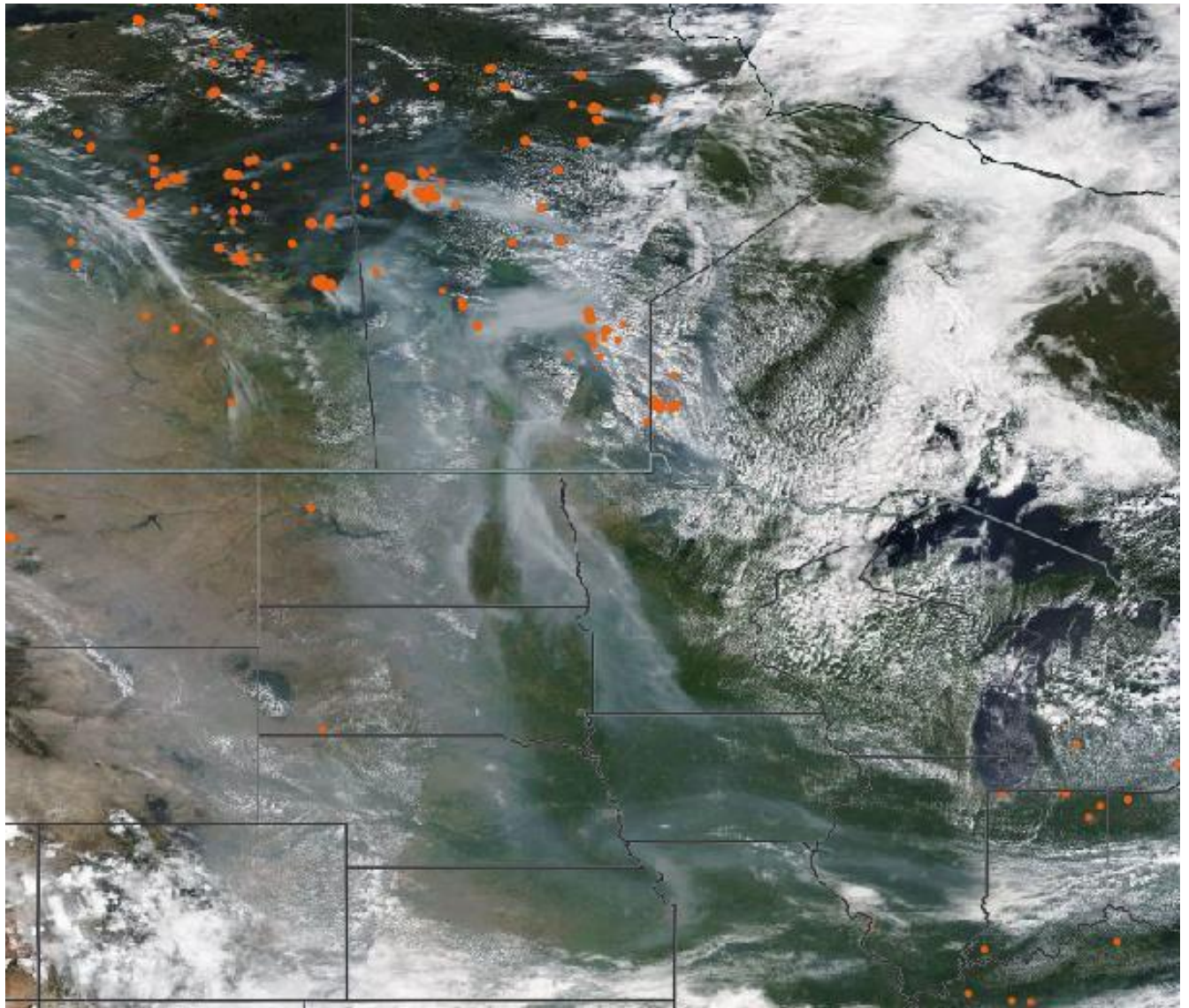


Iowa Wildfire Smoke Episode on 8/1/21: Performance of the T640 and other FEM/FRM Methods

Sean Fitzsimmons-Iowa DNR



Satellite Smoke [Photo](#) with Fires Indicated 8/1/2021, Courtesy NASA.

