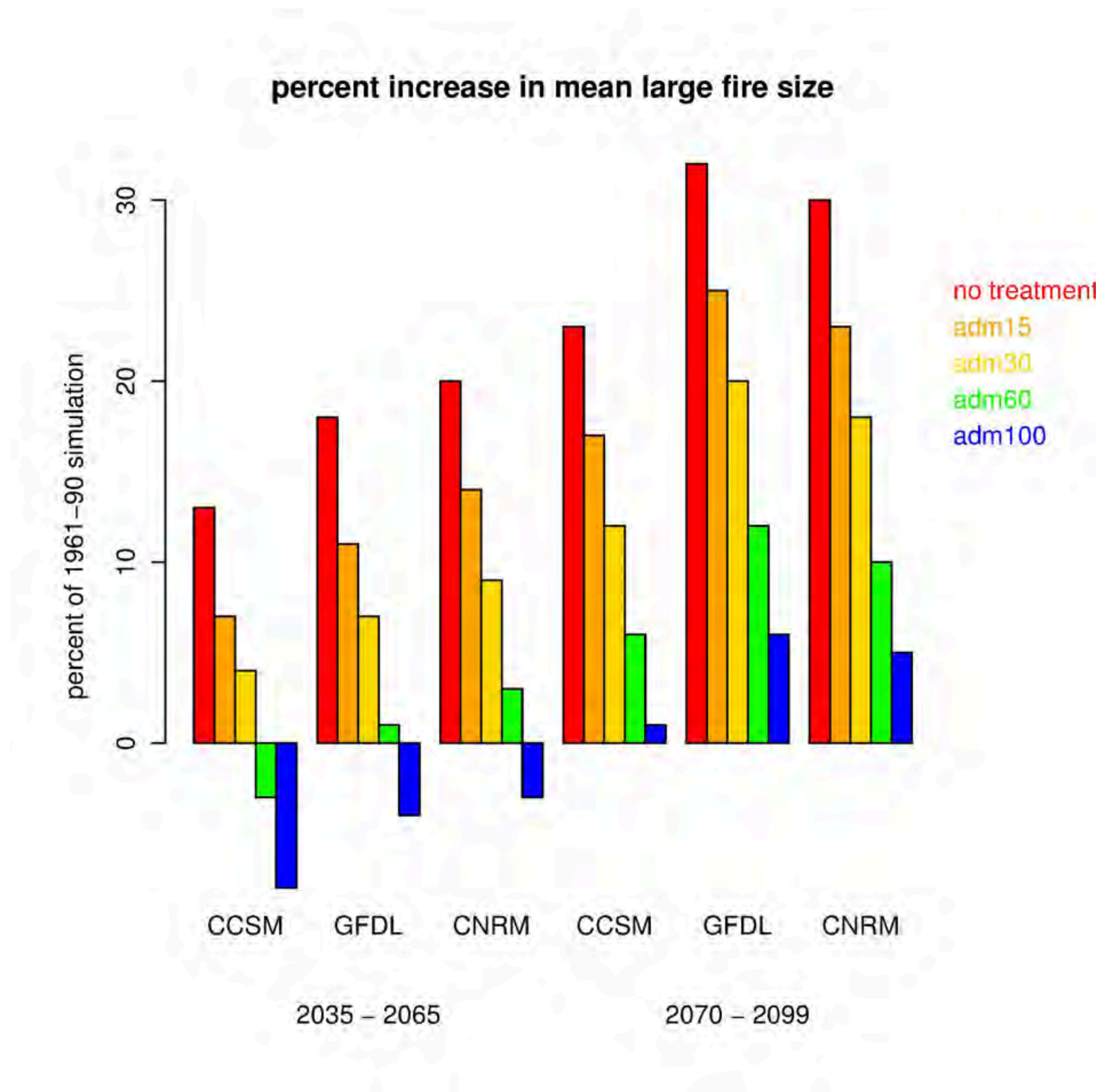


Figure 12. Percent change in mean fire size conditional on a fire > 200 ha occurring, for 3 climate models at mid-century and end of century for 5 fuels restoration scenarios (no treatment, adm15, adm30, adm60, adm100).

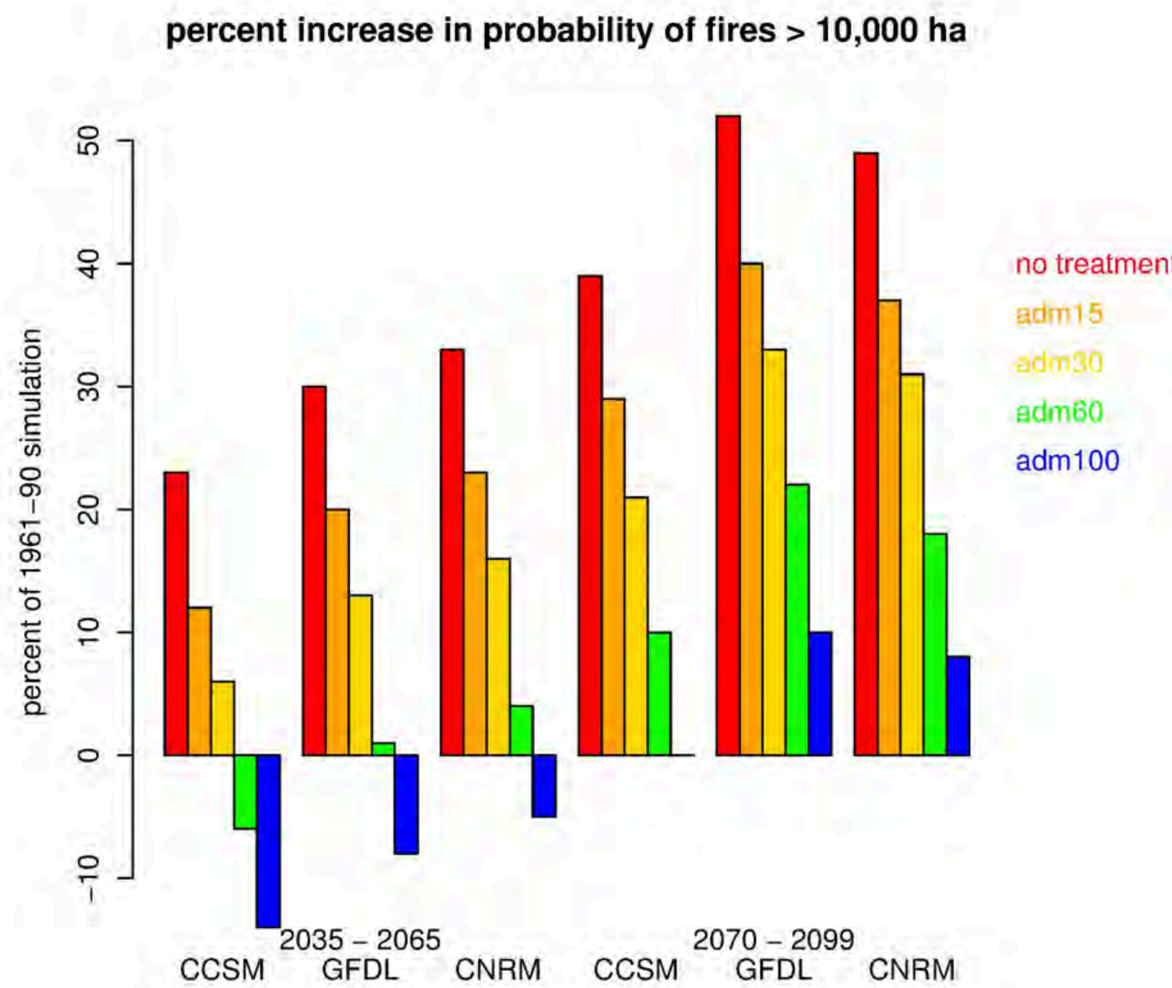


Figure 13. Percent change in probability of a fire > 10,000 ha conditional on a fire > 200 ha occurring, for 3 climate models at mid-century and end of century for 5 fuels restoration scenarios (no treatment, adm15, adm30, adm60, adm100).

