Rapid Assessment of Smoke impacts on OZone and PM for all U.S. Regions- Air Quality (RAZOR-AQ)

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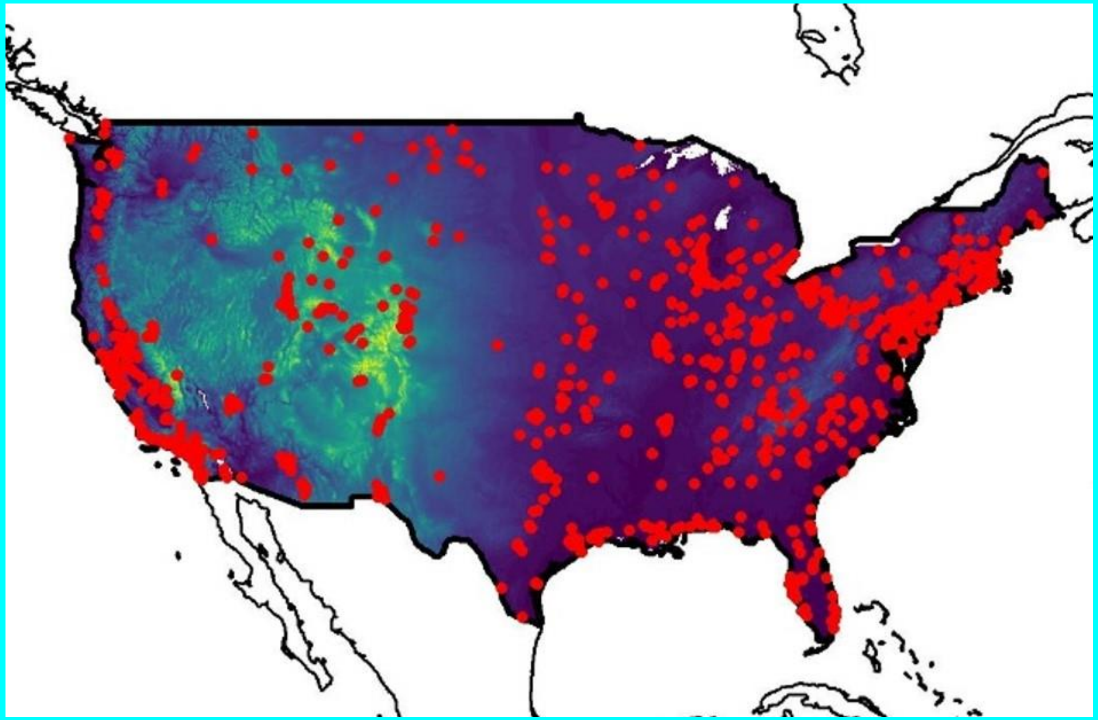
Current work

- Used HMS smoke product and surface $PM_{2.5}$ to assess surface smoke at ~600 AQS with PM and O_3 data for every day in O_3 season (May-September) for 2018-2023.
- Used non-smoke data to train Generalized Additive Models for each site using a variety of met predictors.

Current work



1. **Use surface $PM_{2.5}$ and HMS smoke product to identify smoke non-smoke days at 600 AQS sites for every day in 2018-2023 O_3 season.**
2. **Use GAM to quantify expected O_3 based on meteorology.**
3. **Estimate smoke contribution to daily $PM_{2.5}$ and MDA8 O_3 for every site, for every day.**
4. **Roughly 200 sites in the east, central and western U.S.**

Caveats:

1. **Only applied for May-Sept 2018-2023.**
2. **Only applied to sites in the continental U.S. with both O_3 and $PM_{2.5}$ data (88101).**
3. **Future: Extend to full year, all of U.S. and include non-FRM/FEM $PM_{2.5}$ measurements (88502).**
4. **Western US (> 102° W); Central US (82–102° W); Eastern US (< 82° W)**

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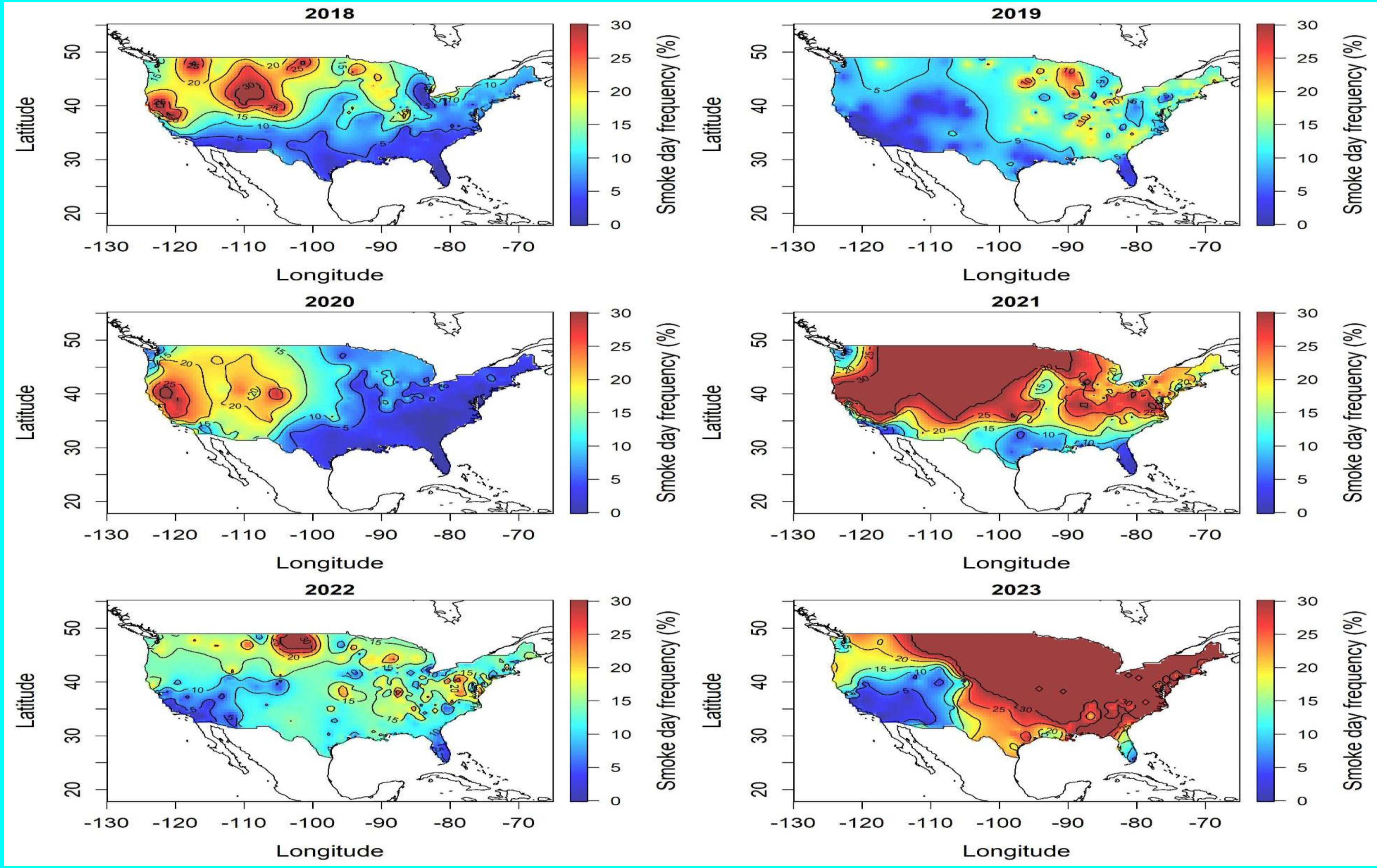
% of days that are smoke days- Surface smoke



