Wildfires, O_3 and Indoor AQ

Dan Jaffe, University of Washington

Seattle, Aug. 21, 2018.
Worst $PM_{2.5}$ ever measured (110 ug/m^3)

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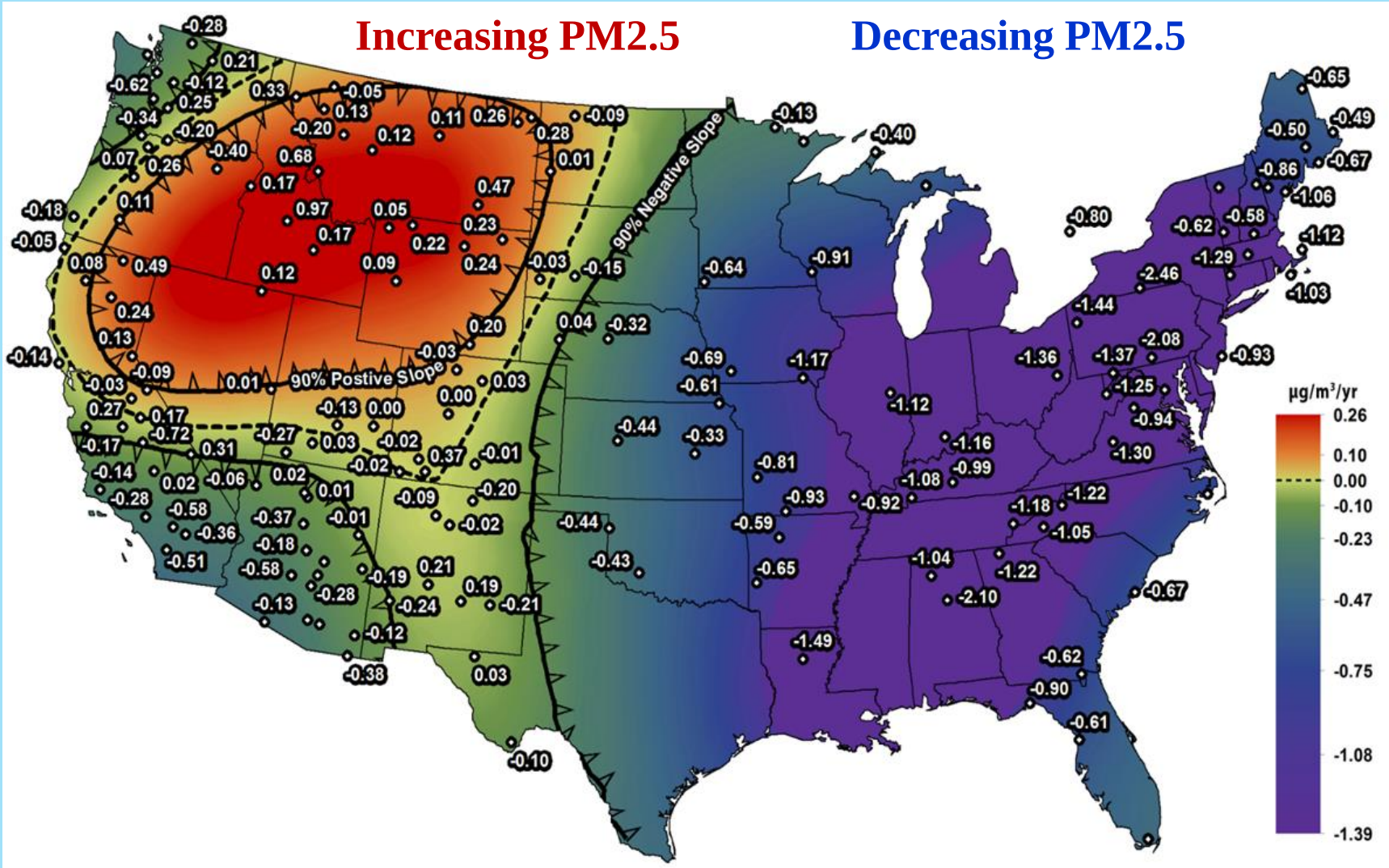
Trend in 98th percentile of $PM_{2.5}$ for 1988-2016
Rural IMPROVE network sites



McClure and Jaffe,
Proc. of Natl. Acad. Sci, 2018.

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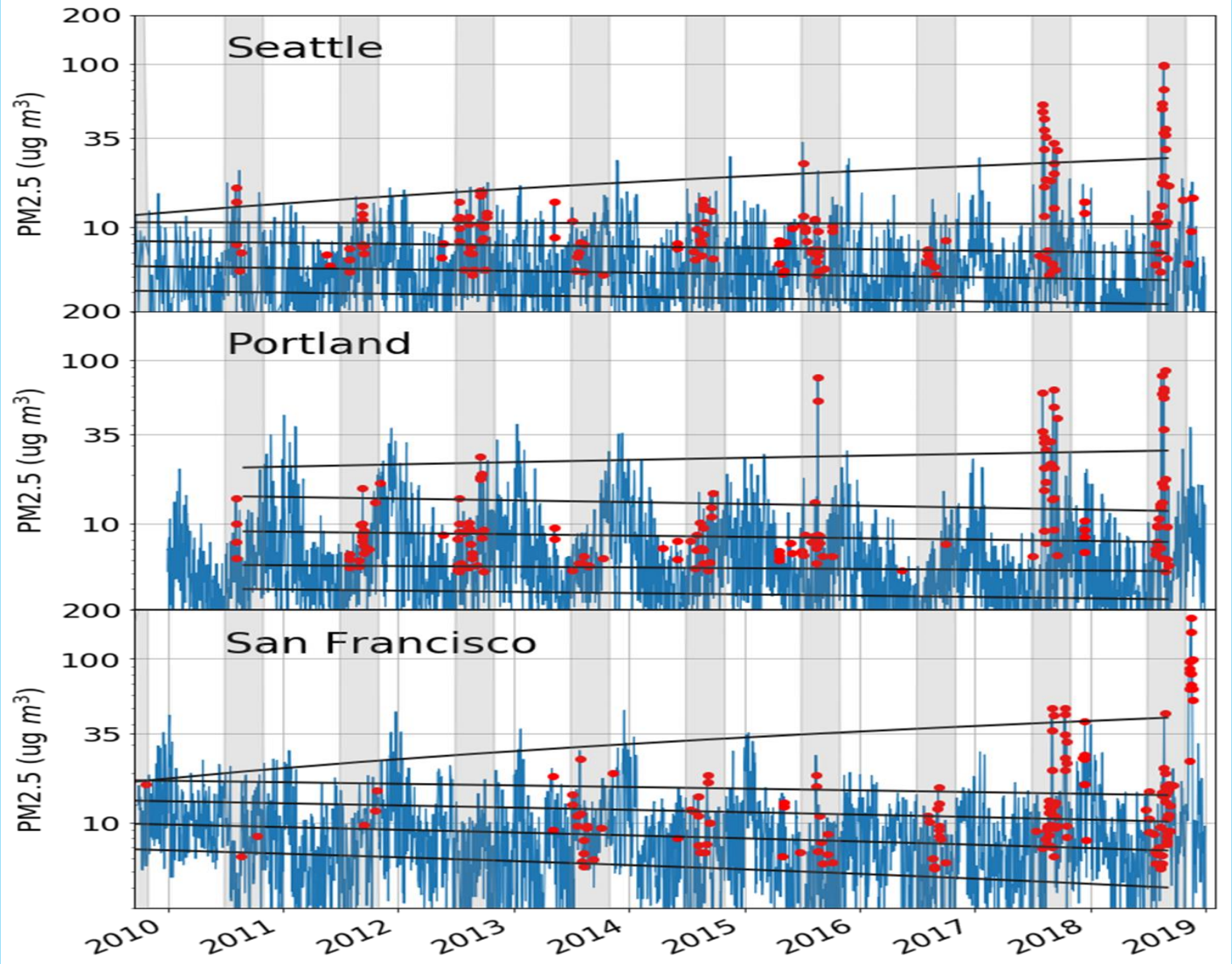
Extreme PM in urban areas



Wildfires are causing extreme $PM_{2.5}$ and O_3 in the W.US

$PM_{2.5}$ in 2017 and 2018	Highest $PM_{2.5}$ ever observed in the US (Seeley Lake, MT), 642 ug/m^3). Highest $PM_{2.5}$ ever observed in Seattle, Portland, San Francisco, Medford, etc.
O_3 in 2017 and 2018	
Seattle area	Highest O_3 in the last 10 years during August 2017 smoke events with 8-hour max of 90-103 ppb (MDA8) over multiple days.
Portland area	Highest O_3 in the last 20 years during August 2017 smoke events with MDA8 values of 90-116 ppb over multiple days.
Sacramento area	Highest O_3 in the last 10 years during August 2018 smokes events with MDA8 values of 90-115 ppb over multiple days.
Etc	

Aug. 21, 2018:
Daily average$PM_{2.5}$ = 110 ug/m^3
Highest $PM_{2.5}$ ever measured in Seattle.