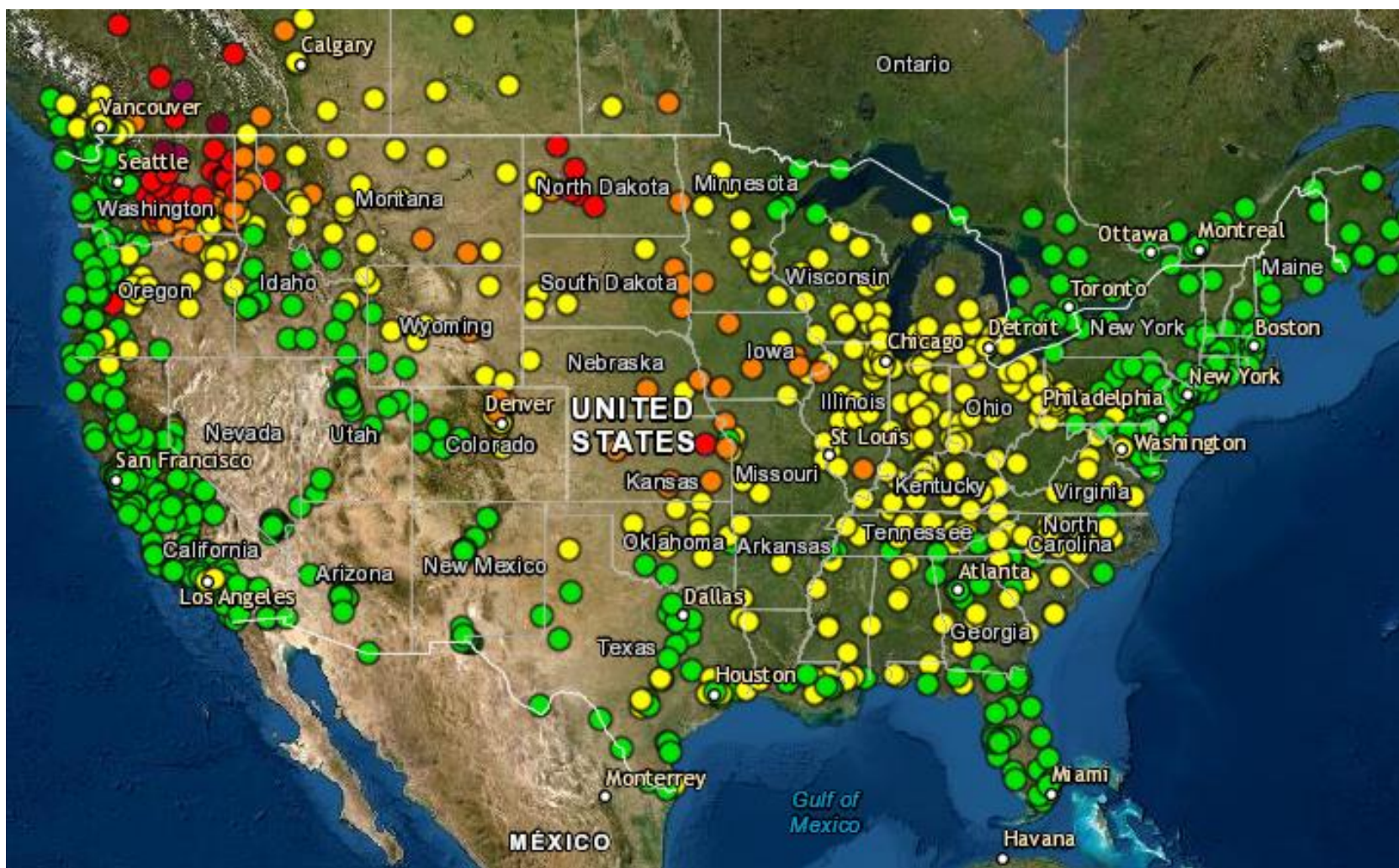
By the Associated Press

Published: Aug. 1, 2021 at 11:33 AM CDT

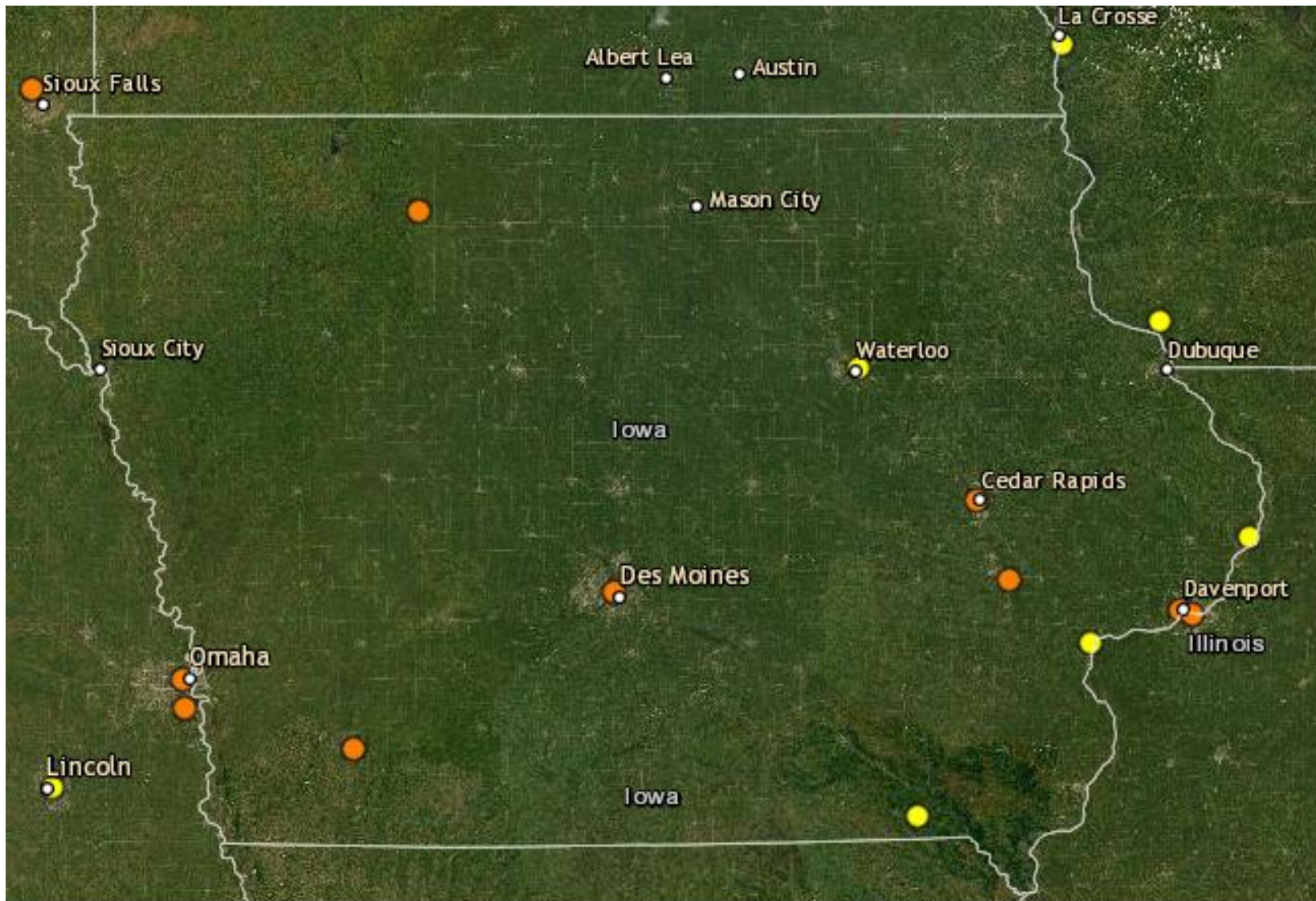
DENVER (AP) — Air quality alerts were posted on Sunday for numerous areas of the U.S. West and Midwest as wildfire smoke continues to linger over much of the country.

