

Projections of Wildfire Impacts on Air Toxics in the Western US

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Introduction: Wildfires Trend in U.S.

- Wildfire areas (2016-2020) is 2.6 times higher than the areas in 30 years ago and keep an increasing rate (+17% per year).
- Firefighting costs also increase dramatically, the 5-year average of 2016-2020 is **6.4 times** higher than the 5-year average of 1985-1989.





Introduction: Wildfires in Western US (WUS)

- 2002–2019 western US (WUS) wildfire activities
 - Contributions of burned areas from WUS mostly > 50%
 - > Contributions of fire counts from WUS mostly < 50%







Introduction: Health Impacts of Wildfire Smoke

- Exposure to wildfire smoke was significant related to the increased risk of asthma, bronchitis, COPD, and combined respiratory disease.
- In addition to particle matters, wildfires would also emit large amounts of air toxics (e.g. benzene and formaldehyde) from combustion and smoldering.

Health Outcome	Age	Case Count	Fire PM (1µg/m3) 3-day average OR & 95% Cl	
	Child	10,184	1.075 (1.035,1.115)	·
Asthma	Adult	10,448	1.091 (1.060,1.122)	
	Elderly	1,286	1.009 (0.920,1.106)	
	All	21,918	1.081 (1.058,1.105)	-
	Child	1,403	0.971 (0.890,1.060)	
Bronchitis	Adult	6,772	1.044 (1.005,1.085)	
	Elderly	1,223	0.908 (0.805,1.024)	•
	All	9,398	1.018 (0.984,1.052)	
	Child	22		
Chronic Obstructive	Adult	4,491	1.056 (1.015,1.100)	
Pulmonary Disease	Elderly	5,486	0.989 (0.951,1.030)	•[
	All	9,999	1.020 (0.991,1.049)	
Respiratory Disease	Child	61,713	1.016 (1.001,1.032)	•
	Adult	56,529	1.030 (1.017,1.044)	•
	Elderly	17,121	1.000 (0.976,1.024)	+
	All	135 363	1.021 (1.012.1.031)	•





Stowell et al. (2019)

Introduction: Climate Projections

- Climate Projections under Representative Concentration Pathways (RCPs) showed that
 - Increasing global mean surface temperature
 - More precipitation under RCP8.5 except for WUS
 - Possible enhanced wildfire activities in WUS
 - Potential enhanced health risks
- Limited study investigated potential enhanced health risks related to air toxics under RCP8.5









• Evaluate the wildfire contributions of selected air toxics in WUS during the historical years (2003-2010) and the projection years under RCP8.5 (2050-2059).

 Assess the exceedance days of air toxics and their spatial distributions during the historical and the projection years under RCP8.5.





Method

- Domain: WUS
- Fire months: April–November
- Historical climate: 2003–2010
- Future climate: 2050–2059 under RCP8.5
- Models
 - ➢ Global (horizontal resolution: 0.9° × 1.25°)
 - The Community Earth System Model (CESM)
 - The Community Atmosphere Model with Chemistry (CAM-Chem)
 - Regional (horizontal resolution: 12 km × 12 km)
 - Dynamical downscaling from global outputs
 - The Weather Research and Forecasting (WRF) Model
 - The Community Multiscale Air Quality (CMAQ) Model







Method: 4 simulations





Methods: Select Air Toxics

- Select wildfire-related air toxics based on California Office of Environmental Health Hazard Assessment (OEHHA) and USEPA Integrated Risk Information System (IRIS)
 - Use benzene and formaldehyde as examples
 - **REL**: Reference Exposure Levels
 - > Acute REL: A level below which no health impact are anticipated for 1-hour exposure
- Extract periodical maximum and exceedance days in historical and future years.

