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Comparative Assessment of the Impacts of Prescribed Fire Versus Wildfire (CAIF): A Case Study in the Western U.S.

Progress Update to the Wildland Fire Leadership Council (WFLC)

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Disclaimer

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Background Information

Rationale for More Prescribed Fire in the Western U.S.:

- Increasing number of large wildfires (> 1,000 acres) and acres burned
- Increased likelihood of wildfire ignitions (e.g., fire suppression, changing climate, poor forest health and growth of wildland-urban interface)

Interagency Policy Challenges:

- USDA, DOI - Need to reduce the potential for negative impacts of wildfire by expanded use of prescribed fire as a management tool
- EPA - Need to limit air quality impacts, and subsequent public health impacts, attributed to different fire management strategies, specifically prescribed fire compared to wildfire

Scientific Approach to Forge a Common Understanding and Reconciliation of the Benefits of Prescribed Fire and the Adverse Health Effects of Smoke:

- EPA proposed in Jan. 2020 and CDC supported conducting a Health Impact Assessment (HIA) of prescribed fire versus wildfire

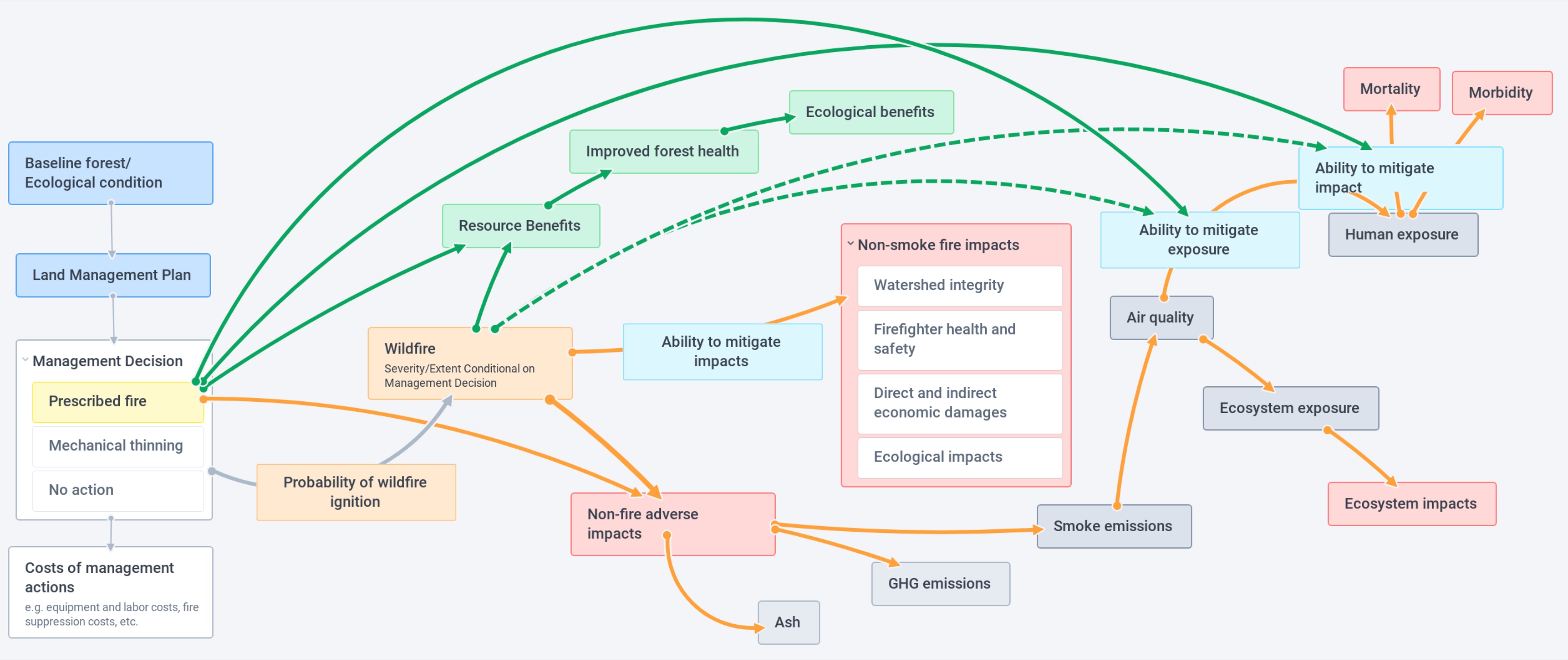
CAIF Goals:

- For two case study fires, compare air quality and health impacts between hypothetical scenarios of different fire management strategies, as well as a comparison between the prescribed fire activities in each fire location and the actual case study fire

CAIF Report Organization

- Consists of 9 chapters that can be divided into four categories:
  - Context
    - Conceptual Framework
    - Baseline Forest Conditions/Fire Regimes
    - Air Quality Monitoring of Wildland Fires
    - Human Health, Ecological Effects, Exposure Reduction Actions
    - Direct/Indirect Fire Damages
  - Modeling
    - Examination of actual fires and hypothetical scenarios based on different land management practices
  - Analysis
    - Environmental Benefits Mapping and Analysis Program – Community Edition (BenMAP – CE)
  - Interpretation/Integration
    - Integrated synthesis
      - Ties the entire report together, puts the results in the proper context, identifies limitations, and future directions

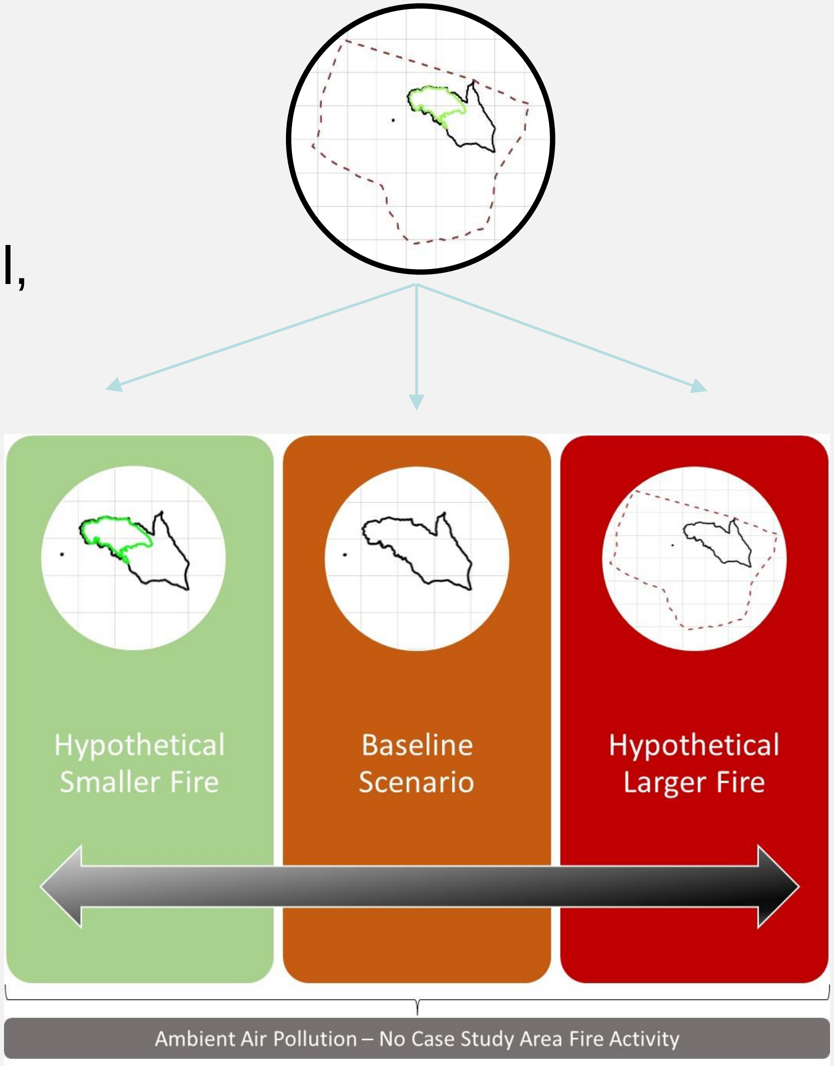
CAIF Report: Conceptual Framework



Note: In the figure, forest management inputs are colored dark blue, management decisions and their non-smoke related effects are colored white, resource benefits are colored green, mitigation actions are colored light blue, fires are colored yellow and orange, fire damages are colored red, and smoke exposure related elements are colored gray. The green arrows indicate positive effects, and the orange arrows indicate negative effects. Dotted lines represent linkages that may occur but are less certain than solid lines.

Comparison of Fire Management Strategies

Hypothetical Wildfire Scenarios:
1: Smaller fire, more prescribed fire, less fuel, less emissions
2: Larger fire, no prescribed fire, more fuel, more emissions



Analyses will compare:
1. Each hypothetical scenario to the actual wildfire
2. Actual wildfire to prescribed fires or wildfire that yielded positive resource benefits for the actual fire location

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Case Study 1: Timber Crater 6 (TC6) Fire

- TC6 Fire
  (~3,000 acres burned)
- Crater Lake National Park (Oregon) July 21-26, 2018
  - USFS and NPS Lands
- Selected because this wildfire is considered a success related to land management activities limiting the overall impact of a wildfire
- Suppression efforts benefited from past prescribed fire and mechanical thinning, which slowed fire spread

Photo of Bybee wildfire in 2016 at Crater Lake NP

TC6 video at https://vimeo.com/287892212

- The TC6 fire and previous land treatments were well characterized providing a platform for modeling hypothetical wildfire scenarios

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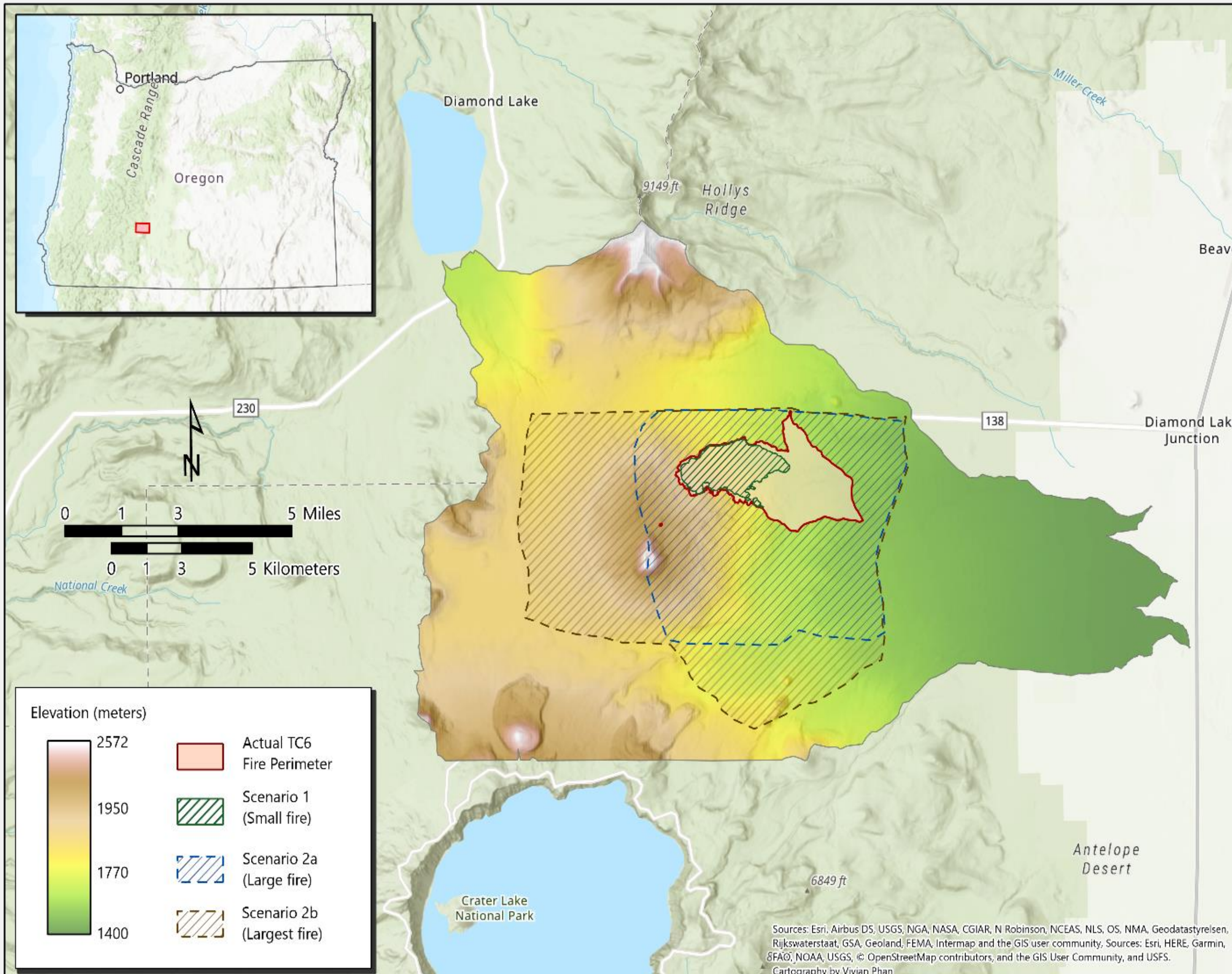
Case Study 1: Timber Crater 6 (TC6) Fire (cont.)