The alerts came across the northern U.S. Rockies, including portions of Colorado, Wyoming, Washington state, and Idaho. Further to the east, smoke from fires burning in Canada was drifting for hundreds of miles and triggering pollution alerts in Wisconsin, Minnesota, and Iowa.

Wildfires emit huge volumes of microscopic smoke particles that researchers say can be harmful if breathed in, leading to both immediate and long-term health impacts. Children, the elderly, and people with underlying health conditions are particularly at risk.



National Map of Daily AQI on 8/1/21 from [Airnow](#) Archive, Courtesy EPA AirNow.



National Map of Daily AQI on 8/1/21 from [Airnow](#) Archive (Iowa Zoom), Courtesy EPA AirNow.

T640 to FRM Comparisons on 8/1/21

City:	Cedar Rapids			Clinton			Davenport			Iowa City		
Monitor:	FRM	T640 #1	T640 #2	FRM	T640 #1	T640 #2	FRM	T640 #1	T640 #2	FRM	T640 #1	T640 #2
Concentration ($\mu\text{g}/\text{m}^3$)	29.3	38.0	38.4	23.7	33.4	34.5	27.4	36.0	34.9	31.0	41.5	43.5
Difference wrst FRM ($\mu\text{g}/\text{m}^3$)	-	8.7	9.1	-	9.7	10.8	-	8.6	7.5	-	10.5	12.5
% Difference wrst FRM ($\mu\text{g}/\text{m}^3$)	-	30%	31%	-	41%	46%	-	31%	27%	-	34%	40%

BAM1022 to FRM Comparisons on 8/1/21

City:	Des Moines		
Monitor:	FRM	BAM1022 #1	BAM1022 #2
Concentration ($\mu\text{g}/\text{m}^3$)	37.3	37.9	39.3
Difference wrst FRM ($\mu\text{g}/\text{m}^3$)	-	0.6	2.0
% Difference wrst FRM ($\mu\text{g}/\text{m}^3$)	-	2%	5%

Similar enhancement of the response of the T640 in a wildfire smoke event was noted in California in 2019. A field evaluation was performed at three sites in Sacramento, Chico, and Brawley. Each site was impacted by a major wildfire during the field study. The concentration range at the Sacramento site was most like the August 1, 2021, event in Iowa.