> Exceedance day: a day with at least 1-hour concentration value higher than the acute REL

Air toxics	Acute REL (μg/m³)	8-Hour Inhalation REL (μg/m ³)	Chronic Inhalation REL (μg/m ³)	Target Organs
Benzene	27	3	3	Hematologic system, nervous system, reproductive/development
Formaldehyde	55	9	9	Eye, respiratory system





Results: Wildfire Contributed Conc. (ΔC)

- Hot spots:
 - San Joaquin Valley, CA
 - North Cascades, WA
 - Oregon Cascades, OR
 - Upper Rocky Mountains
- Similar spatial pattern
- Limited impacts in the Middle WUS

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- Wildfire Contributed Conc.
 (ΔC) ↓ under RCP8.5
 - Reduced NMVOC emission (IPCC, 2013)

Historical years (2003-2010)



Future years (2050-2059)









Formaldehyde (ug/m3) -3.1 - 3.4 3.4 - 10.9

	10.9 - 21.5
١.	21.5 - 36.8
	36.8 - 58.2
	58.2 - 87.2
	87.2 - 154.2
	154.2 - 331.4

Results: Wildfire Contribution (%)

- Spatial distribution
 - Benzene: most of WUS
 - Formaldehyde: hot spots
- Under RCP8.5
 - Benzene: expand and increase
 - Formaldehyde: increase

Historical years (2003-2010)

Future years (2050-2059)

















Results: Exceedance Days of Benzene

- Hot spots:
 - San Joaquin Valley, CA
 - > North Cascades, WA
 - > Oregon Cascades, OR
 - > Upper Rocky Mountains
- All exceedance days and most peak values are contributed by wildfire emissions.
- Hots spots are close to cities
- Exceedance days decrease under RCP8.5 due to reduced NMVOC emission *(IPCC, 2013)*
 - > 12.1 \rightarrow 5.7 days/year (-53%)



exceedance (days/yr) 0.1 - 0.2 0.2 - 0.3 0.3 - 0.4 0.4 - 0.5 0.5 - 0.6 0.6 - 0.8

> Benzene maximum (ug/m3) 0.10 - 1.98 1.98 - 4.99 4.99 - 9.54 9.54 - 16.72 16.72 - 29.51 29.51 - 55.67 55.67 - 103.52



Results: Exceedance Days of Formaldehyde

- Extra hot spots not related to wildfires
 - Farmington, NM
 - ➢ Roswell, NM

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- Fertilizers and Pesticides
- The spatial pattern is similar within years
 - > Wildfire: WA, OR, ID, and CA
 - > Non-wildfire: WY, UT, and NM
- Exceedance days **decrease** under RCP8.5 due to reduced NMVOC emission (*IPCC*, 2013)
 - much higher than benzene
 - \succ 61.4 \rightarrow 23.8 days/year (-61%)



Summary

Period	Seenaria	Exceedance	Wildfire related	
	Scenario	Benzene	Formaldehyde	Exceedance days
Historical (2003-2010)	SIM 1 (Base)	12.1 (100%)	61.4 (100%)	200/
	SIM 2 (No Fire)	0.0 (0%)	38.1 (62%)	30 %
Future (2050-2059)	SIM 3 (IIASA)	5.7 (100%)	23.8 (100%)	70%
	SIM 4 (No Fire)	0.0 (0%)	5.0 (21%)	1370

- Exceedance days: formaldehyde > benzene
- Exceedance days under RCP8.5 \downarrow
- Benzene: 100% of exceedance was related to wildfires
- Formaldehyde: the ratio of wildfire-related exceedance days increase from 38% to 79% under RCP8.5





Conclusion

- Wildfires have significant contribution to ambient benzene and formaldehyde either in historical or future years in WUS region.
- Air toxics from wildfires may decrease under RCP8.5, but the percentage of wildfirerelated days will increase (38% → 79% for formaldehyde) and become a non-negligible risk of acute health impact, especially for the cities close to hot spots.
- In the future works, the observation data from Photochemical Assessment Monitoring Stations (PAMS) will be fused to improve model performance.





Thanks for your attention. Q&A



