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Projections of Wildfire Impacts on Air Toxics in the Western US

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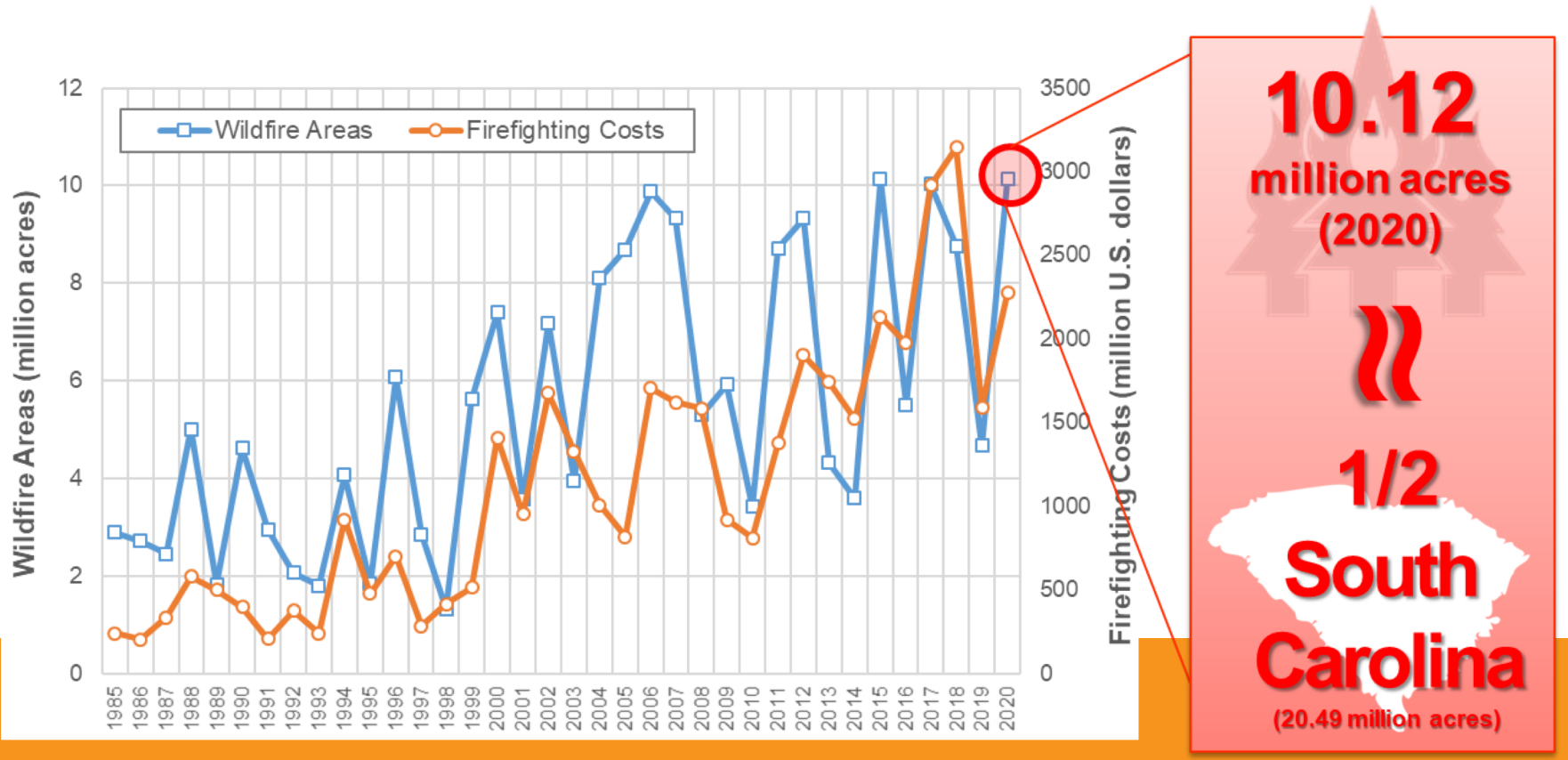
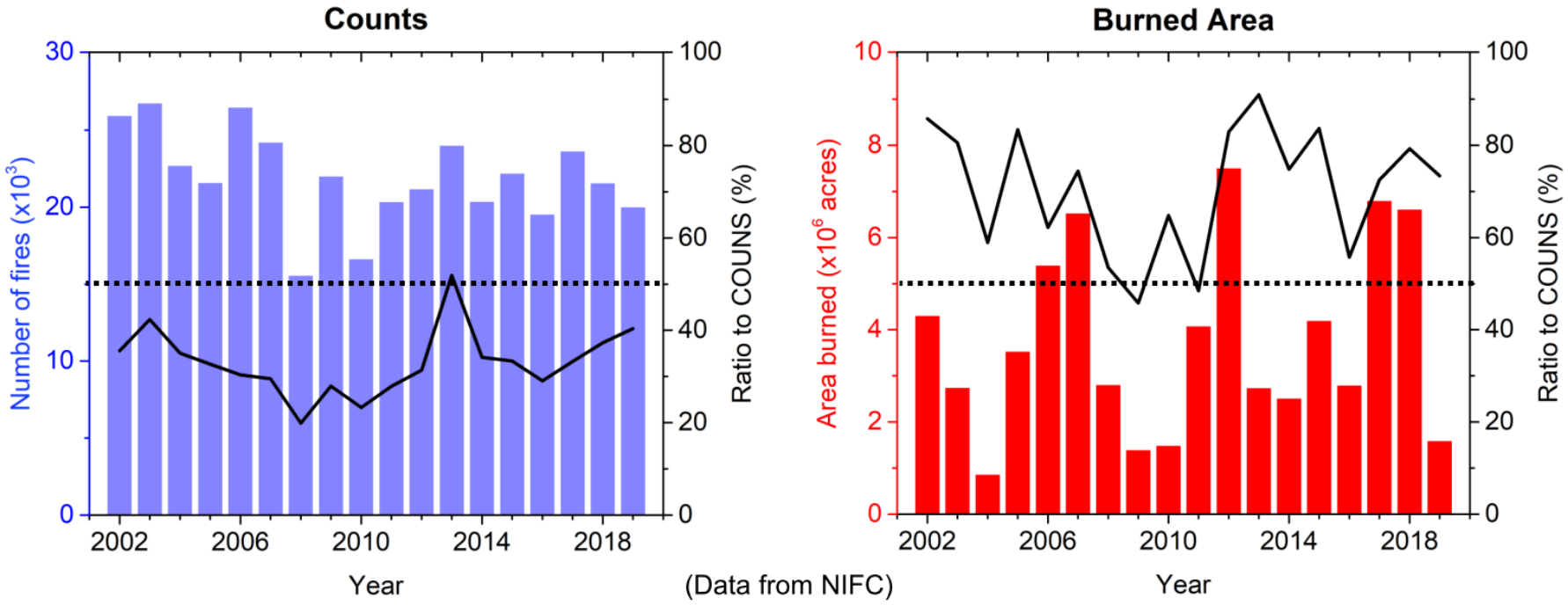
Introduction: Wildfires Trend in U.S.