PQAO TRAINING 2019

Technology Update Regulatory PM Monitoring

June 6, 2019

Simon Cheung

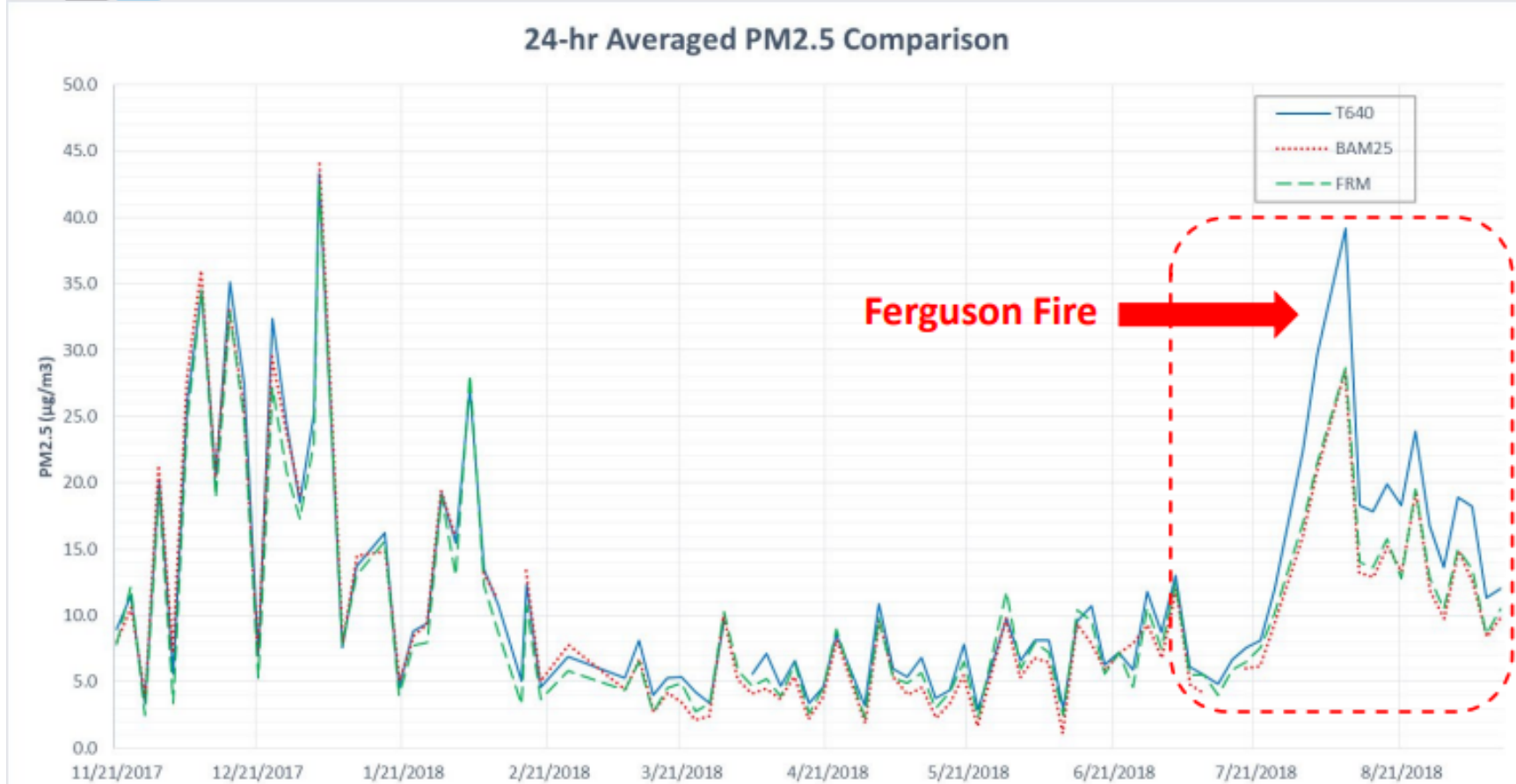
Air Quality Surveillance Branch

Monitoring and Laboratory Division

California Air Resources Board

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Sacramento – T Street



Technology Update Regulatory PM Monitoring, June 6, 2019. Courtesy Simon Cheung, CARB.

Summary of Sac-T's Daily PM2.5 comparison between T640, BAM25, and FRM.

Y vs. X	First 90 Days	Last 90 Days
T640 vs. BAM25	$Y = 0.9885X + 0.1323$ $R^2 = 0.9762$	$Y = 1.4017X - 0.6547$ $R^2 = 0.9726$
T640 vs. FRM	$Y = 1.0087X + 1.1985$ $R^2 = 0.9864$	$Y = 1.4014X - 1.8162$ $R^2 = 0.9783$
BAM25 vs. FRM	$Y = 1.0005X + 1.3830$ $R^2 = 0.9870$	$Y = 0.9885X - 0.4220$ $R^2 = 0.9738$

* During the smoky days, T640 reported ~40% higher than the collocated monitors.

Why are the T640 Readings Enhanced in Wildfire Smoke?

Some hints from Researchers:

Landis MS, Long RW, Krug J, Colón M, Vanderpool R, Habel A, Urbanski SP.

The U.S. EPA wildland fire sensor challenge: Performance and evaluation of solver submitted multi-pollutant sensor systems.

Atmos Environ (1994). 2021;247:10.1016/j.atmosenv.2020.118165. doi: 10.1016/j.atmosenv.2020.118165. PMID: 33889052; PMCID: PMC8059620.

...

High time resolution (1 min) EPA PM_{2.5} mass reference measurements were made using Teledyne API Model T640 continuous FEM instruments that were normalized to Tisch Environmental (Cleveland, OH, USA) Model TE-WILBUR filter-based (1 h) FRM measurements on a test (Phase I) or burn (Phase II) specific basis. The API T640 FEM indicated PM_{2.5} concentration was suspected of being sensitive to chamber aerosol size distribution (Phase I & Phase II testing) and BC concentration (Phase II testing) necessitating normalization to the hourly FRM concentration. The Phase I testing FEM correction factor averaged 1.30 ± 0.19 (mean \pm standard deviation) and ranged from 1.08 to 1.80 for T640 instrument 296 (serial number). The Phase II testing FEM correction factors averaged 0.99 ± 0.38 and 1.01 ± 0.36 and ranged from 0.58 to 2.11 and 0.50 to 1.86 for T640 instruments 294 and 296, respectively. The T640 PM_{2.5} instruments were zeroed before each chamber test day. Leak checks and multi-point flow calibrations were conducted on the PM_{2.5} FRM samplers on a weekly basis.

...

Holder AL, Mebust AK, Maghran LA, et al. Field Evaluation of Low-Cost Particulate Matter Sensors for Measuring Wildfire Smoke. *Sensors (Basel)*. 2020;20(17):4796. Published 2020 Aug 25. doi:10.3390/s20174796

...