The highest O_3 days are not the highest $PM_{2.5}$ days.

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Extreme PM

Wildfires Are Causing Extreme $PM_{2.5}$ Concentrations in the Western US

How increases in wildfire smoke have impacted air quality in the western United States

James R. Laing and Daniel A. Jaffe* are both with the University of Washington Bothell in Bothell, WA.
*Corresponding author.

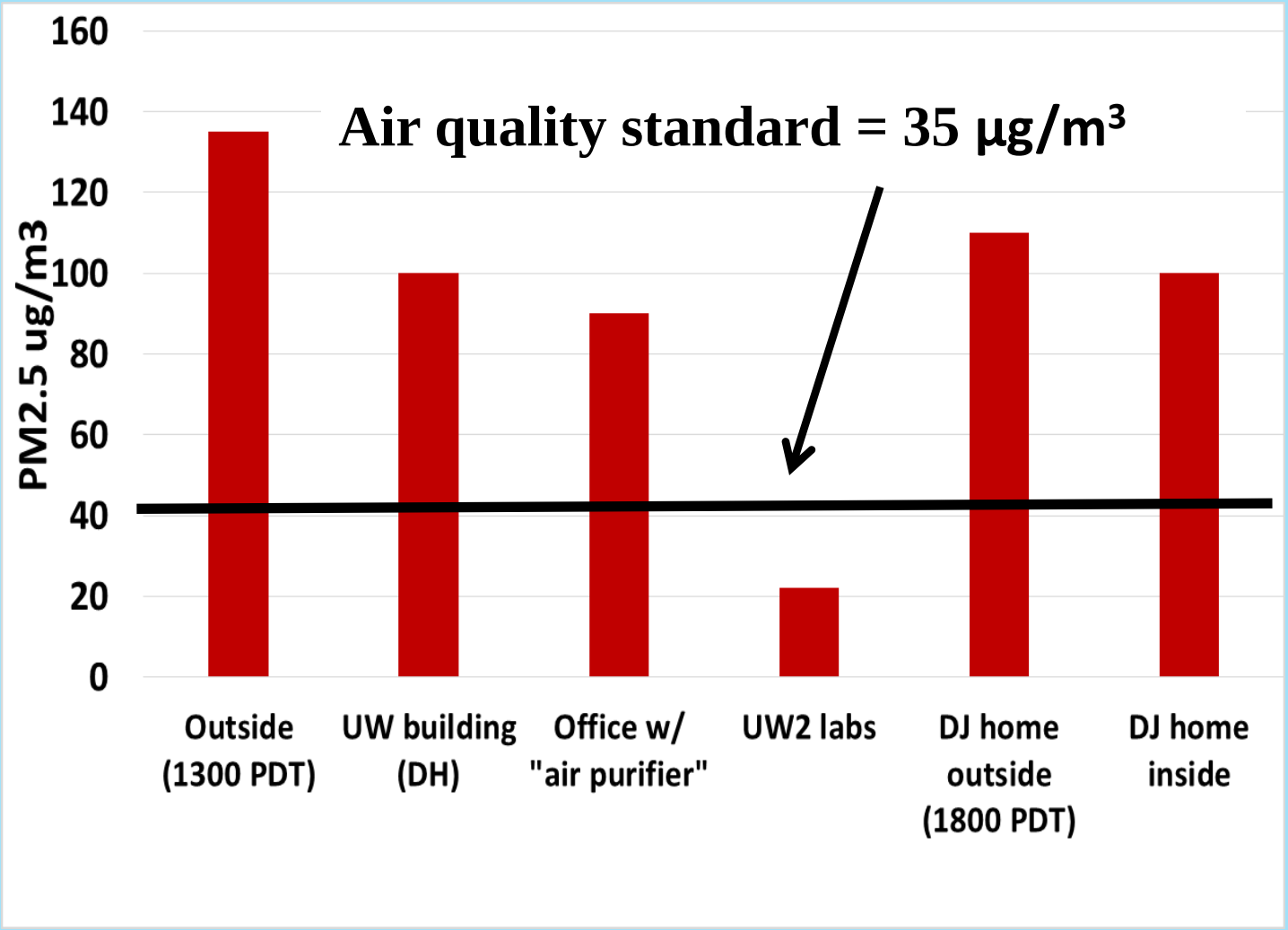
- Laing J.R. and Jaffe D.A. Environmental Manager, June 2019.

What is our advice for protecting your health during smoke emergencies?

- **Don't exercise, except in controlled spaces.**
- **Stay indoors.**
- **Keep windows and doors closed. Run AC if you have it.**
- **Wear a mask if you have to be outside.**
- **Leave area if smoke persists for days.**
- **Many communities cancelled school and other outdoor events and sent people home.**

➢ **Several health studies now under way to examine impacts of 2015, 2017 and 2018 extreme smoke events.**

How good is our advice? Data from Aug 22, 2018



Need for better information on

- **Indoor AQ**
- **Simple home purifiers.**
- **Use of low cost sensors.**

Data by D.Jaffe and Alex Margarito using a calibrated DustTrak.

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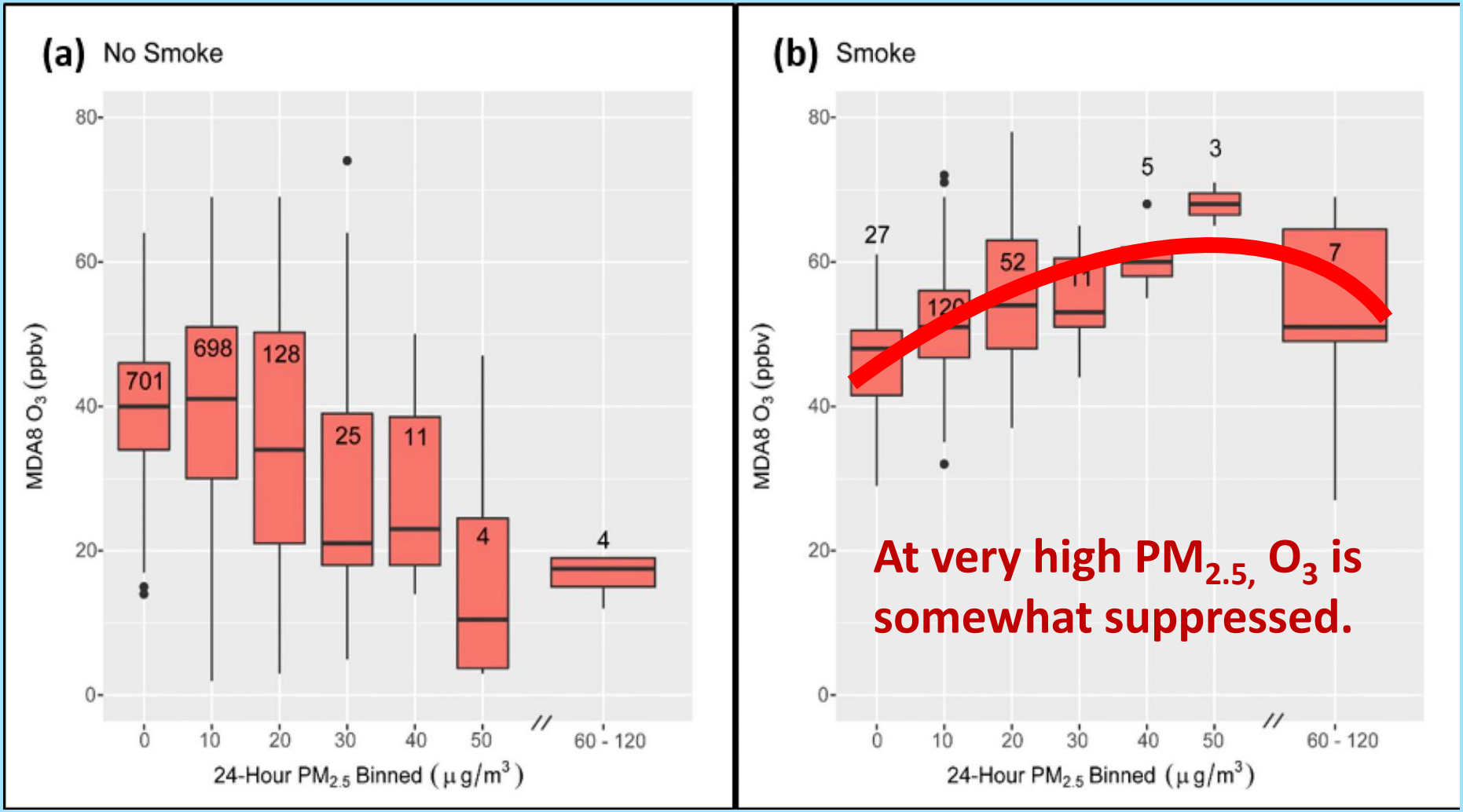
O_3 and fires- current knowledge