- 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.



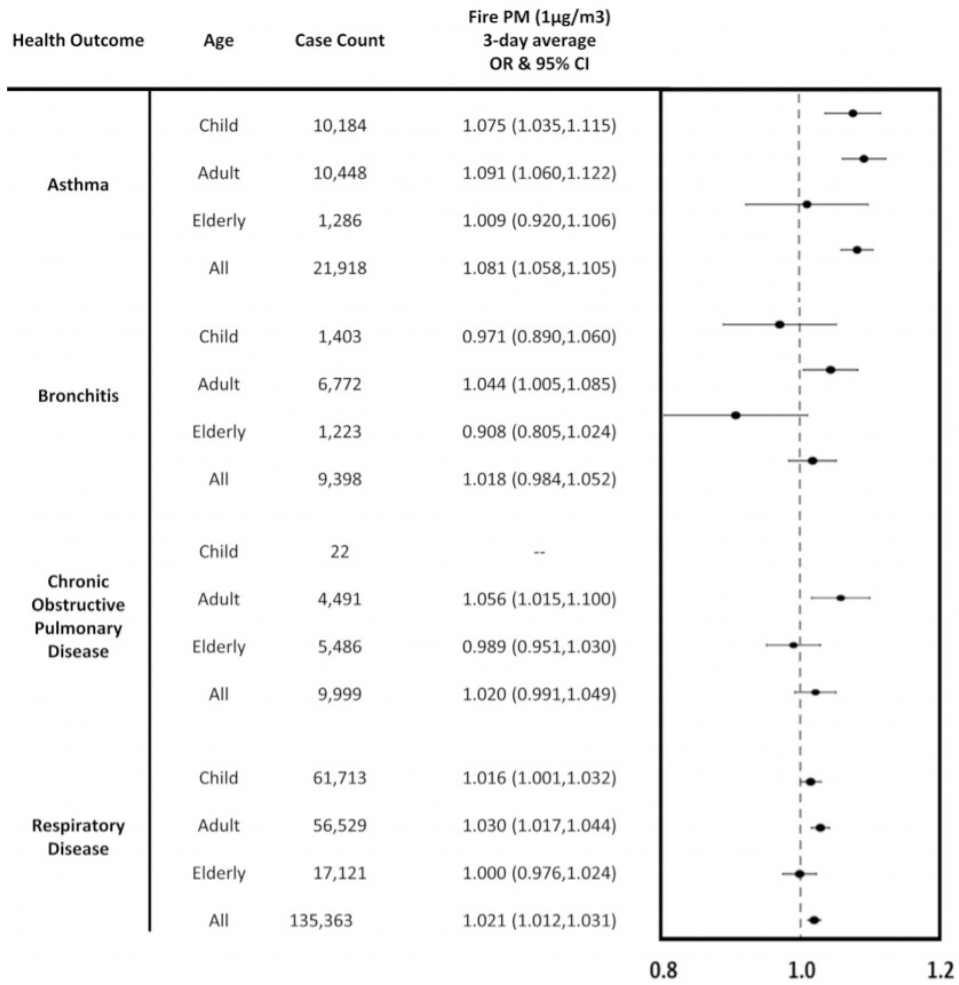
Introduction: Wildfires in Western US (WUS)