PM_{2.5} measurement during smoke impacted times represents a unique measurement challenge that is not explicitly addressed in the federal reference and equivalency method designations. For example, the high organic PM loadings that occur during smoke can evaporate from the federal reference method (FRM) samples and lead to a low bias [43]. Although FEMs are required to be validated against FRM filter samples at concentrations ranging from 3 to 200 µg/m³ at multiple locations across the U.S. [26], this does not specifically include smoke impacted times, where the concentrations can be much greater. The performance of FEMs and near-FEM grade instruments during these high pollution times have not been validated in the field. For example, Schweizer et al. [44] found that the EBAMs commonly used for temporary smoke monitoring networks overreported PM_{2.5} compared to BAMs, but only when RH was above 40%. These potential variations in the reference measurement accuracy and precision during smoke impacted times may have led to weaker correlations and introduced variation in the slope of the linear regressions across sites. The magnitude of these effects is difficult to quantify.

...

[26] Revisions to Ambient Air Monitoring Regulations. In 71 FR 61235; USEPA (Ed.) USEPA: Washington, DC, USA, 2006.

...

[43] Chow, J.C.; Watson, J.G.; Lowenthal, D.H.; Antony Chen, L.W.; Tropp, R.J.; Park, K.; Magliano, K.A. PM_{2.5} and PM₁₀ mass measurements in California's San Joaquin Valley. *Aerosol Sci. Technol.* 2006, 40, 796–810.

[44] Schweizer, D.; Cisneros, R.; Shaw, G. A comparative analysis of temporary and permanent beta attenuation monitors: The importance of understanding data and equipment limitations when creating PM_{2.5} air quality health advisories. *Atmos. Pollut. Res.* 2016, 7, 865–875.

Test Sites for Class III Methods: 40 CFR 53.35(b)(1)(i)

PM_{2.5} Class II and Class III candidate methods. Test sites should be chosen to provide representative chemical and meteorological characteristics with respect to nitrates, sulfates, organic compounds, and various levels of temperature, humidity, wind, and elevation. For Class III methods, one test site shall be selected in each of the following four general locations (A, B, C, and D). For Class II methods, two test sites, one western site (A or B) and one midwestern or eastern site (C or D), shall be selected from these locations.

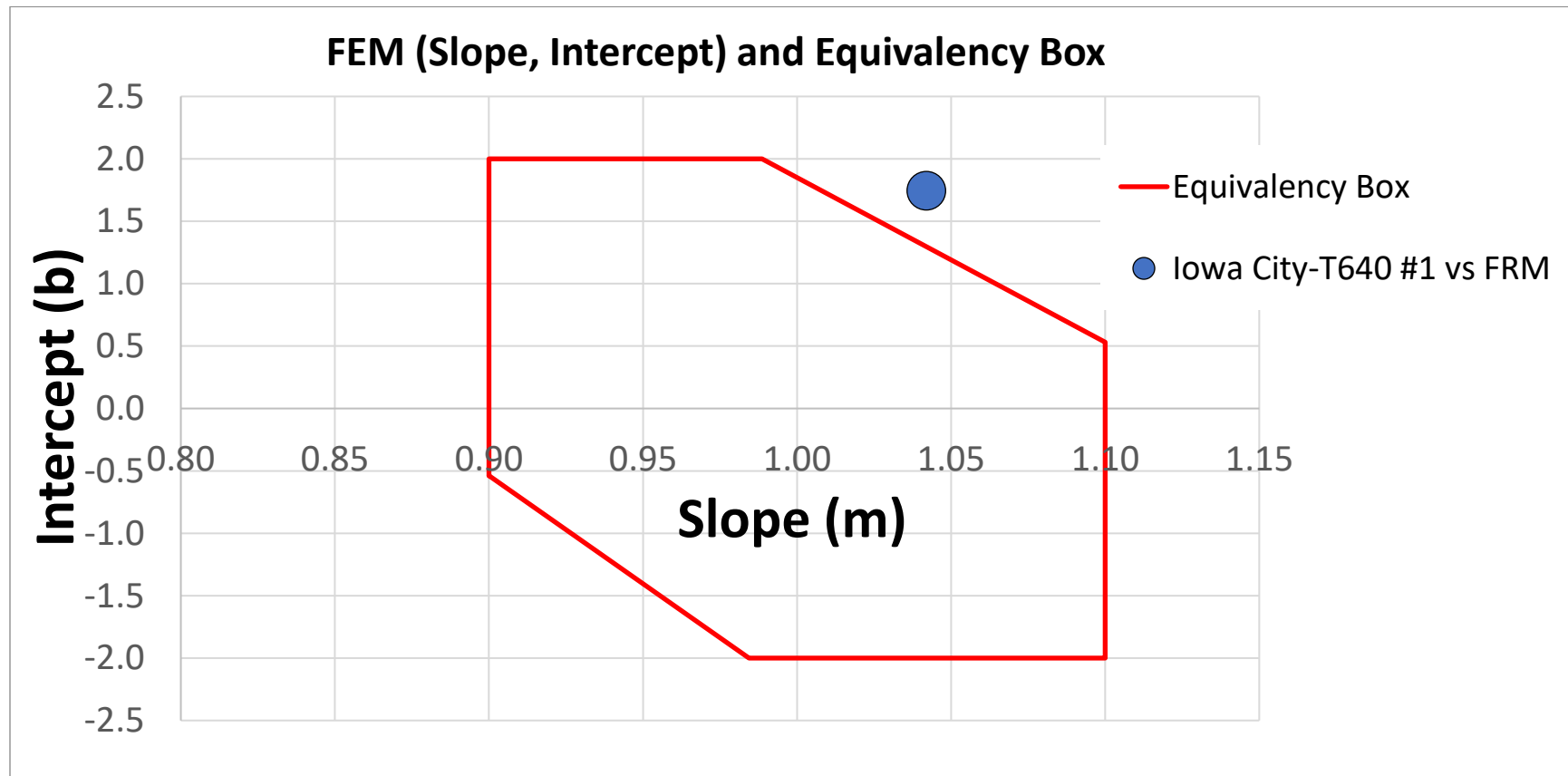
(A) Test site A shall be in the Los Angeles basin or California Central Valley area in a location that is characterized by relatively high PM_{2.5}, nitrates, and semi-volatile organic pollutants.