Case Study 2: Rough Fire

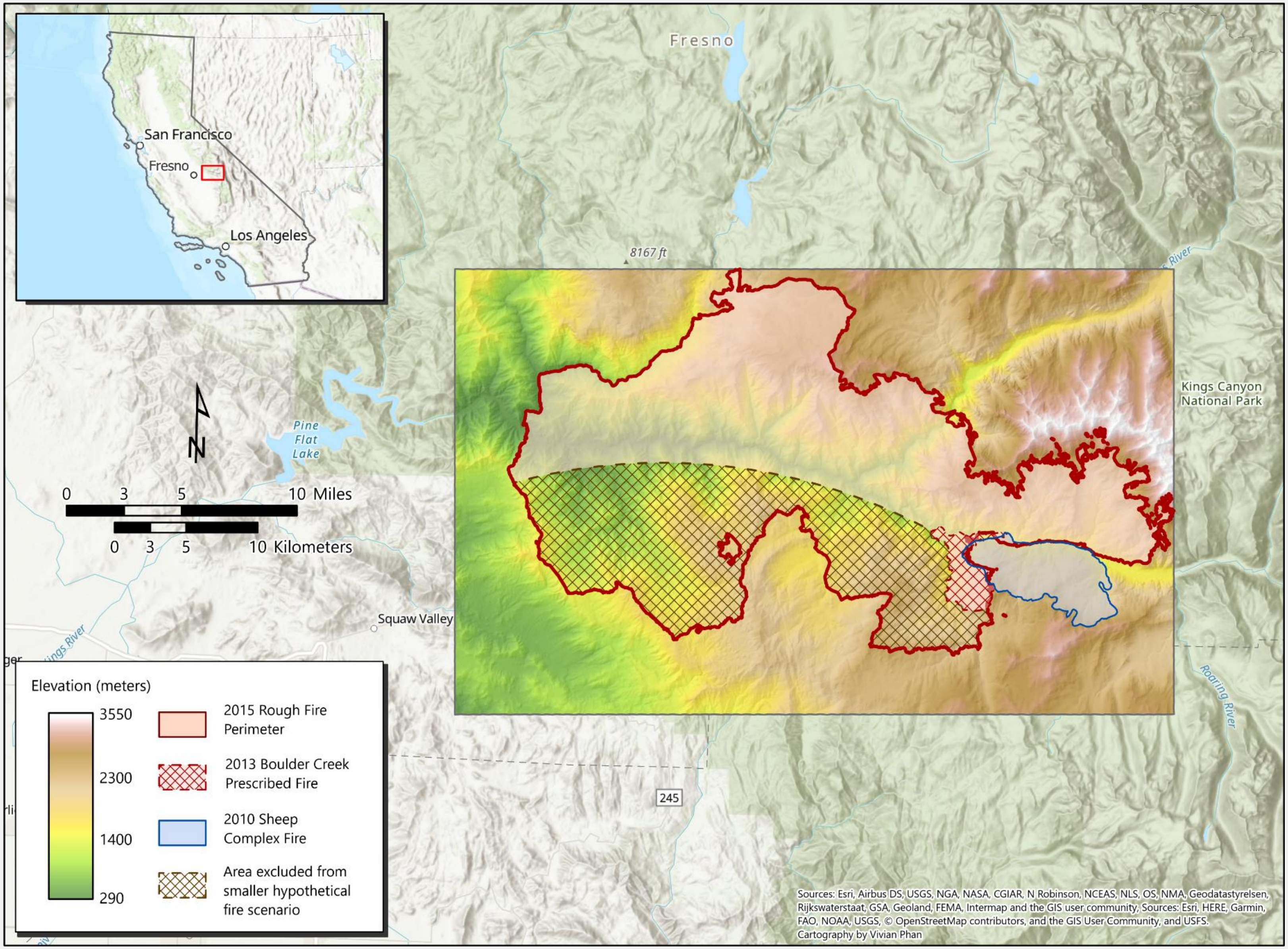
- Rough Fire (~150,000 acres burned)
- Sierra National Forest and Sequoia National Forest (California) July 31 – Oct 1, 2015
- Selected because it represented a larger fire in a different part of the U.S. to provide a compliment to the TC6 wildfire
- USFS has provided information suggesting the spread of this wildfire was slowed in certain areas due to past land management that allowed for better success of containment

Source: National Park Service

https://www.nps.gov/seki/learn/nature/rough-fire-interactive-map.htm

- The comparison for this case study includes an area that would have burned as part of the Rough Fire had it not been for past land management

Case Study 2: Rough Fire (cont.)



Air Quality and Health Impact Modeling Approach

Major Steps of the Process	Model(s) for each step of the process
Fire location & size	• Incident information for actual fires • Fire spread model/expert judgement for hypothetical fires
	Blue Sky Pipeline
Fuel type & loading	FCCSv3/LANDFIRE ⟷ VELMA
Fuel consumed	CONSUME
Fire emission factors	SERA database
Other emissions	SMOKE (emissions from mobile, EGUs , etc.)
Chemistry & transport	CMAQ photochemical grid model
Human health impacts	BenMAP

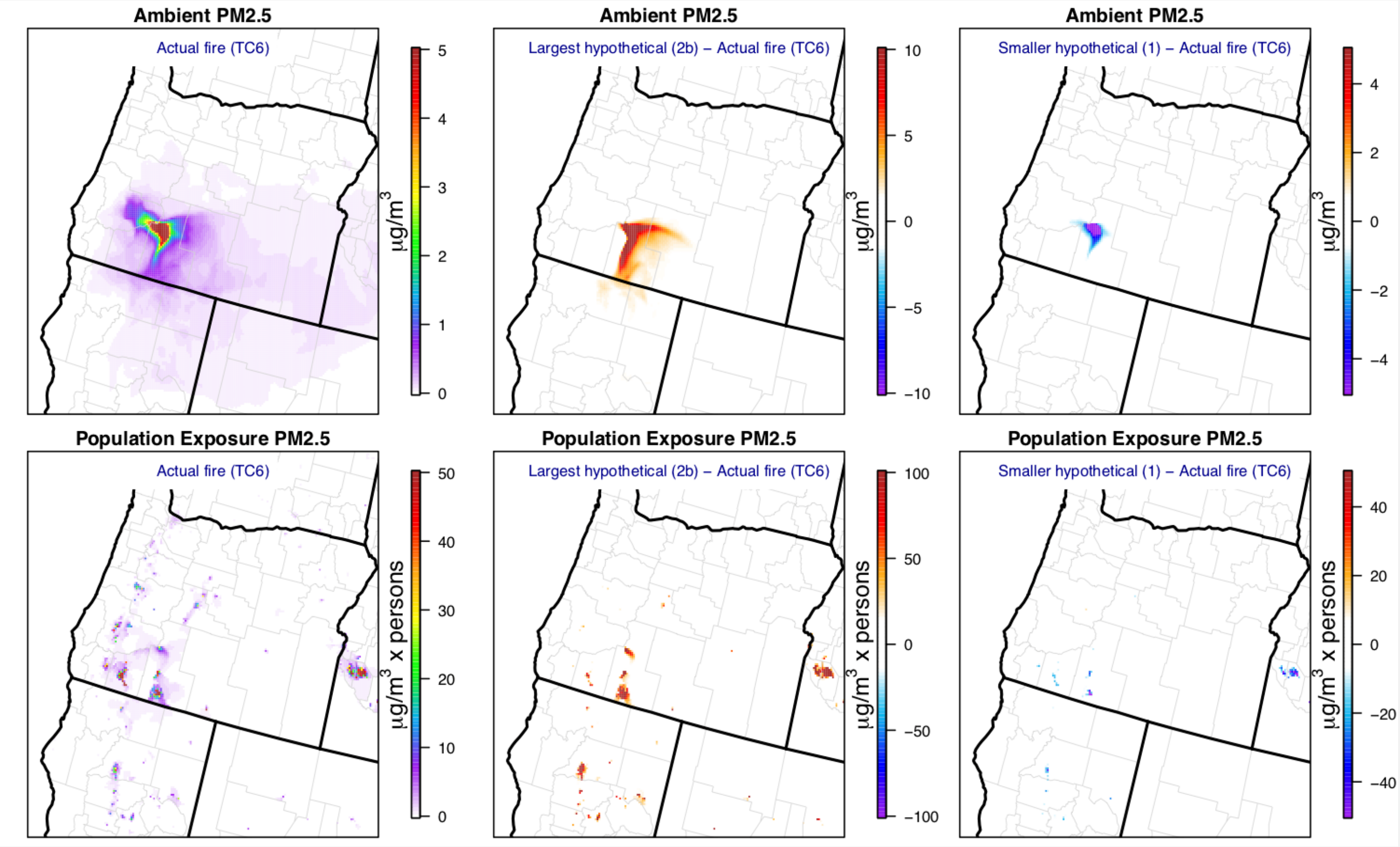
Characteristics of Case Study Air Quality Modeling

Fire/Burn Unit Name	Type	Modeled Time Period	Acres Burned (acres)	Total fuel consumption (tons)	Total fuel (tons)	PM2.5 emissions (tons)
Timber Crater 6	Actual wildfire	Jul 15 to 31, 2018	3,123	213,454	145,985	1,869
TC6 hypothetical smaller fire (1)	Hypothetical wildfire	Jul 15 to 31, 2018	1,237	37,954	91,419	1,041
TC6 hypothetical larger fire (2a)	Hypothetical wildfire	Jul 15 to 31, 2018	20,878	468,843	1,249,089	12,794
TC6 hypothetical larger fire (2b)	Hypothetical wildfire	Jul 15 to 31, 2018	27,373	727,180	1,825,606	20,015
Timber Crater 1978	Hypothetical prescribed fire	Sep 1 to 30, 2019	2,049	26,992	112,362	565
Cornerstone	Hypothetical prescribed fire	Sep 1 to 30, 2019	772	10,671	69,787	232
Timber Crater 1/2	Hypothetical prescribed fire	Sep 1 to 30, 2019	633	7,751	37,649	157
2019 actual prescribed fires	Actual prescribed fire	Sep 1 to 30, 2019	886	6,206	20,955	117
Rough fire	Actual fire	Aug 1 to Sep 30, 2015	145,438	3,284,638	7,128,199	85,638
Rough hypothetical smaller fire (1)	Hypothetical wildfire	Aug 1 to Sep 30, 2015	113,349	2,631,258	6,450,696	68,949
Rough hypothetical larger fire (2)	Hypothetical wildfire	Aug 1 to Sep 30, 2015	154,354	3,448,094	7,562,392	89,349
Boulder Creek Unit 1	Hypothetical prescribed fire	Sep 26 to Oct 7, 2014	3,289	30,163	90,452	499
Sheep Complex fire	Actual fire	Jul 30 to Sep 30, 2010	8,916	103,037	434,193	2,344

Table 5-2. Wildfire and prescribed fires modeled as part of the Timber Crater 6 (TC6) and Rough Fire case studies.