- 2019: Low year, but not zero.
- Canadian and US wildfires + Agric + prescribed burning.

2020:

- CO 27%
- NV 23%
- CA 20%
- UT 20%

2021:

- WY 49%
- ND 42%
- MT 40%
- CO 40%

2023:

- MN 70%
- ND 70%
- WI 53%
- SD 52%
- MI 48%
- IL 46%
- VT 41%

How to quantify the O_3 in an urban area due to smoke? Use machine learning to predict MDA8 O_3 w/wo smoke.

- **Generalized Additive Modeling (GAM), uses a training dataset to identify patterns and relationships.**
- **This approach can incorporate linear, non-linear and categorical relationships.**

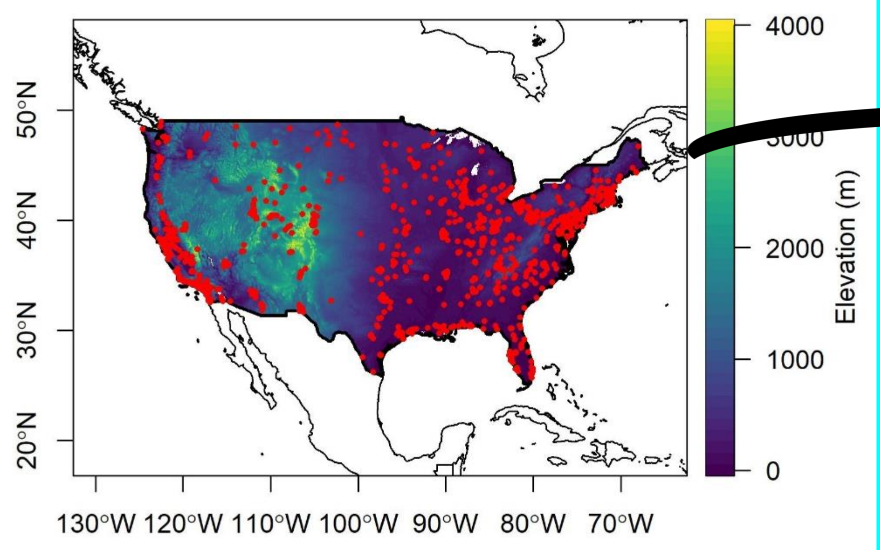
$$g(O_{3i}) = f_1(temp_i) + f_2(WS_i) + f_3(WD_i) + \ldots + residual_i$$

Where f_1, f_2, etc from spline fits to the obs. "*i*" refers to daily obs.

- **Typical predictors are daily max temp, ws, wd, trajectory distance, RH, GPH, etc.**
- **Various steps for model QC, including cross-validation with data that was not part of training dataset.**
- **<u>For this analysis, we calculate a separate GAM for each of the ~600 sites.</u>**
- **<u>Smoke is not include in the model, so we attribute difference between modeled and predicted to smoke influence.</u>**

Camalier et al 2007; CARB 2011; Sun et al 2015; Gong et al 2017; 2018; McClure and Jaffe 2018; Jaffe et al 2018; 2021; Lee et al 2023.