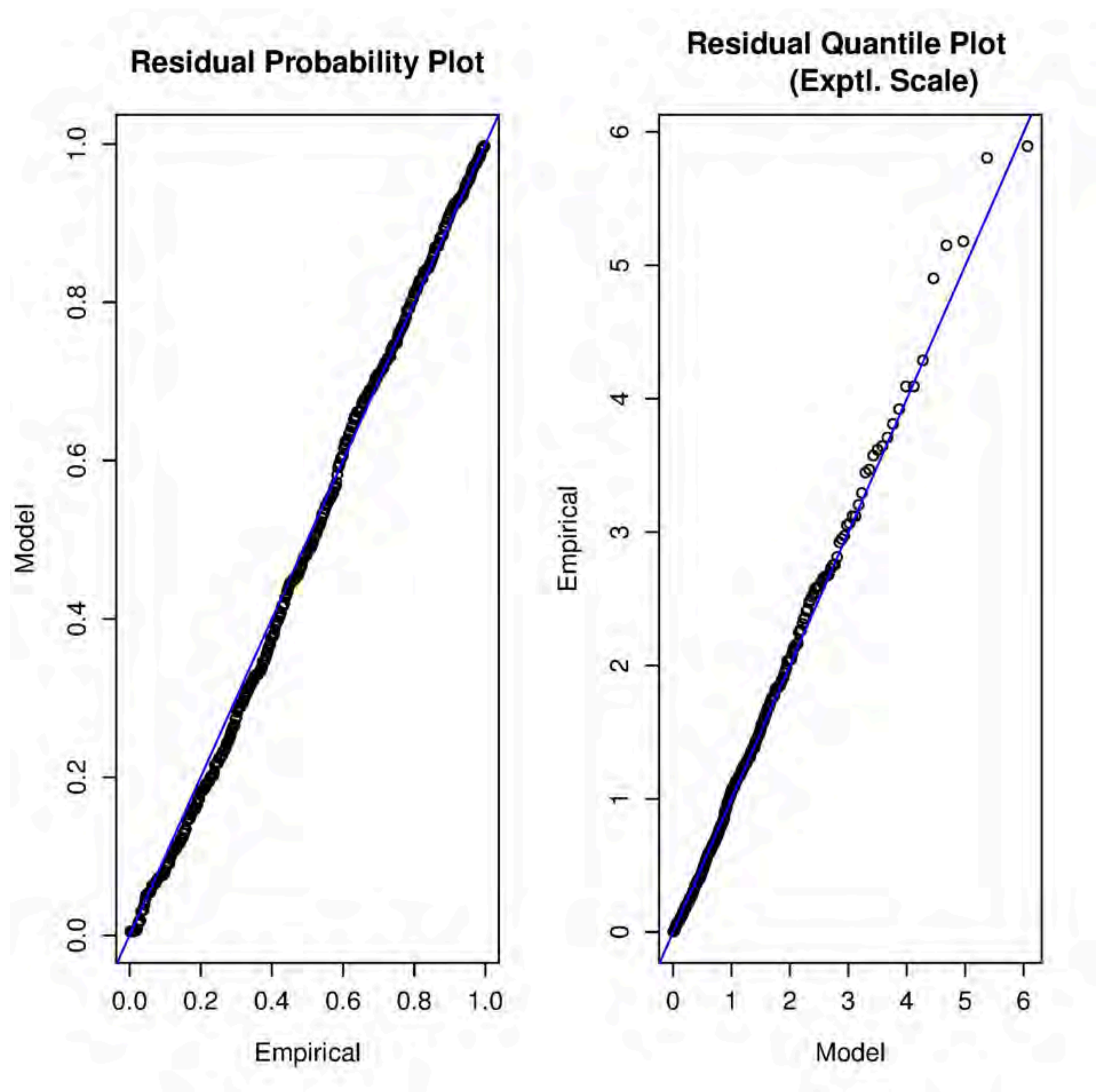


Figure 14. PP and QQ plots for generalized Pareto distribution fit to logarithm of fire size for Sierra Nevada fires > 200 ha.