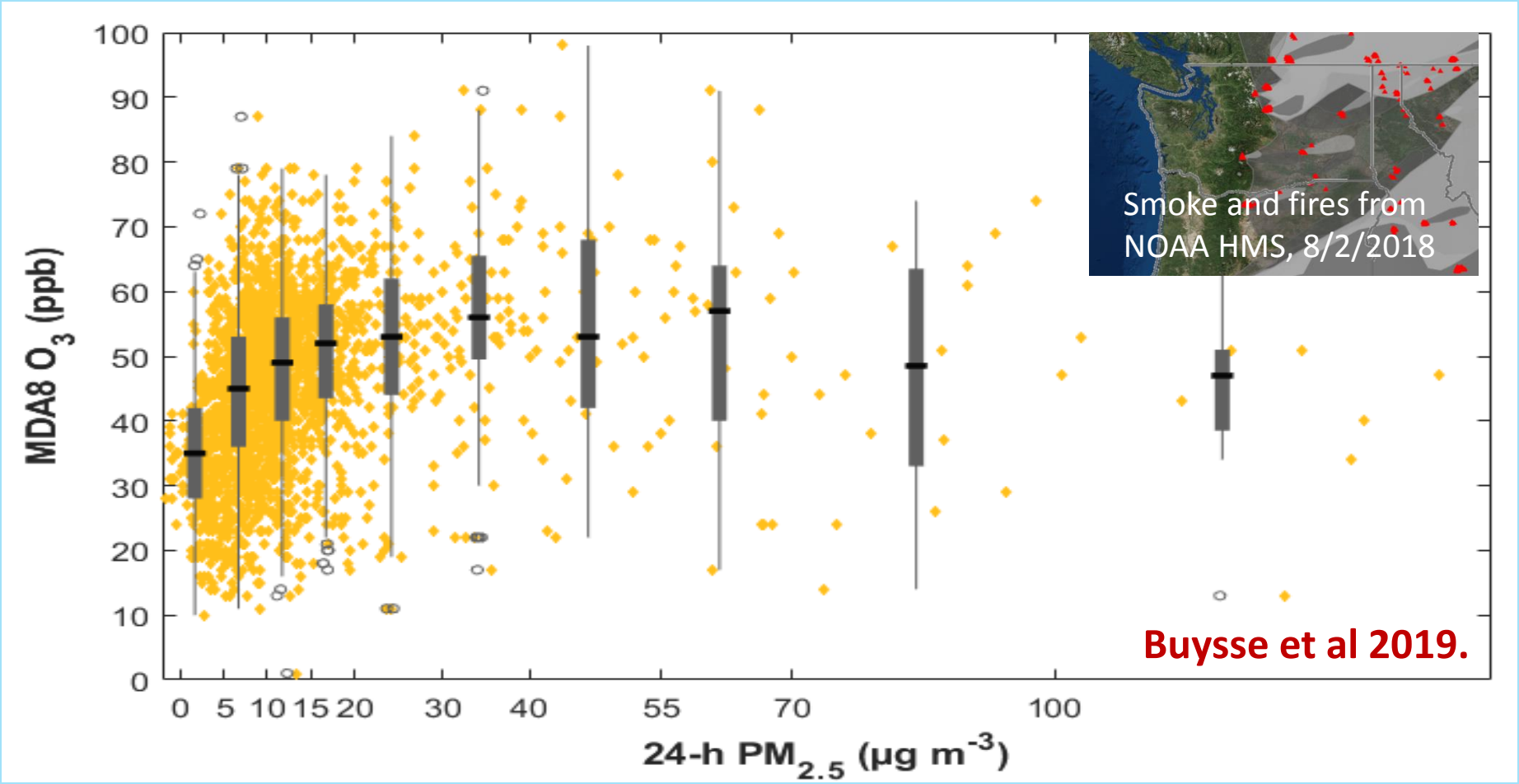
- **Significant inter-annual variations in mean O_3 and exceedance days in W.US due to wildfires (Jaffe et al 2008; 2011, 2018).**
- **Review of more than 100 studies found large variability in O_3 production, but most fires make O_3 (Jaffe and Wigder 2012).**
- **Zhang et al (2014), Baker et al (2017) and Vaughan et al (2017) all show significant over-estimate in O_3 produced from wildfires using Eulerian models.**
- **Using a statistical modeling approach we found that smoke added an average of 3-6 ppb to the MDA8 for 6 W.US cities (Gong et al 2018). In summer 2018, smoke added an average of ~13 ppb to MDA8 in Boise ID (McClure and Jaffe 2018).**
- **At very high $PM_{2.5}$ (>50 ug/m^3) O_3 is not enhanced or suppressed. (McClure and Jaffe 2018; Buysse et al 2019).**

Results from Boise, Summer 2017



McClure and Jaffe, Atmos Env. 2018.
Similar results in Buysse et al 2019 for 18 western monitoring locations.

PM-O_3 relationship with overhead smoke



1. At low PM, smoke not influencing surface.
2. At moderate PM, O_3 increases, but large degree of variability.
3. At high PM, O_3 declines.
4. Need for better tools to id smoke at low conc:

<u>Development for more routine BB tracers.</u>

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Since Eulerian models have difficulty in modeling wildfire O_3, in urban areas how can we find the "extra O_3" due to the fires?

- We use Generalized Additive Modeling (GAM), which is a type of machine learning that uses a training dataset to identify patterns and relationships. This approach can incorporate linear, non-linear and categorical relationships.