TC6 Fire: Air Quality Modeling Results ($PM_{2.5}$)

Figure 5-8. Episode average $PM_{2.5}$ impacts and aggregate population exposure from the actual Timber Crater 6 fire and the difference between the actual fire and largest (2b) and smallest (1) hypothetical scenarios.



- Hypothetical 1 – small fire, has a shorter duration, and smaller daily average $PM_{2.5}$ impacts
- Hypothetical 2b – largest, “worst-case” scenario has larger daily fire perimeters and extends several more days longer than the actual TC6 fire, resulting in larger impacts near the fire and downwind

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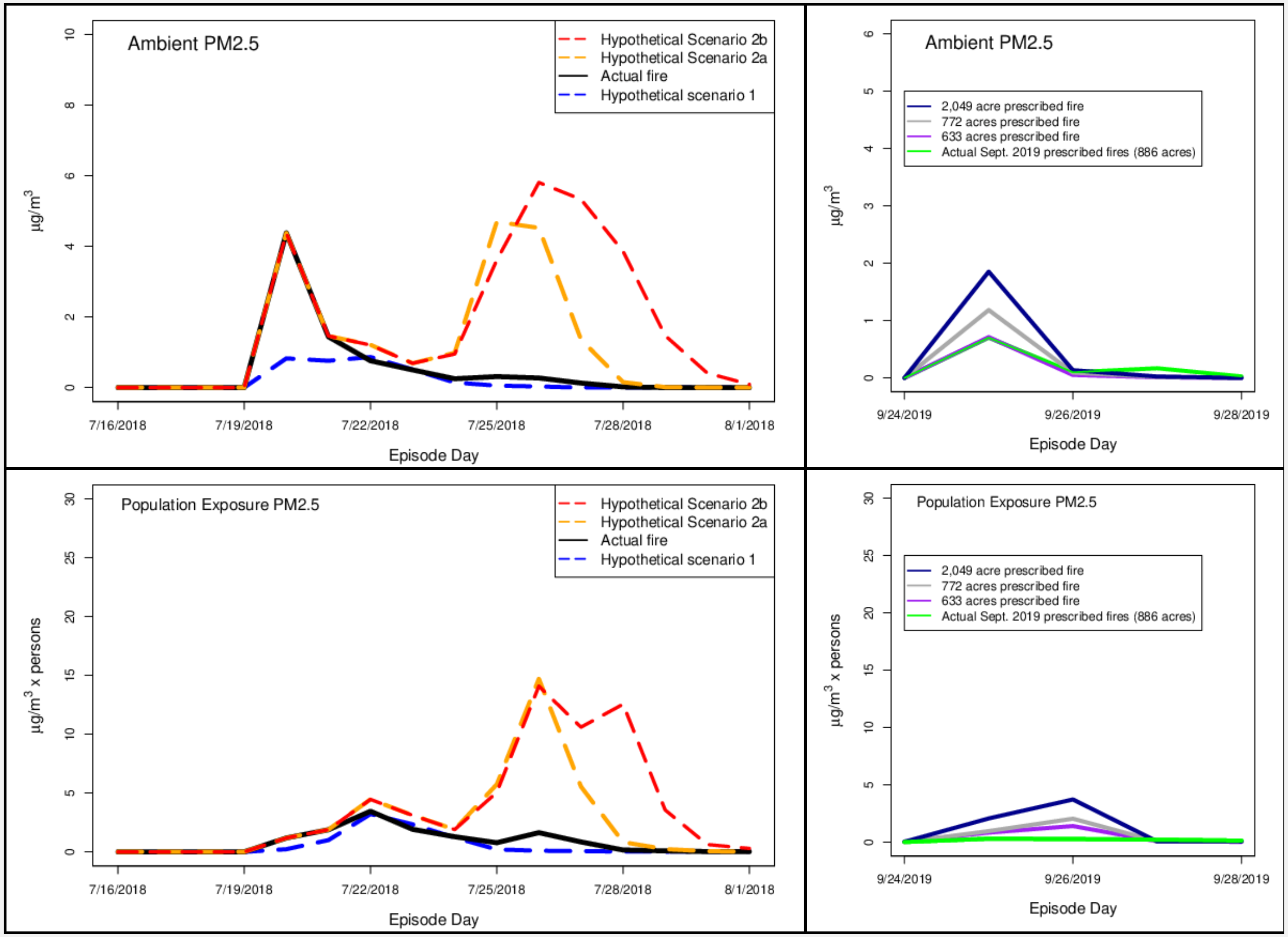
TC6 Fire: Comparison of $PM_{2.5}$ Concentrations and Population Exposures between Hypothetical Scenarios and Prescribed

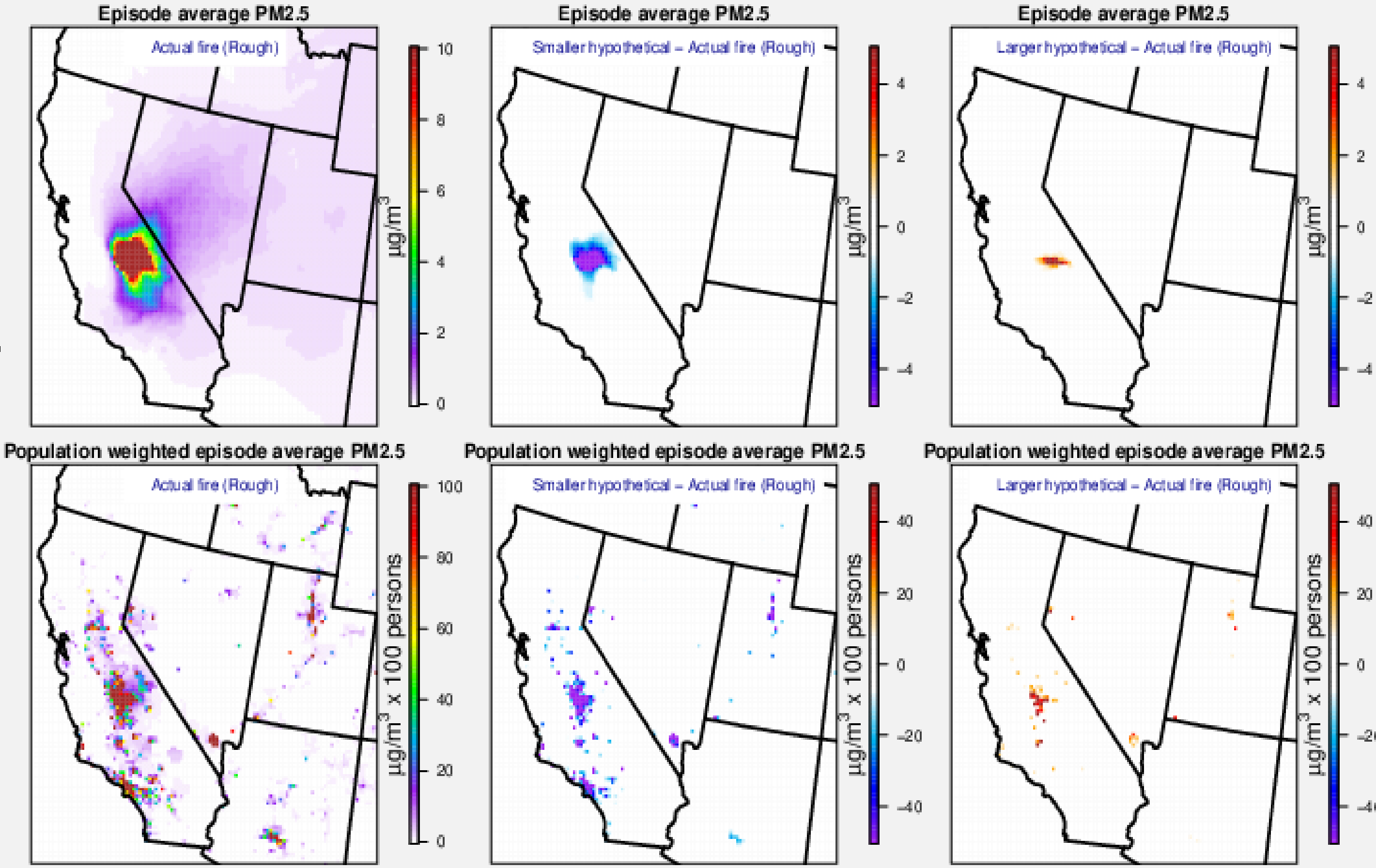
Figure 5-10. Daily average $PM_{2.5}$ ambient (top row) impacts and estimates of aggregate population exposure (bottom row) from the Timber Crater (TC6) scenarios (left) and prescribed fire scenarios (right).



- TC6 Fire was short in duration, larger hypothetical scenarios lasted for several more days leading to higher average $PM_{2.5}$ concentrations and population exposures
- Atmospheric conditions during actual TC6 Fire and prescribed fires reduced population exposure

Rough Fire: Air Quality Modeling Results ($PM_{2.5}$)

Figure 5-15. Episode average $PM_{2.5}$ impacts from the actual fire scenario and the difference between the actual scenario and largest and smallest hypothetical scenarios.