- 2002–2019 western US (WUS) wildfire activities
  - Contributions from WUS mostly < 50%
  - Contributions from WUS mostly > 50%



Introduction: Health Impacts of Wildfire Smoke

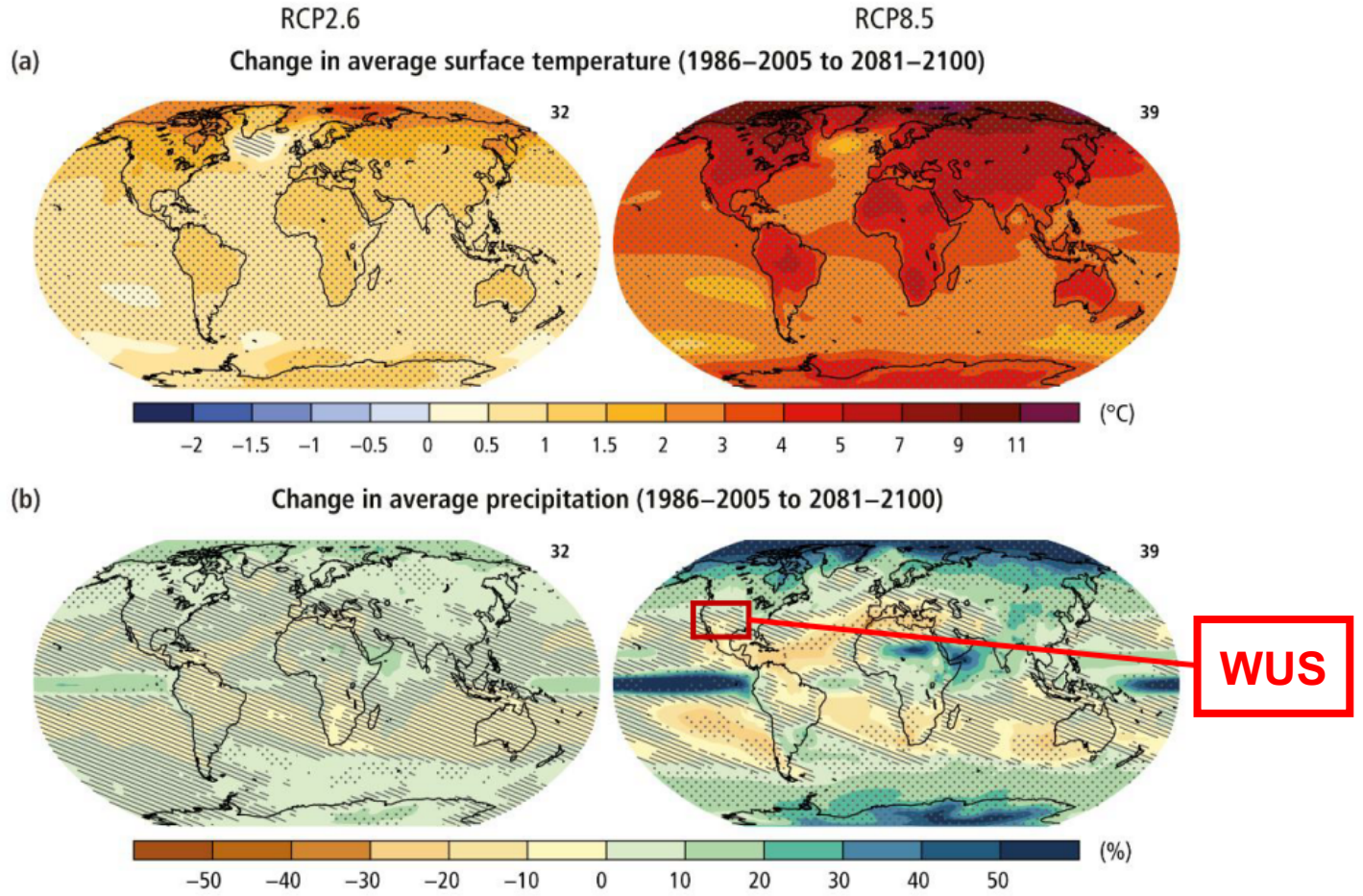
- Exposure to wildfire smoke was significant related to the increased risk of **asthma, bronchitis, COPD**, and **combined respiratory disease.**
- In addition to particle matters, wildfires would also emit large amounts of **hazardous air pollutants (HAPs, e.g. acetaldehyde, benzene, and formaldehyde)** from combustion and smoldering.
- Did newest CMAQ version include PAHs? If not, just suggest in the limitation. (confirm again)