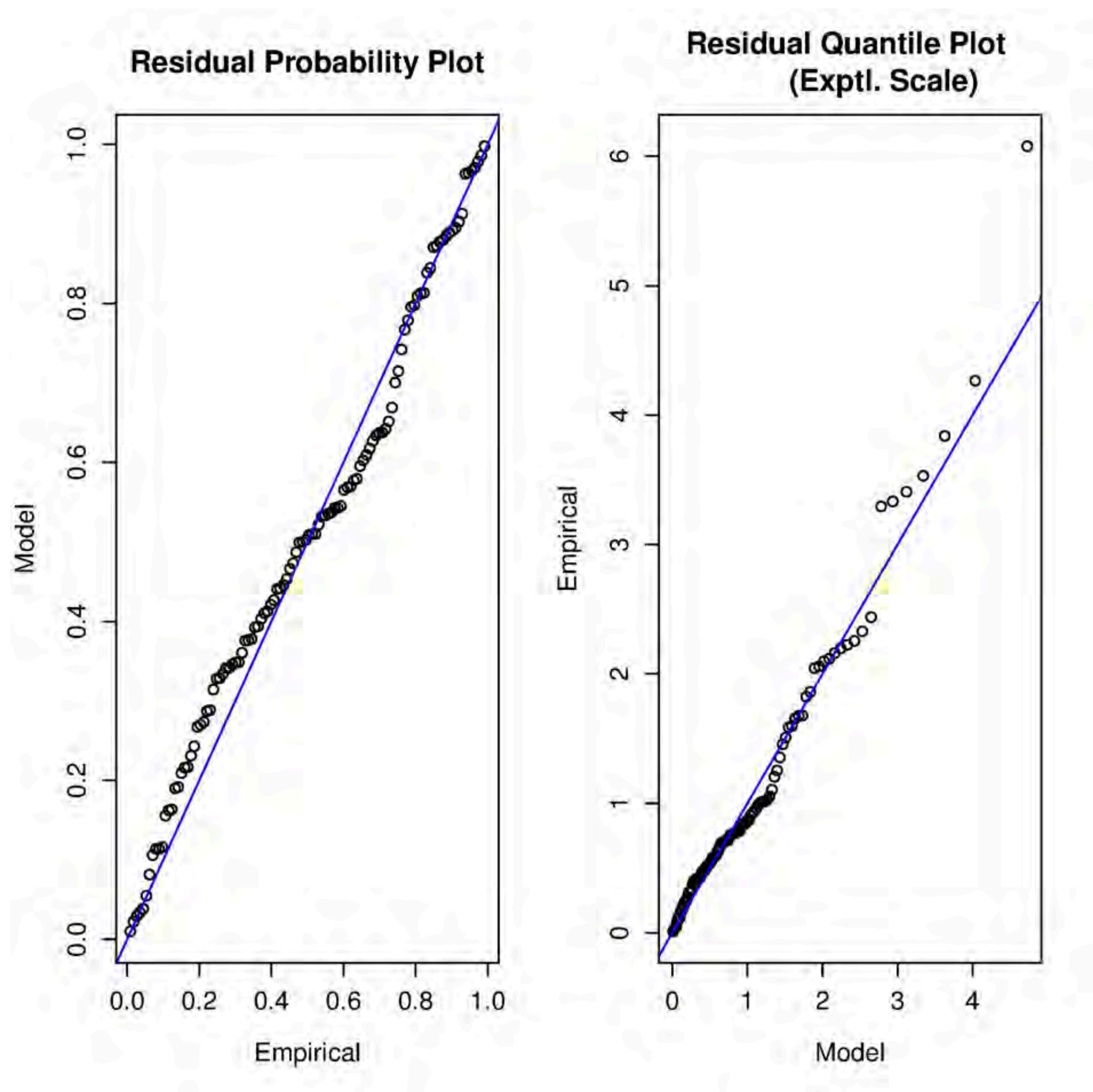


Figure 15. PP and QQ plots for generalized Pareto distribution fit to logarithm of high severity burned area for Sierra Nevada fires with > 200 ha high severity burned area.

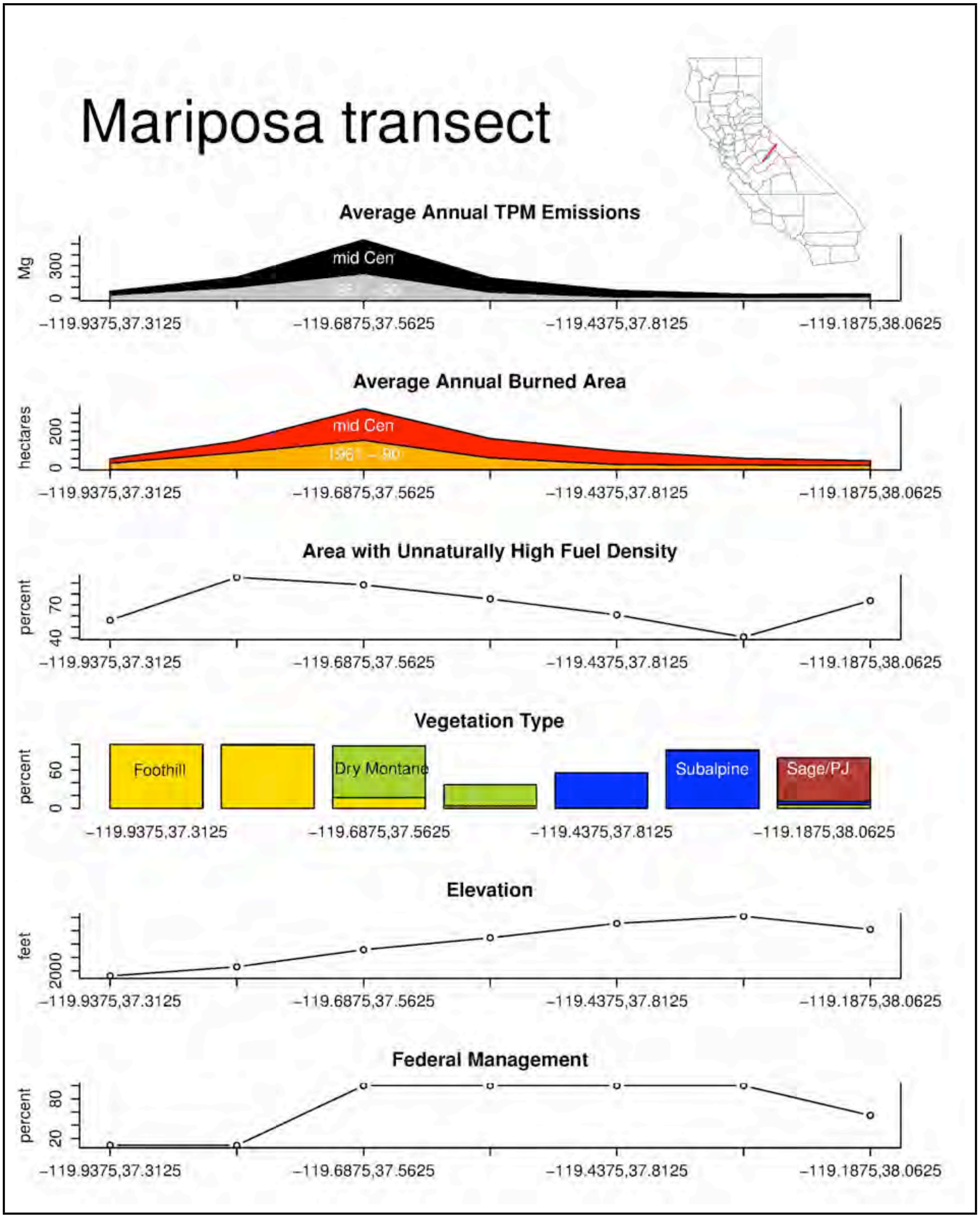
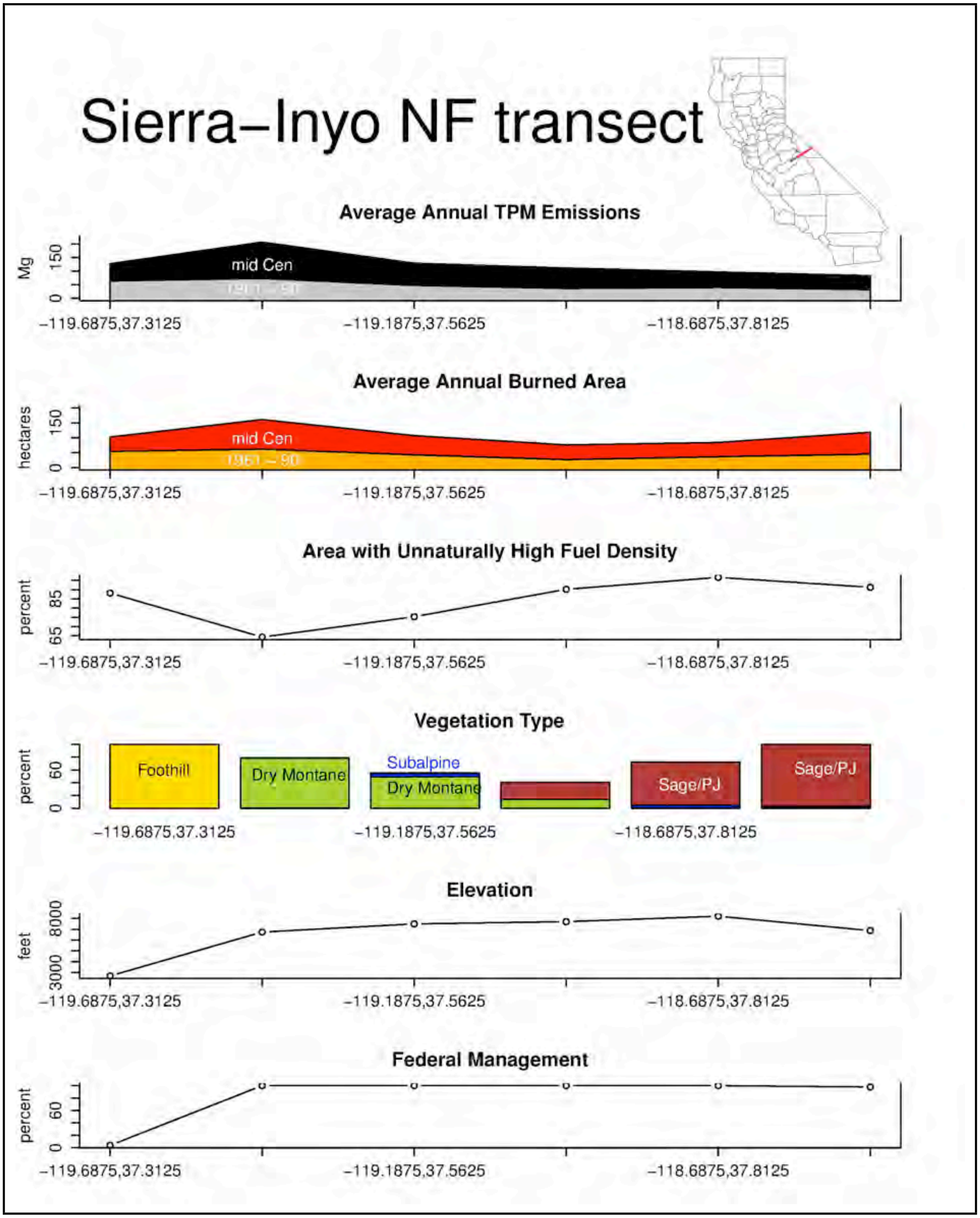

