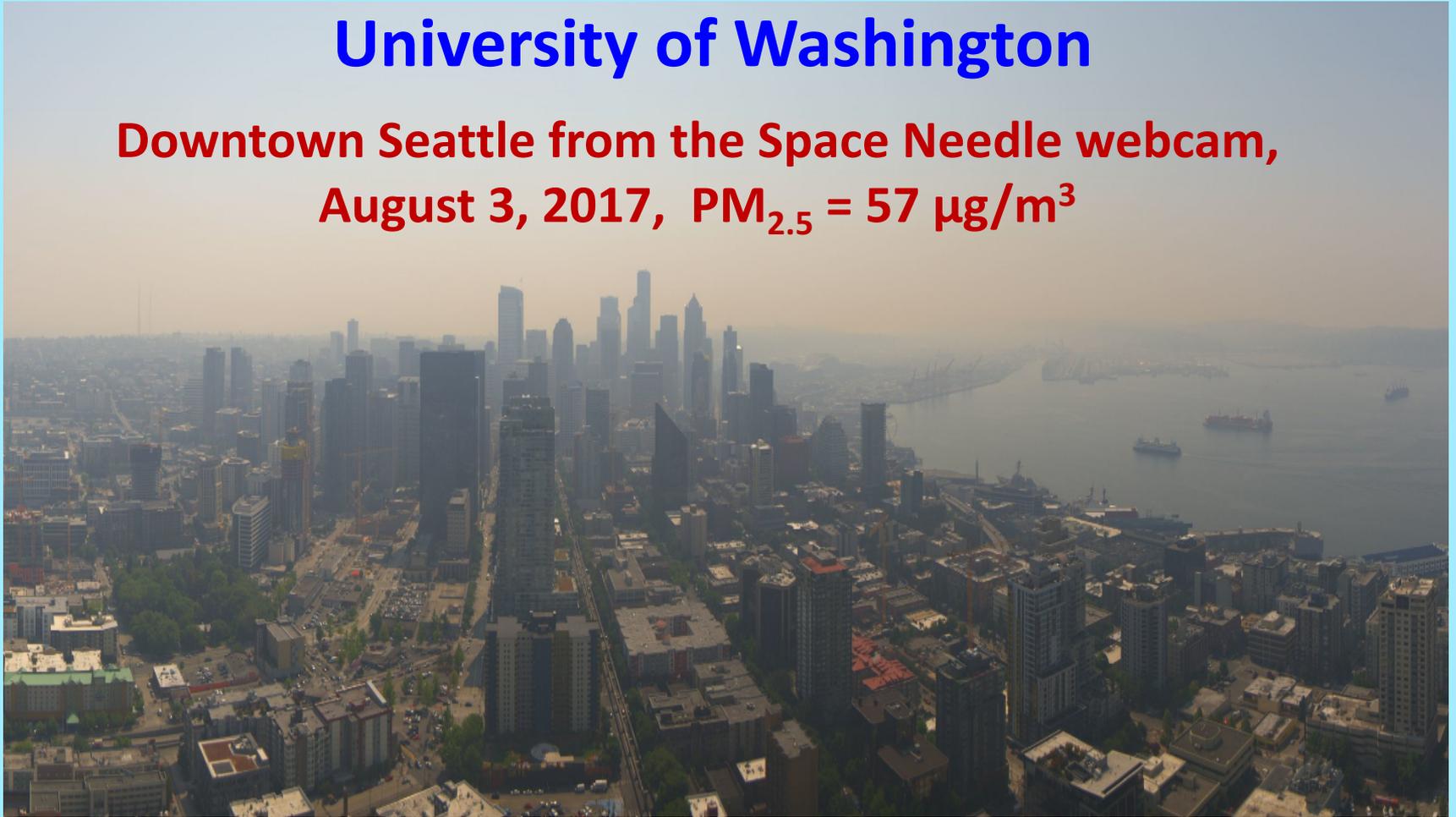


Impacts of the 2017 Wildfires on O₃ around the PNW

Dan Jaffe, Crystal McClure, Honglian Gao, Claire Buysse, Aaron Kaulfus (UAH)

University of Washington

Downtown Seattle from the Space Needle webcam,
August 3, 2017, PM_{2.5} = 57 μg/m³



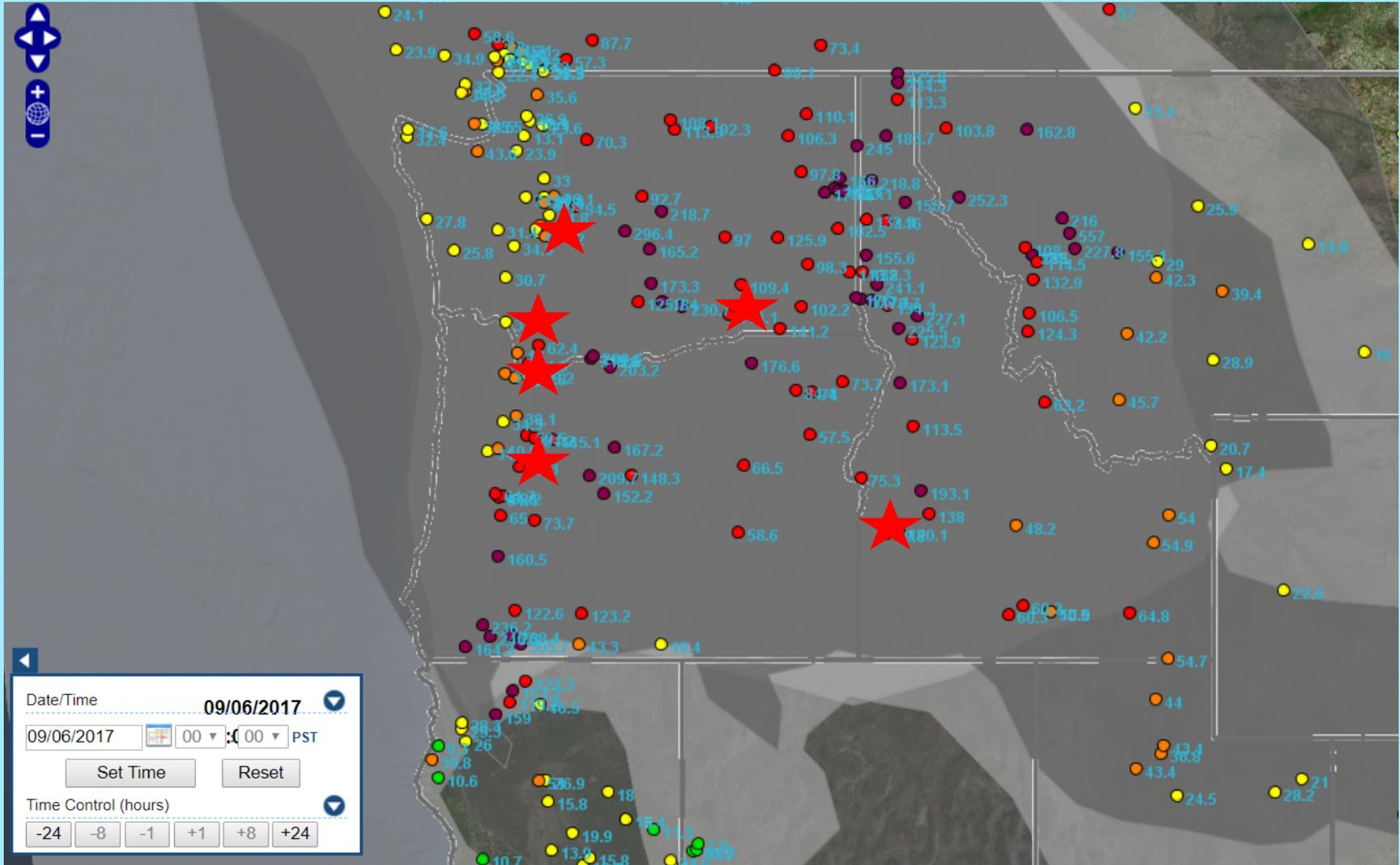
Funding from NOAA-FIREX program



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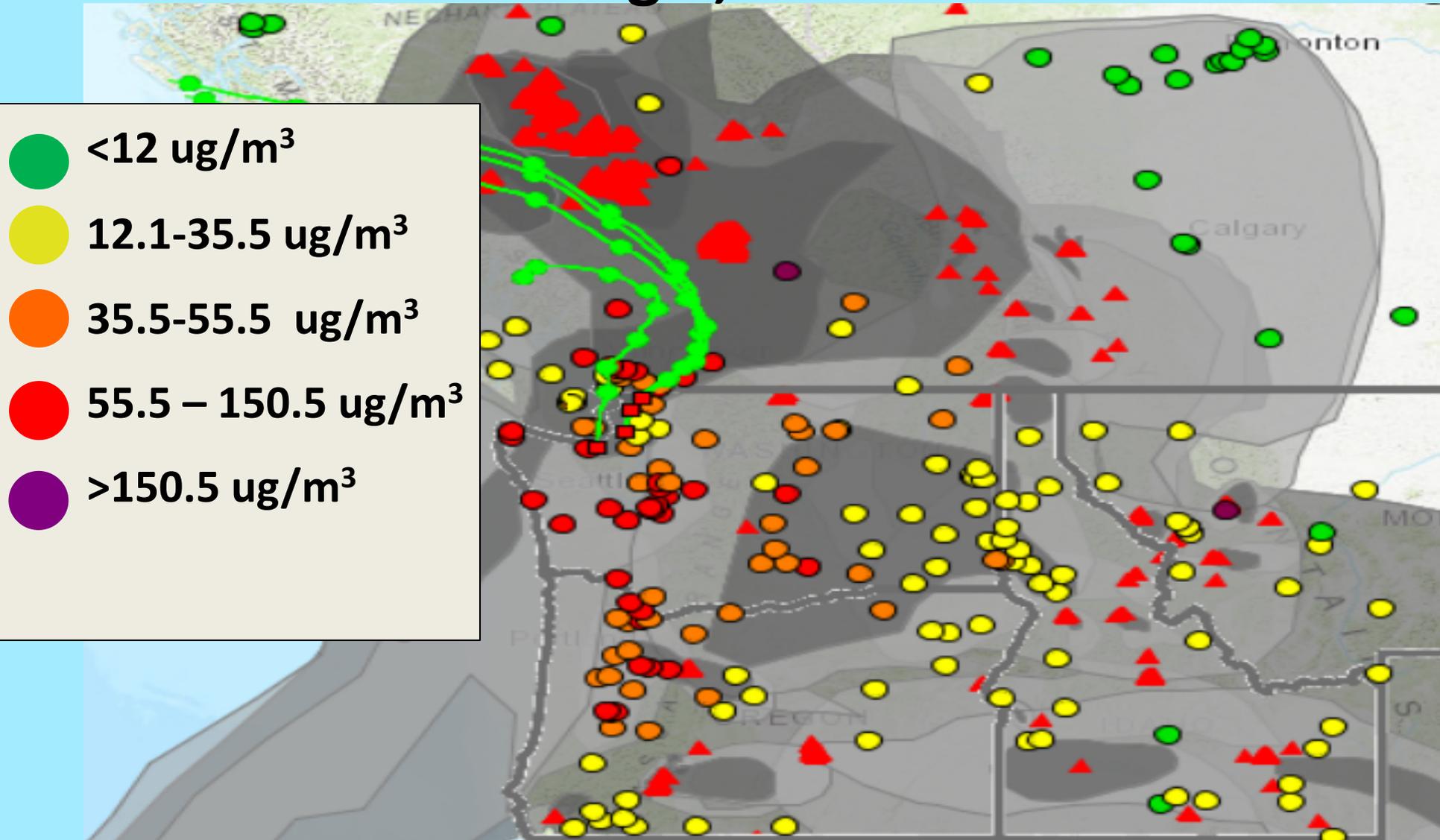
NOAA-HMS Fire and Smoke Product with PM2.5