Data used



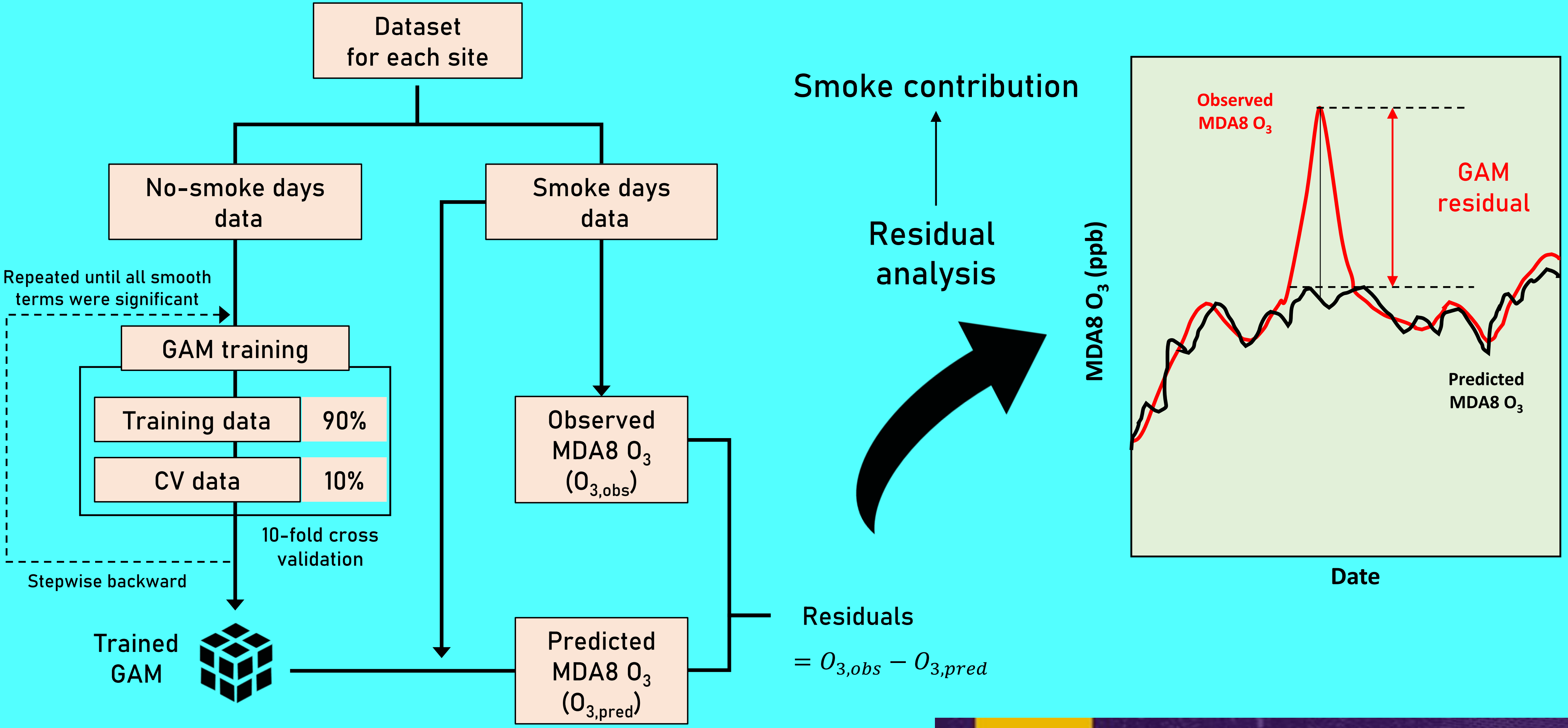
~ 600 sites

May to Sep, 2018–2023

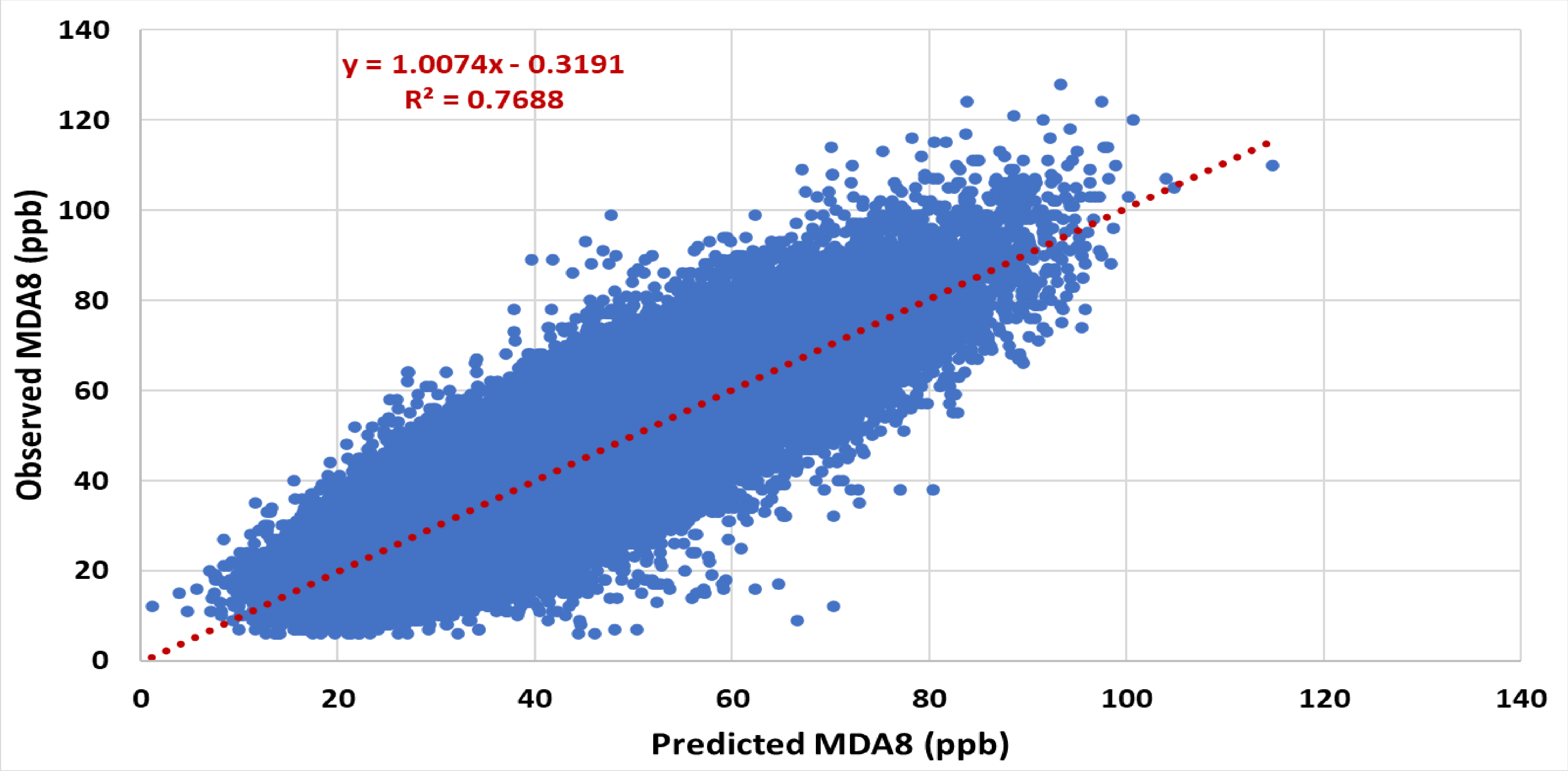
EPA AQS	MDA8 O_3 & $PM_{2.5}$
NOAA	Hazard Mapping System Fire and Smoke (HMS)
NASA-OMI	Satellite NO_2 (Vertical column density)
MERRA-2	Surface Solar radiation
IEM-ASOS	TMAX & RH (Iowa Environmental Mesonet)
NOAA-HYSPLIT	12-h backward trajectory (distance, direction, and H_2O mix ratio)

Source	Parameter	Unit	Description
EPA	MDA8 O_3	ppb	Maximum daily 8-hour average ozone concentrations for individual sites
	$PM_{2.5}$	μg m^{-3}	Daily mean $PM_{2.5}$ mass concentrations for individual sites
NOAA	HMS	-	Daily smoke plume polygon area (overhead = 1 (HMS = 1), none-overhead = 0 (HMS = 0))
OMI	NO2VCD	molec. cm^{-2}	Daily mean OMI NO_2 tropospheric vertical column density for 15-day window for individual sites
MERRA-2	SRAD	W m^{-2}	Daily mean surface solar radiation for individual sites
IEM	TMAX	ºC	Daily maximum surface temperature for individual sites
	RH	%	Daily mean relative humidity for individual sites
HYSPLIT	TrajH2O	g kg^{-1}	Daily mean water vapor mix ratio for 12 hours of transport for a backward trajectory initialized at 1 p m local standard time for individual sites
	TrajDist	km	Daily endpoint distance (point to point) after 12 hours of transport for a backward trajectory initialize d at 1 pm local standard time for individual sites
	TrajDir	deg	Daily endpoint distance (point to point) after 12 hours of transport for a backward trajectory initialize d at 1 pm local standard time for individual sites