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 HAPs under RCP8.5



(Adopted from *Summary for Policymakers*, IPCC, 2013)

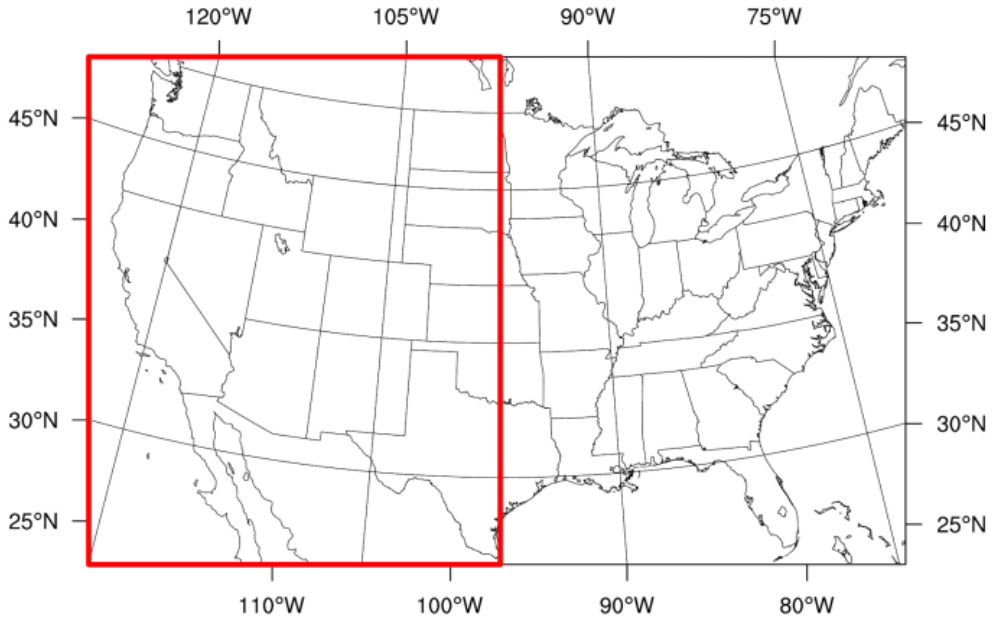
Objectives

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

- Assess the HAPs exceedance days 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: $0.9^{\circ} \times 1.25^{\circ}$)
    - 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