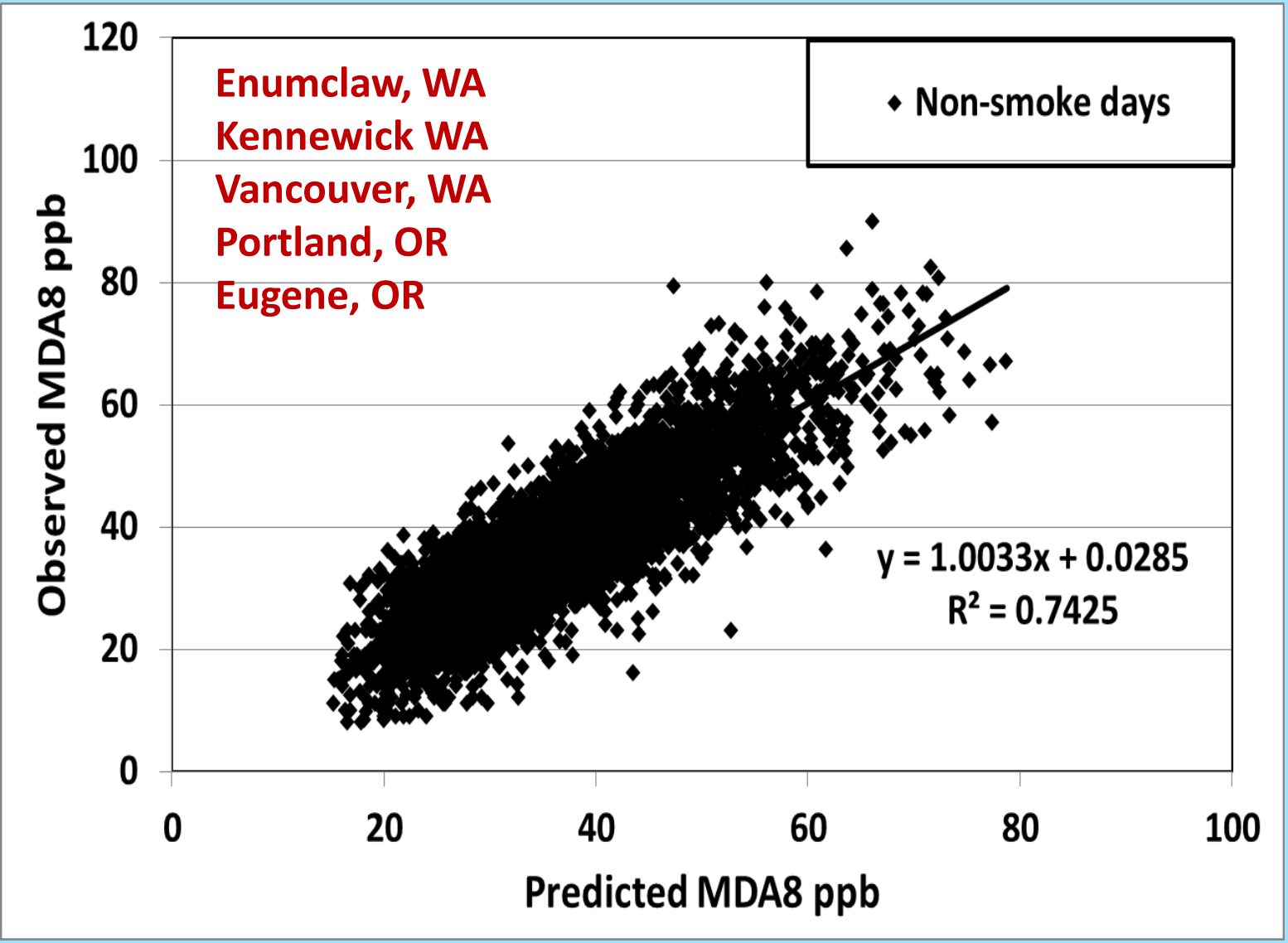
$$g(O_{3i}) = f_1(temp_i) + f_2(WS_i) + f_3(WD_i) + \ldots + residual_i$$

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, geopotential height, etc.
- Residuals give information on unusual O_3 sources and may be useful to support state requests for exceptional event designation.

Camalier et al 2007; CARB 2011; Sun et al 2015; Gong et al 2017; 2018; Jaffe et al 2018; McClure and Jaffe 2018; Gao et al 2019.

GAM O_3 results for 5 sites in PNW: 2007-2017 data



Use HMS Fire and Smoke Product plus surface $PM_{2.5}$ to identify smoke/non-smoke days

Work of Honglian Gao.
Manuscript in prep.

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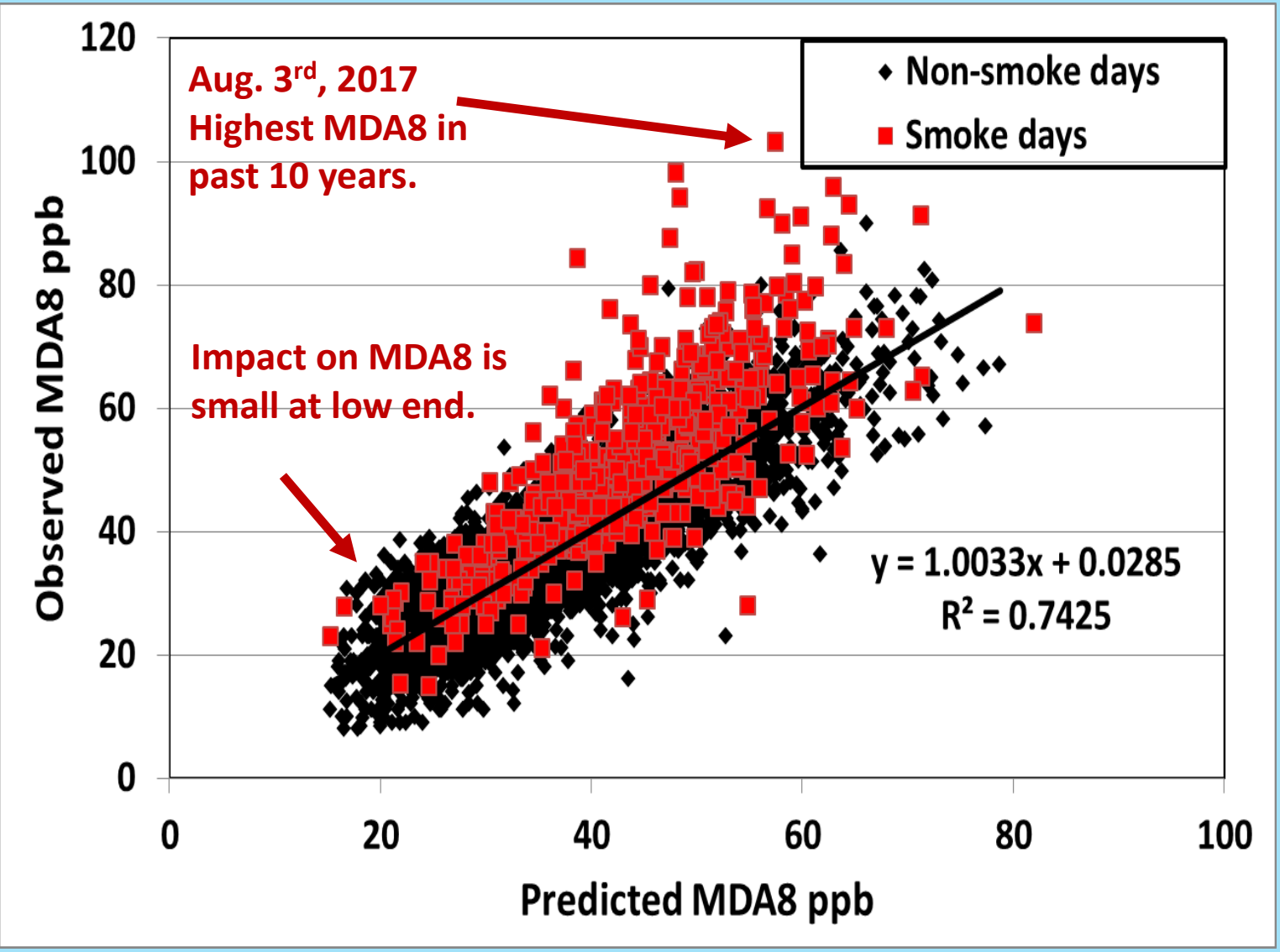
Impact of smoke on O_3 for 5 sites in PNW: 2007-2017 data



Use HMS Fire and Smoke Product plus surface $PM_{2.5}$ to identify smoke.

Results suggest that enhanced O_3 is largely driven by enhanced in-situ photochem.