Mariposa transect
Average Annual TPM Emissions
Mg
0
300
mid Cen
Average Annual Burned Area
hectares
0
200
mid Cen
1961 – 90
Area with Unnaturally High Fuel Density
percent
40
70
Vegetation Type
percent
0
60
Foothill
Dry Montane
Subalpine
Sage/PJ
Elevation
feet
2000
Federal Management
percent
20
80
−119.9375,37.3125
−119.6875,37.5625
−119.4375,37.8125
−119.1875,38.0625

Figure 16. Transect through Mariposa County, Sierra National Forest and Yosemite National Park. From top to bottom panels, average annual total particulate matter emissions and average annual burned area simulated for historic (grey) and midcentury (black) climate using a GFDL A2 climate run. Percent of area with unnaturally high fuel density (percent area with FRCC 2 & 3). Fraction of vegetation in coarse categories (Foothill, Dry Montaine, Subalpine, Sage/PJ). Elevation. Percent of area under federal land management agency jurisdiction. Values are averages for 1/8-degree lat/lon grid cells.



Sierra–Inyo NF transect
Average Annual TPM Emissions
Mg
0
150
mid Cen
1961 – 90
–119.6875,37.3125
–119.1875,37.5625
–118.6875,37.8125
Average Annual Burned Area
hectares
0
150
mid Cen
1961 – 90
–119.6875,37.3125
–119.1875,37.5625
–118.6875,37.8125
Area with Unnaturally High Fuel Density
percent
65
85
–119.6875,37.3125
–119.1875,37.5625
–118.6875,37.8125
Vegetation Type
percent
0
60
Foothill
Dry Montane
Subalpine
Dry Montane
Sage/PJ
Sage/PJ
–119.6875,37.3125
–119.1875,37.5625
–118.6875,37.8125
Elevation
feet
3000
8000
–119.6875,37.3125
–119.1875,37.5625
–118.6875,37.8125
Federal Management
percent
0
60
–119.6875,37.3125
–119.1875,37.5625
–118.6875,37.8125

Figure 17. Transect through Sierra and Inyo National Forests. From top to bottom panels, average annual total particulate matter emissions and average annual burned area simulated for historic (grey) and midcentury (black) climate using a GFDL A2 climate run. Percent of area with unnaturally high fuel density (percent area with FRCC 2 & 3). Fraction of vegetation in coarse categories (Foothill, Dry Montaine, Subalpine, Sage/PJ). Elevation. Percent of area under federal land management agency jurisdiction. Values are averages for 1/8-degree lat/lon grid cells.