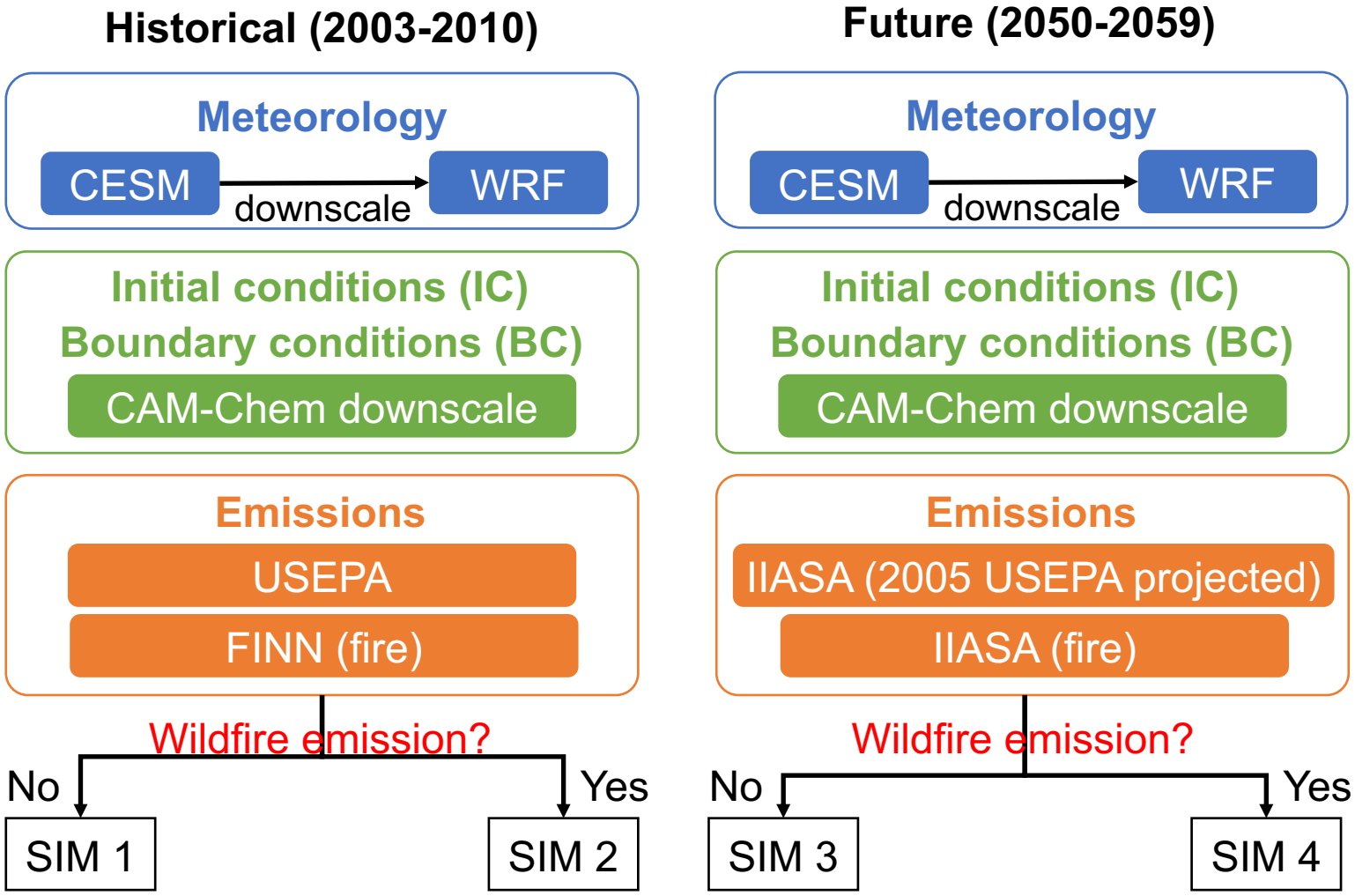


(Yang et al. submitted)

Method

- Historical emissions (2003–2010)
  - From U.S. EPA (USEPA)
  - Fire emissions adjusted by Fire INventory from NCAR (FINN)
- Future emission data sets (2050–2059)
  - RCP8.5 scenario from the International Institute for Applied Systems Analysis (IIASA)
  - Based on socioeconomic activities

Method: 4 simulations



ΔC

2003-2010
Wildfire contribution

= SIM 2 – SIM 1

2050-2059
Wildfire contribution

= SIM 4 – SIM 3

Methods: Select Air Toxics

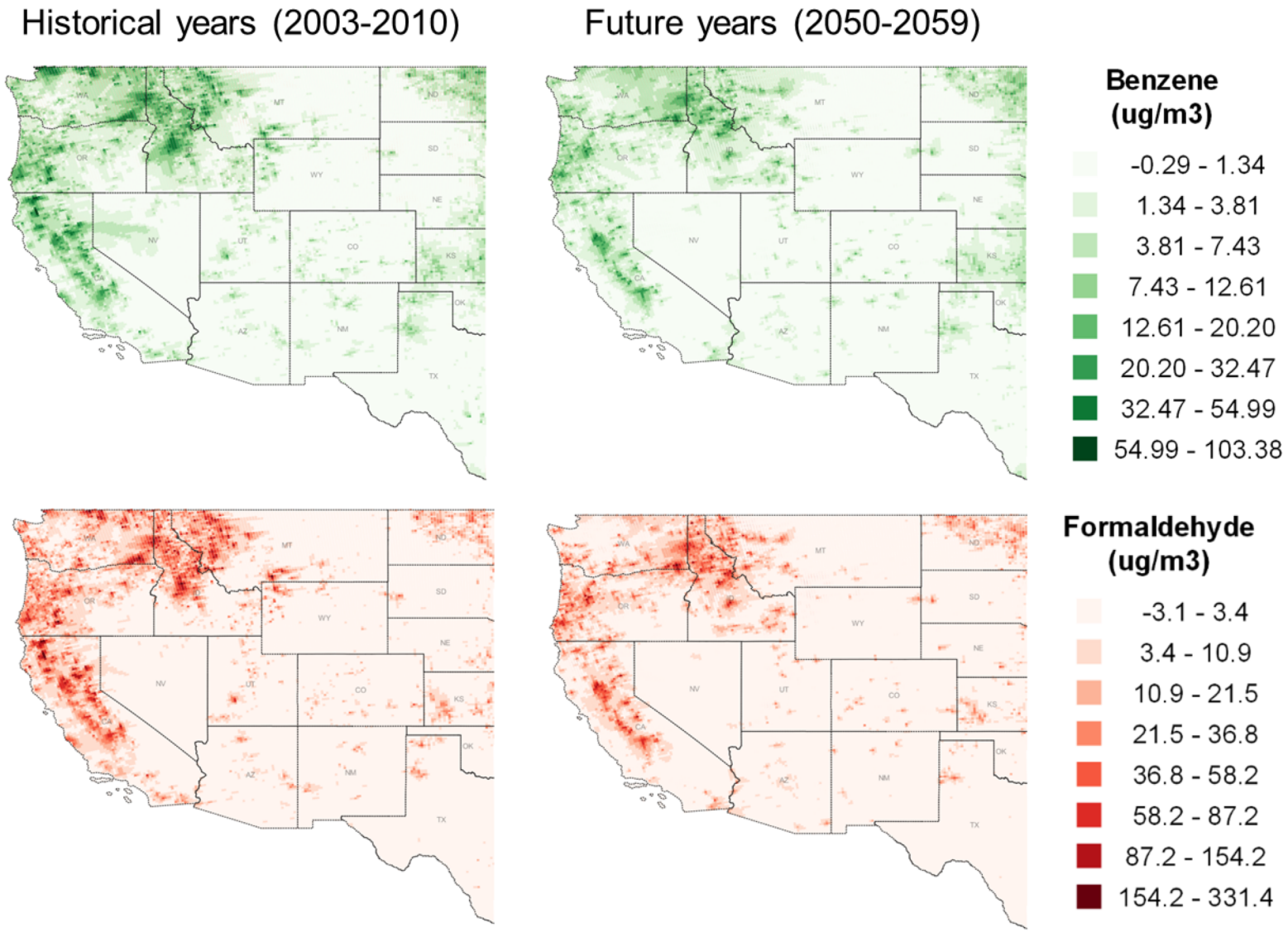
- Select wildfire-related air toxics based on **California Office of Environmental Health Hazard Assessment (OEHHA)** and **USEPA Integrated Risk Information System (IRIS)**
  - Use **benzene** and **formaldehyde** as examples
  - **REL**: Reference Exposure Levels
  - **Acute REL:** A level below which 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 ($\mu g/m^3$)	8-Hour Inhalation REL ($\mu g/m^3$)	Chronic Inhalation REL ($\mu g/m^3$)	Target Organs
Benzene	27	3	3	Hematologic system, nervous system, reproductive/development
Formaldehyde	55	9	9	Eye, respiratory system