- Average $PM_{2.5}$ concentrations and population exposure are greatest in CA and decrease downwind
- Hypothetical scenario 1, smaller fire, substantially smaller average $PM_{2.5}$ concentrations and population exposure
- Hypothetical scenario 2, larger fire, $PM_{2.5}$ impacts were relatively similar to the actual Rough Fire

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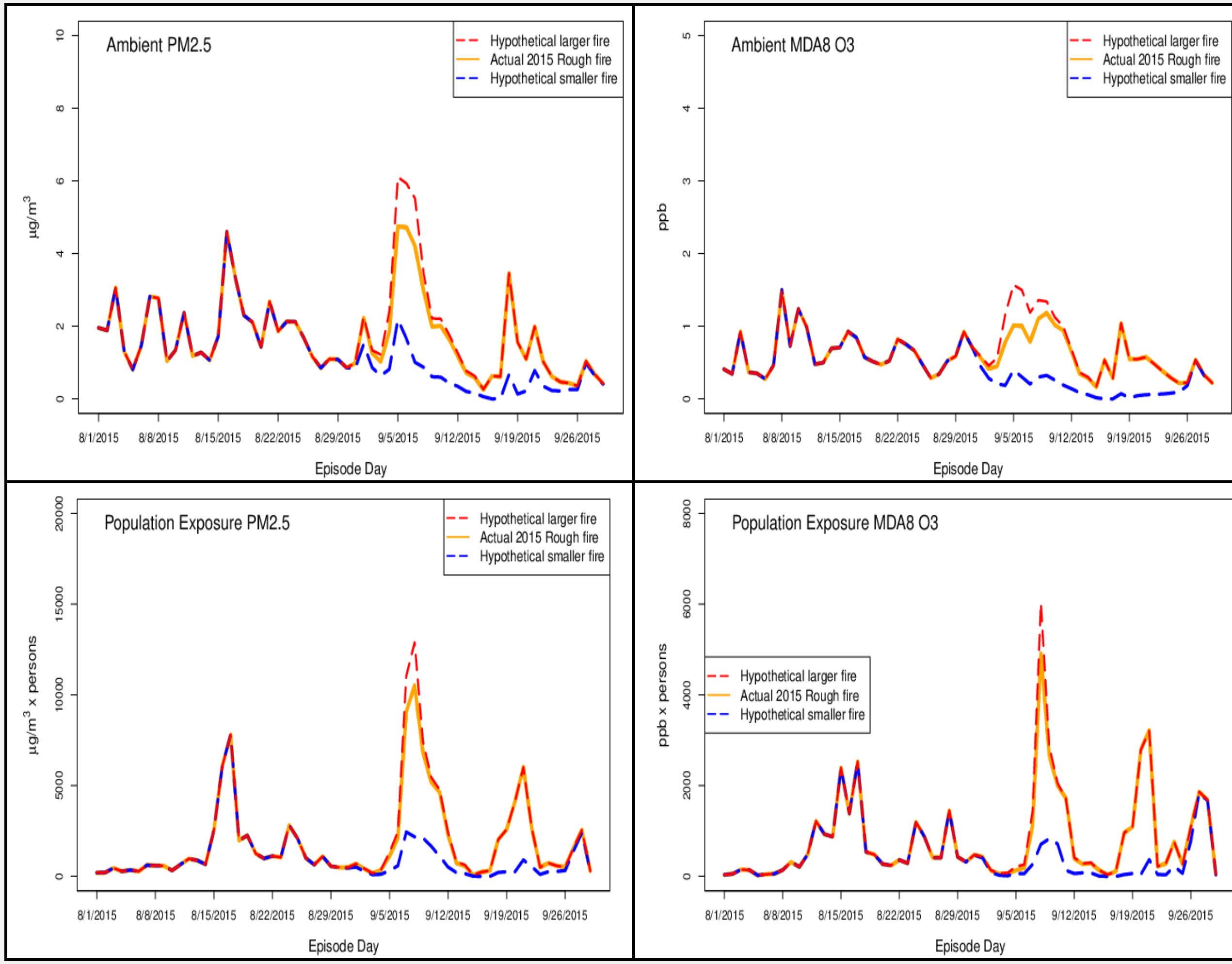
Rough Fire: Comparison of $PM_{2.5}$ and O_3 Concentrations and Exposures between Actual and Hypothetical Scenarios

Figure 5-17. Daily average $PM_{2.5}$ ambient (left) and MDA8 O_3 (right) impacts and aggregate population exposure (bottom row) from the Rough fire scenarios.



- Duration of the actual Rough Fire and hypothetical scenarios was similar
- Atmospheric conditions influence population exposure
- Compared to $PM_{2.5}$, ozone population exposure is more variable, and does not follow the temporal pattern of concentrations

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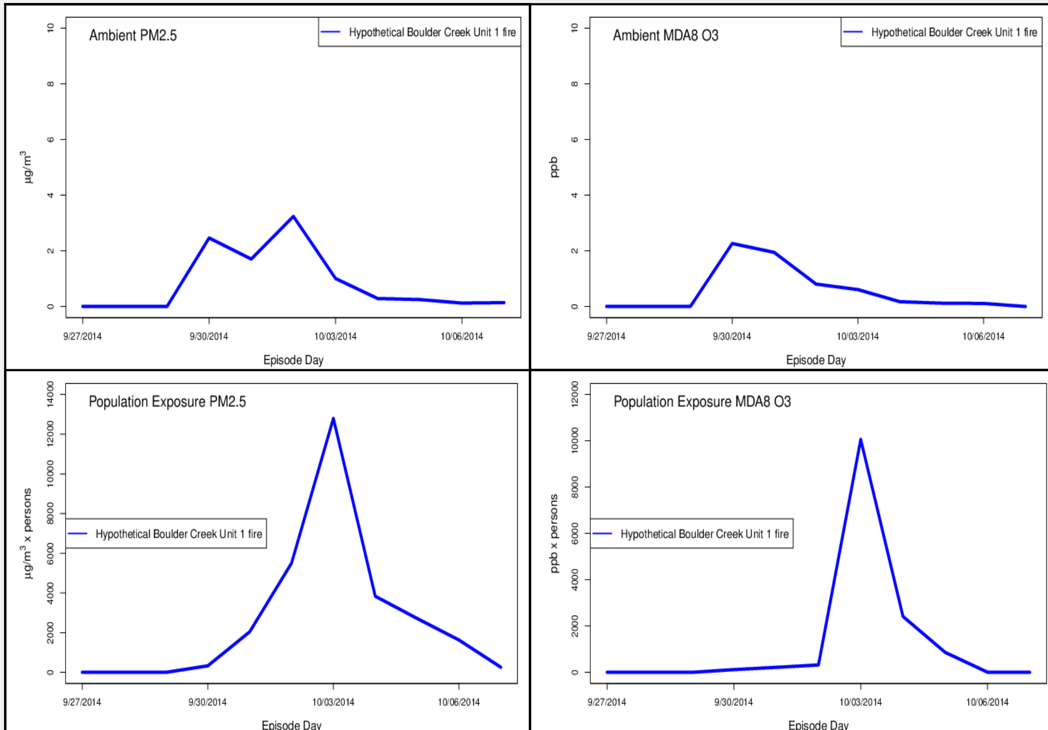
Rough Fire: Comparison of $PM_{2.5}$ and O_3 Concentrations and Exposures between Sheep Complex Fire and Boulder Creek Prescribed Fire



- Proposed Boulder Creek Prescribed Fire had higher population exposure, lasted only a few days
- Sheep Complex Fire for a few months, resulting in a low concentration, but persistent population exposure

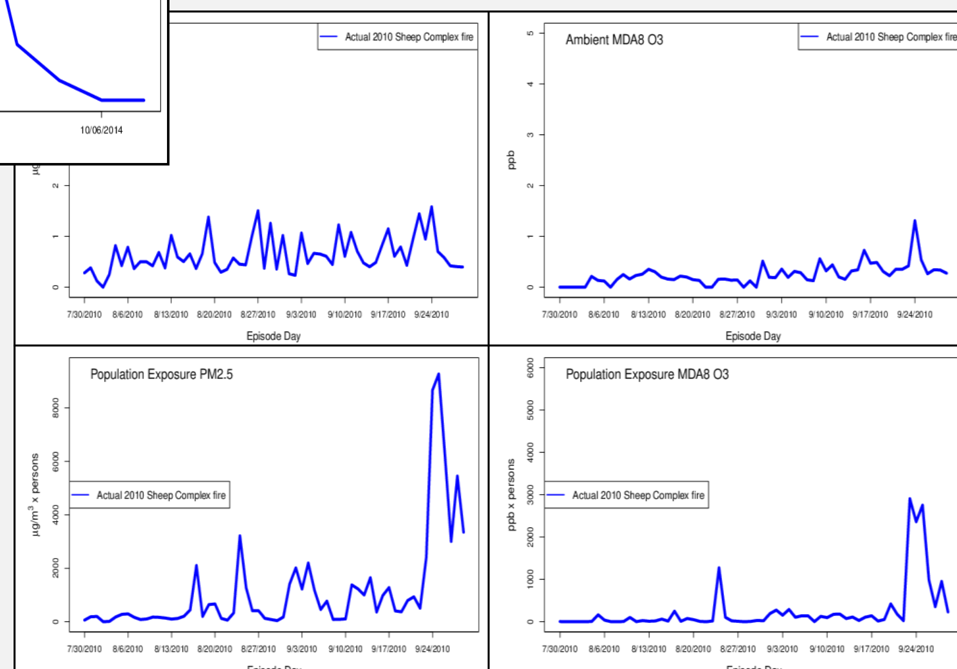


Figure 5-19 (<u>Top</u>). Daily average $PM_{2.5}$ ambient (left) and MDA8 O_3 (right) impacts and aggregate population exposure (bottom row) from the hypothetical Boulder Creek Unit 1 Prescribed Fire.

Figure 5-20 (<u>Bottom</u>). Daily average ambient $PM_{2.5}$ (left) and MDA8 O_3 (right) concentrations and estimates of aggregate population exposure (bottom row) from the 2010 Sheep Complex Fire.

Evaluation of Health Effects Evidence to Support BenMAP – CE Analyses

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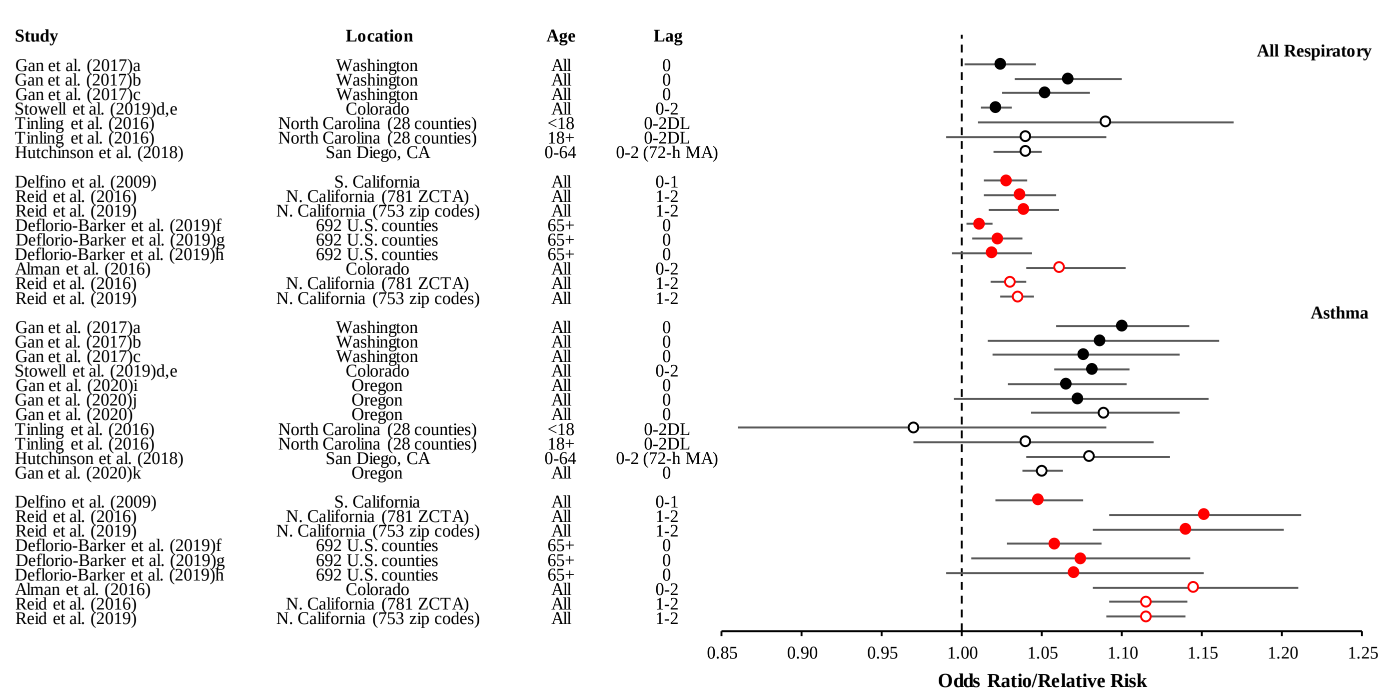
- Decades of research demonstrating the health effects of ambient air pollution, including $PM_{2.5}$ and Ozone, forms the basis of the evidence for the health effects of wildland fire smoke
- Assessment of wildland fire studies focused on U.S.-based epidemiologic studies
  - Different exposure metrics used across studies
- Consistent, positive associations across studies examining respiratory-related and asthma hospital admissions and emergency department visits
- Fewer U.S.-based studies examining cardiovascular outcomes and mortality
- Evaluation supported use of standard EPA functions ($PM_{2.5}$ and ozone) for BenMAP analysis