(B) Test site B shall be in a western city such as Denver, Salt Lake City, or Albuquerque in an area characterized by cold weather, higher elevation, winds, and dust.

(C) Test site C shall be in a midwestern city characterized by substantial temperature variation, high nitrates, and wintertime conditions.

(D) Test site D shall be in a northeastern or mid-Atlantic city that is seasonally characterized by high sulfate concentrations and high relative humidity.

If the test sites that were used to Qualify a Method as a (Class III) PM2.5 Equivalent method relative to the FRM (as specified in Part 53) are not representative of all the locations where the FEMs are used by regulatory agencies, then agencies may experience poor comparability of the FEM and the FRM method in the field. However, in this case, the regulatory agency may request that the data be excluded from NAAQS comparisons under the provisions of Part 58.



However, agencies are not required to perform extensive comparability testing:

Table A-1 of Appendix A to Part 58 - Minimum Data Assessment Requirements for NAAQS Related Criteria Pollutant Monitors

Method	Assessment method	Coverage	Minimum frequency	Parameters reported	AQS assessment type
Particulate Methods					
Continuous ⁴ method - collocated quality control sampling PM _{2.5}	Collocated samplers	15%	1-in-12 days	Primary sampler concentration and duplicate sampler concentration. ³	No Transaction reported as raw data.

³ Both primary and collocated sampler values are reported as raw data.

⁴ PM_{2.5} is the only particulate criteria pollutant requiring collocation of continuous and manual primary monitors.

and exclusion of FEM data that fails comparability testing is also not required. Taken together, this may lead to large differences between the FEM and FRM under field conditions in cases where equivalency testing was not representative of locations where agencies deploy their monitors.

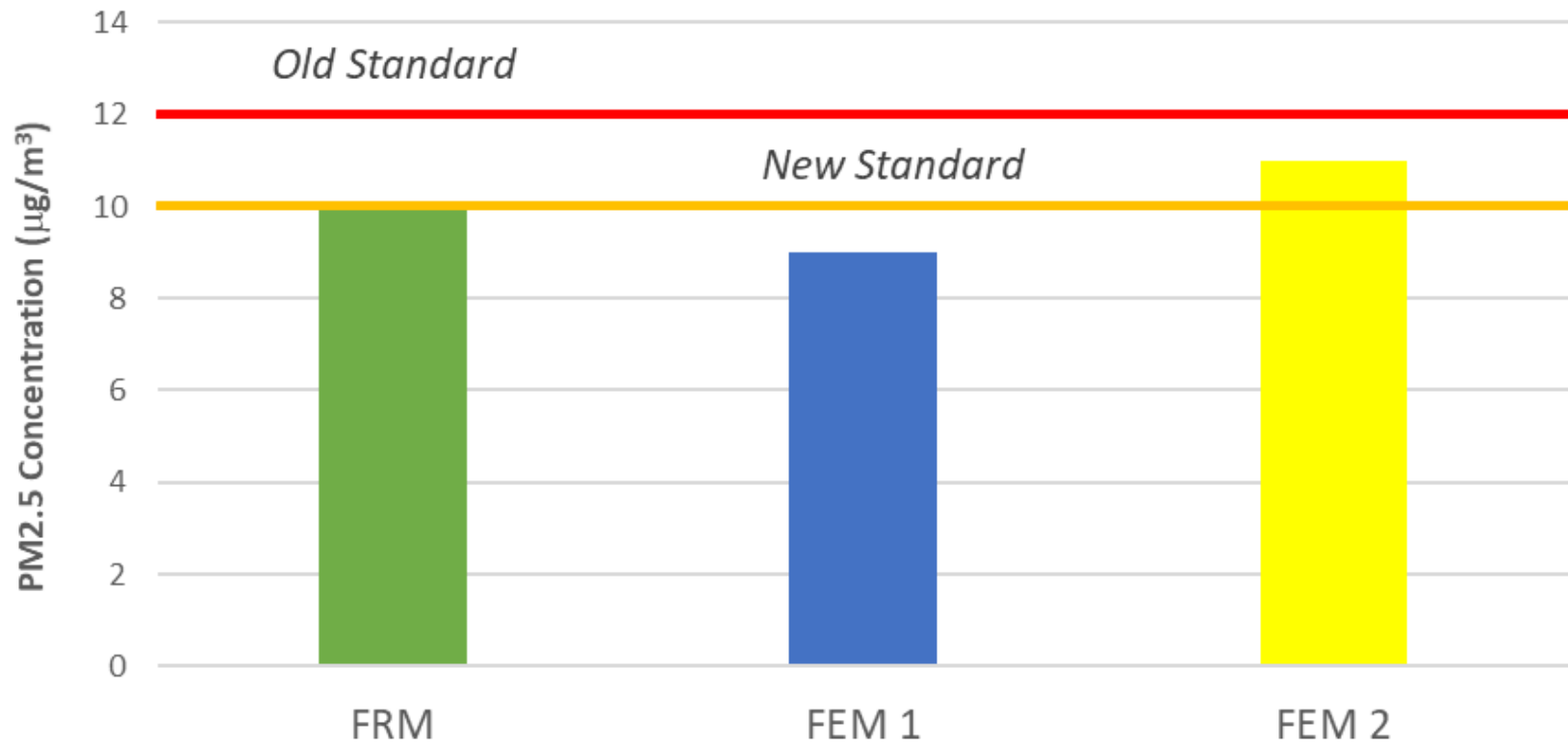
T640 to FRM Comparisons from 1/1/21 - 9/30/21