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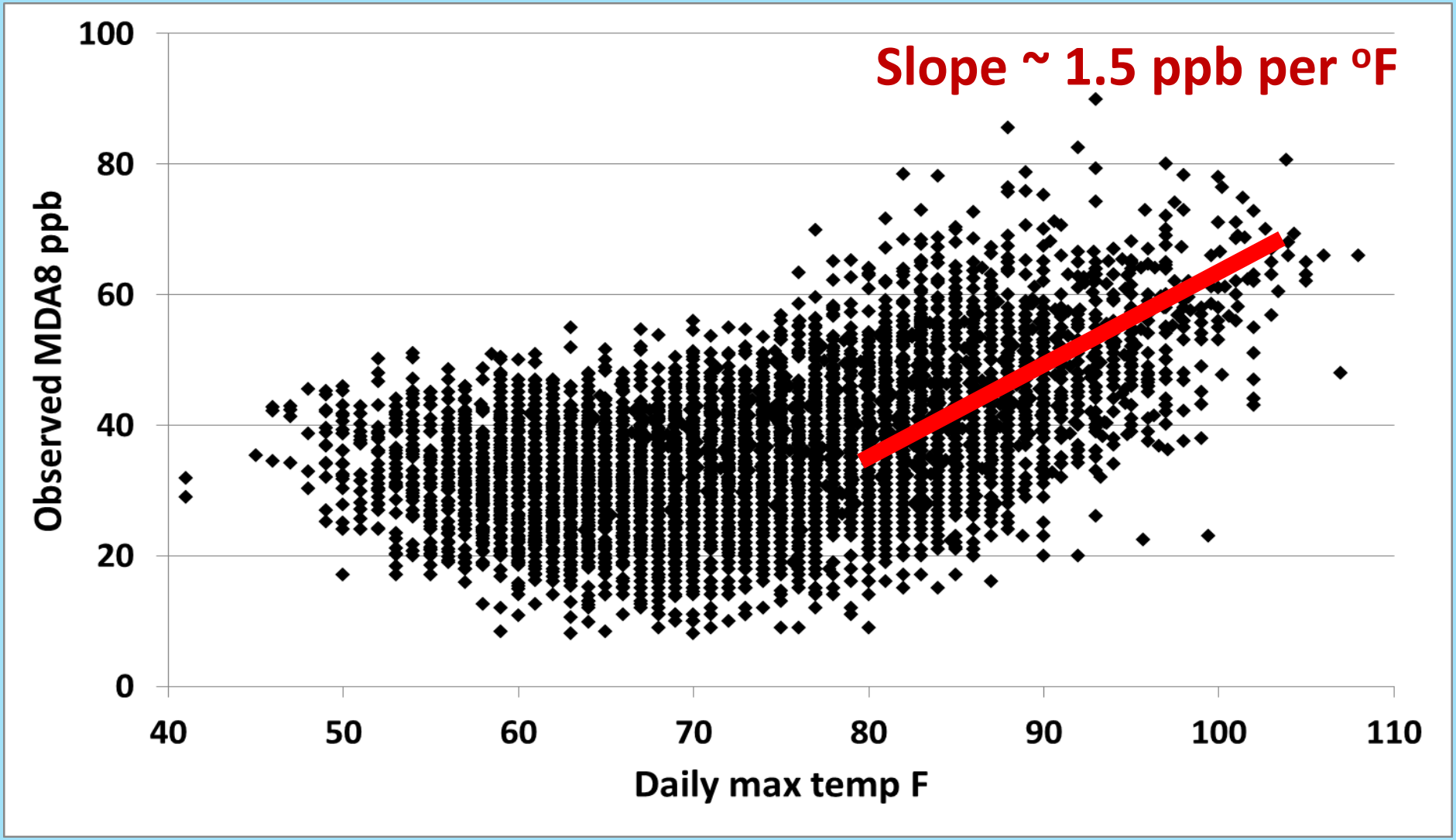
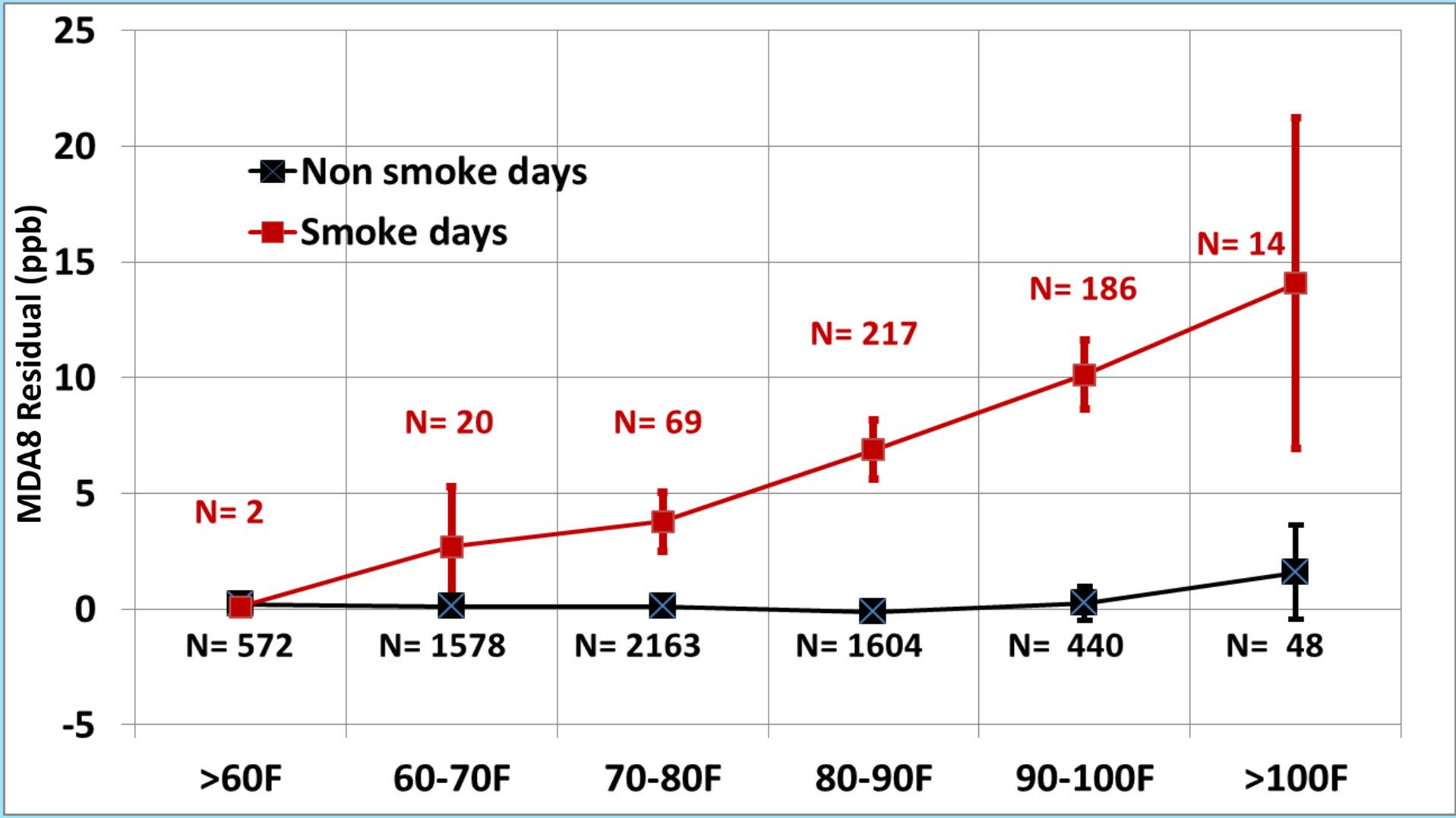
Role of daily max temp on MDA8 O_3- Observations
5 sites in PNW: 2007-2017 data



MDA8 residual for 5 sites in PNW: 2007-2017 data (mean +/- 95% CI, ppb)