Legend:
● = studies that used smoke/wildfire $PM_{2.5}$ as the exposure indicator
● = studies that used ambient $PM_{2.5}$ measurements as the exposure indicator
Solid circles = hospital admissions
Open circles = ED visits

Fig. 6-1. U.S.-based Epidemiologic Studies Examining the Relationship Between Short-term Wildfire Smoke Exposure and Combinations of Respiratory-Related Diseases and Asthma Hospital Admissions and Emergency Department Visits

Mitigation of Prescribed Fire and Wildfire Smoke Exposure

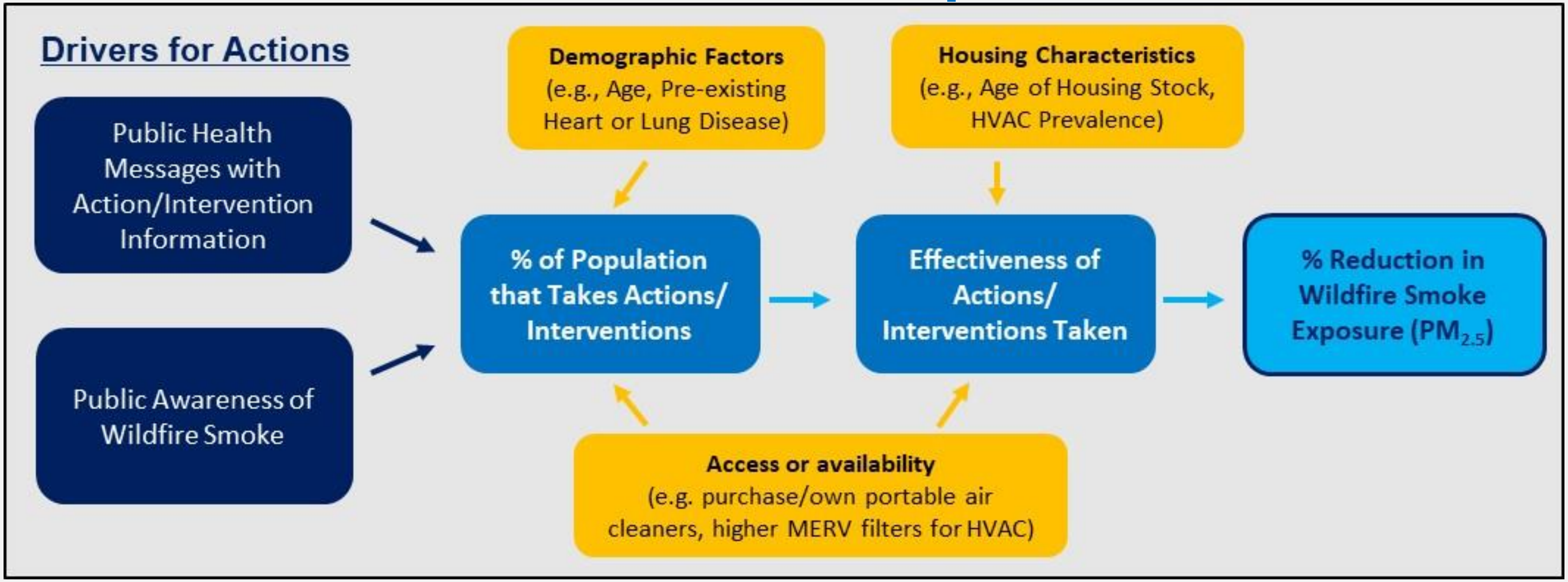
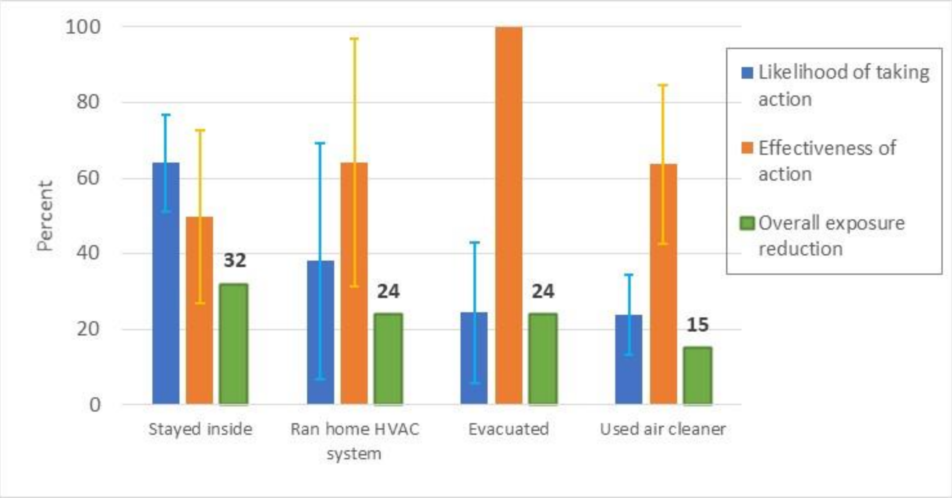


Figure 6-4. Framework for estimating potential reduction in wildfire smoke exposure due to actions and interventions



Overview:

- Exposure/mitigation data mostly wildfires
- Variability high between studies, and within studies (between homes/filters)
- Available data used to provide a crude estimation of potential reduction in $PM_{2.5}$ exposure from wildfire smoke for different actions/interventions

Note: Both the TC6 and Rough Fires had ARAs deployed, and they disseminated exposure reduction actions to the public

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BenMAP – CE Analyses: Overview

Objectives:

- To quantify the number and economic value of health outcomes associated with actual/hypothetical wildfire and prescribed fire scenarios

Analysis Plan:

- Burden analysis for each scenario, i.e., each air quality surface compared to a baseline of ambient air pollution – no case study fire activity
- Main analyses used standard EPA health impact functions for ambient exposures to $PM_{2.5}$ and ozone
  - <u>$PM_{2.5}$</u>: health outcomes examined include mortality, respiratory- and cardiovascular-related emergency department visits and hospital admissions
  - <u>Ozone</u>: health outcomes examined include mortality, respiratory-related emergency department visits and hospital admissions

Sensitivity Analyses:

- Use risk coefficients from epidemiologic studies focusing on wildfire-specific $PM_{2.5}$ exposure for asthma emergency department visits, respiratory- and cardiovascular-related hospital admissions
- Calculated crude estimation of reduction in total number of health impacts that could be realized based on different exposure reduction actions/interventions

TC6 Fire Case Study

BenMAP – CE Results: Estimated $PM_{2.5}$ Premature Deaths and Illnesses (95% CI)

Scenario	ED Visits		Hospital Admissions		Mortality	
	Respiratory	CV	Respiratory	CV	ST	LT
Actual Fire	0.2 (0.0 to 0.4)	0.1 (-0.0 to 0.2)	0.0 (0.0 to 0.0)	0.0 (0.0 to 0.1)	0.04 (0.01 to 0.08)	---
Scenario 1 (small)	0.1 (0.0 to 0.2)	0.1 (-0.0 to 0.1)	0.0 (0.0 to 0.0)	0.0 (0.0 to 0.0)	0.03 (0.01 to 0.5)	---
Scenario 2a (large)	0.8 (0.2 to 1.6)	0.4 (-0.1 to 0.9)	0.1 (0.0 to 0.1)	0.2 (0.1 to 0.2)	0.16 (0.01 to 0.32)	---
Scenario 2b (largest)	1.2 (0.2 to 2.5)	0.6 (-0.2 to 1.3)	0.1 (0.1 to 0.2)	0.3 (0.2 to 0.3)	0.25 (0.01 to 0.49)	---
Prescribed Fires	0.04 (0.01 to 0.08)	0.02 (-0.01 to 0.05)	0.00 (0.00 to 0.01)	0.01 (0.01 to 0.01)	0.01 (0.001 to 0.02)	---

Note: Prescribed fires estimates represent the combined impact from the 4 prescribed fires that were modeled.

Rough Fire Case Study

BenMAP – CE Results: Estimated $PM_{2.5}$ Premature Deaths and Illnesses (95% CI)

Scenario	ED Visits		Hospital Admissions		Mortality	
	Respiratory	CV	Respiratory	CV	ST	LT
Actual Fire	47.3 (9.3 to 98.5)	19.7 (-7.6 to 46.0)	6.9 (3.0 to 10.7)	8.6 (6.2 to 10.9)	---	80.0 (53.6 to 105.4)
Scenario 1 (small)	28.2 (5.5 to 58.7)	11.8 (-4.6 to 27.6)	4.2 (1.8 to 6.5)	5.0 (3.6 to 6.3)	---	48.1 (32.2 to 63.4)
Scenario 2 (large)	49.8 (9.8 to 103.7)	20.7 (-8.0 to 48.4)	7.3 (3.2 to 11.2)	9.1 (6.6 to 11.5)	---	84.3 (56.5 to 111.1)
Sheep Complex Fire	6.6 (1.3 to 13.7)	2.7 (-1.0 to 6.2)	0.9 (0.4 to 1.4)	0.9 (0.7 to 1.2)	---	10.1 (6.7 to 13.3)
Boulder Creek Fire: Prescribed Fire	1.1 (0.2 to 2.4)	0.5 (-0.2 to 1.1)	0.2 (0.1 to 0.3)	0.2 (0.2 to 0.3)	---	1.9 (1.3 to 2.5)

Rough Fire and TC6 Fire Case Studies

BenMAP – CE Results: Estimated Value of Deaths and Illnesses (95% CI; millions 2015$)

TC6 Fire

Scenario	Sum of value of morbidity and short-term exposure mortality
Actual Fire	$18 ($2 to $47)
Scenario 1 (small)	$10 ($1 to $26)
Scenario 2a (large)	$66 ($6 to $170)
Scenario 2b (largest)	$100 ($9 to $270)
Prescribed Fires	$4 ($0 to $9)

Rough Fire

Scenario	Sum of value of morbidity and long-term exposure mortality
Actual Fire	$3,000 ($260 to $7,900)
Scenario 1 (small)	$1,800 ($160 to $4,700)
Scenario 2 (large)	$3,100 ($270 to $8,300)
Sheep Complex Fire	$350 ($20 to $960)
Boulder Creek Fire: Prescribed Fire	$60 ($5 to $160)