Sept. 6th, 2017



Airnowtech tool with HMS smoke and PM_{2.5}

Aug 3, 2017



Daily O₃ in Enumclaw, WA

Daily Max 8-hour Ozone Concentrations from 01/01/08 to 12/31/17

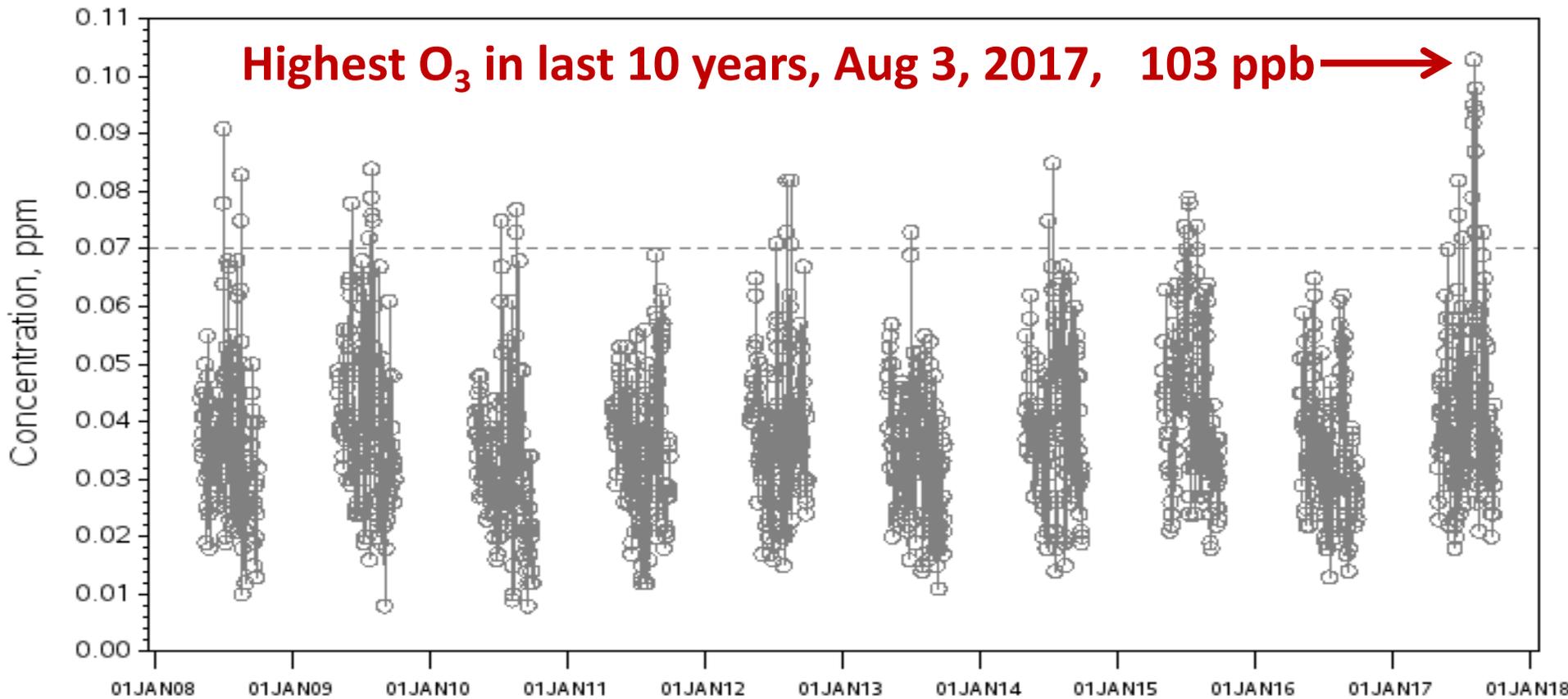
Parameter: Ozone (Applicable standard is .070 ppm)

CBSA: Seattle-Tacoma-Bellevue, WA

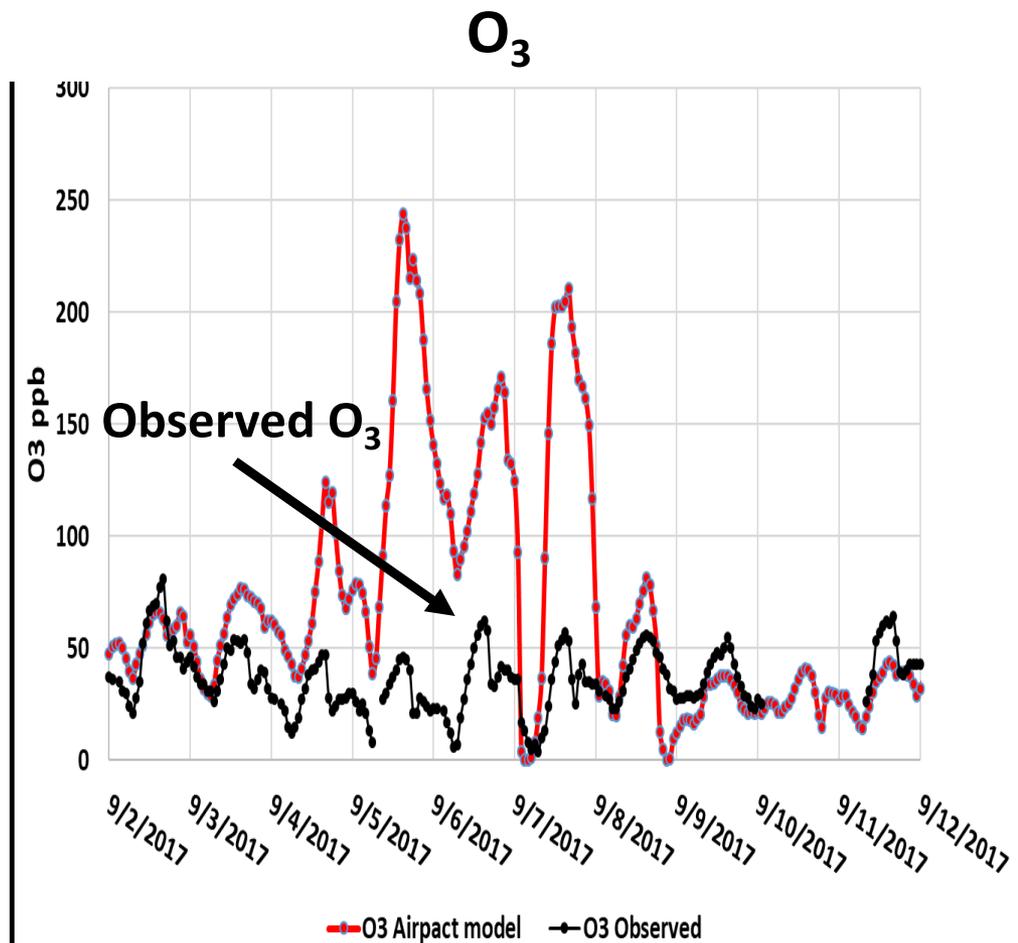
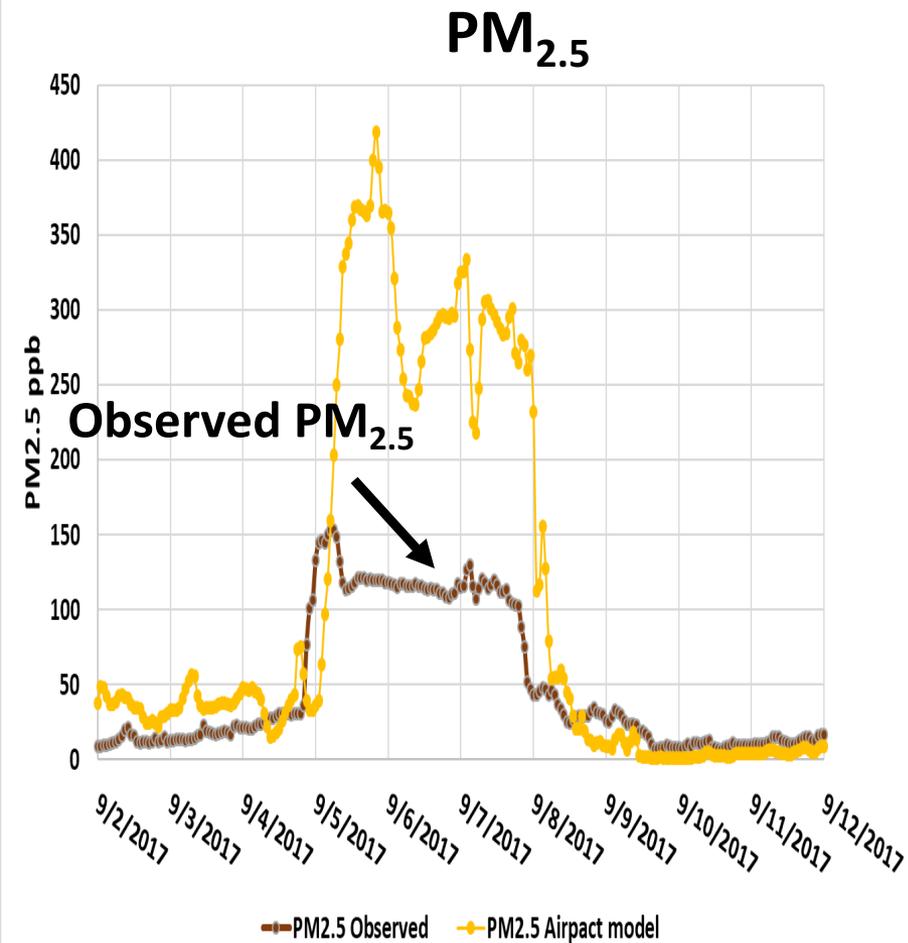
County: King