GAM procedure



Observed vs GAM predicted MDA8, 600 sites, training data (no-smoke), May-Sept, 2018-2023



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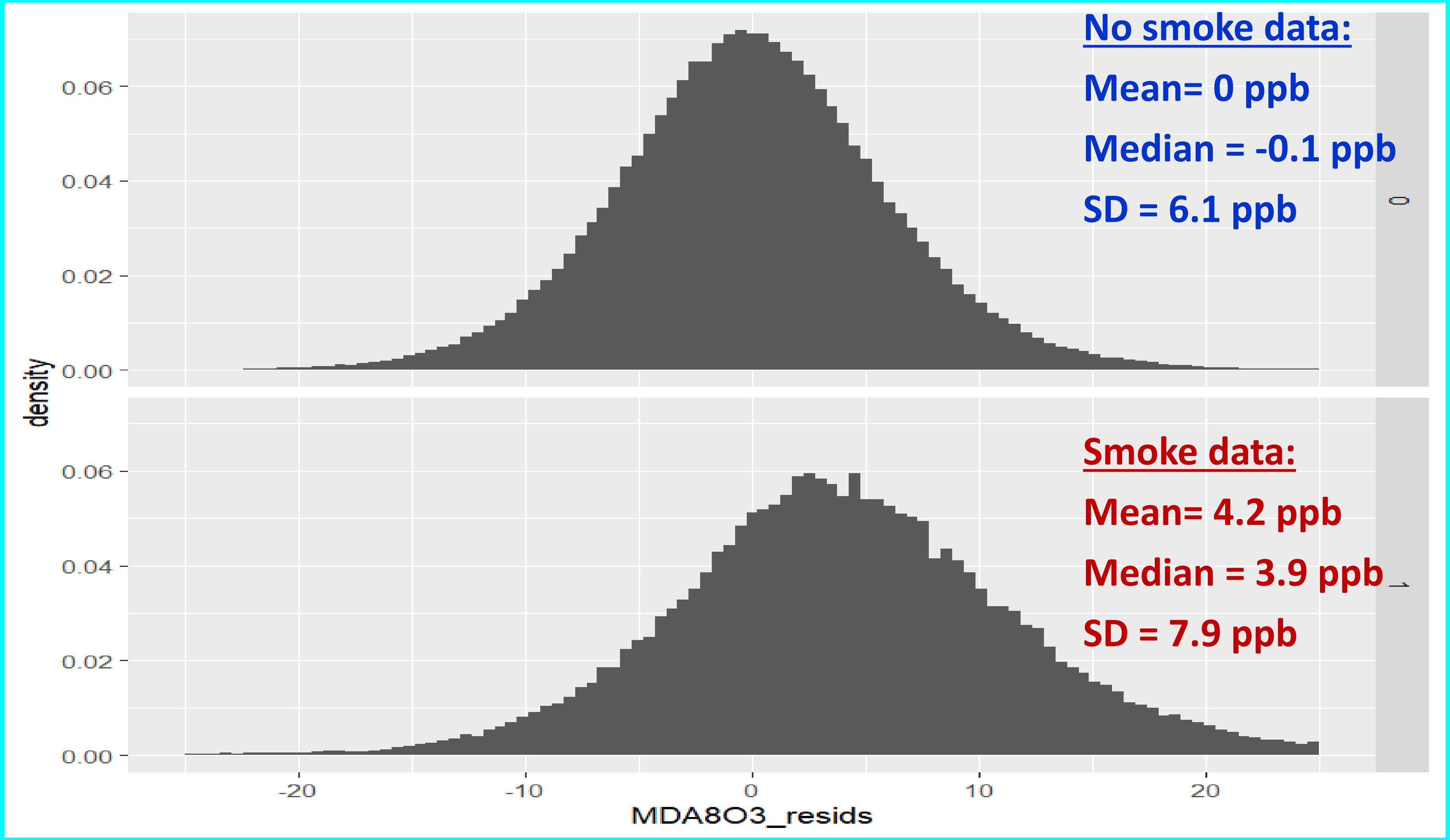
Residuals = Observed - GAM predicted MDA8, No-smoke and smoke data



- **High degree of variability is not well understood at this time. This will be key focus for future work.**
- **"Residual quantile" which provides a measure of how far out on the distribution a single residual point lies.**