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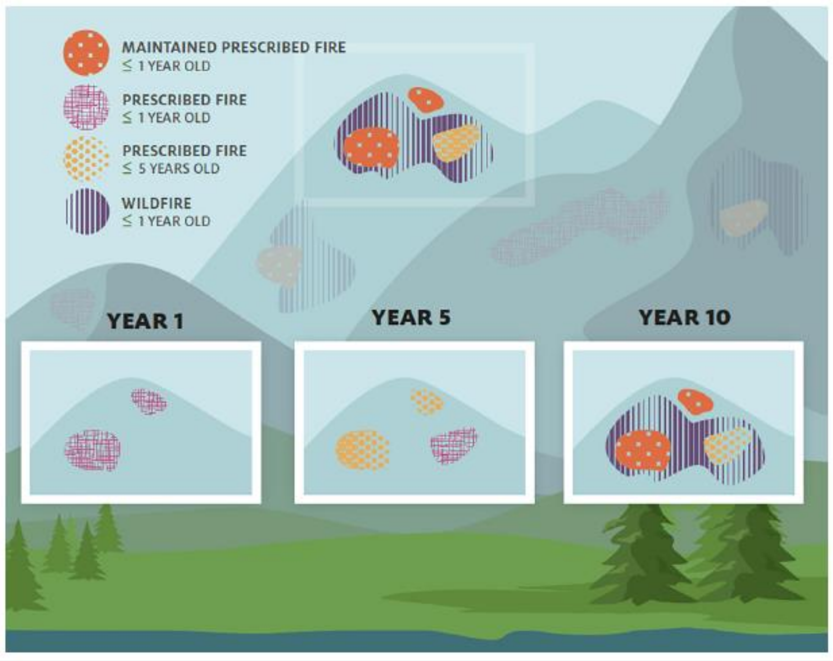
Limitations of Analyses

- Results are specific to the locations of the case study fires
  - Cannot be extrapolated to other geographic locations
- Analyses are retrospective and conducted in areas that experienced a wildfire
- Analyses **do not incorporate an estimate of uncertainty** to account for **the probability that a wildfire may (or may not) occur** within an area where there was prescribed fire activity
- Analyses **do not consider the temporal and spatial components of prescribed fire activity** and their influence on wildfire size and duration; ignition probabilities for wildfires; and other factors that could influence wildfire occurrence
- Expert judgment was relied upon to determine fire spread and perimeters of hypothetical scenarios for both case studies
- Analyses **do not factor in the growth of the WUI** and how this could change the composition of smoke and the likelihood of population exposures over time
- Additional data gaps identified that are not specific to the analyses conducted within the assessment
  - Air quality monitoring, exposure assessment, health effects

Key Insights of Case Study Analyses

- Smoke impacts are dependent upon proximity to population centers to wildland fire events
- Predicted concentrations of $PM_{2.5}$ from prescribed fires are smaller in magnitude and shorter in duration than hypothetical scenarios or actual wildfires
  - Smaller estimated aggregate population $PM_{2.5}$ exposures for prescribed fires can be attributed to the small size of each prescribed fire and the meteorological characteristics of the days in which the prescribed fires occurred
  - Although prescribed fires occur on specific days to minimize population exposures, analyses show that air quality and public health impacts are still observed
- Within case study areas, ozone had minimal air quality and public health impacts
- Wildfires that are short in duration and size and not near large population centers, such as the TC6 Fire, can still result in public health impacts
- Well designed prescribed fires targeted for specific locations (e.g., Boulder Creek Prescribed Fire and prescribed fires around TC6 Fire), can potentially reduce the size and resulting air quality and public health impacts of future wildfires
- Communicating the benefits of actions and interventions that can be used to reduce or mitigate $PM_{2.5}$ exposures can contribute to reducing the public health impacts attributed to wildland fire smoke

Future Considerations

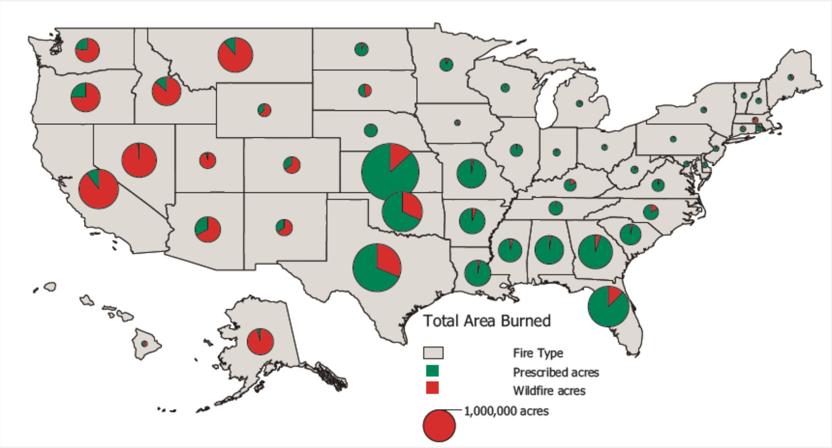


Source: Hunter and Robles (2020). Forest Eco. Manage.

Spatial/Temporal Comparison of Prescribed Fire and Wildfire

- Characterization of prescribed fire and wildfire air quality impacts in different parts of the country
- Centralized repository of prescribed fire data to enhance future assessments

- Identification/development of methods to account for temporal and spatial component of prescribed fires and relationship with wildfires
- Enhanced characterization of relationship between prescribed fire and wildfire
- Characterization of role of topography and meteorology, and frequency of prescribed fires on population exposures to smoke



Source: Baker et al. (2020). EM Magazine.

Fig. 1-3. Acres burned by wildfire (red) and prescribed fire (green) in the U.S. in 2018.

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Timeline

Report

- Draft Report: Completed and sent to contractor for peer review
- External Peer Review: Scheduled to be completed by end of May
- Final Report: Scheduled to be delivered to WFLC end of August

Next Steps

- Identify portions of the report that can be turned into peer reviewed publications
- Develop messaging materials with the WFLC Joint Communications workgroup
- Plan post-report workshop to identify future directions to build upon this initial interagency collaboration

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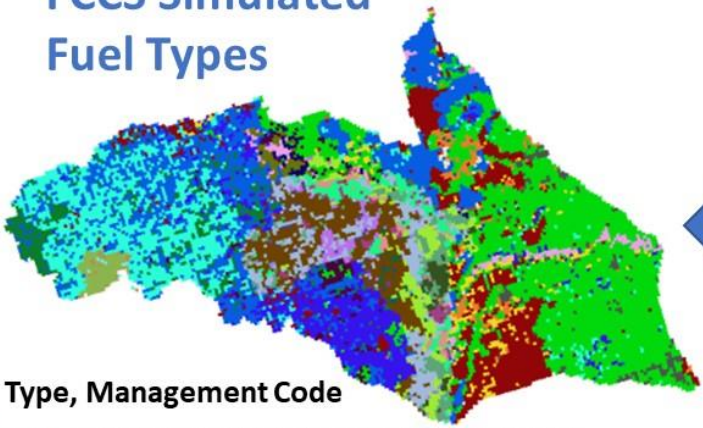
Questions?

Fuel Type and Loading – VELMA and FCCS: Example from TC6

FCCS Simulated Fuel Types

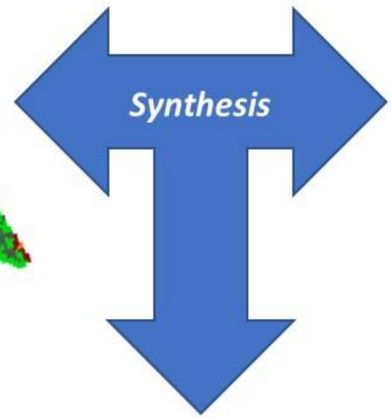


Fuel Type, Management Code

- 530,133 Temperate Pacific subalpine-montane wet meadow
- 506,133 Idaho fescue-California oatgrass grassland
- 319,133 Pacific silver fir-Sitka alder forest
- 315,133 Showy sedge-black alpine sedge grassland
- 273,133 Engelmann spruce-Douglas-fir-white fir-ponderosa pine forest
- 238,133 Pacific silver fir-mountain hemlock forest
- 238,132 Pacific silver fir-mountain hemlock forest
- 237,133 Huckleberry heather shrubland
- <.................> 18 Other Fuelbeds

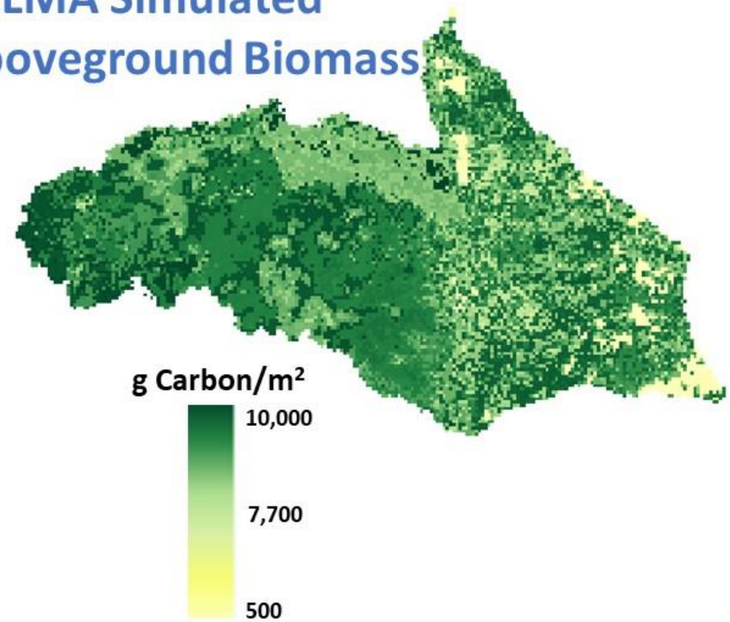
Management Code

111: Rx burn
132: 0 – 5 years since WF burn
133: 5 – 10 years since WF burn



Bluesky Pipeline

VELMA Simulated Aboveground Biomass



Synthesis of fuel type details and loadings will better characterize smoke emissions and dispersion

TC6 Fire: Air Quality Modeling Results (O_3)