State: Washington

AQS Site ID: 53-033-0023, poc 1



Observed and AIRPACT fire impacts for Kennewick



Are high PM levels suppressing O₃ formation?

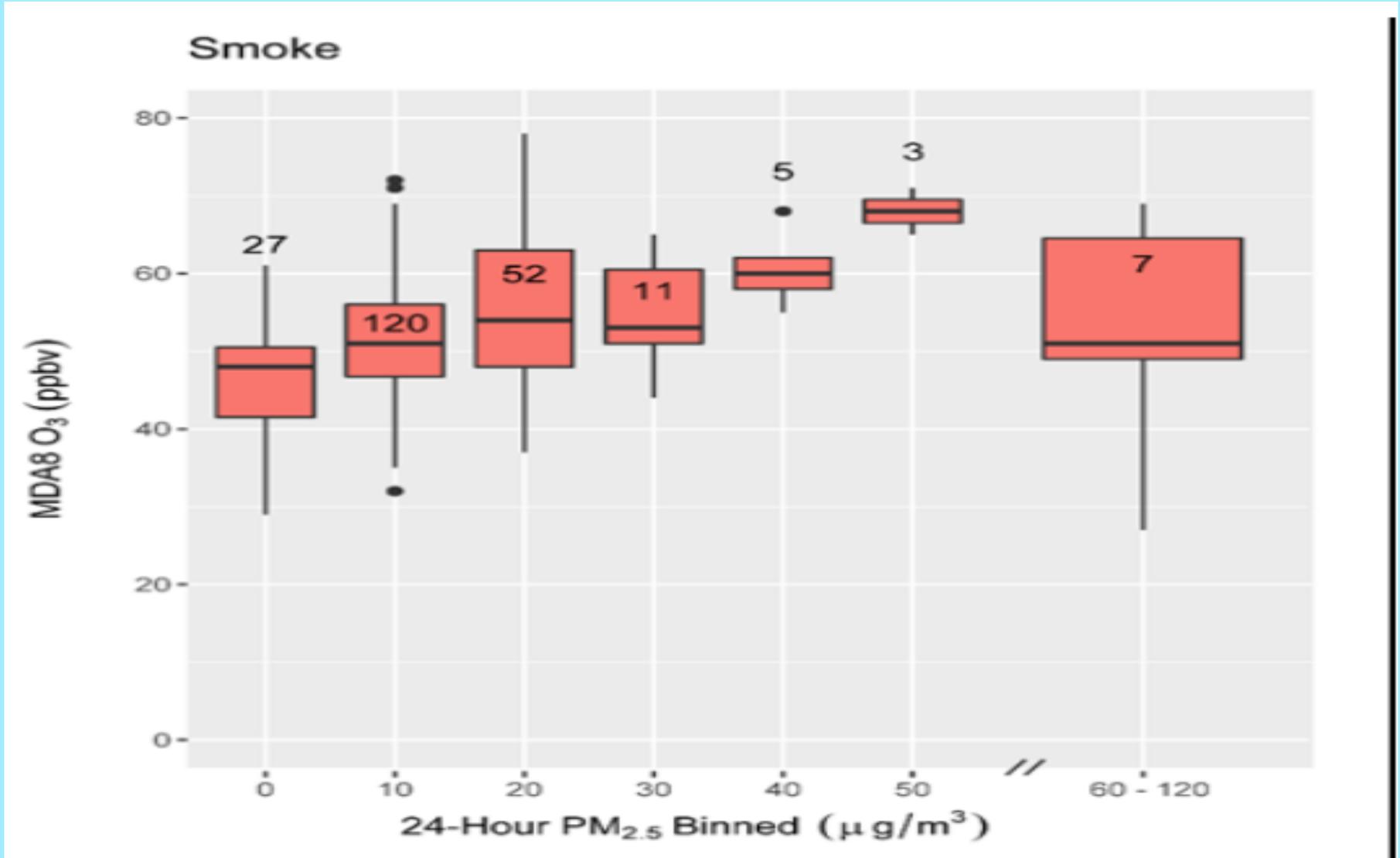


Results from Boise, Summer 2017

Averages	PM _{2.5} μg/m ³	CO ppb	MDA8 ppb	NO _y ppbv	PAN ppb	PAN/NO _y ppb/ppb
Fire influenced	34.5	464	58.4*	17.3	0.90	0.0626
Non-fire influenced	9.2	261	41.5	14.1	0.61	0.0479

1. Experiment dates: Aug 1-Oct 1, 2017; 45 days with smoke!
2. Enhancement in MDA8 on smoke days: ~17 ppb.
3. Smoke days had ~3 ppb more NO_y, but only ~0.3 ppb more PAN.
4. Both NO_y and VOCs likely contributed to the enhanced O₃.
(McClure and Jaffe, 2018)

Results from Boise, Summer 2017



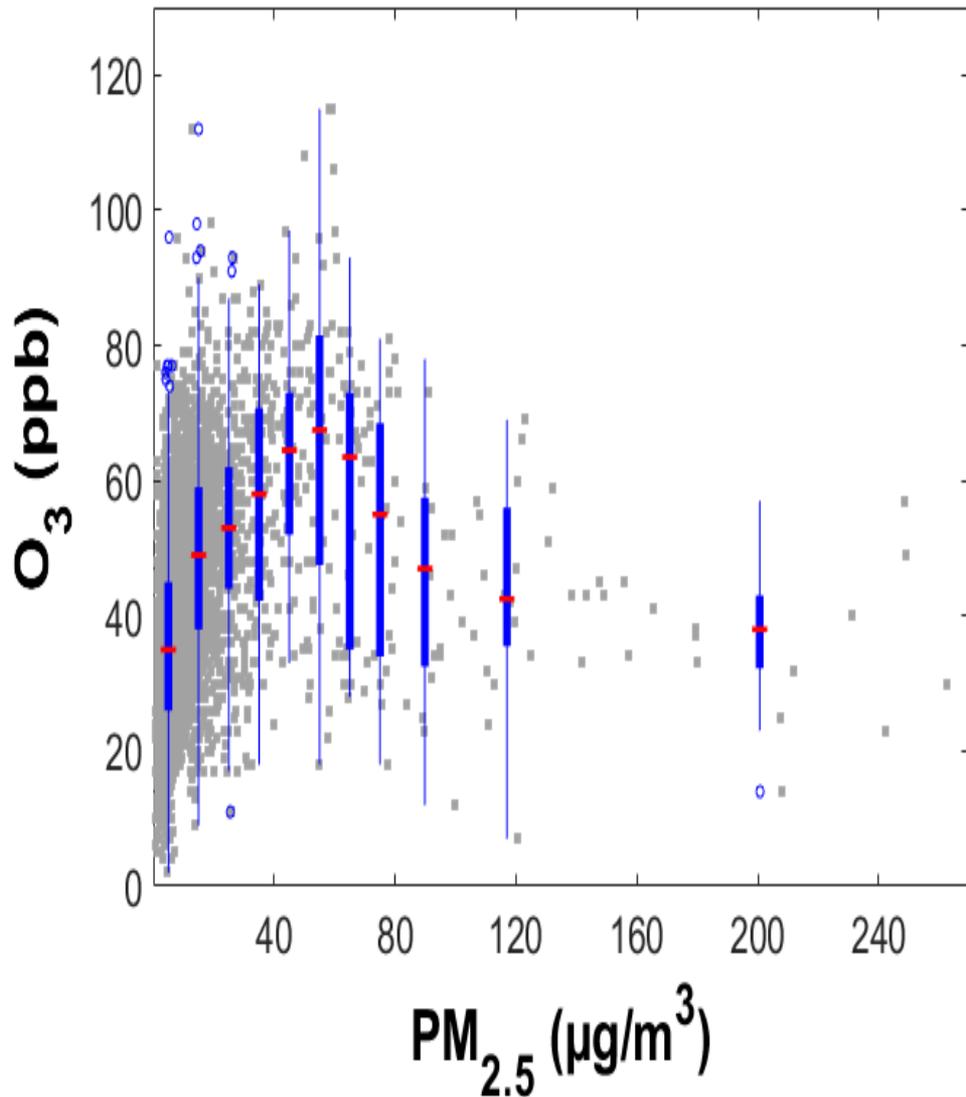
McClure and Jaffe, 2018 (in-review)



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How do O₃ and PM relate in urban smoke events?

Afternoon O₃ when HMS shows smoke overhead.