Results: Wildfire Contributed Conc. (ΔC)

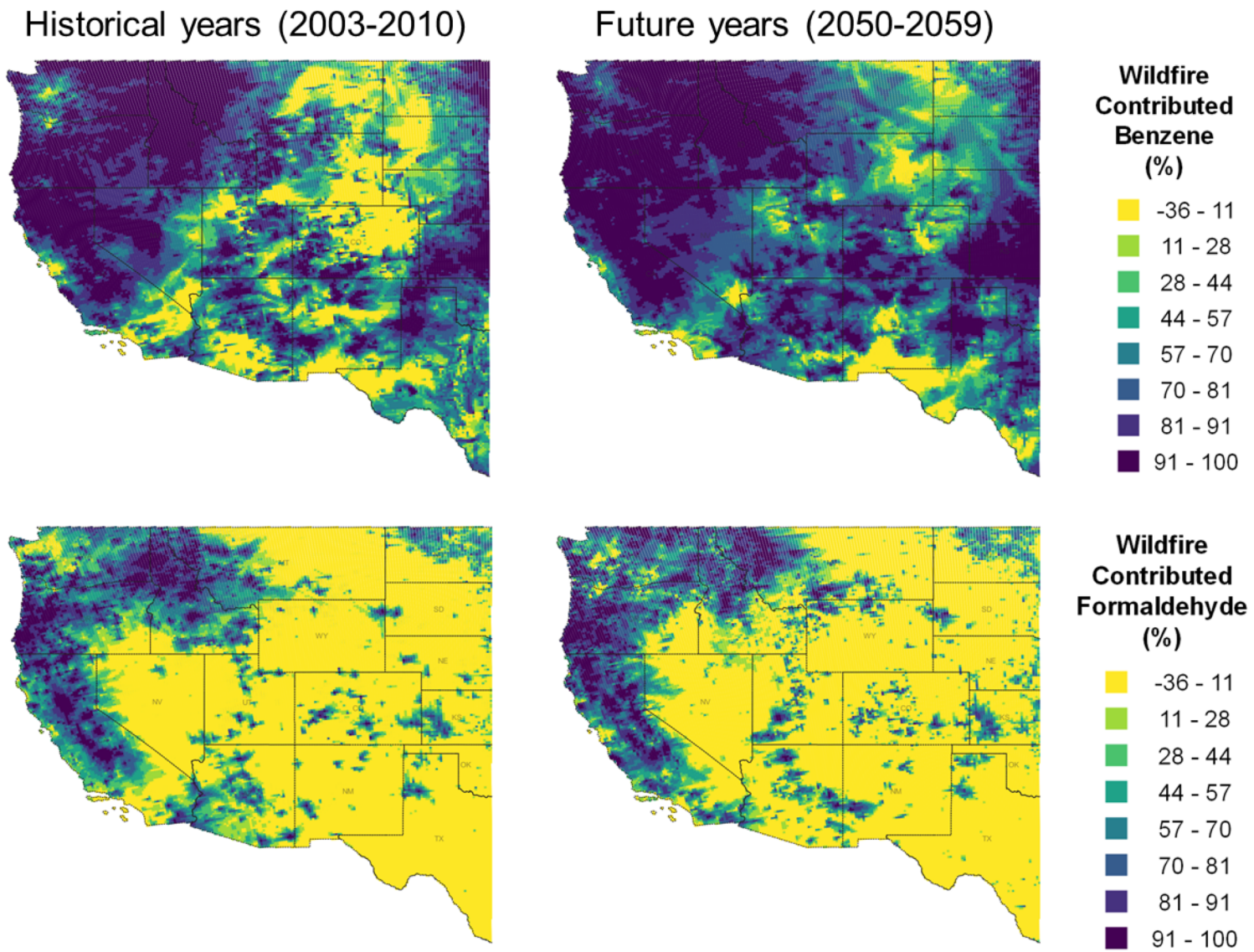
- **Hot spots:**
  - San Joaquin Valley, CA
  - North Cascades, WA
  - Oregon Cascades, OR
  - Upper Rocky Mountains
- Limited impacts in the Middle WUS
- Similar spatial pattern
- Wildfire Contributed Conc. (ΔC) ↓ under RCP8.5
  - Reduced NMVOC emission