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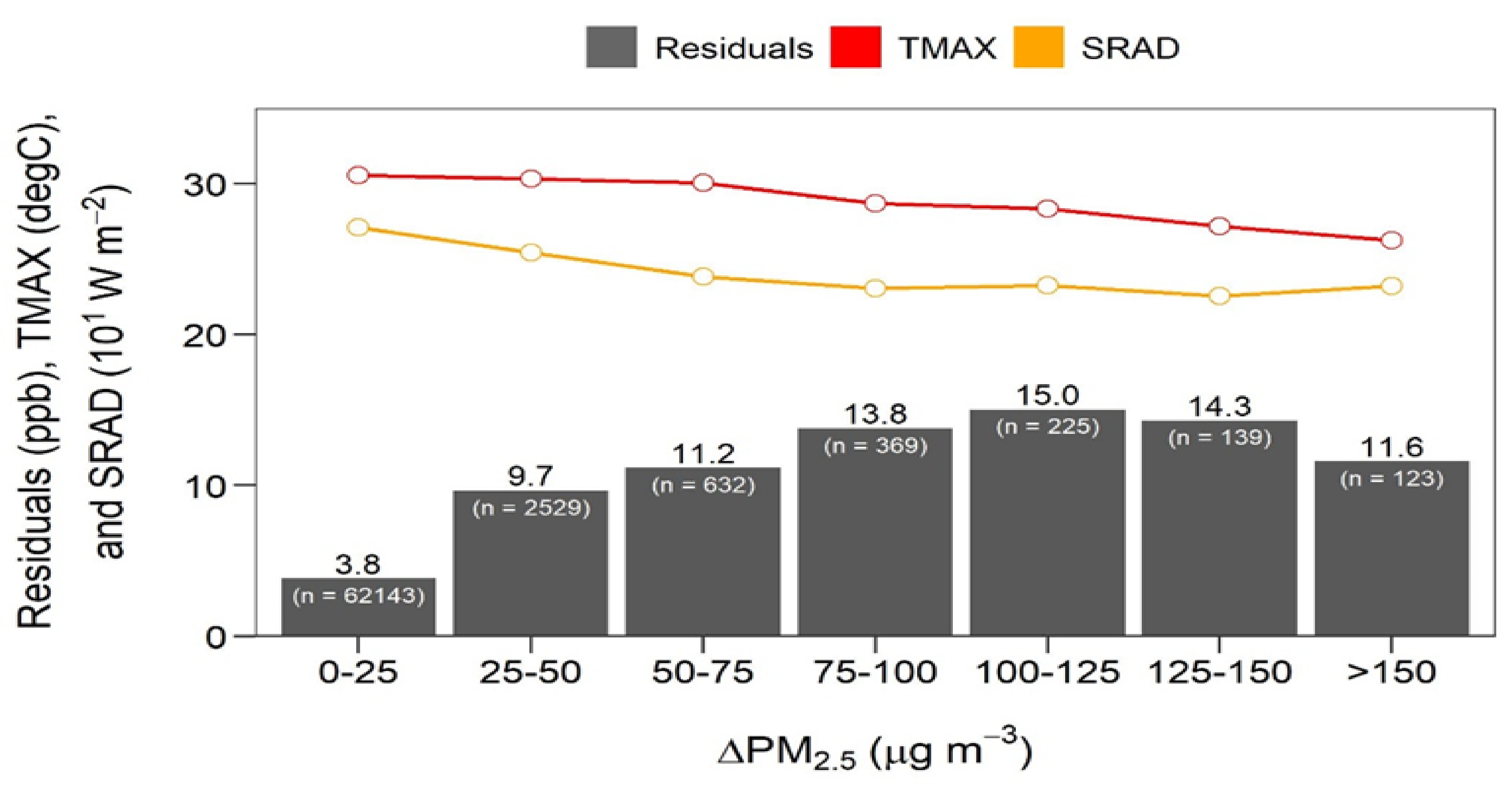
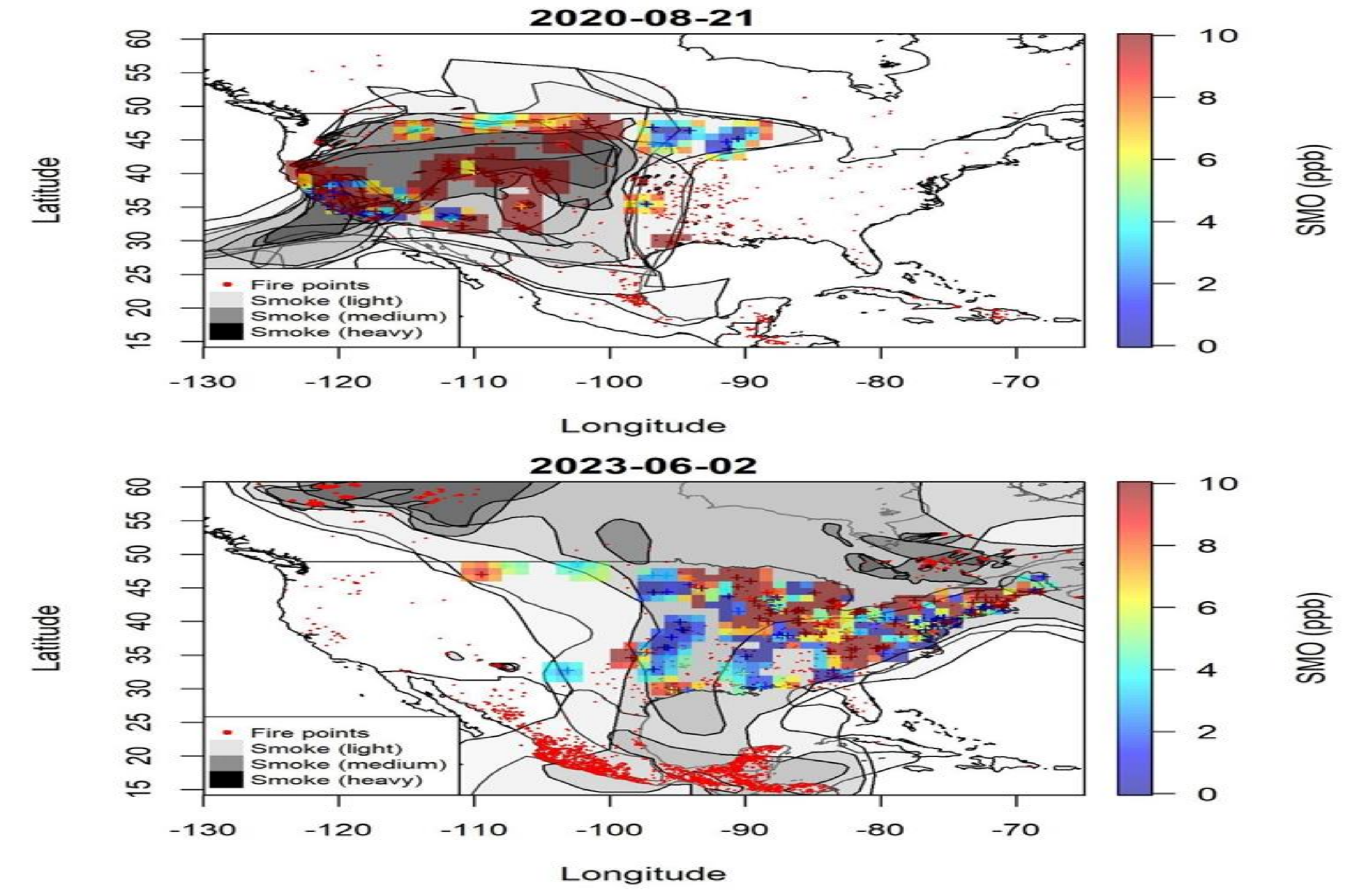
MDA8 O_3 residuals vs $\Delta PM_{2.5}$



$\Delta PM_{2.5} = PM_{2.5}$ (observed)- $PM_{2.5}$ (smoke criteria)