- Afternoon O₃ (1-6 pm) for May-Sept 2013-2017 for 7 cities in western U.S. (North Bend WA, Portland OR, St. Lukes IR, Eugene OR, Chico CA, Arden Arcade/Sacramento CA).
- HMS smoke product is not a perfect indicator of boundary layer smoke. PM and O₃ positively correlated up to ~50 µg/m³, negatively correlated or uncorrelated at higher concs.
- Work of Claire Buysse (UW)

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

- We have developed a statistical approach that models O_3 as a function of numerous meteorological variables.
- We use Generalized Additive Modeling (GAM), which is a flexible method, similar to machine learning that uses a training dataset to identify patterns and relationships. This approach can incorporate linear, non-linear and categorical relationships.
- Good O_3 predictors are daily max temp, RH, daily avg vector wind speed, daily average vector wind direction, back-trajectory distance and direction, 500 mb heights, etc.
- Model can capture between 50-80% of the variance in daily MDA8s, depending on the city.
- Gong et al 2017 (EST).

Statistical Approach: Generalized Additive Model

- Examines the relationship between the observed maximum daily 8-hour average (MDA8) and meteorological factors. This is a type of “machine learning” using a training dataset.

$$g(O_{3i}) = f_1(\text{temp}_i) + f_2(\text{WS}_i) + f_3(\text{WD}_i) + \dots + \text{residual}_i$$

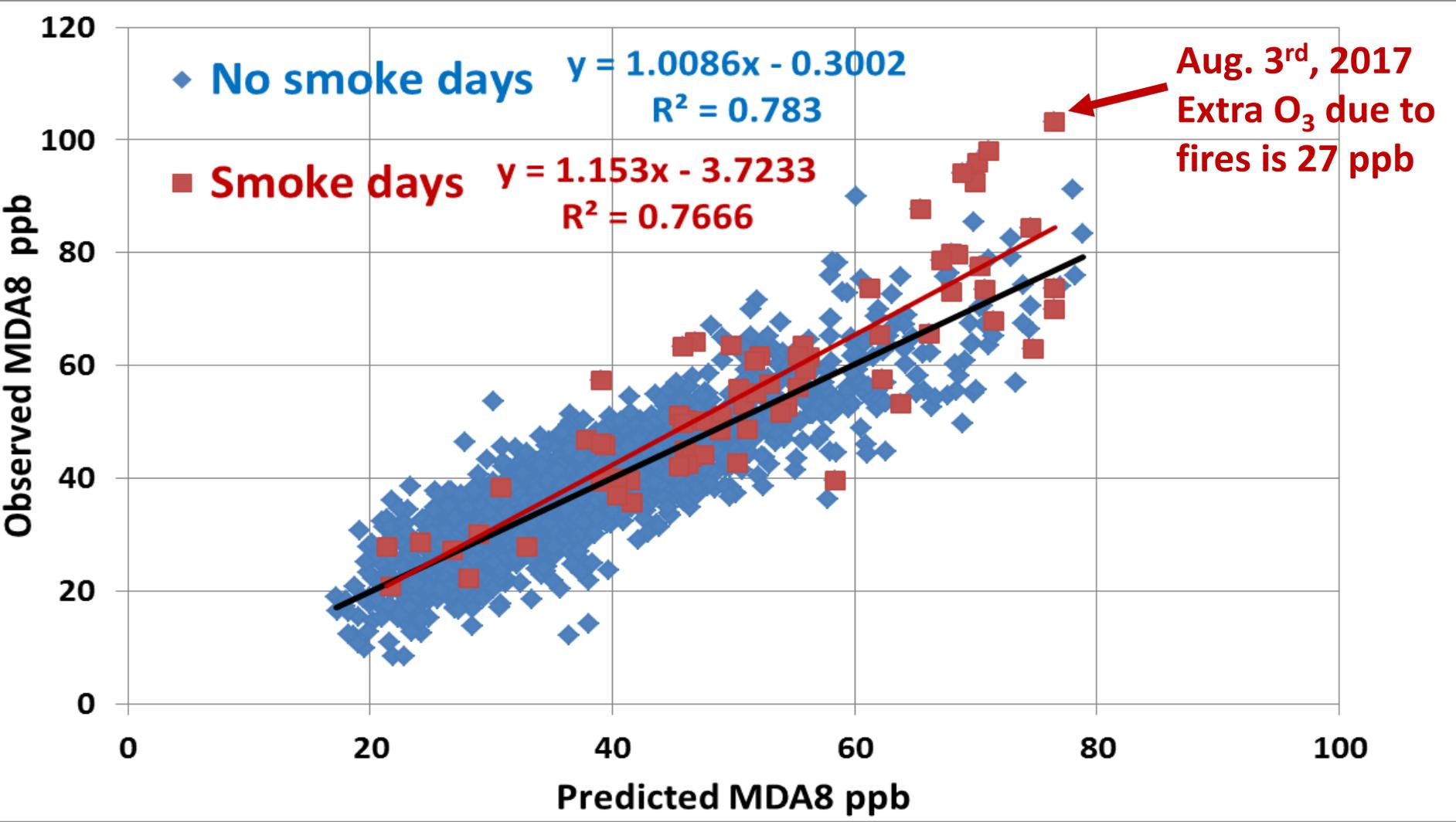
Where f_1, f_2 , etc are “link” functions which are obtained from spline fits to the observations. The “ i ” refers to each daily observation.

- GAMs can incorporate numerical, ordinal or categorical variables.
- Possible factors to include are temp, WS, WD, RH, solar flux, trajectory distance, etc.
- Use “mgcv” package in “R” software.
- Outliers (high residuals) represent an additional O_3 source and are candidates for further investigation. In some cases, statistical modeling can support exceptional event designations.

Jaffe et al 2004; 2013; Camalier et al 2007;
CARB 2011; EPA 2015; Sun 2015; Gong et
al 2017

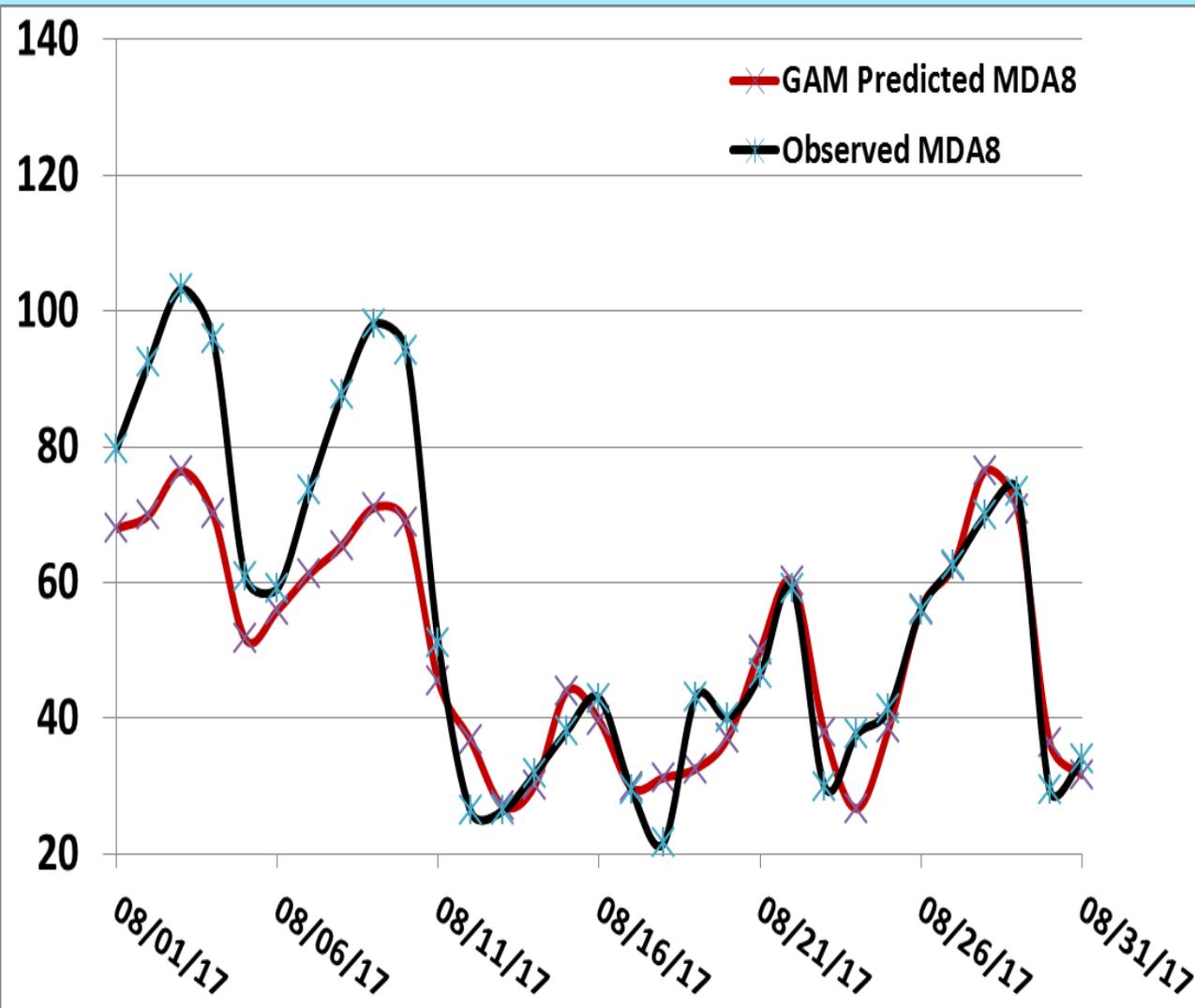


Impact on O₃ in smoke at Enumclaw: 2008-2017 data



Gong et al 2017, Jaffe et al 2018,
Gao et al 2018

Enumclaw-August 2017



Aug. 3rd:

PM_{2.5} 56 ug/m³

O₃ residual = 27 ppb

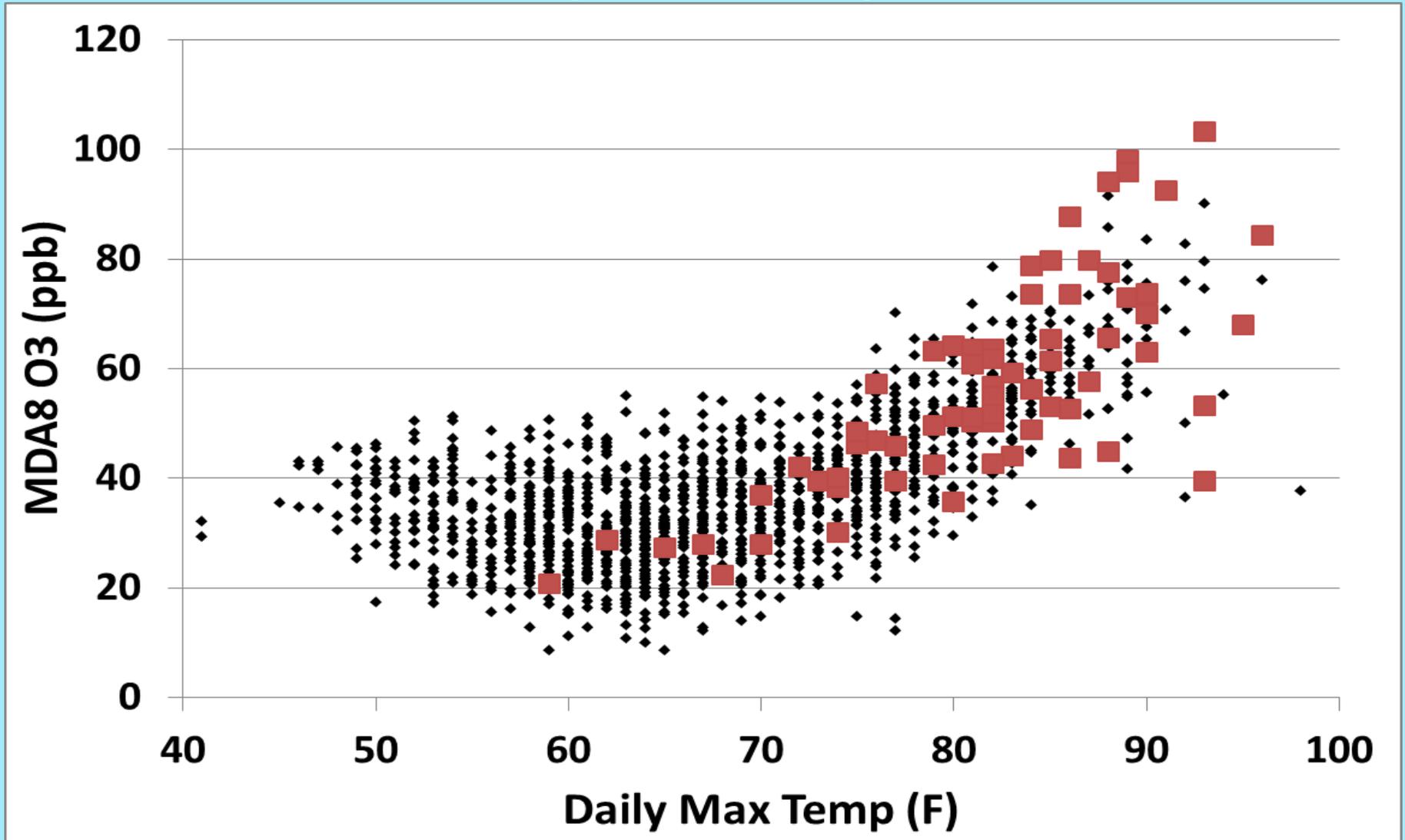
Aug. 9th:

PM_{2.5} 46 ug/m³

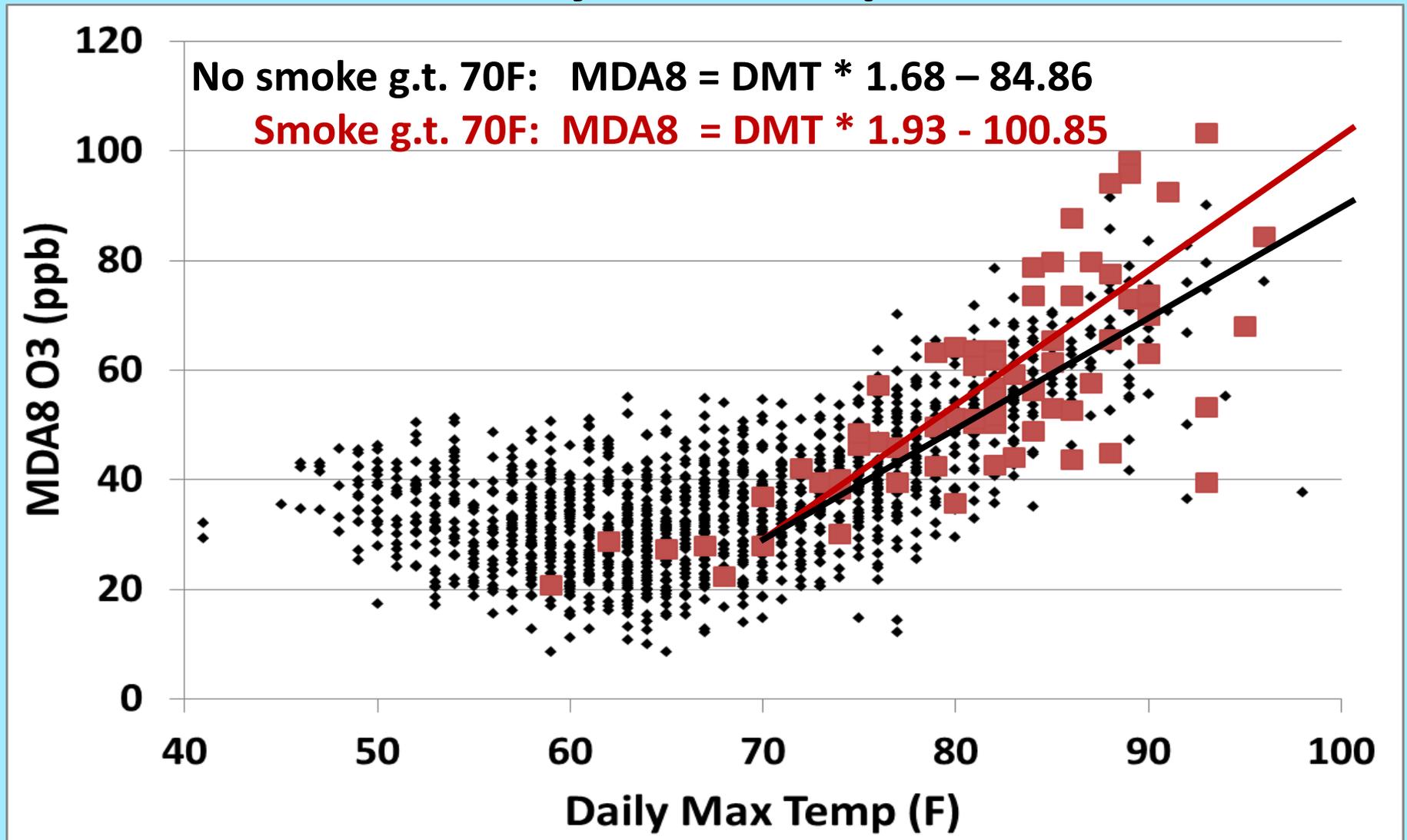
O₃ residual 27 ppb



MDA8 vs Daily Max Temp-Enumclaw

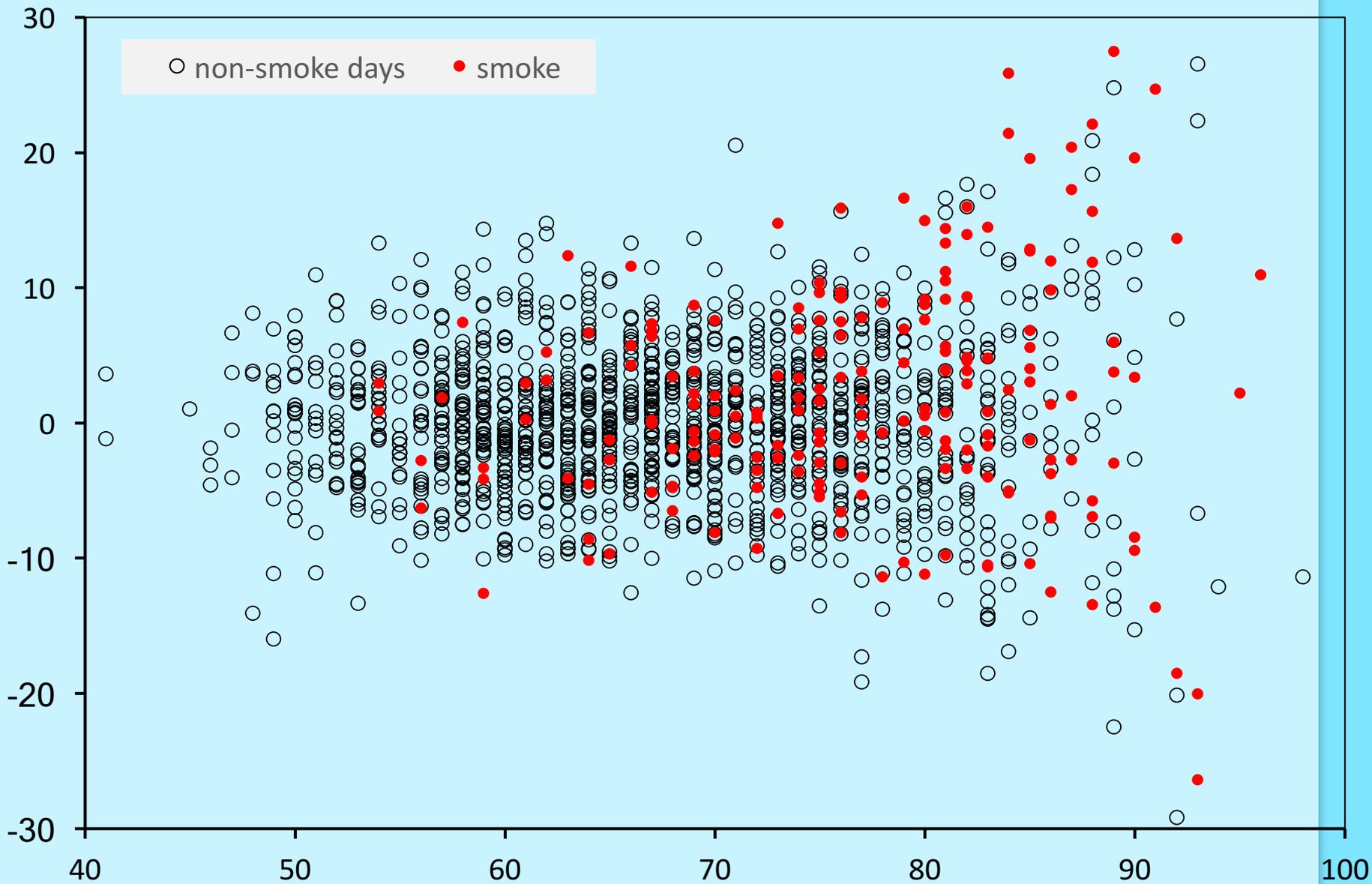


MDA8 vs Daily Max Temp-Enumclaw



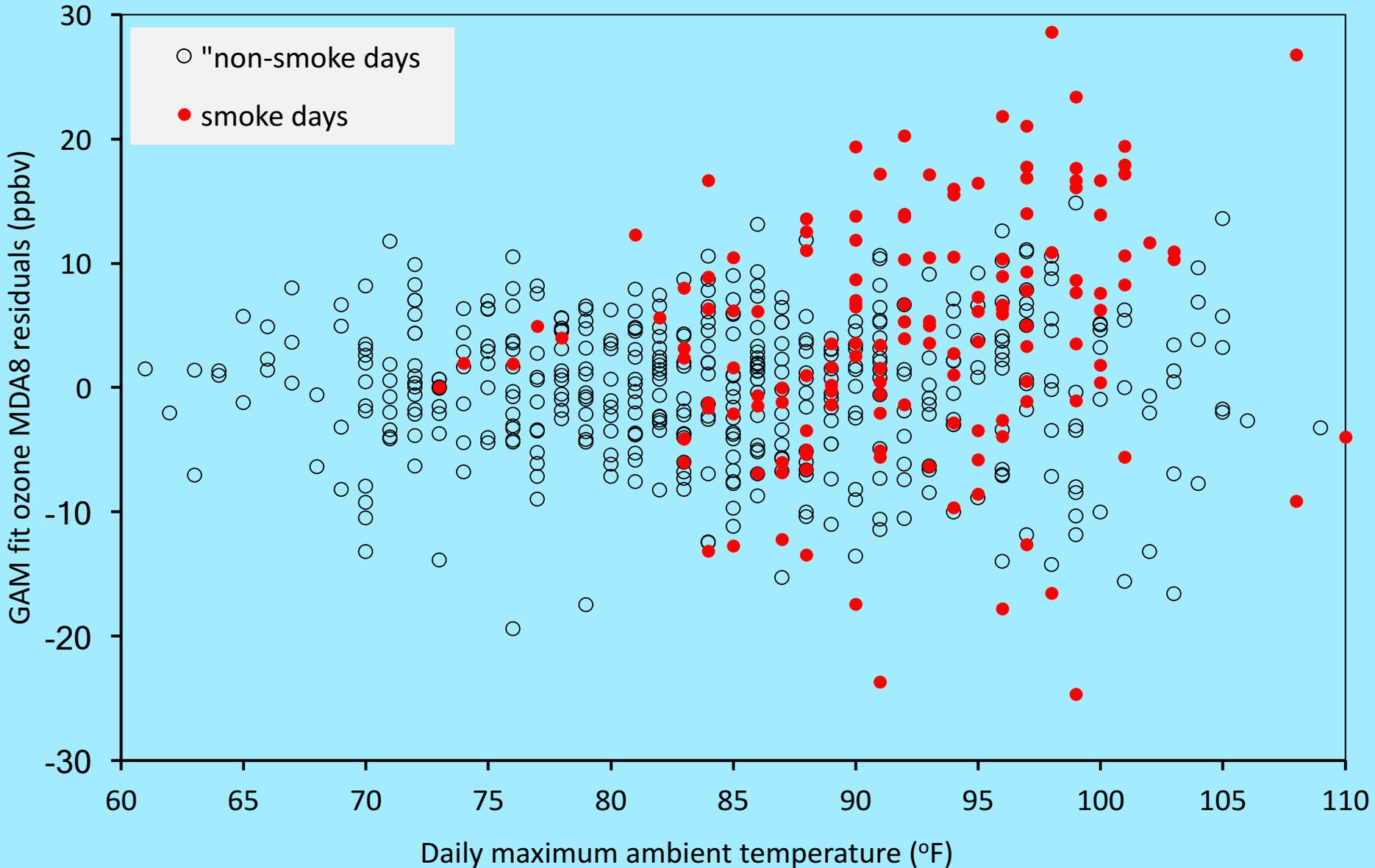
Enumclaw, WA

GAM fit ozone MDA8 residuals (ppbv)

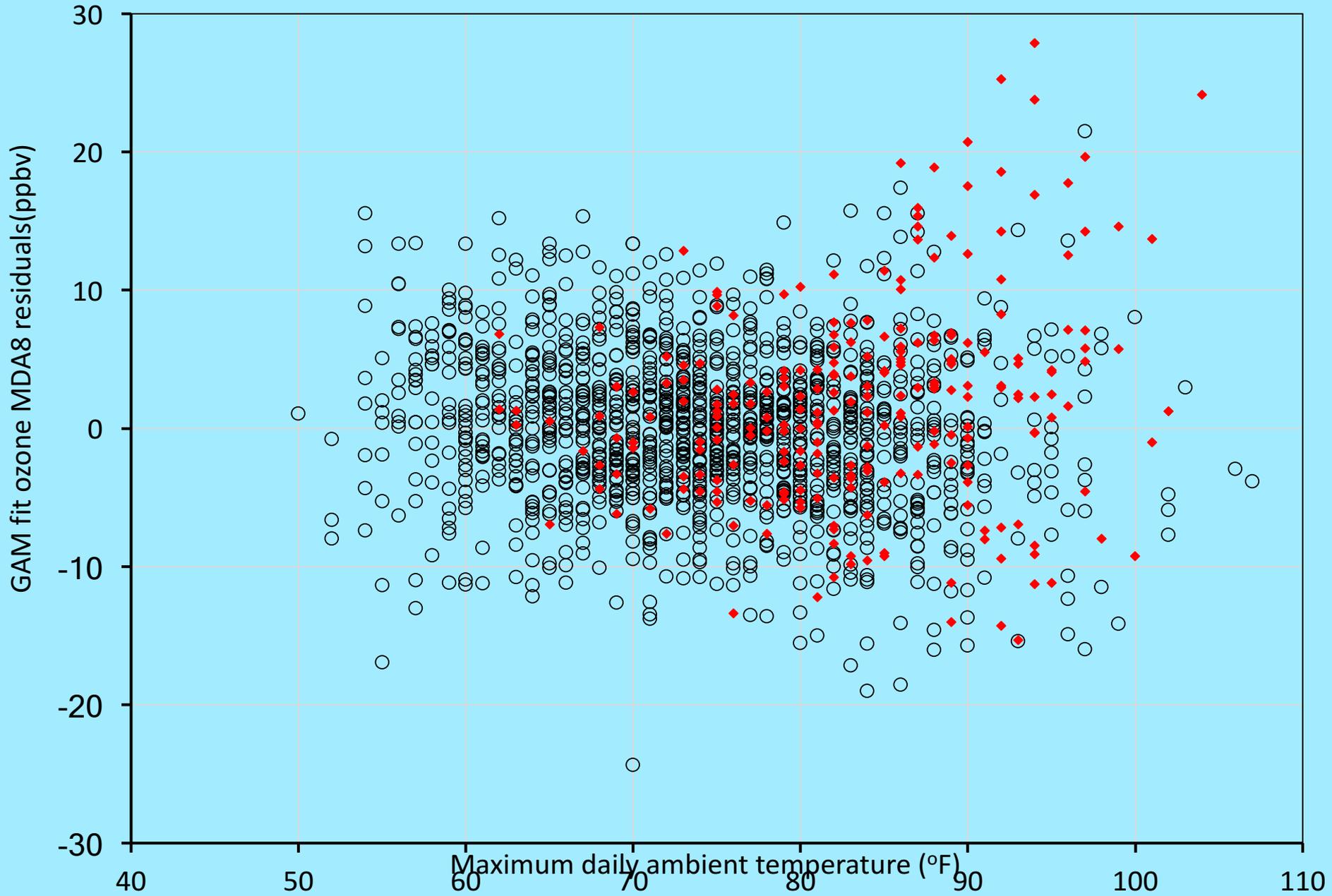


Daily maximum ambient temperature (°F)