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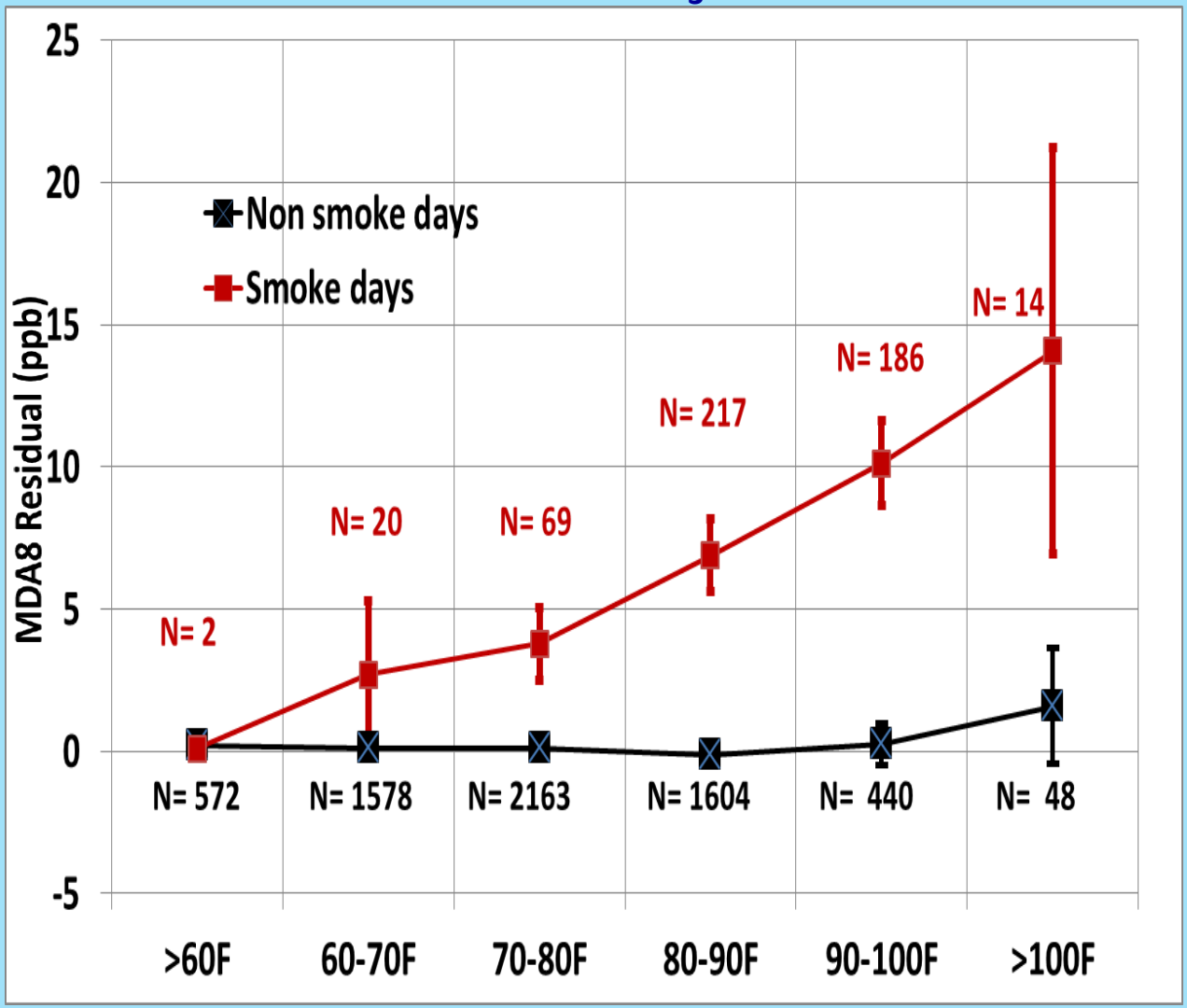
GAM residuals vs daily max temp (mean +/- CI, ppb)

MDA8 residual O_3 for 5 sites in PNW: 2007-2017 data



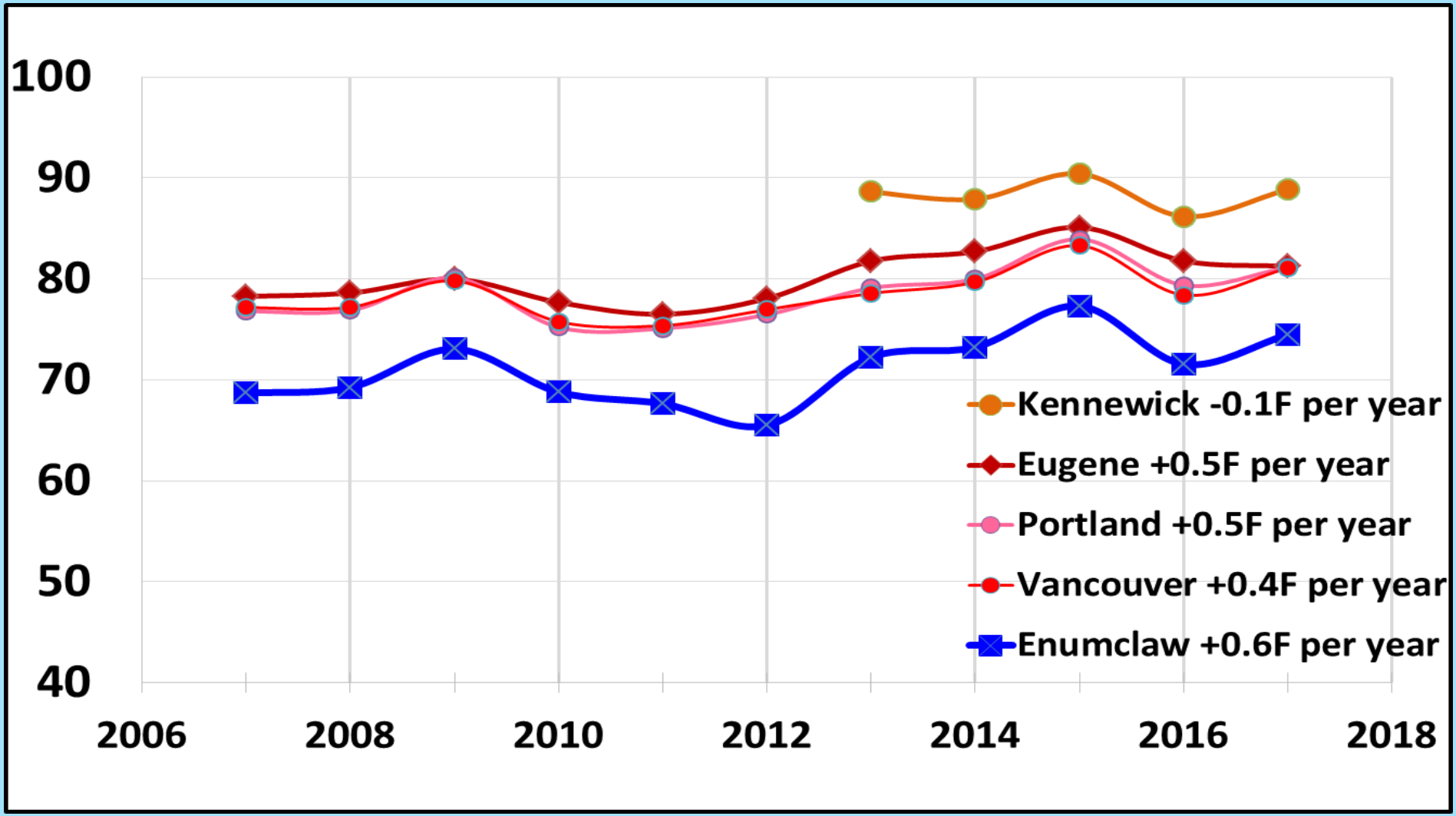
1. Temperature is important control on O_3 on both smoke and non-smoke days.
2. GAM predictions captures temp relationship well for non-smoke days.
3. GAM predictions are significantly low on smoke days. This tells us that smoke chemistry adds an average of ~10-15 ppb, with greatest impact on warmer days

What about climate change?

Will CC influence O_3 in the W. US?

Is CC influencing O_3 now?

Observed mean (June-Aug) daily max temp (°F) at 5 sites in the PNW



All trends significant at P<0.1, except for Kennewick.