Smoke contributions to the MDA8 O_3



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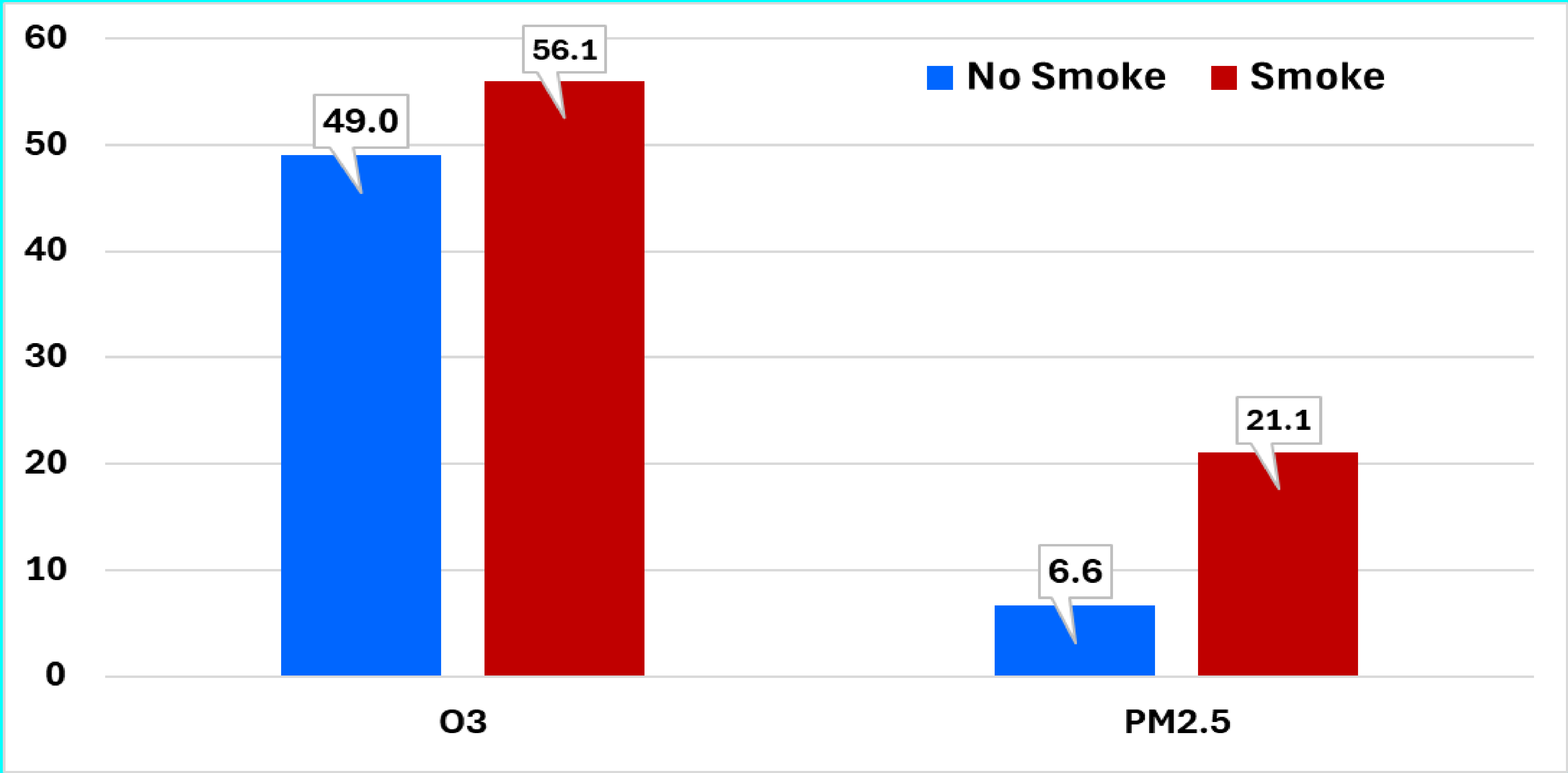
Mean O_3 MDA8 and $PM_{2.5}$ (ug/m3) in smoke and non-smoke, Western U.S.



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Dataset for ~600 sites for May-Sept 2018-2023 now available !

CT first to use in their EE demonstration for 2023 smoke.

AQS	Date	MDA8_obs	PM2.5_obs	HMS	PM2.5_criteria	Smoke day	MDA8_predicted	Smoke O_3 (ppb)	Smoke $PM_{2.5}$ (ug/m^3)	O3_perc	Daily Max Temp	RH	TRAJ-DIR	TRAJ_DIST
990110024	8/1/2023	57	8	0	9.5	N	55	NA	NA	NA				
9930110024	8/2/2023	63	5	0	9.5	N	66	NA	NA	NA				
990110024	8/3/2023	65	9	1	9.5	N	62	NA	NA	NA				
990110024	8/4/2023	71	18	1	9.5	Y	68	3	8.5	60				
990110024	8/5/2023	87	45	1	9.5	Y	67	20	35.5	98				

Cite as:

H. Lee and D. Jaffe. Wildfire Impacts on O_3 and $PM_{2.5}$ in the Continental United States using a Generalized Additive Model (2018–2023). In review for ES+T, Feb. 2024.

Dataset is now at the UW ResearchWorks archive:
http://hdl.handle.net/1773/51276

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Application of GAMs to CT EE demonstration

Thanks to Michal Geigert, Connecticut Department of Energy and Environmental Protection

Site name	East Hartford			Cornwall			Groton		
AQS ID	90031003			90050005			90110124		
Date	Surface Smoke (yes/no)	GAM residual (ppb)	Residual quantile	Surface Smoke (yes/no)	GAM residual (ppb)	Residual quantile	Surface Smoke (yes/no)	GAM residual (ppb)	Residual quantile
6/30/23	yes	18.04	99.2	yes	26.36	99.9	yes	22.99	99.6
7/1/23	yes	30.39	99.9	yes	29.00	99.9	yes	29.00	99.9
7/12/23	yes	8.95	91.3	yes	2.27	69.4	yes	20.48	99.6