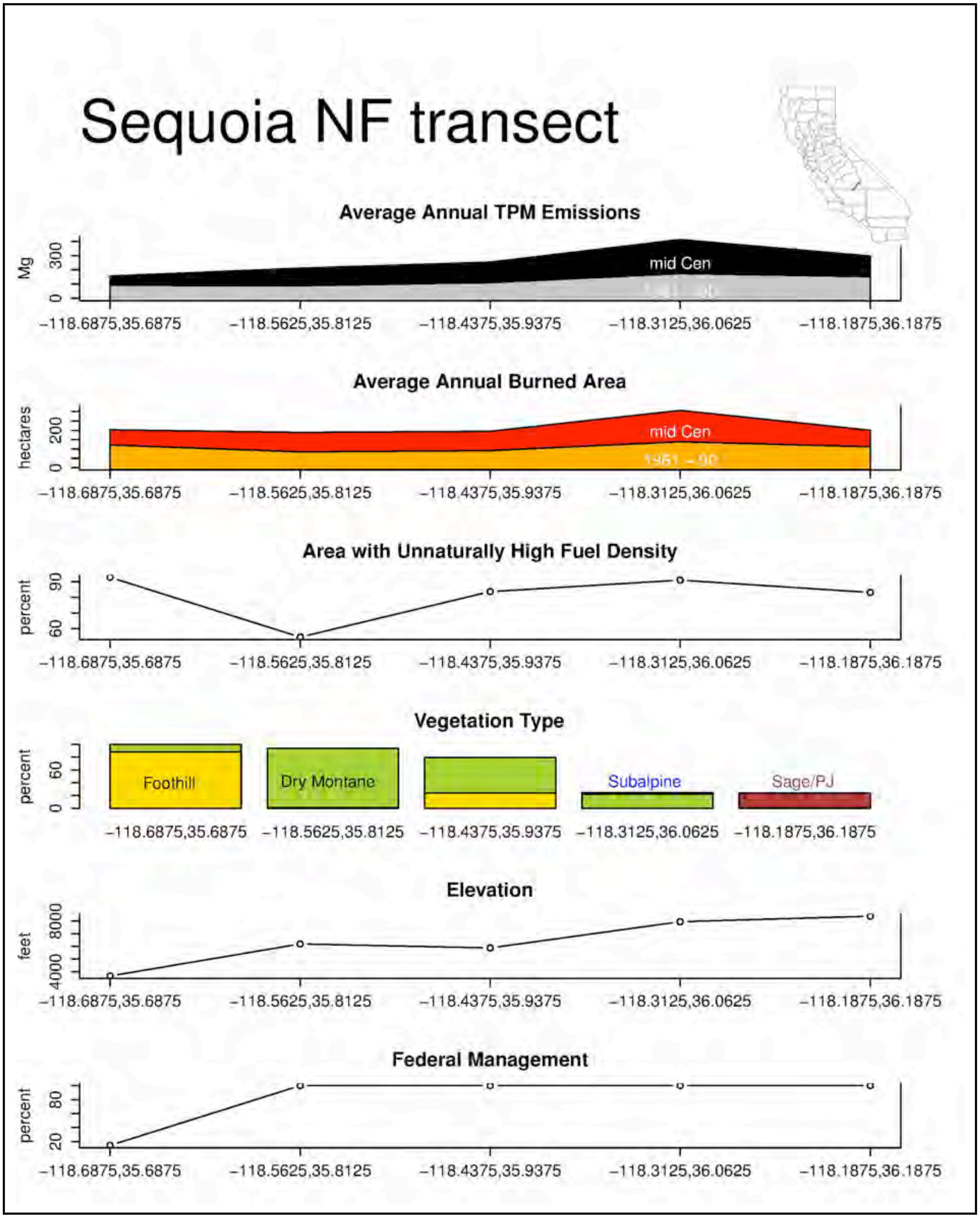

Sequoia NF transect
Average Annual TPM Emissions
Mg
0
300
mid Cen
−118.6875,35.6875
−118.5625,35.8125
−118.4375,35.9375
−118.3125,36.0625
−118.1875,36.1875
Average Annual Burned Area
hectares
0
200
mid Cen
1961 – 90
−118.6875,35.6875
−118.5625,35.8125
−118.4375,35.9375
−118.3125,36.0625
−118.1875,36.1875
Area with Unnaturally High Fuel Density
percent
60
90
−118.6875,35.6875
−118.5625,35.8125
−118.4375,35.9375
−118.3125,36.0625
−118.1875,36.1875
Vegetation Type
percent
0
60
Foothill
Dry Montane
Subalpine
Sage/PJ
−118.6875,35.6875
−118.5625,35.8125
−118.4375,35.9375
−118.3125,36.0625
−118.1875,36.1875
Elevation
feet
4000
8000
−118.6875,35.6875
−118.5625,35.8125
−118.4375,35.9375
−118.3125,36.0625
−118.1875,36.1875
Federal Management
percent
20
80
−118.6875,35.6875
−118.5625,35.8125
−118.4375,35.9375
−118.3125,36.0625
−118.1875,36.1875

Figure 18. Transect through Sequoia National Forest. From top to bottom panels, average annual total particulate matter emissions and average annual burned area simulated for historic (grey) and midcentury (black) climate using a GFDL A2 climate run. Percent of area with unnaturally high fuel density (percent area with FRCC 2 & 3). Fraction of vegetation in coarse categories (Foothill, Dry Montaine, Subalpine, Sage/PJ). Elevation. Percent of area under federal land management agency jurisdiction. Values are averages for 1/8-degree lat/lon grid cells.

Table A1a: **All Vegetation Types**

mean July - August expected fire size conditional on large (>200 ha) fire occurrence

(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)

CLIMATE	FRCC Historic	Admin 15%	Admin 30%	Admin 60%	Admin 100%	Bio 15%	Bio 30%	Bio 60%	Bio 100%
Historic 1961-90	1622	1500	1481	1392	1331	1585	1558	1526	1502
CCSM A2 2035-64	1832	1728	1679	1568	1493	1789	1765	1724	1695
GFDL A2 2035-64	1907	1806	1743	1634	1555	1865	1839	1801	1766
CNRM A2 2035-64	1944	1842	1771	1664	1581	1901	1872	1831	1798
CCSM A2 2070-99	1996	1897	1822	1713	1632	1954	1928	1881	1849
GFDL A2 2070-99	2137	2025	1947	1820	1726	2086	2059	2004	1972
CNRM A2 2070-99	2101	1989	1921	1792	1703	2044	2018	1973	1941

Table A1b:

percent change in mean July - August expected fire size conditional on large (>200 ha) fire occurrence

(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)

CLIMATE	FRCC Historic	Admin 15%	Admin 30%	Admin 60%	Admin 100%	Bio 15%	Bio 30%	Bio 60%	Bio 100%
Historic 1961-90	-	-8%	-9%	-14%	-18%	-2%	-4%	-6%	-7%
CCSM A2 2035-64	13%	7%	4%	-3%	-8%	10%	9%	6%	5%
GFDL A2 2035-64	18%	11%	7%	1%	-4%	15%	13%	11%	9%
CNRM A2 2035-64	20%	14%	9%	3%	-3%	17%	15%	13%	11%
CCSM A2 2070-99	23%	17%	12%	6%	1%	20%	19%	16%	14%
GFDL A2 2070-99	32%	25%	20%	12%	6%	29%	27%	24%	22%
CNRM A2 2070-99	30%	23%	18%	10%	5%	26%	24%	22%	20%

Table

mean July - August expected fire size conditional on large (>200 ha) fire occurrence

grid cells with more than 50% of vegetation in sagebrush + grass combined excluded

(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)

CLIMATE	FRCC Historic	Admin 15%	Admin 30%	Admin 60%	Admin 100%

Historic 1961-90	1746	1570	1569	1445	1380
CCSM A2 2035-64	2046	1905	1840	1697	1599
GFDL A2 2035-64	2145	2014	1932	1785	1682
CNRM A2 2035-64	2184	2057	1965	1817	1710
CCSM A2 2070-99	2277	2145	2049	1903	1794
GFDL A2 2070-99	2467	2329	2225	2053	1926
CNRM A2 2070-99	2435	2277	2197	2018	1898

Table

percent change in mean July - August expected fire size conditional on large (>200 ha) fire occurrence

grid cells with more than 50% of vegetation in sagebrush + grass combined excluded

(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)

CLIMATE	FRCC Historic	Admin 15%	Admin 30%	Admin 60%	Admin 100%
Historic 1961-90	-	-3%	-3%	-11%	-15%
CCSM A2 2035-64	26%	17%	13%	5%	-1%
GFDL A2 2035-64	32%	24%	19%	10%	4%
CNRM A2 2035-64	35%	27%	21%	12%	5%
CCSM A2 2070-99	40%	32%	26%	17%	11%
GFDL A2 2070-99	52%	44%	37%	27%	19%
CNRM A2 2070-99	50%	40%	35%	24%	17%