IPCC (2013)



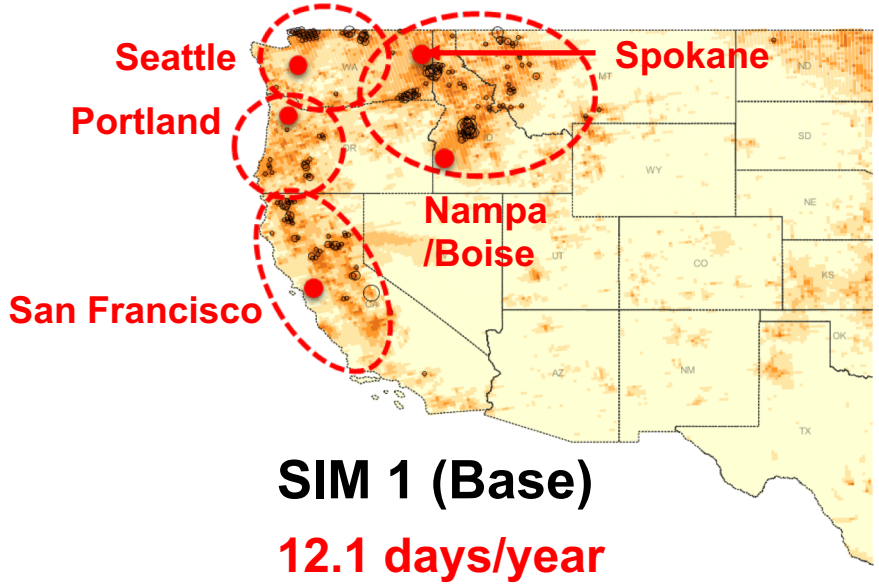
Results: Wildfire Contribution (%)

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



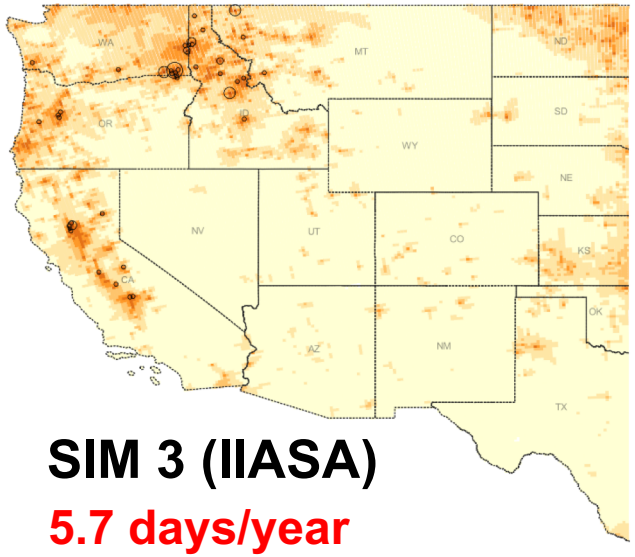
Results: Exceedance Days of Benzene

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



SIM 1 (Base)

12.1 days/year



SIM 3 (IIASA)

5.7 days/year

Benzene exceedance (days/yr)