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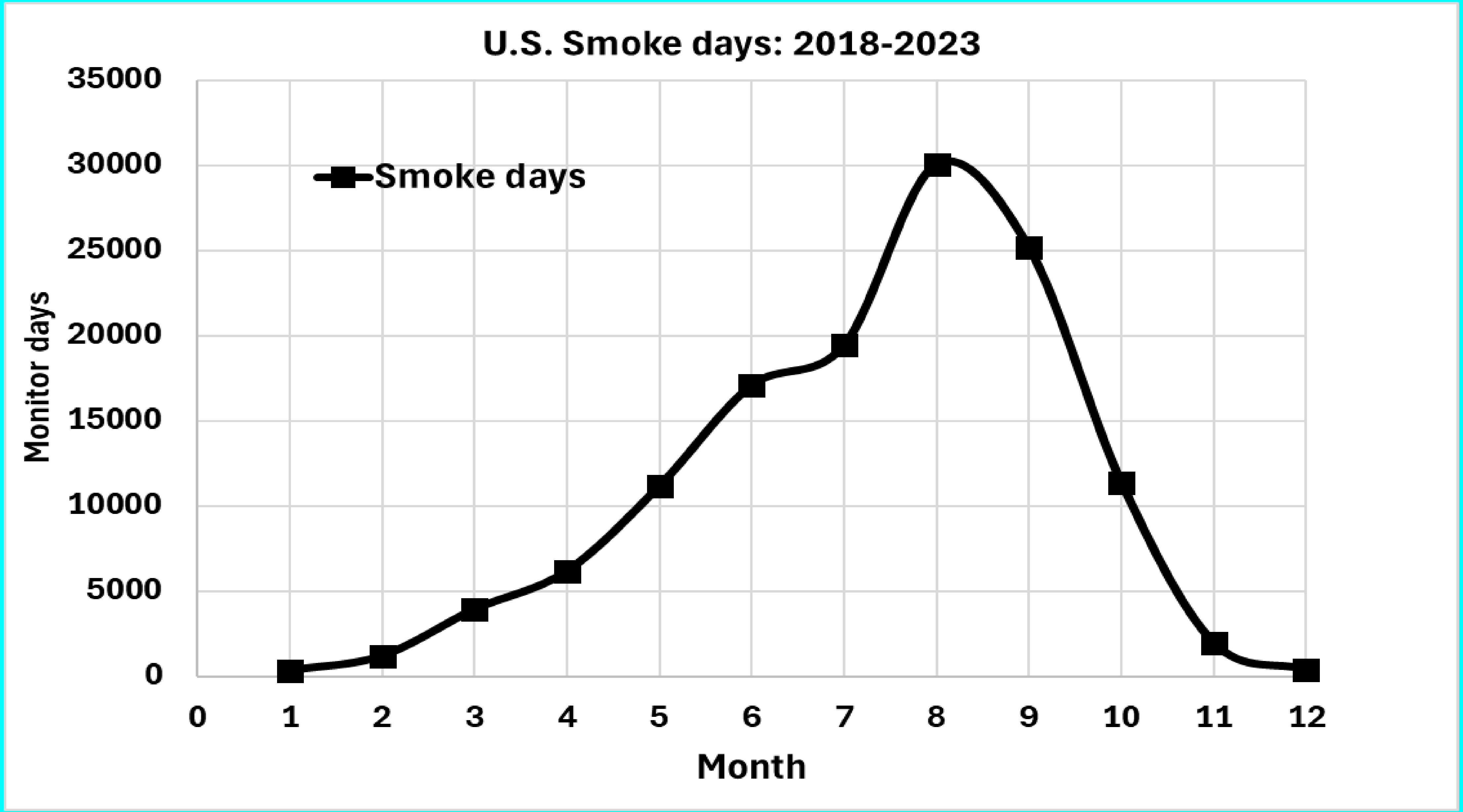

Total smoke days = 128,175

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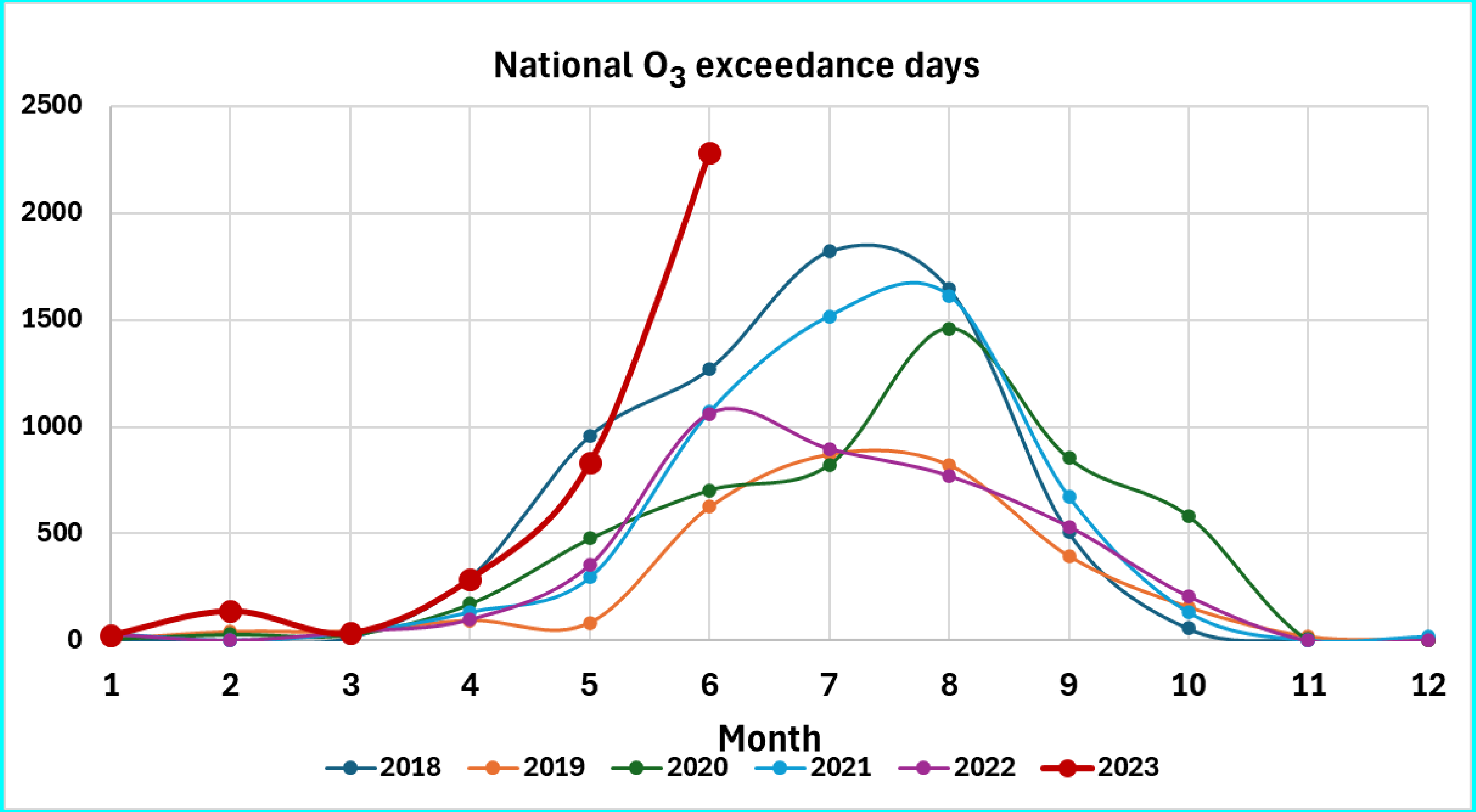

- For O_3, should we expand focus period beyond May-Sept?