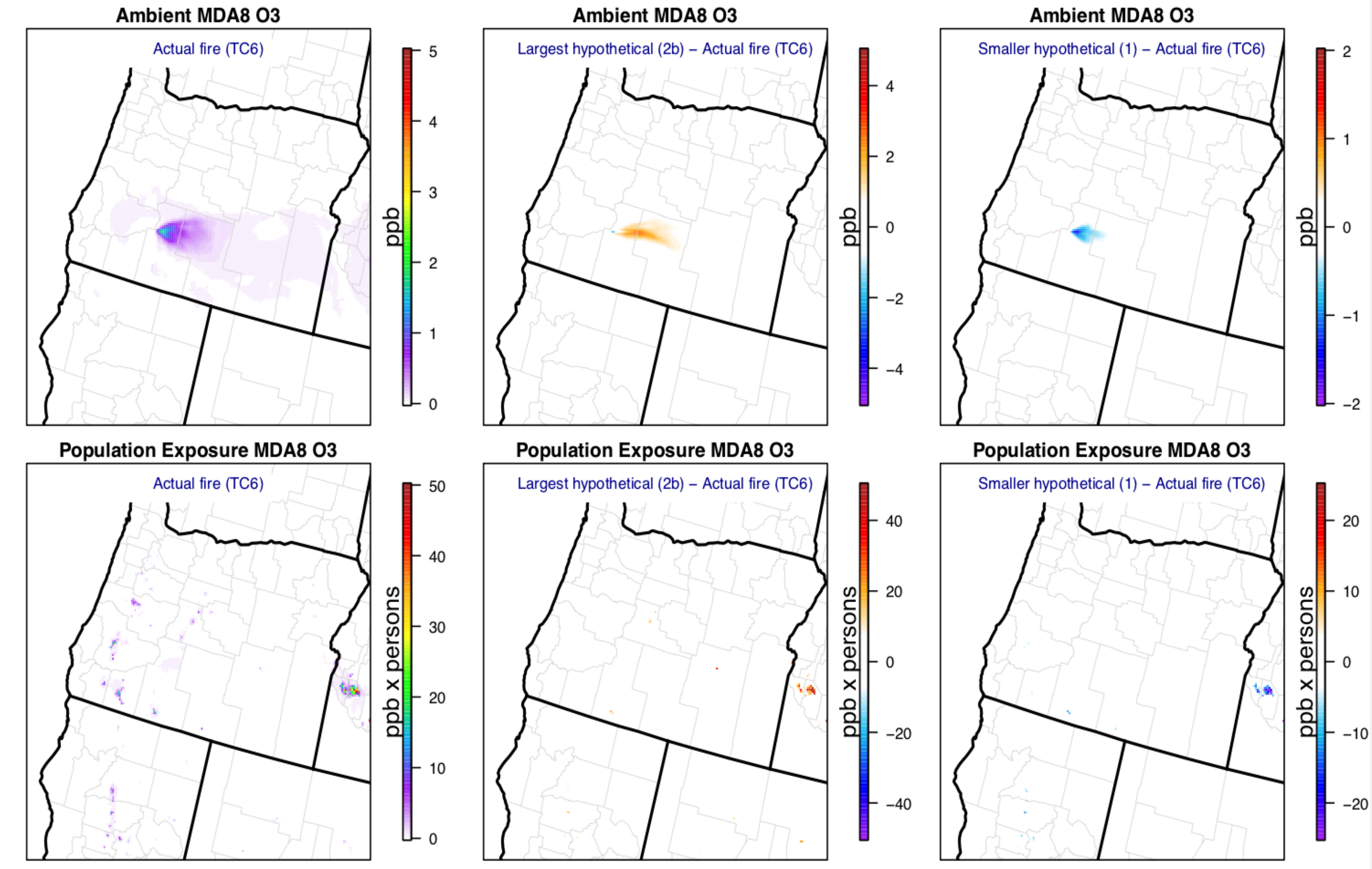


Figure 5-9. Episode average MDA8 O_3 impacts and aggregate population exposure from the actual Timber Crater 6 (TC6) fire and the difference between the actual fire and largest (2b) and smallest (1) hypothetical scenarios.

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TC6 Fire: Comparison of O_3 Concentrations and Exposures between Hypothetical Scenarios and Prescribed Fires

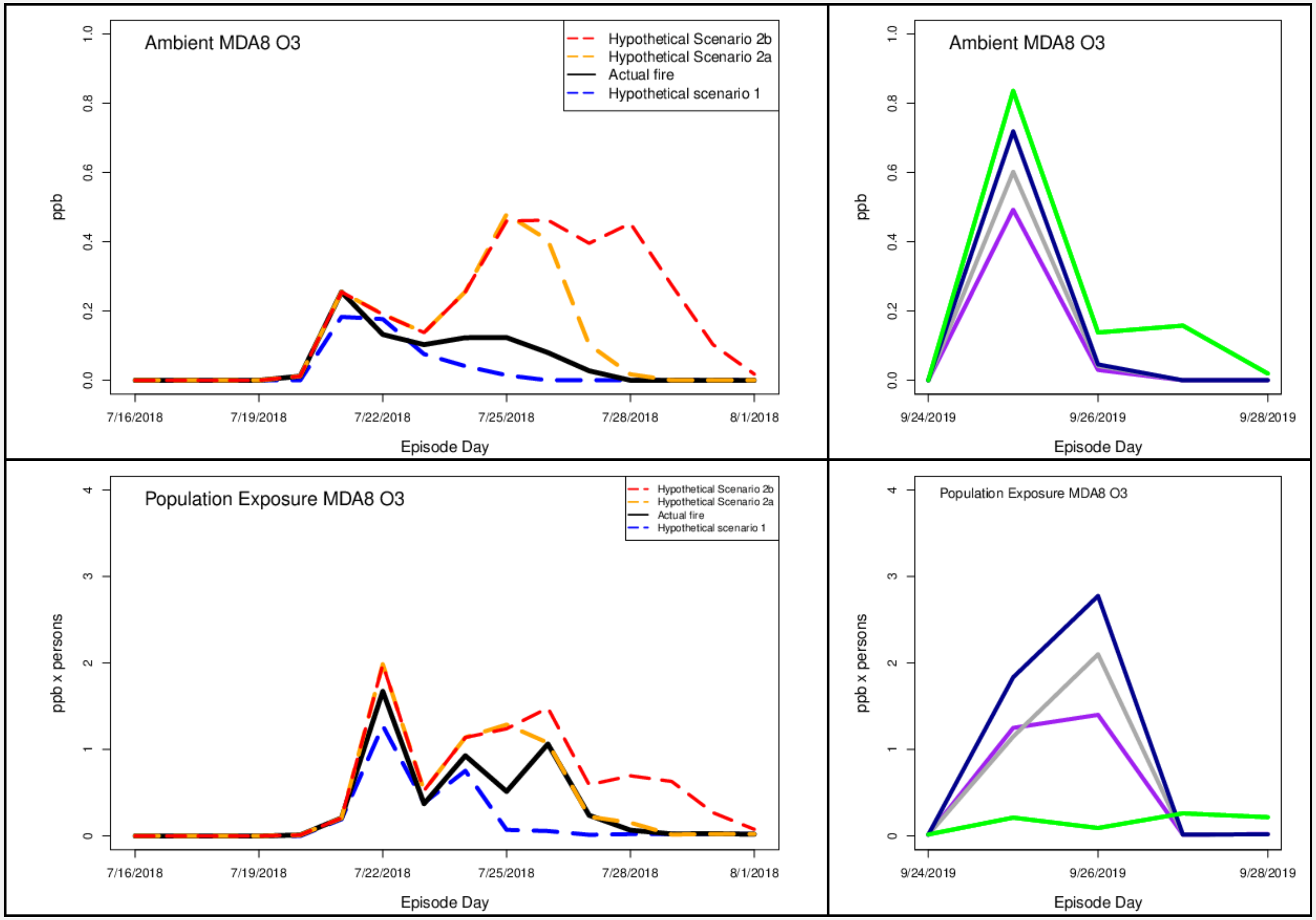


Figure 5-11. Daily average MDA8 O_3 ambient (top row) impacts and estimates of aggregate population exposure (bottom row) from the Timber Crater 6 (TC6) scenarios (left) and prescribed fire scenarios (right).

Rough Fire: Air Quality Modeling Results (O_3)

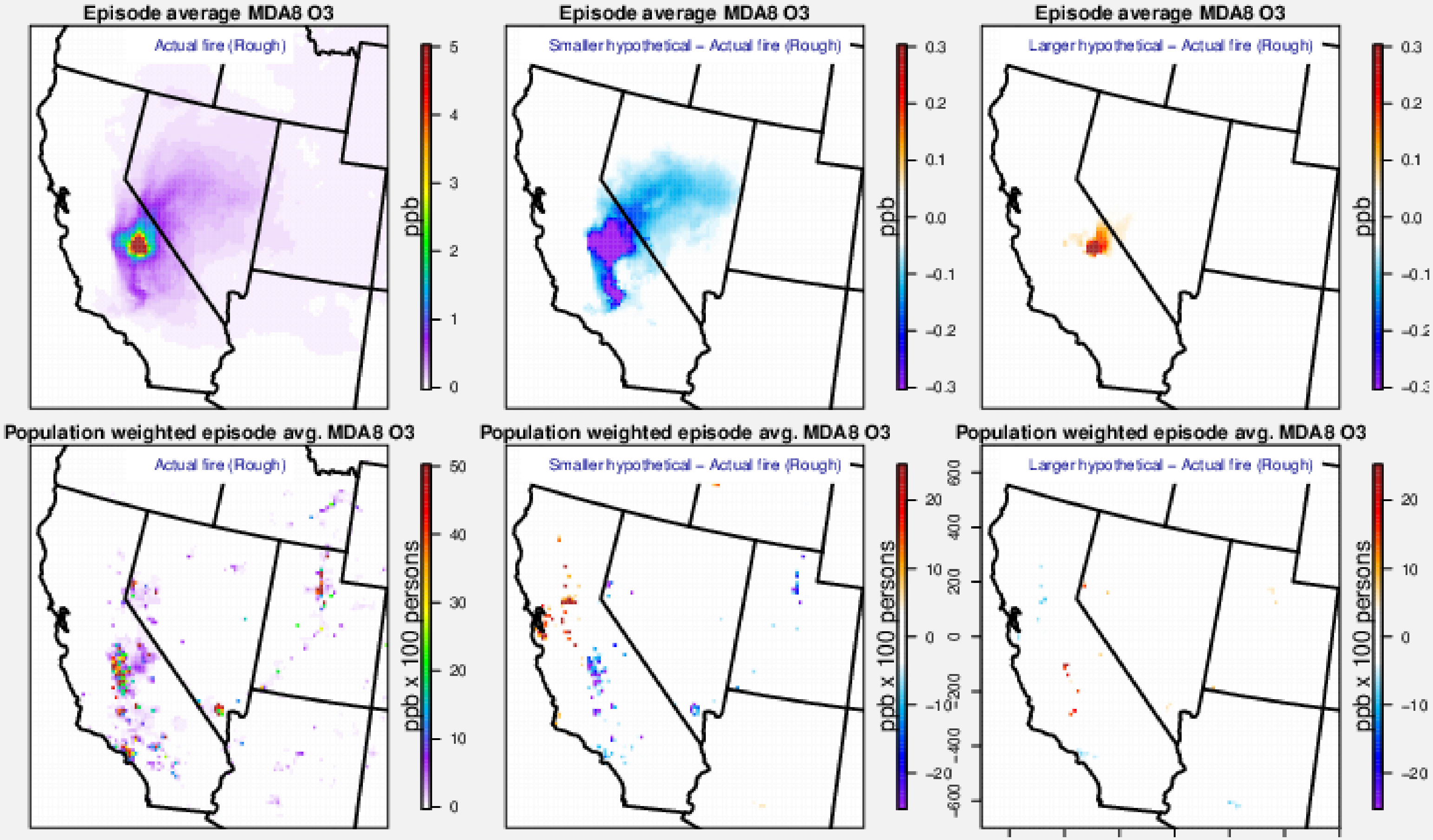
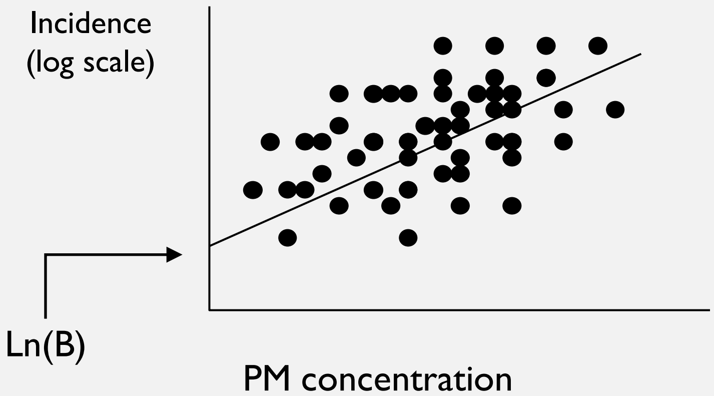


Figure 5-16. Episode average MDA8 O_3 impacts from the actual fire scenario and the difference between the actual scenario and smallest (scenario 1) and largest (scenario 2) hypothetical scenarios.