Table A2a:		All Vegetation Types							
fraction July - August simulated fire sizes >= 1,000 ha conditional on large (>200 ha) fire occurrence									
	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	0.306	0.2958	0.2951	0.2868	0.28	0.3034	0.3011	0.2983	0.2961
CCSM A2 2035-64	0.3198	0.3132	0.3092	0.3013	0.2949	0.3168	0.315	0.3131	0.3099
GFDL A2 2035-64	0.3246	0.3185	0.3145	0.307	0.2999	0.3225	0.3204	0.318	0.3146
CNRM A2 2035-64	0.3266	0.3198	0.3163	0.3086	0.3019	0.3236	0.3223	0.3192	0.3168
CCSM A2 2070-99	0.3294	0.3236	0.3191	0.3122	0.3054	0.3269	0.3258	0.3229	0.32
GFDL A2 2070-99	0.3369	0.331	0.3269	0.3197	0.3128	0.3347	0.3328	0.3298	0.3279
CNRM A2 2070-99	0.3351	0.3292	0.3253	0.3178	0.3116	0.3326	0.3312	0.3285	0.3257

Table A2b:									
percent change in fraction July - August simulated fire sizes >= 1,000ha conditional on large (>200 ha) fire occurrence									
	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	-	-3%	-4%	-6%	-8%	-1%	-2%	-3%	-3%
CCSM A2 2035-64	5%	2%	1%	-2%	-4%	4%	3%	2%	1%
GFDL A2 2035-64	6%	4%	3%	0%	-2%	5%	5%	4%	3%
CNRM A2 2035-64	7%	5%	3%	1%	-1%	6%	5%	4%	4%
CCSM A2 2070-99	8%	6%	4%	2%	0%	7%	6%	6%	5%
GFDL A2 2070-99	10%	8%	7%	4%	2%	9%	9%	8%	7%
CNRM A2 2070-99	10%	8%	6%	4%	2%	9%	8%	7%	6%

Table A2c:					
fraction July - August simulated fire sizes >= 1,000 ha conditional on large (>200 ha) fire occurrence					
grid cells with more than 50% of vegetation in sagebrush + grass combined excluded					
	FRCC	(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)			
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**

Historic 1961-90	0.3193	0.3049	0.3055	0.2949	0.2863
CCSM A2 2035-64	0.3372	0.328	0.3234	0.3138	0.3052
GFDL A2 2035-64	0.3429	0.3354	0.3305	0.3211	0.312
CNRM A2 2035-64	0.3447	0.3359	0.3314	0.322	0.3235
CCSM A2 2070-99	0.3495	0.342	0.3363	0.3276	0.3192
GFDL A2 2070-99	0.3591	0.3512	0.3464	0.3376	0.3288
CNRM A2 2070-99	0.3567	0.3492	0.3448	0.3352	0.3283

Table

percent change in fraction July - August simulated fire sizes >= 1,000ha conditional on large (>200 ha) fire occurrence

grid cells with more than 50% of vegetation in sagebrush + grass combined excluded

	FRCC	(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)			
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**
Historic 1961-90	-	0%	0%	-4%	-6%
CCSM A2 2035-64	10%	7%	6%	3%	0%
GFDL A2 2035-64	12%	10%	8%	5%	2%
CNRM A2 2035-64	13%	10%	8%	5%	6%
CCSM A2 2070-99	14%	12%	10%	7%	4%
GFDL A2 2070-99	17%	15%	13%	10%	7%
CNRM A2 2070-99	17%	14%	13%	10%	7%

Table A3a:		All Vegetation Types							
fraction July - August simulated fire sizes >= 10,000 ha conditional on large (>200 ha) fire occurrence									
	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	0.0251	0.0217	0.0213	0.0188	0.017	0.0242	0.0235	0.0227	0.0219
CCSM A2 2035-64	0.0308	0.028	0.0266	0.0236	0.0215	0.0297	0.029	0.0279	0.0271
GFDL A2 2035-64	0.0327	0.03	0.0283	0.0254	0.0232	0.0317	0.031	0.0297	0.0289
CNRM A2 2035-64	0.0333	0.0308	0.029	0.0261	0.0239	0.0322	0.0316	0.0305	0.0297
CCSM A2 2070-99	0.0348	0.0324	0.0304	0.0276	0.0252	0.0336	0.0331	0.0319	0.0309
GFDL A2 2070-99	0.0382	0.0352	0.0333	0.0305	0.0277	0.0368	0.0364	0.0347	0.0339
CNRM A2 2070-99	0.0374	0.0344	0.0328	0.0297	0.0272	0.0361	0.0351	0.0342	0.0332

Table A3b:									
percent change in fraction July - August simulated fire sizes >= 10,000ha conditional on large (>200 ha) fire occurrence									
	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	-	-14%	-15%	-25%	-32%	-4%	-6%	-10%	-13%
CCSM A2 2035-64	23%	12%	6%	-6%	-14%	18%	16%	11%	8%
GFDL A2 2035-64	30%	20%	13%	1%	-8%	26%	24%	18%	15%
CNRM A2 2035-64	33%	23%	16%	4%	-5%	28%	26%	22%	18%
CCSM A2 2070-99	39%	29%	21%	10%	0%	34%	32%	27%	23%
GFDL A2 2070-99	52%	40%	33%	22%	10%	47%	45%	38%	35%
CNRM A2 2070-99	49%	37%	31%	18%	8%	44%	40%	36%	32%

Table	
fraction July - August simulated fire sizes >= 10,000 ha conditional on large (>200 ha) fire occurrence	
grid cells with more than 50% of vegetation in sagebrush + grass combined excluded	
	FRCC (averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)

CLIMATE	Historic	Admin 15%	Admin 30%	Admin 60%	Admin 100%
Historic 1961-90	0.0287	0.0238	0.024	0.0208	0.0185
CCSM A2 2035-64	0.0367	0.0328	0.0311	0.0273	0.0246
GFDL A2 2035-64	0.0391	0.0357	0.0336	0.0296	0.027
CNRM A2 2035-64	0.0398	0.0366	0.0343	0.0304	0.0275
CCSM A2 2070-99	0.0422	0.039	0.0366	0.0329	0.0297
GFDL A2 2070-99	0.0465	0.043	0.0405	0.0368	0.0332
CNRM A2 2070-99	0.0459	0.042	0.0401	0.036	0.0325

Table

percent change in fraction July - August simulated fire sizes >= 10,000ha conditional on large (>200 ha) fire occurrence

	FRCC	(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)			
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**
Historic 1961-90	-	-5%	-4%	-17%	-26%
CCSM A2 2035-64	46%	31%	24%	9%	-2%
GFDL A2 2035-64	56%	42%	34%	18%	8%
CNRM A2 2035-64	59%	46%	37%	21%	10%
CCSM A2 2070-99	68%	55%	46%	31%	18%
GFDL A2 2070-99	85%	71%	61%	47%	32%
CNRM A2 2070-99	83%	67%	60%	43%	29%

Table A4a: **Foothill4 (area weighted)**

fraction July - August simulated fire sizes >= 10,000 ha conditional on large (>200 ha) fire occurrence