City:	Cedar Rapids			Clinton			Davenport			Iowa City		
Monitor:	FRM	T640 #1	T60 #2	FRM	T640 #1	T640 #2	FRM	T640 #1	T640 #2	FRM	T640 #1	T640 #2
Avg Concentration ($\mu\text{g}/\text{m}^3$)	9.5	10.9	11.3	9.4	11.9	11.7	9.0	10.7	9.9	8.9	10.8	10.8
Difference wrst FRM ($\mu\text{g}/\text{m}^3$)	-	1.4	1.9	-	2.5	2.3	-	1.7	0.9	-	1.9	1.9
% Difference wrst FRM ($\mu\text{g}/\text{m}^3$)	-	15%	20%	-	27%	24%	-	19%	10%	-	22%	22%

T640 to BAM1022 FRM Comparisons from 1/1/21 - 9/30/21

City:	Des Moines		
Monitor:	FRM	BAM1022 #1	BAM1022 #2
Concentration ($\mu\text{g}/\text{m}^3$)	8.9	7.9	8.4
Difference wrst FRM ($\mu\text{g}/\text{m}^3$)	-	-1.0	-0.5
% Difference wrst FRM ($\mu\text{g}/\text{m}^3$)	-	-11%	-6%

Method Comparability and Tighter Standards



**An example of how poor comparability of the
T640 and the FRM may arise owing to the Voluntary Nature of
Part 58 Comparability Exclusions.**

T640/T640x FEM Update



Slides for EPA R5 and Ohio.

8/5/2019

U.S. Environmental Protection Agency

T640/T640X Update: Slides for EPA R5 and Ohio, 8/5/19, Courtesy US EPA.