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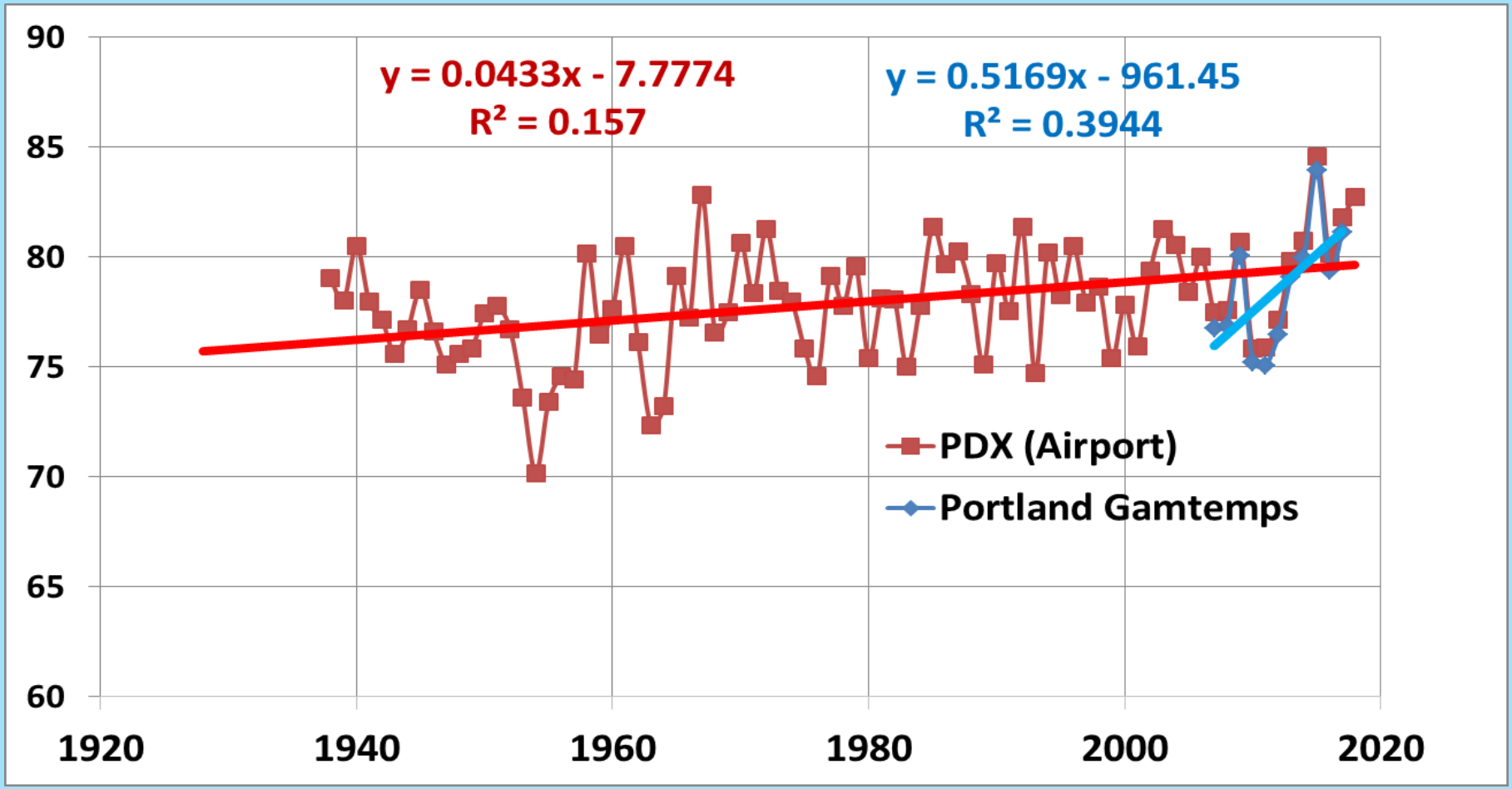
Summer avg daily max temp- Portland, OR



- For Portland, the long-term temp increase of 0.04°F/year is adding about 0.6 ppb per decade to the average MDA8.

Plans for Summer 2019

Major smoke experiments in 2018+2019: WECAN/FIREX/FIREX-AQ

NSF/NOAA/NASA

Multiple aircraft, ground and mobile sites in the W. US.

Broad goals:

- **Improved understanding of emissions for western fuels.**
- **Improved understanding of chemistry and processing during transport.**
- **Improved understanding of mixing of smoke with urban pollution.**
- **Better tools to identify low concentrations of smoke in urban areas.**

Collaboration with City of Seattle

- **Installation of filtration and calibrated Purple Air sensors to provide clean air spaces for residents at several community centers (International District and Rainier Beach).**

Observations at Boise/St. Lukes site in 2019

D. Jaffe (UW), E.Wood (Drexel), R.Long/ M. Landis (EPA)

Jaffe group previously used this site to examine O_3 production in urban smoke (McClure and Jaffe 2018- Atm.Env.).

Goals:

1. Evaluate different methods to get O_3 production in smoke influenced airmasses (e.g. NO*HOx, dO_3/dT).
2. Evaluate consistency of extended Leighton relationship with obs of NOx and HOx.
3. Examine NOx and VOC sensitivity to O_3 production in urban influenced/smoke plumes.
4. Examine J values as a function of PM in smoke plumes.
5. Test new Oxy-VOC sampler ("suitcase sampler") as a tool to identify presence of smoke at low concentrations in urban areas.

Observations

a. Idaho DEQ (host): Standard NCORE obs. including CO, NOy, O_3, $PM_{2.5}$)
b. Jaffe group, UW: "Suitcase OVOC sampler", spectrally resolved UV flux (w/Flynn and Hall), NO.
c. Wood group, Drexel U: HOx, NO_2
d. Long/Landis, EPA-ORD: variety of inst. specific to their goals.

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Mt. Bachelor, Oregon, (MBO) 2.8 km asl: Summer 2019

Measurements:

- SP-AMS (Qi Zhang's group at UCD)
- CIMS (Joel Thornton, UWS)
- PTRMS (Lu Hu's group at UMt)
- J values (Lefer/Flynn/Hall)
- NOx,PAN,O_3, CO, CO_2, σ_{scat}, σ_{abs}, size distributions, etc (my group)

Goals:

1. Evaluate the NOx photostationary state and O_3 production.
2. Identify sources of HONO in plumes and p-NO_3^- recycling.
3. Relationship of aerosol chem to absorption.