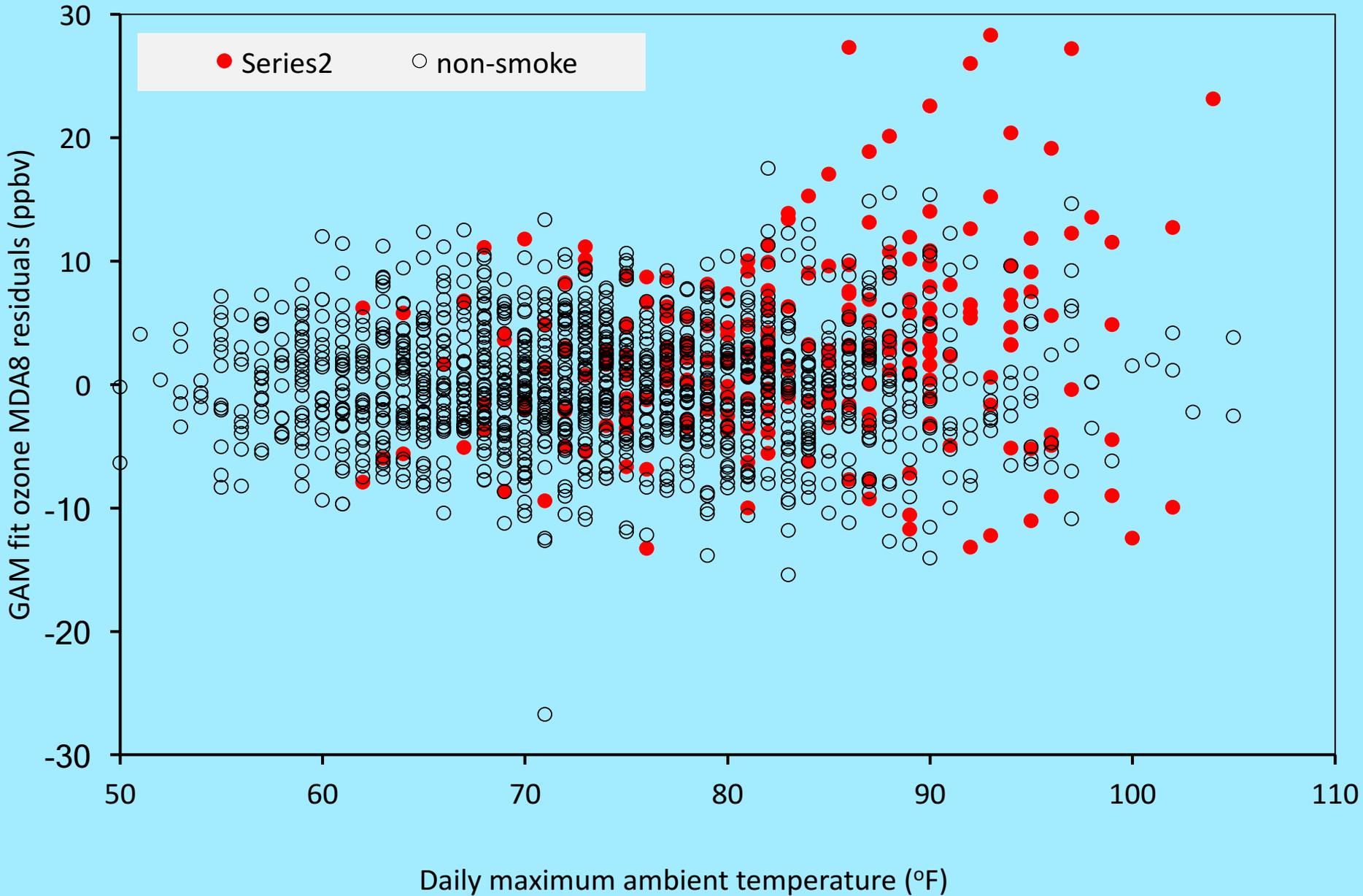
Kennewick, WA



Vancouver, WA



Portland, OR



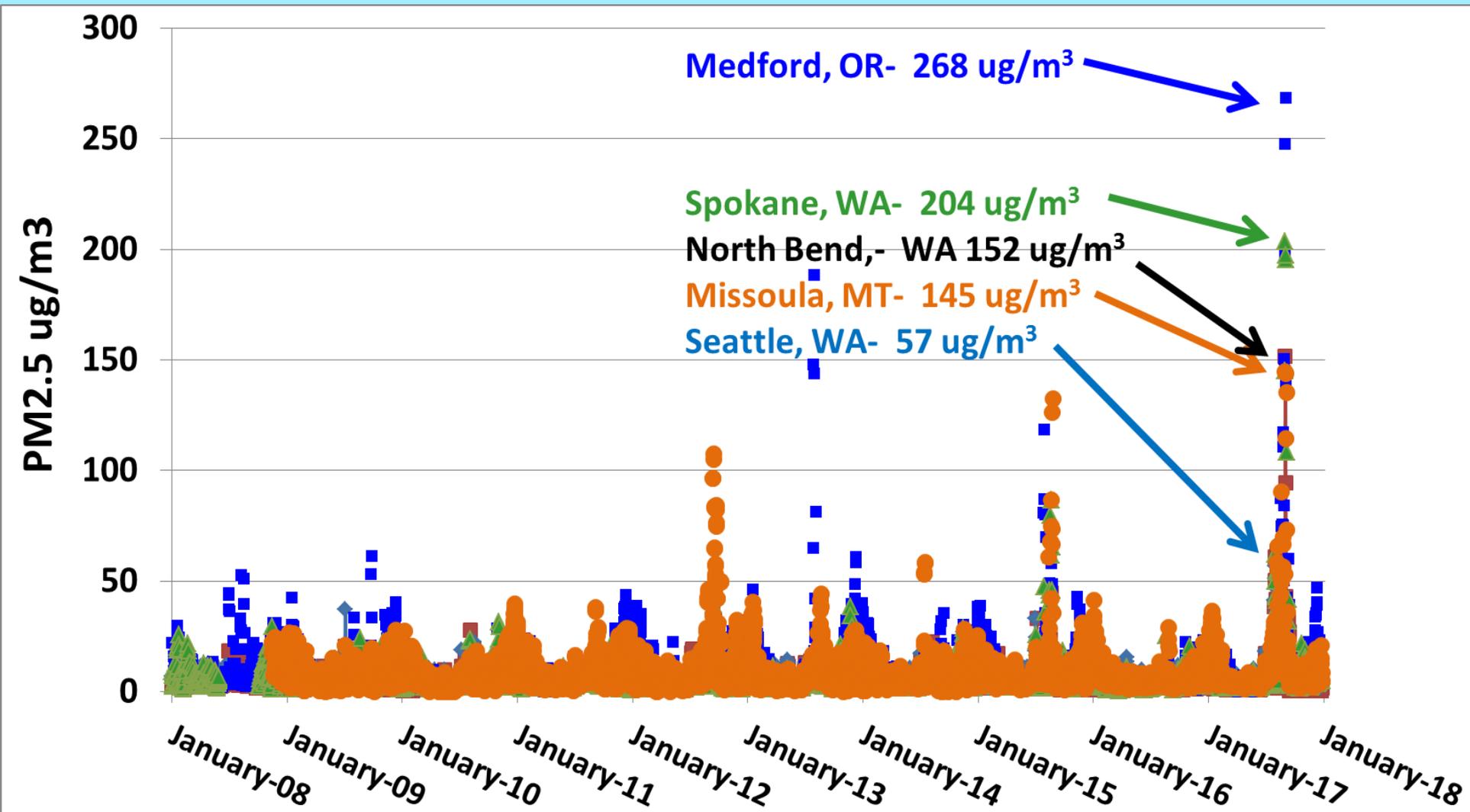
Some key Conclusions on smoke

- Smoke effects on the MDA8 are generally subtle adding, on average ~5-8 ppb to the MDA8 (range 0-30 ppb)
- Smoke impacts on O₃ are most significant on warm days, when O₃ would have been high already.
- At very high PM levels (>60 ug/m³) smoke impacts on O₃ are reduced.

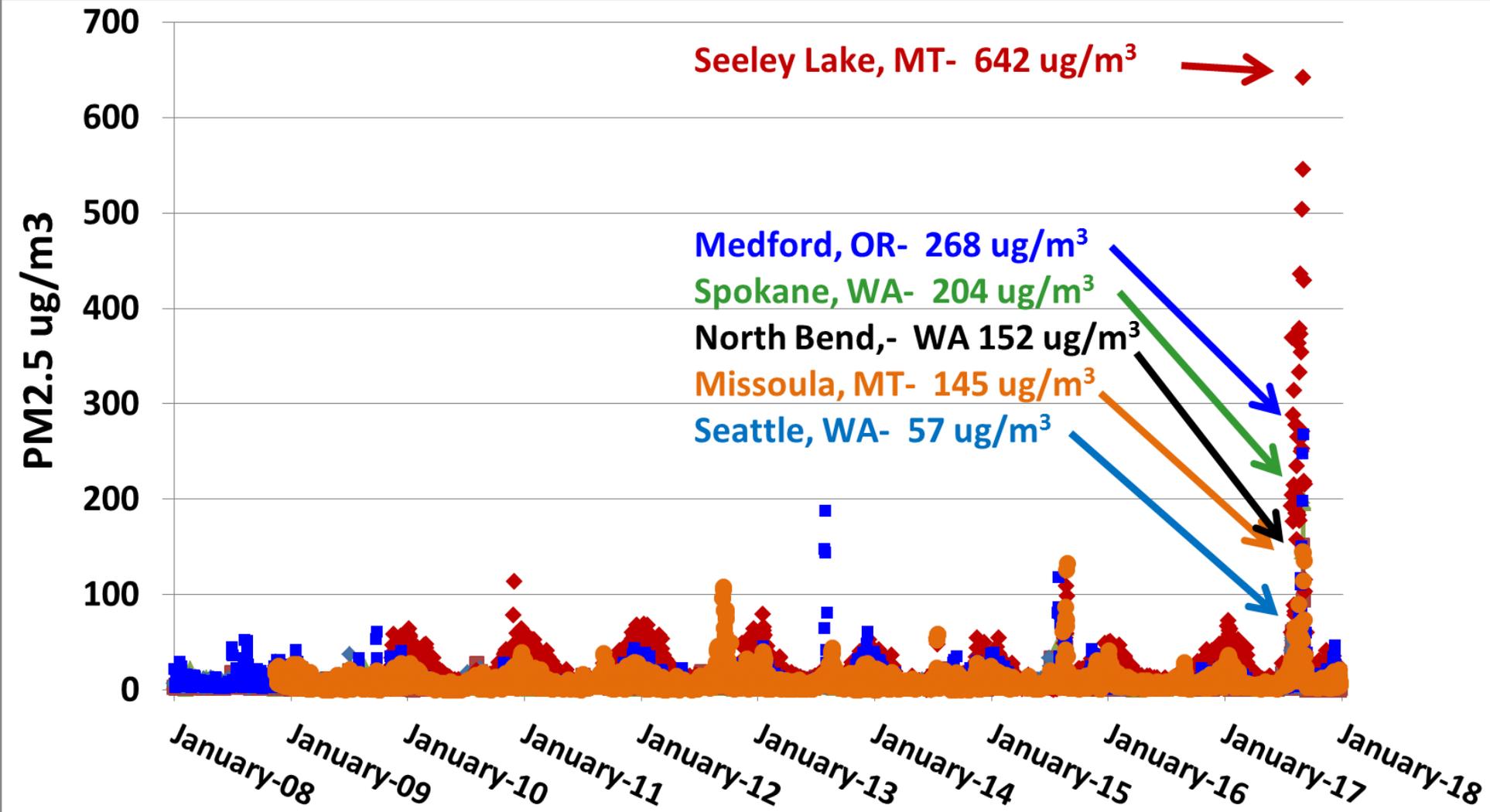
Are fires getting worse?