Environmental Benefits Mapping and Analysis Program – Community Edition (BenMAP – CE): Background

Epidemiology study



$$\text{Ln}(y) = \text{Ln}(B) + \beta(PM)$$

Health impact function

$$\Delta Y = Yo\ (1 - e^{-\beta \Delta PM}) * Pop$$

Yo – Baseline Incidence

ß - Effect estimate

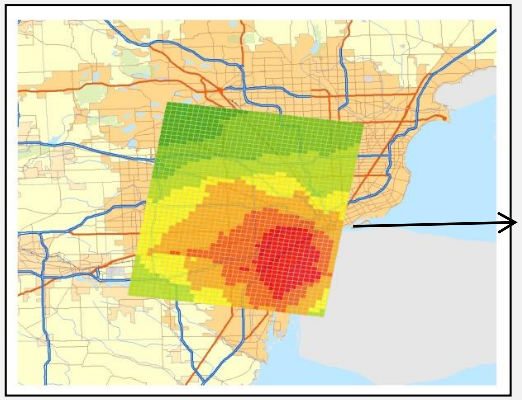
ΔPM – Air quality change

Pop – Exposed population

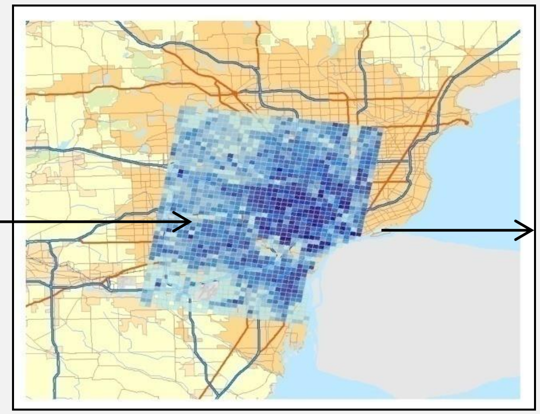
BenMAP – CE: Steps to Calculating Health Impacts

$$\Delta Y = Yo\,(1 - e^{-\beta \Delta PM}) * Pop$$

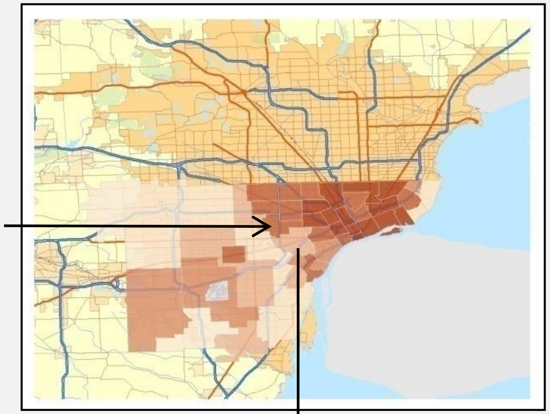
Pollutant change



Population



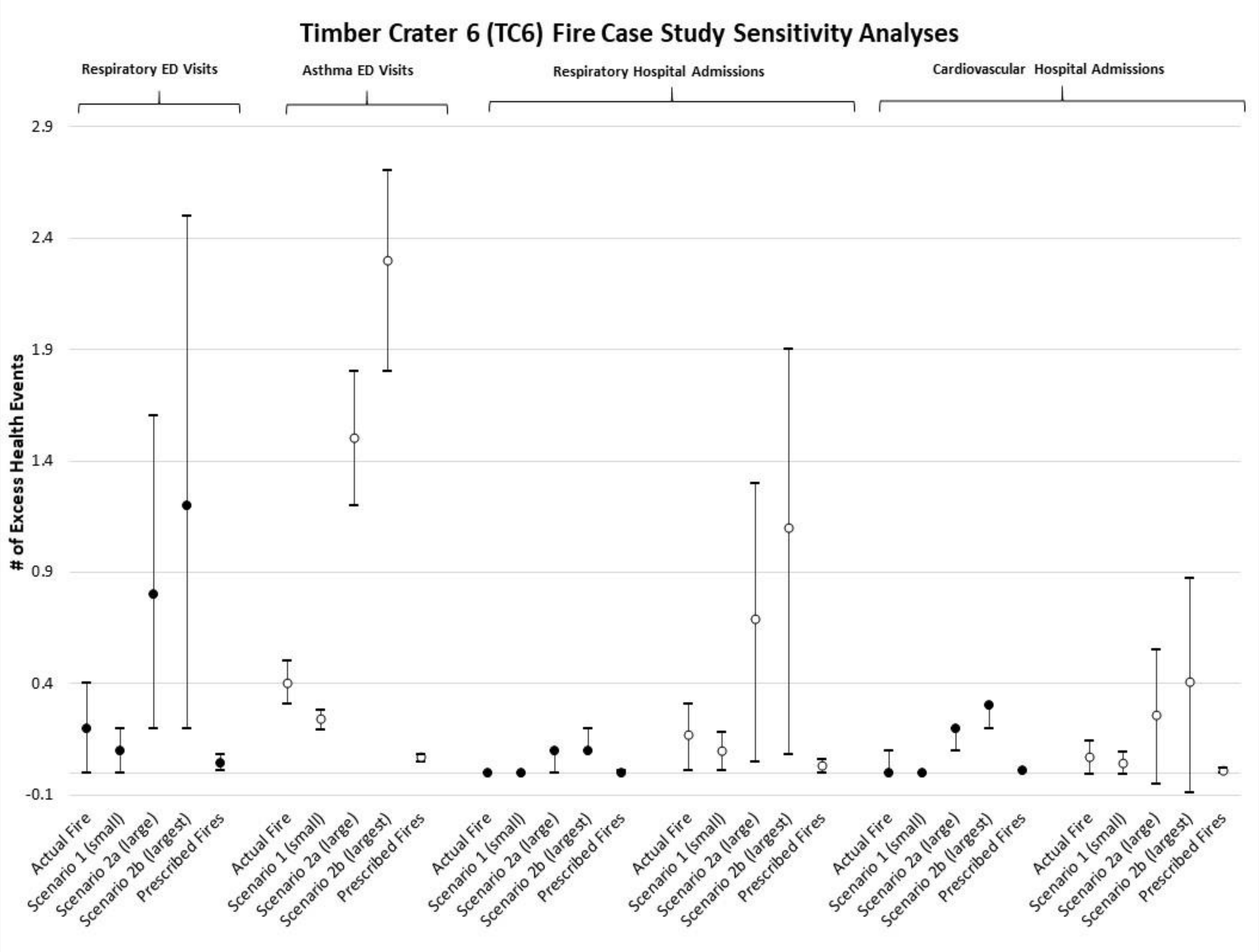
Baseline incidence



Effect estimate

Health impact

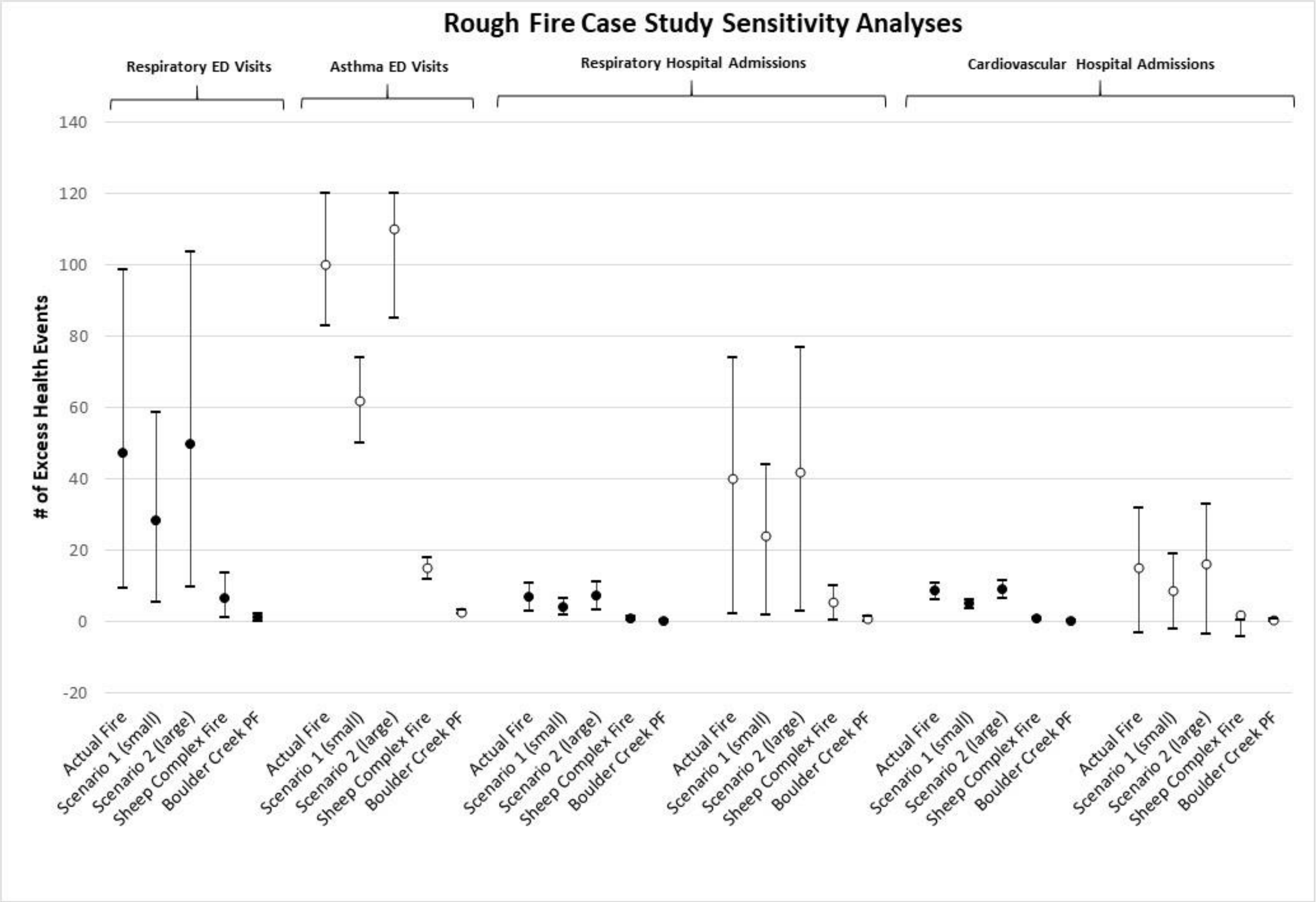
Sensitivity Analysis: TC6 Fire



Main analysis – ambient $PM_{2.5}$ health impact function

Sensitivity analysis – wildfire-specific $PM_{2.5}$ health impact function

Sensitivity Analysis: Rough Fire



● Main analysis – ambient $PM_{2.5}$ health impact function

○ Sensitivity analysis – wildfire-specific $PM_{2.5}$ health impact function