	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	0.0265	0.0236	0.0229	0.0206	0.0198	0.0256	0.0252	0.0245	0.0241
CCSM A2 2035-64	0.031	0.0283	0.0269	0.0248	0.0237	0.0299	0.0294	0.0286	0.0281
GFDL A2 2035-64	0.0319	0.0295	0.0279	0.026	0.0248	0.0313	0.0307	0.0295	0.0291
CNRM A2 2035-64	0.0324	0.0303	0.0287	0.0265	0.0254	0.0316	0.0311	0.0305	0.0298
CCSM A2 2070-99	0.0336	0.0313	0.0292	0.0276	0.0262	0.0328	0.0321	0.0313	0.0307
GFDL A2 2070-99	0.035	0.0316	0.0305	0.0282	0.0268	0.0336	0.0334	0.032	0.0315
CNRM A2 2070-99	0.0353	0.0324	0.0313	0.029	0.0277	0.0347	0.0338	0.0332	0.0322

Table A4b:

percent change in fraction July - August simulated fire sizes >= 10,000ha conditional on large (>200 ha) fire occurrence

	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	-	-11%	-14%	-22%	-25%	-3%	-5%	-8%	-9%
CCSM A2 2035-64	17%	7%	2%	-6%	-11%	13%	11%	8%	6%
GFDL A2 2035-64	20%	11%	5%	-2%	-6%	18%	16%	11%	10%
CNRM A2 2035-64	22%	14%	8%	0%	-4%	19%	17%	15%	12%
CCSM A2 2070-99	27%	18%	10%	4%	-1%	24%	21%	18%	16%
GFDL A2 2070-99	32%	19%	15%	6%	1%	27%	26%	21%	19%
CNRM A2 2070-99	33%	22%	18%	9%	5%	31%	28%	25%	22%

Table A5a: **MontaneDry1 (area weighted)**

fraction July - August simulated fire sizes >= 10,000 ha conditional on large (>200 ha) fire occurrence

	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	0.0312	0.0246	0.0256	0.0222	0.0192	0.0294	0.0277	0.0261	0.0246
CCSM A2 2035-64	0.0383	0.0338	0.032	0.0277	0.0244	0.0363	0.0346	0.0324	0.0307
GFDL A2 2035-64	0.0407	0.0367	0.0344	0.0299	0.0267	0.0388	0.0372	0.0345	0.0328
CNRM A2 2035-64	0.0409	0.0366	0.034	0.03	0.0268	0.0381	0.037	0.0349	0.0332
CCSM A2 2070-99	0.0427	0.0386	0.0359	0.032	0.0284	0.0403	0.0389	0.0365	0.0347
GFDL A2 2070-99	0.0454	0.0409	0.0385	0.0345	0.0304	0.0428	0.0416	0.0389	0.0371
CNRM A2 2070-99	0.0458	0.0413	0.0388	0.0346	0.0305	0.0428	0.0414	0.0389	0.0372

Table A5b:

percent change in fraction July - August simulated fire sizes >= 10,000ha conditional on large (>200 ha) fire occurrence

	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	-	-21%	-18%	-29%	-38%	-6%	-11%	-16%	-21%
CCSM A2 2035-64	23%	8%	3%	-11%	-22%	16%	11%	4%	-2%
GFDL A2 2035-64	30%	18%	10%	-4%	-14%	24%	19%	11%	5%
CNRM A2 2035-64	31%	17%	9%	-4%	-14%	22%	19%	12%	6%
CCSM A2 2070-99	37%	24%	15%	3%	-9%	29%	25%	17%	11%
GFDL A2 2070-99	46%	31%	23%	11%	-3%	37%	33%	25%	19%
CNRM A2 2070-99	47%	32%	24%	11%	-2%	37%	33%	25%	19%

Table A6a: **MontaneMesic6 (area weighted)**

fraction July - August simulated fire sizes >= 10,000 ha conditional on large (>200 ha) fire occurrence

	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	0.0187	0.0142	0.0163	0.0136	0.012	0.0179	0.017	0.0148	0.0152
CCSM A2 2035-64	0.0302	0.0263	0.0251	0.0214	0.0211	0.0292	0.0272	0.0248	0.0233
GFDL A2 2035-64	0.0344	0.0317	0.0294	0.0253	0.0234	0.0316	0.0307	0.029	0.028
CNRM A2 2035-64	0.0326	0.0297	0.0285	0.0232	0.021	0.0287	0.0284	0.0278	0.0262
CCSM A2 2070-99	0.0366	0.0318	0.0323	0.0275	0.0258	0.0322	0.0313	0.0318	0.029
GFDL A2 2070-99	0.0395	0.0367	0.0335	0.0312	0.0284	0.0369	0.0359	0.0333	0.0336
CNRM A2 2070-99	0.037	0.0352	0.033	0.0299	0.0266	0.0368	0.0336	0.034	0.0316

Table A6b:

percent change in fraction July - August simulated fire sizes >= 10,000ha conditional on large (>200 ha) fire occurrence

	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	-	-24%	-13%	-27%	-36%	-4%	-9%	-21%	-19%
CCSM A2 2035-64	61%	41%	34%	14%	13%	56%	45%	33%	25%
GFDL A2 2035-64	84%	70%	57%	35%	25%	69%	64%	55%	50%
CNRM A2 2035-64	74%	59%	52%	24%	12%	53%	52%	49%	40%
CCSM A2 2070-99	96%	70%	73%	47%	38%	72%	67%	70%	55%
GFDL A2 2070-99	111%	96%	79%	67%	52%	97%	92%	78%	80%
CNRM A2 2070-99	98%	88%	76%	60%	42%	97%	80%	82%	69%

Table A7a: **Null Vegetation type (area weighted)**

fraction July - August simulated fire sizes >= 10,000 ha conditional on large (>200 ha) fire occurrence

	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	0.0187	0.0142	0.0163	0.0136	0.012	0.0179	0.017	0.0148	0.0152
CCSM A2 2035-64	0.0302	0.0263	0.0251	0.0214	0.0211	0.0292	0.0272	0.0248	0.0233
GFDL A2 2035-64	0.0344	0.0317	0.0294	0.0253	0.0234	0.0316	0.0307	0.029	0.028
CNRM A2 2035-64	0.0326	0.0297	0.0285	0.0232	0.021	0.0287	0.0284	0.0278	0.0262
CCSM A2 2070-99	0.0366	0.0318	0.0323	0.0275	0.0258	0.0322	0.0313	0.0318	0.029
GFDL A2 2070-99	0.0395	0.0367	0.0335	0.0312	0.0284	0.0369	0.0359	0.0333	0.0336
CNRM A2 2070-99	0.037	0.0352	0.033	0.0299	0.0266	0.0368	0.0336	0.034	0.0316

Table A7b:

percent change in fraction July - August simulated fire sizes >= 10,000ha conditional on large (>200 ha) fire occurrence