National Science Foundation
WHERE DISCOVERIES BEGIN

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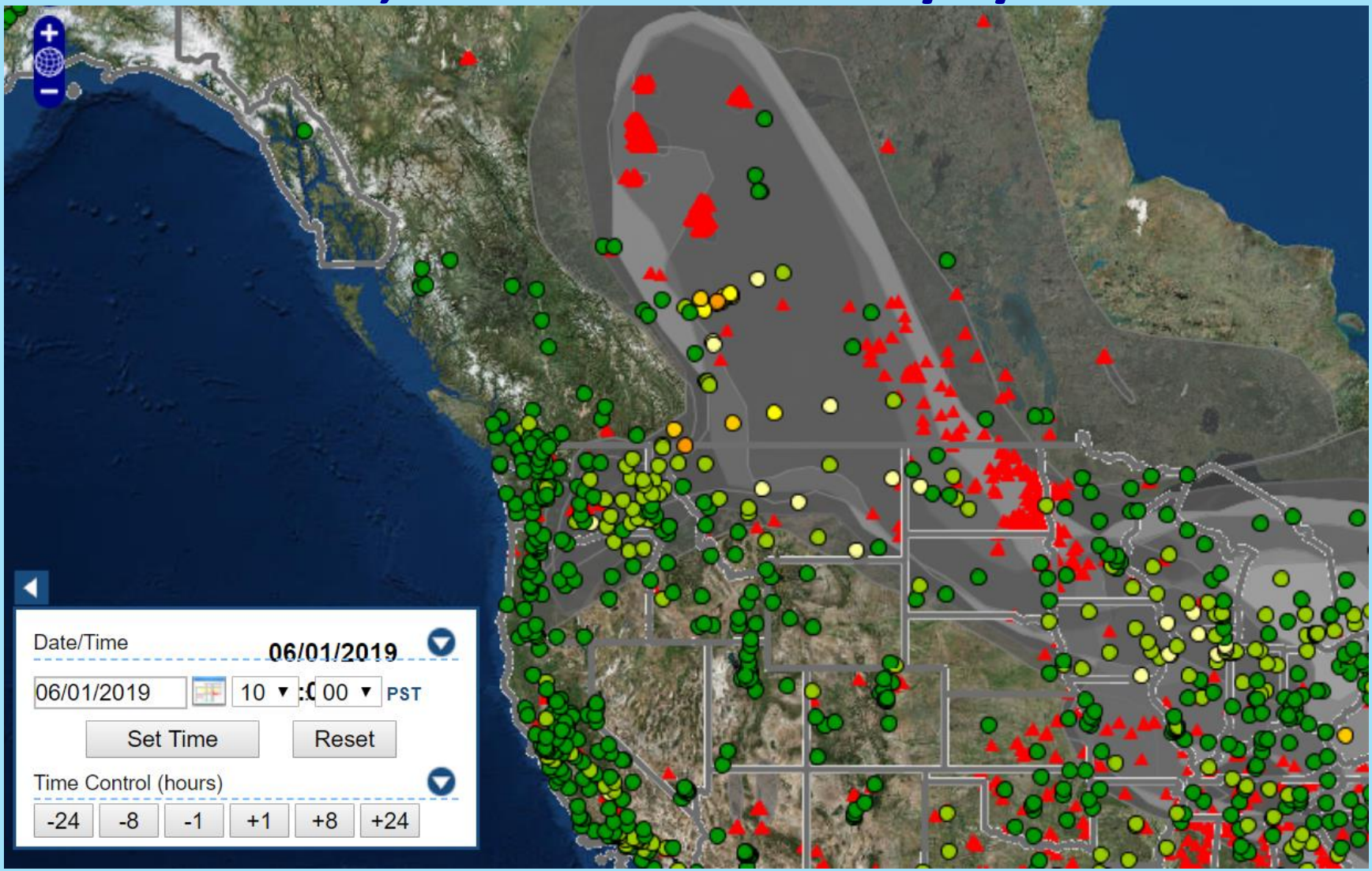
Smoke, fires and PM: 6/1/2019



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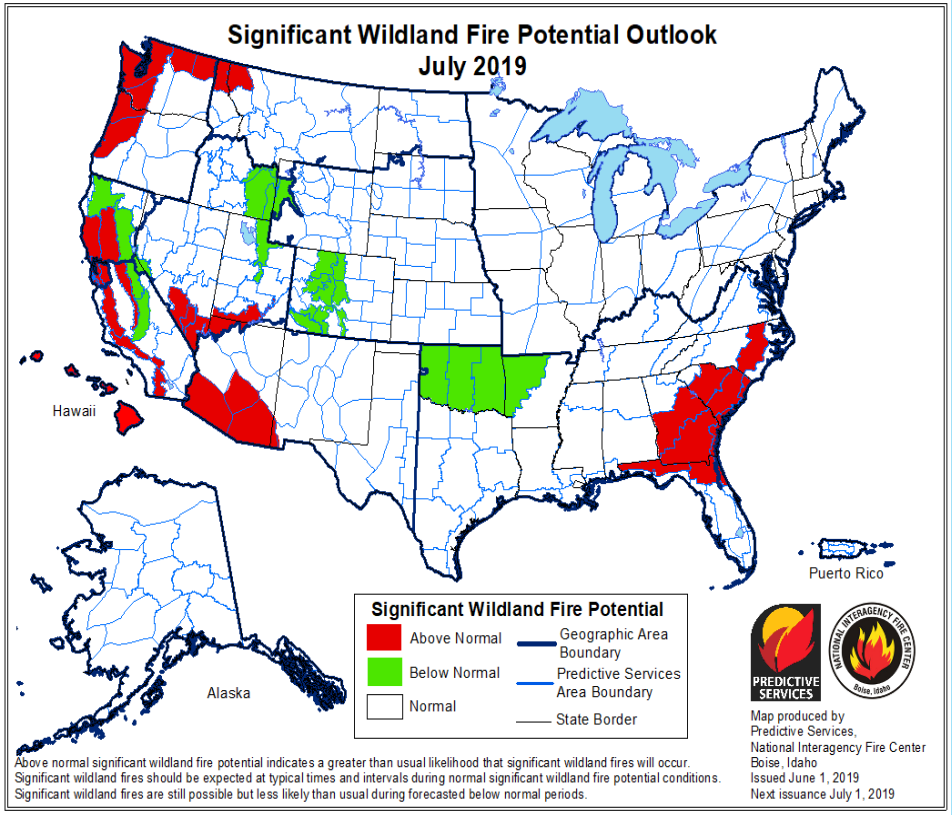
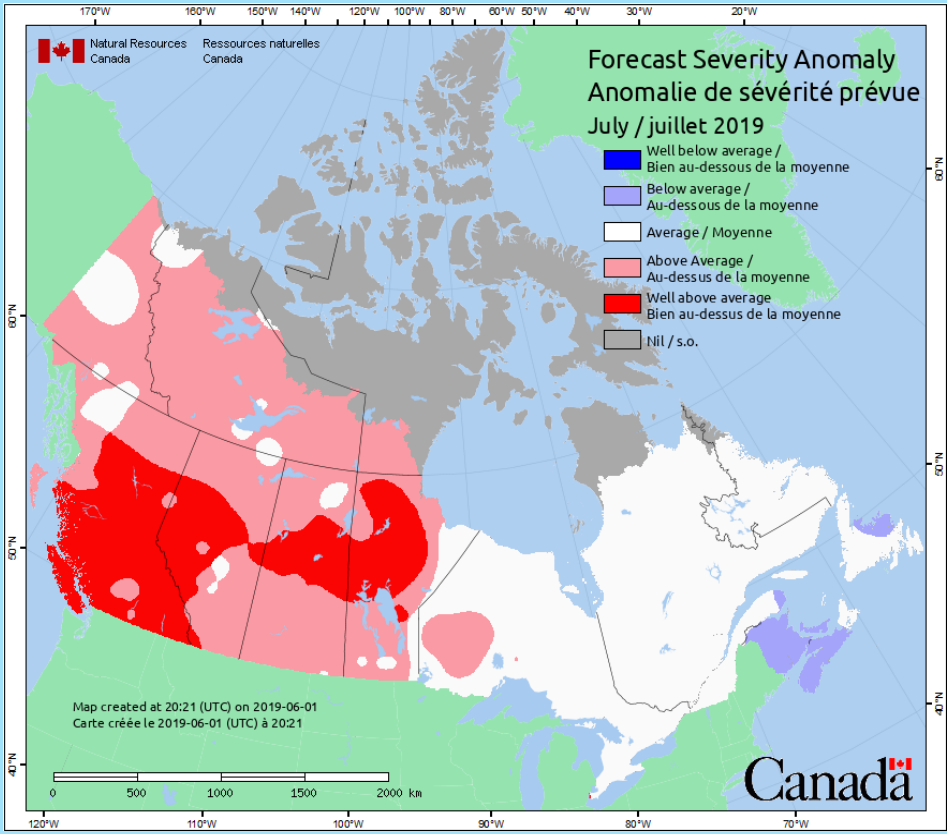
Fires and Smoke forecasts: July 2019





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Summary

1. In 2017 and 2018, wildfires resulted in extreme $PM_{2.5}$ in many parts of the West, incl. the highest ever observed $PM_{2.5}$ and the highest O_3 in past 20 years for many cities
2. Indoor air quality may or may not be much better than outdoors. Need to come up with better tools to identify clean spaces during smoke emergencies.
3. Wildfire emissions enhance O_3 in urban areas. We use Generalized Additive Modeling (GAM) to quantify smoke contribution to MDA8.
4. In many areas in the western US, the annual 4th highest MDA8 is flat or increasing. This is likely due to a combination of fire influence and climate change.
5. In the future: more of the same! Preparing for smoke and climate change are becoming increasingly critical.