Map of T640 and T640x sites

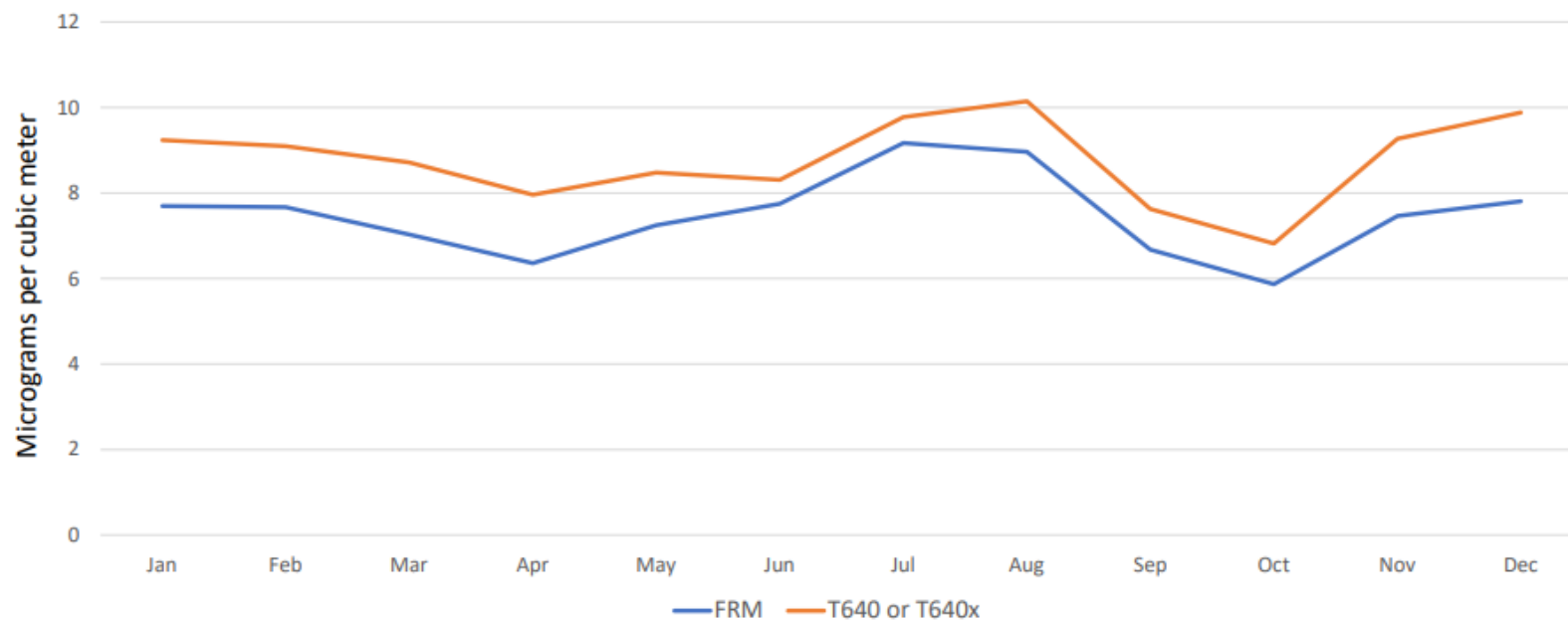


As of August 1, 2019
159 sites with a T640 or T640x
are reporting data to AQS.

104 sites have collocated
FEM/FRM data

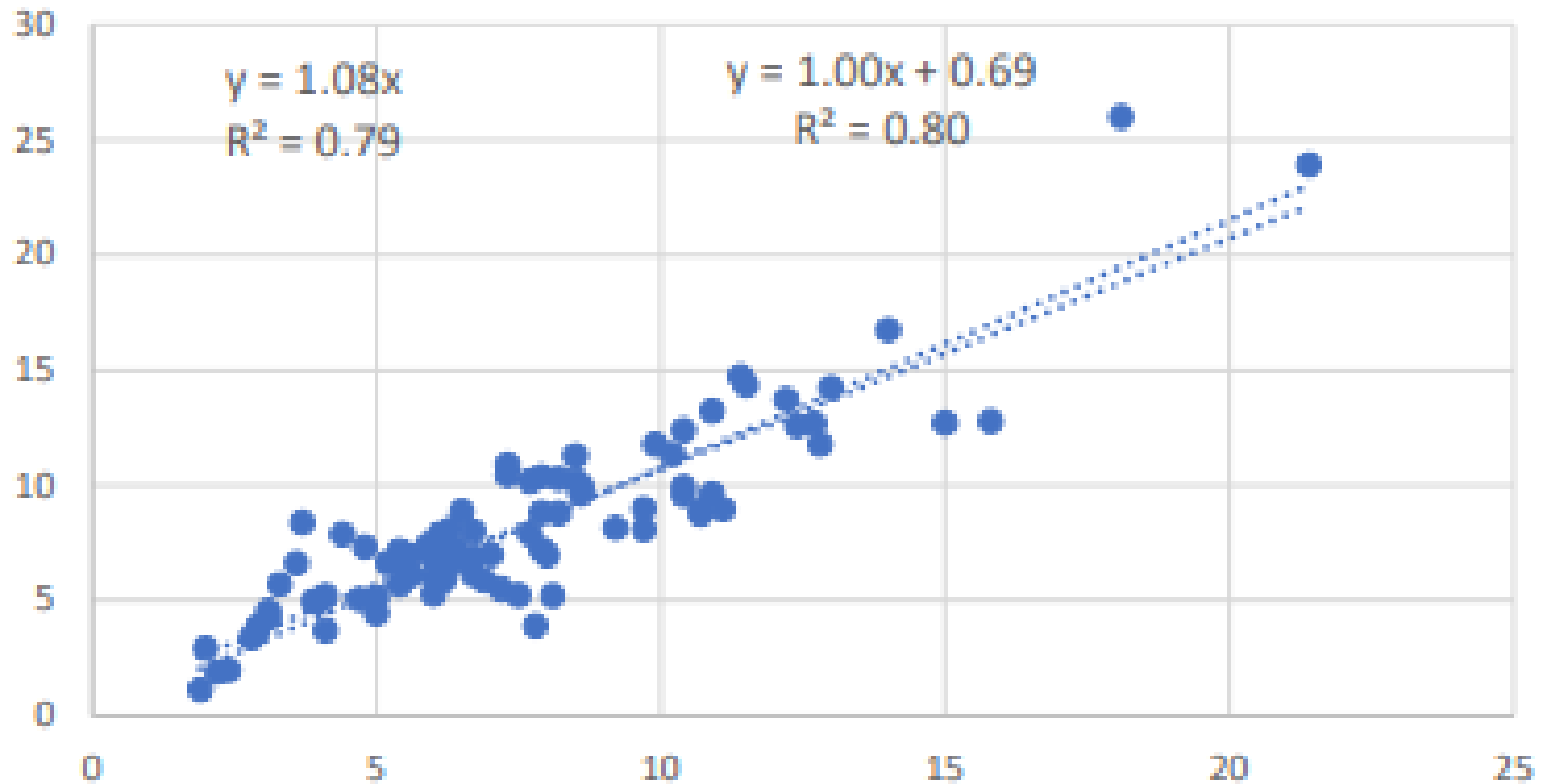
T640/T640X Update: Slides for EPA R5 and Ohio, 8/5/19, Courtesy US EPA.

Monthly comparison of T640 and T640x vs. FRM (monitoring agency operated)



T640/T640X Update: Slides for EPA R5 and Ohio, 8/5/19, Courtesy US EPA.

PEP Program - T640 and T640x



Performance Evaluation Program (PEP) FRMs typically operate ~5% higher than Monitoring Agency FRMs

T640/T640X Update: Slides for EPA R5 and Ohio, 8/5/19, Courtesy US EPA.