	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	-	-24%	-13%	-27%	-36%	-4%	-9%	-21%	-19%
CCSM A2 2035-64	61%	41%	34%	14%	13%	56%	45%	33%	25%
GFDL A2 2035-64	84%	70%	57%	35%	25%	69%	64%	55%	50%
CNRM A2 2035-64	74%	59%	52%	24%	12%	53%	52%	49%	40%
CCSM A2 2070-99	96%	70%	73%	47%	38%	72%	67%	70%	55%
GFDL A2 2070-99	111%	96%	79%	67%	52%	97%	92%	78%	80%
CNRM A2 2070-99	98%	88%	76%	60%	42%	97%	80%	82%	69%

Table A8a:		SagebrushPJ5 (area weighted)							
fraction July - August simulated fire sizes >= 10,000 ha conditional on large (>200 ha) fire occurrence									
	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	0.028	0.0247	0.0225	0.0191	0.0166	0.0271	0.0264	0.0258	0.0249
CCSM A2 2035-64	0.032	0.0282	0.0262	0.0223	0.0195	0.0311	0.0306	0.0294	0.0287
GFDL A2 2035-64	0.0338	0.0301	0.0277	0.0242	0.0206	0.0329	0.032	0.0313	0.0303
CNRM A2 2035-64	0.0346	0.0309	0.0283	0.025	0.0213	0.0335	0.0332	0.0321	0.0314
CCSM A2 2070-99	0.0347	0.031	0.0285	0.0249	0.0214	0.0329	0.0329	0.0318	0.0309
GFDL A2 2070-99	0.0382	0.0342	0.0314	0.0278	0.0238	0.0369	0.0362	0.0348	0.0343
CNRM A2 2070-99	0.0355	0.0316	0.029	0.0252	0.0222	0.0343	0.0334	0.033	0.032

Table A8b:									
percent change in fraction July - August simulated fire sizes >= 10,000ha conditional on large (>200 ha) fire occurrence									
	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	-	-12%	-20%	-32%	-41%	-3%	-6%	-8%	-11%
CCSM A2 2035-64	14%	1%	-6%	-20%	-30%	11%	9%	5%	3%
GFDL A2 2035-64	21%	7%	-1%	-14%	-26%	18%	14%	12%	8%
CNRM A2 2035-64	24%	10%	1%	-11%	-24%	20%	19%	15%	12%
CCSM A2 2070-99	24%	11%	2%	-11%	-24%	18%	18%	14%	10%
GFDL A2 2070-99	36%	22%	12%	-1%	-15%	32%	29%	24%	23%
CNRM A2 2070-99	27%	13%	4%	-10%	-21%	23%	19%	18%	14%

Table A9a: **SubAlpineAlpine2 (area weighted)**

fraction July - August simulated fire sizes >= 10,000 ha conditional on large (>200 ha) fire occurrence

(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)

CLIMATE	FRCC Historic	Admin 15%	Admin 30%	Admin 60%	Admin 100%	Bio 15%	Bio 30%	Bio 60%	Bio 100%
Historic 1961-90	0.0252	0.0235	0.0232	0.0216	0.0205	0.0249	0.0246	0.0242	0.0234
CCSM A2 2035-64	0.0325	0.0316	0.0309	0.0285	0.0271	0.0321	0.032	0.0318	0.0312
GFDL A2 2035-64	0.036	0.0349	0.0332	0.0317	0.0301	0.0352	0.0355	0.0352	0.0344
CNRM A2 2035-64	0.0382	0.0379	0.0364	0.034	0.0325	0.0382	0.0378	0.0369	0.0368
CCSM A2 2070-99	0.0403	0.0398	0.0384	0.0365	0.0345	0.0404	0.0401	0.0394	0.0389
GFDL A2 2070-99	0.0483	0.0474	0.0458	0.0438	0.0417	0.048	0.0485	0.0469	0.0462
CNRM A2 2070-99	0.0455	0.0441	0.0434	0.041	0.0389	0.0446	0.0438	0.0437	0.0434

Table A9b:

percent change in fraction July - August simulated fire sizes >= 10,000ha conditional on large (>200 ha) fire occurrence

(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)

CLIMATE	FRCC Historic	Admin 15%	Admin 30%	Admin 60%	Admin 100%	Bio 15%	Bio 30%	Bio 60%	Bio 100%
Historic 1961-90	-	-7%	-8%	-14%	-19%	-1%	-2%	-4%	-7%
CCSM A2 2035-64	29%	25%	23%	13%	8%	27%	27%	26%	24%
GFDL A2 2035-64	43%	38%	32%	26%	19%	40%	41%	40%	37%
CNRM A2 2035-64	52%	50%	44%	35%	29%	52%	50%	46%	46%
CCSM A2 2070-99	60%	58%	52%	45%	37%	60%	59%	56%	54%
GFDL A2 2070-99	92%	88%	82%	74%	65%	90%	92%	86%	83%
CNRM A2 2070-99	81%	75%	72%	63%	54%	77%	74%	73%	72%

Table A10a:	UpperMontane3 (area weighted)								
fraction July - August simulated fire sizes >= 10,000 ha conditional on large (>200 ha) fire occurrence									
	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	0.026	0.0215	0.0223	0.0191	0.0163	0.0249	0.0239	0.0227	0.0216
CCSM A2 2035-64	0.037	0.0337	0.0321	0.0281	0.0246	0.0352	0.0339	0.0325	0.0312
GFDL A2 2035-64	0.0398	0.037	0.0353	0.0306	0.0275	0.0384	0.0374	0.0359	0.0345
CNRM A2 2035-64	0.0405	0.0382	0.0362	0.0318	0.0286	0.0393	0.0381	0.0367	0.0354
CCSM A2 2070-99	0.0454	0.0431	0.0407	0.0363	0.0329	0.0439	0.0432	0.0412	0.0395
GFDL A2 2070-99	0.0517	0.0493	0.0467	0.0425	0.0379	0.0502	0.0499	0.0475	0.0459
CNRM A2 2070-99	0.0511	0.0482	0.0456	0.0413	0.0367	0.049	0.0477	0.0459	0.0445

Table A10b:									
percent change in fraction July - August simulated fire sizes >= 10,000ha conditional on large (>200 ha) fire occurrence									
	FRCC	*(averaged over 100 simulations per each of 445 Southern Sierra grid cells per month for 30 years)*							
CLIMATE	**Historic**	**Admin 15%**	**Admin 30%**	**Admin 60%**	**Admin 100%**	**Bio 15%**	**Bio 30%**	**Bio 60%**	**Bio 100%**
Historic 1961-90	-	-17%	-14%	-27%	-37%	-4%	-8%	-13%	-17%
CCSM A2 2035-64	42%	30%	23%	8%	-5%	35%	30%	25%	20%
GFDL A2 2035-64	53%	42%	36%	18%	6%	48%	44%	38%	33%
CNRM A2 2035-64	56%	47%	39%	22%	10%	51%	47%	41%	36%
CCSM A2 2070-99	75%	66%	57%	40%	27%	69%	66%	58%	52%
GFDL A2 2070-99	99%	90%	80%	63%	46%	93%	92%	83%	77%
CNRM A2 2070-99	97%	85%	75%	59%	41%	88%	83%	77%	71%