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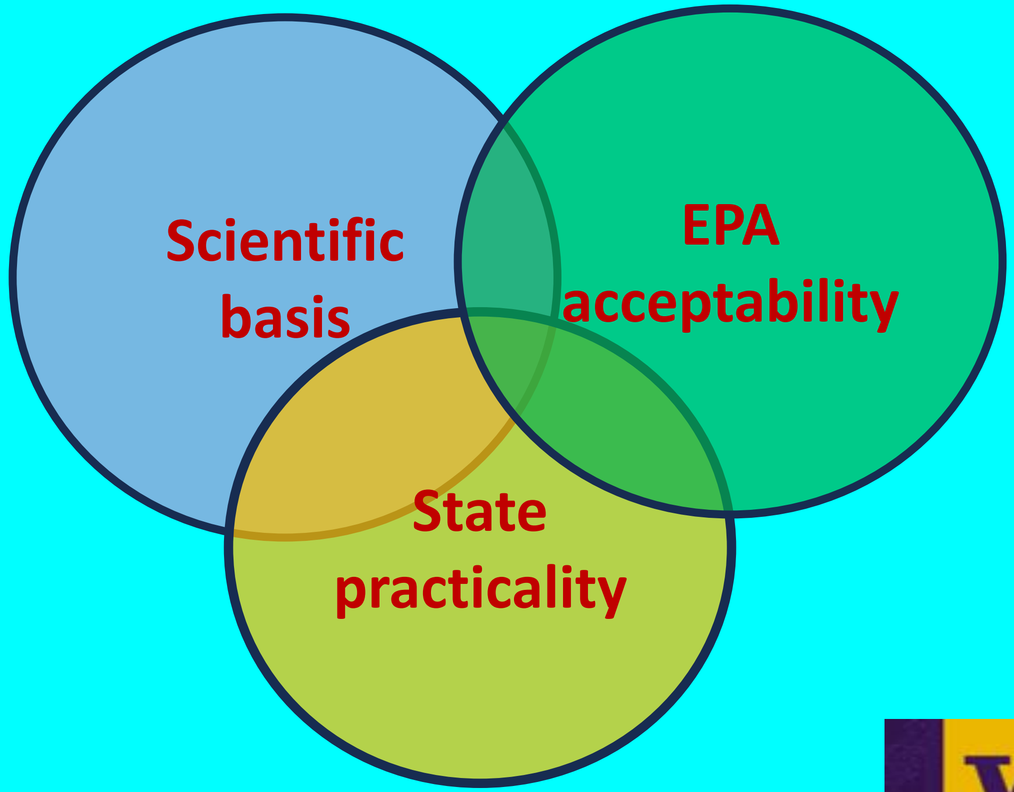
Progress to date

GAM version	Type	N AQS sites	Overall R^2 (training data)	Mean R^2 (all sites)	S.D. residual (ppb)	Citation
V1	May-Sept, O_3 GAMs and PM from smoke	593	0.77	0.63	6.1	EST paper in review
V2a	May-Sept, O_3 GAMs and PM from smoke	729	0.84	0.74	5.1	Expect paper submission in summer
V2b	Full year, PM from smoke	951	NA	NA	NA	Expect paper submission in summer

Including the full year adds about 25% to the number of "smoke days" we identify. A larger fraction of these are likely due to prescribed and ag fires.

Moving forward

1. Need to keep improving the scientific basis and statistical robustness of this method.
2. Need to gain "acceptance" of this approach by working with EPA and the states to get nationally consistent approach.
3. Need to id $ to continue and expand work.



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NASA-Earth Action: Health and Air Quality
(PI: D.Jaffe; Co-Investigator: Mary Uhl, WESTAR)

Earth Action: Health and Air Quality: **LOI 7/8/24** **Full proposal due 8/6/24**	➢ **Framed around partner problems and improved decision making.** ➢ **Improvements to decision-making using an array of Earth observations and related products.** ➢ **The area promotes uses of Earth observing data and models regarding implementation of air quality standards, policy, and regulations for economic and human welfare.** ➢ **Develop and prove the potential enhancements of an application of specific Earth observations to one or more decision-making activities** ➢ **Transfer and enable the adoption of this application by one or more specific end user organizations in a sustainable manner.**

Rapid Assessment of Smoke impacts on Ozone and PM for all U.S. Regions- Air Quality

1. Develop system for identification of wildfire and prescribed fire smoke at ~700 regulatory air quality monitoring sites in the U.S.
2. Daily estimate of $PM_{2.5}$ and O_3 contribution from smoke at each site.
3. Provide additional high time resolution satellite data to provide more insight into smoke and non-smoke photochemistry at each site.
4. Improve our understanding of smoke photochemistry and controls on O_3 production.
5. Provide a high quality dataset of O3 and PM2.5 impacts from smoke for 700+ AQS sites that can support health and modeling studies.
6. Partner directly with states and EPA to provide most useful data products.

Key question: Can we separately identify WF and PF impacts? Should we try?

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Key elements:
Note that each element is archived for each site for each day

Data stream	Why?	Operational?
$PM_{2.5}$, O_3, met, MERRA-2 and trajectories	Base dataset for GAM@700 sites	Yes
HMS	Smoke column	Yes
Smoke day identification using $PM_{2.5}$ and HMS	Identify smoke days; quantify smoke $PM_{2.5}$ contribution.	Yes
Predicted O_3 using GAMs	Estimated smoke O_3 contribution	Yes
***************	***********	***********
Possible updates:		
HRRRs $PM_{2.5}$ ($\mu g/m^3$)	Confirmation of surface smoke	No
TEMPO daytime BL O_3, col NO_2 and CH_2O (and/or TROPOMI products??)	Incorporate TEMPO NO_2 and CH_2O into GAMs. Calc dO_3/dT (daytime production rate), Calc FNR to corroborate smoke impacts and to understand chemistry for both smoke and non-smoke days.	No
TEMPO AOD (4x per day) and/or GOES 16+17 AOD	Improved understanding of influence of AOD on O_3 production.	

Proposed Schedule

What	When	Products	
Smoke contributions to O_3 and $PM_{2.5}$ at each AQS site for 2018-2023	Now	http://hdl.handle.net/1773/51276	
Smoke contributions to O_3 and $PM_{2.5}$ at each AQS site for 2024	March 2025	Similar dataset to current	
Improved estimates of smoke contributions for 2024	July 2025	Updated dataset	
Continue for 3 years….			

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Comments, questions, feedback:
How can I make this more useful to you?

What I need from you?

- Letters of support
- Participation on stakeholder steering committee.