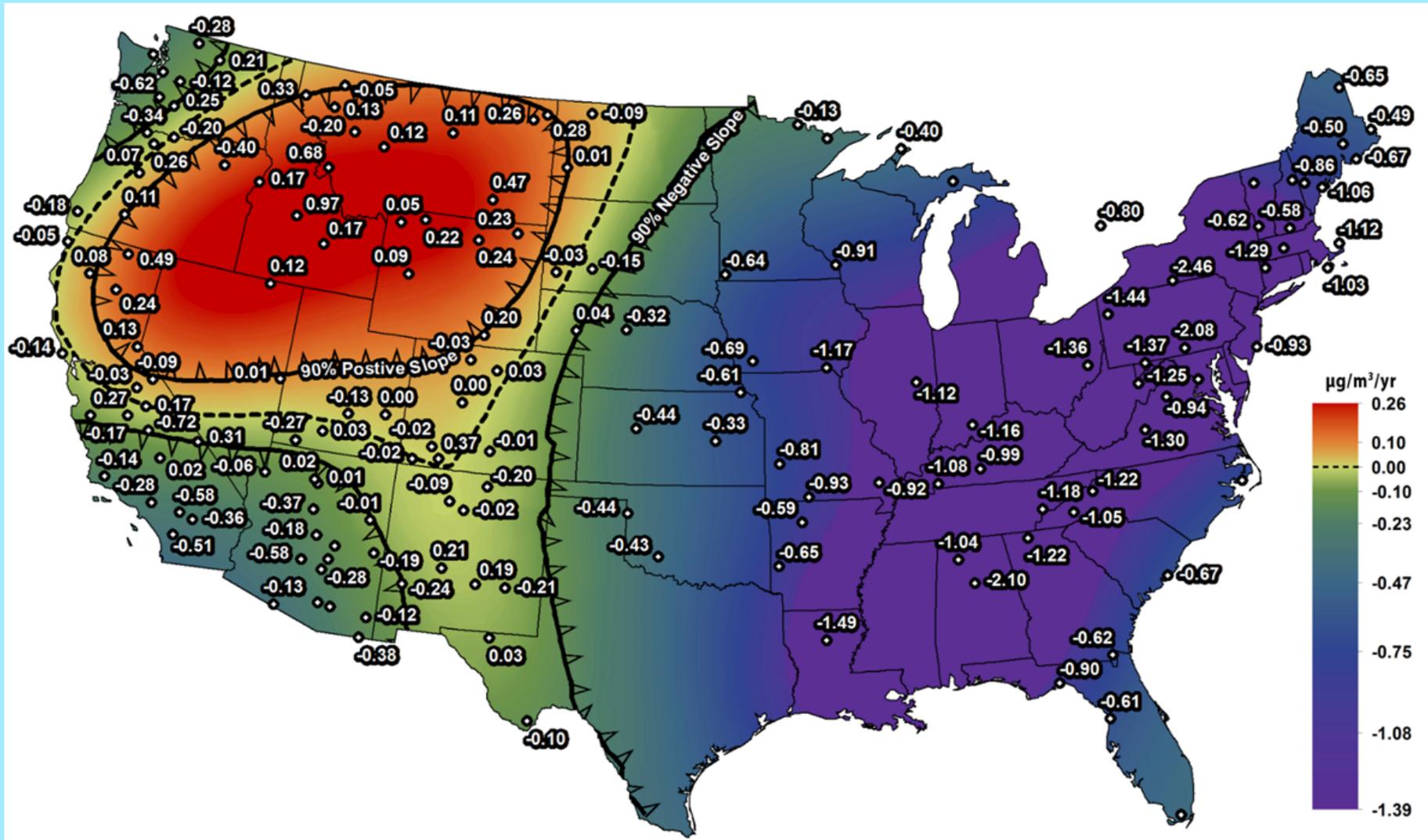
Summer 2017: Worst air quality in decades



Summer 2017: Worst air quality in decades



Trend in 98th percentile of PM_{2.5} for 1988-2016



McClure and Jaffe, PNAS, in-press.



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Summary

- Summer 2017 had the worst air quality in decades for both PM and O₃ in the NW due to wildfires.
- Satellite data provide critical information on fires and smoke transport, but not necessarily surface level PM. When HMS smoke present, we find an enhancement in surface PM 40-70% of the time in PNW.
- Wildfire emissions can enhance O₃ in urban areas. We use a statistical model to show that fires contribute 0-30 ppb (8-hour average), which is sufficient to put many sites over the 70 ppb standard. Smoke impacts on O₃ are greatest on warm days.
- At high PM_{2.5} (greater than ~60 ug/m³) O₃ enhancements are reduced.
- Over the last several decades the annual 98th percentile for PM_{2.5} concentrations are increasing due to wildfires over large parts of the western U.S.

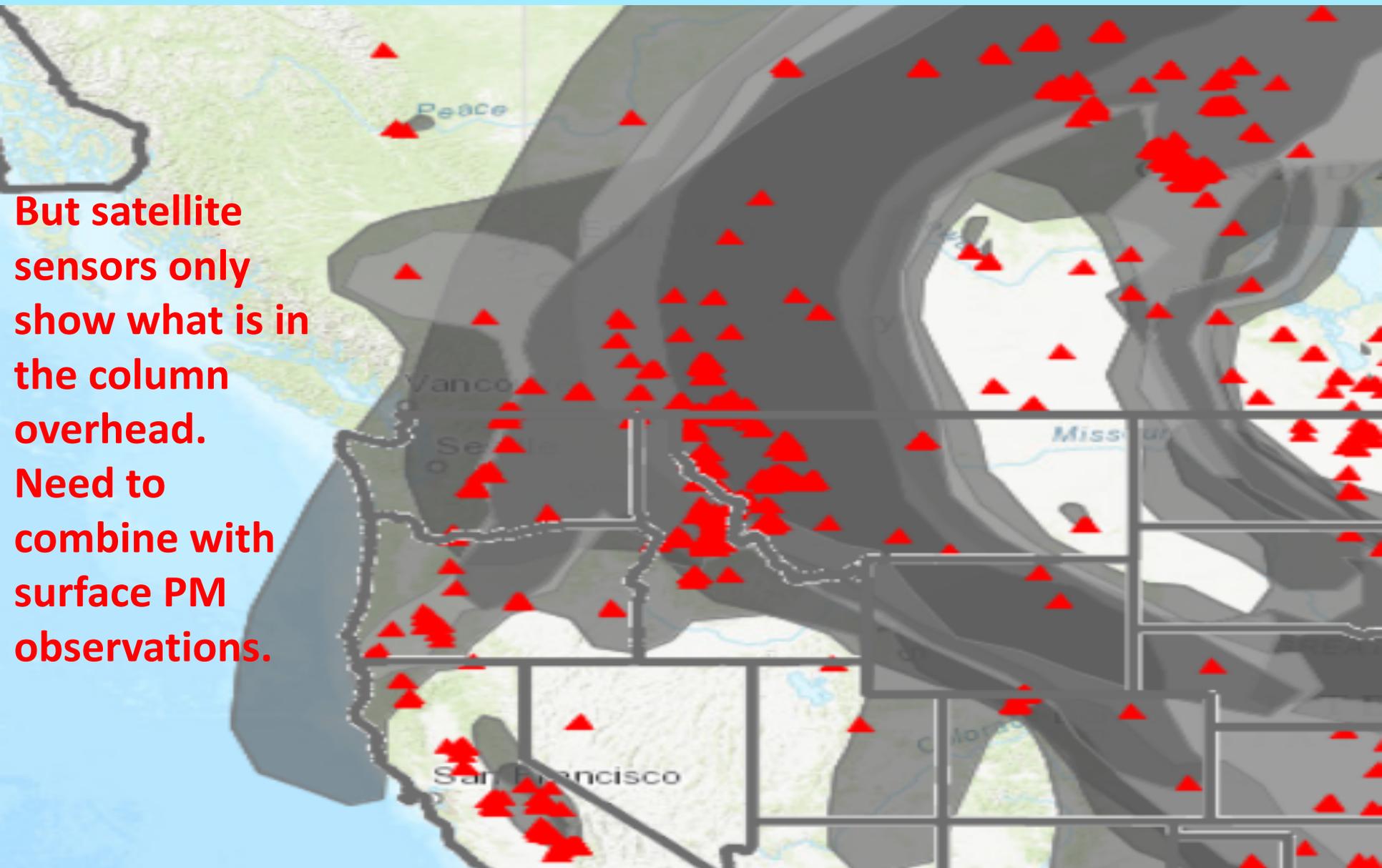


Spares



NOAA HMS Fire and Smoke Product (via Airnowtech)

Sept. 8th, 2017



But satellite sensors only show what is in the column overhead. Need to combine with surface PM observations.

HMS days/HMS days with PM (2006-2017 data)

Location	Days per year with HMS smoke	Fraction of HMS days with enhanced PM
Arden/Sacramento, CA	35.8	0.53
Chico, CA	40.6	0.69
St.Lukes/Boise, ID	43.0	0.74
North Bend, WA	23.6	0.54
Vancouver, WA	26.5	0.45
Enumclaw, WA	24.8	0.40
Eugene, OR	31.7	0.53
Portland, OR	26.5	0.42
El Paso, TX	11.9	0.19
Houston, T X	32.4	0.28

Enhanced PM is defined as mean + 1 SD of non-HMS smoke days.