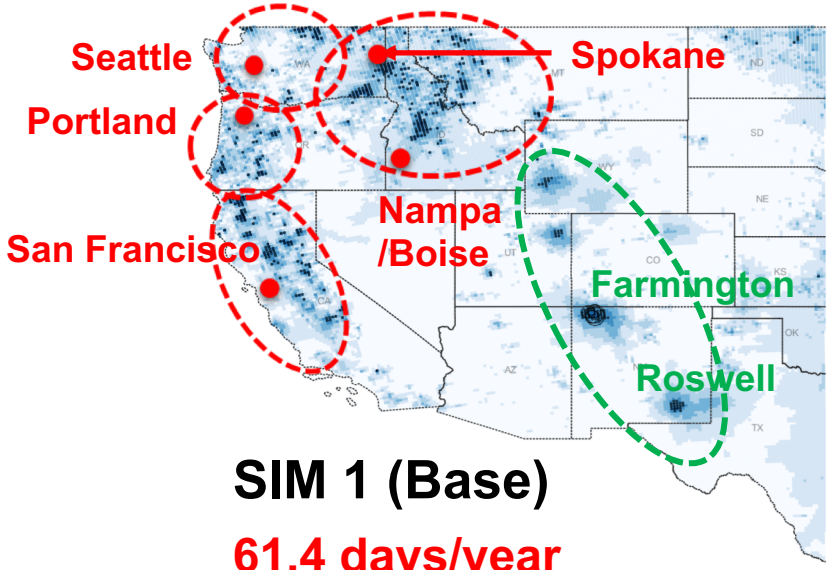
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.8

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

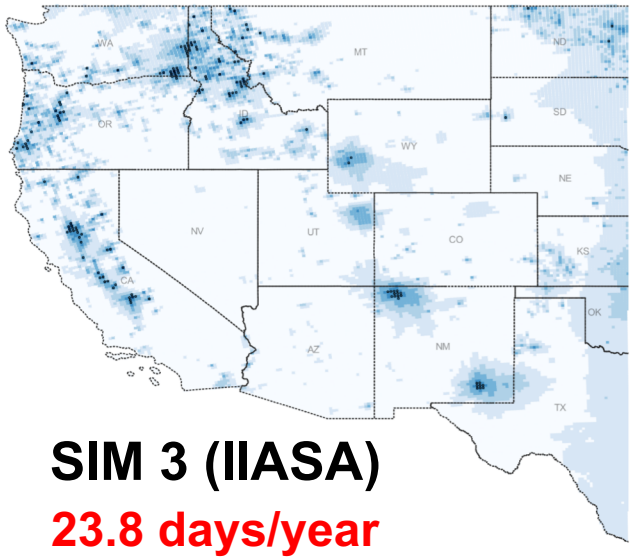
Results: Exceedance Days of Formaldehyde

- **Extra hot spots** not related to wildfires
  - Farmington, NM
  - Roswell, NM
  - 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
  - much higher than benzene
  - **61.4 → 23.8 days/year (-61%)**



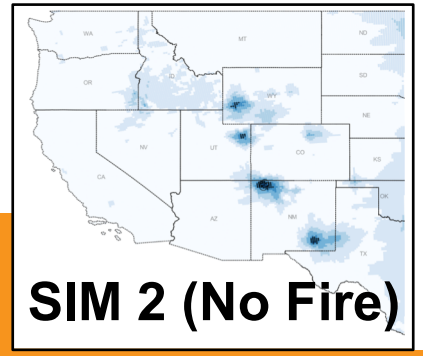
SIM 1 (Base)

61.4 days/year

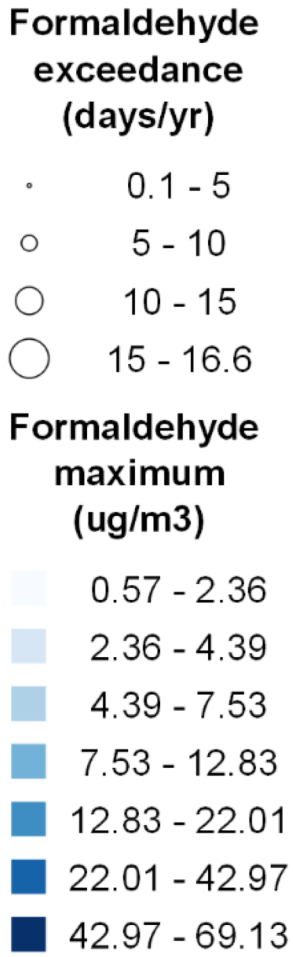


SIM 3 (IIASA)

23.8 days/year



SIM 2 (No Fire)



Summary

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

Wildfire-related Exceedance days

38%

79%

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

Conclusion

- **Wildfires** have significant contribution to ambient **benzene** and **formaldehyde** either in historical or future years in WUS region.
- HAPs from wildfires may decrease under RCP8.5, but **the ratio of wildfire-related 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

Air Quality Engineering & Climate Studies Research Group

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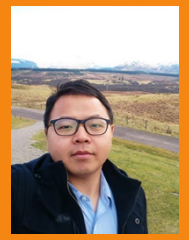

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