MEASURING THE AIR INSIDE DURING A WILDFIRE: HOW DO I KNOW IF IT IS OK? IS THERE ANYTHING I CAN DO ABOUT IT?

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BAYREN

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Looked cool

Looked ~~cool~~ bad, was it?

PM 101

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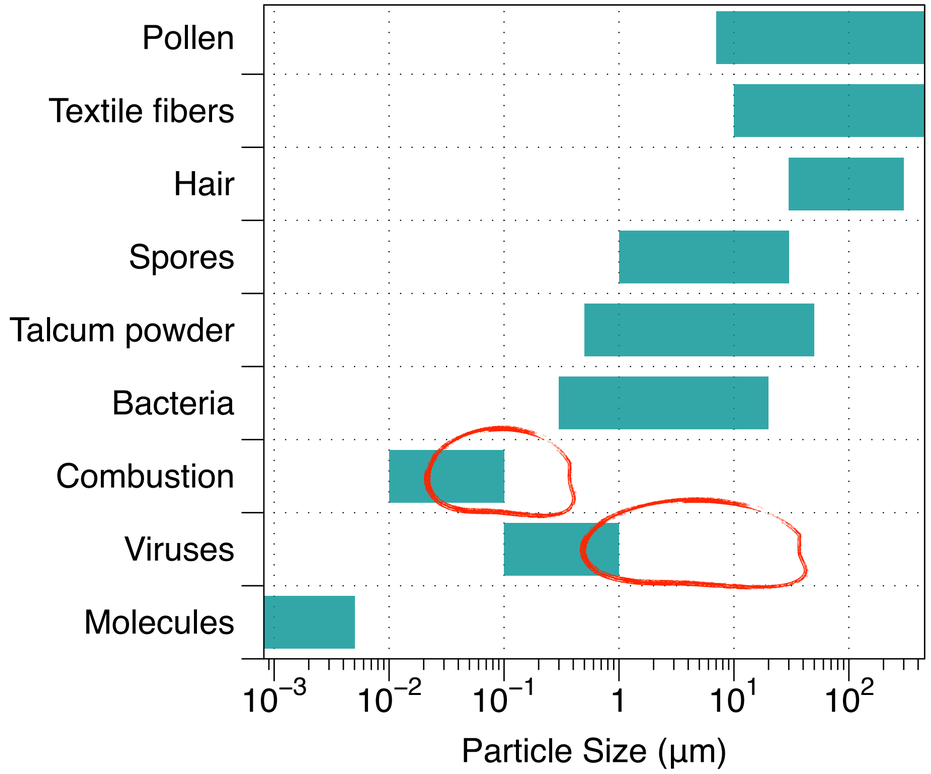
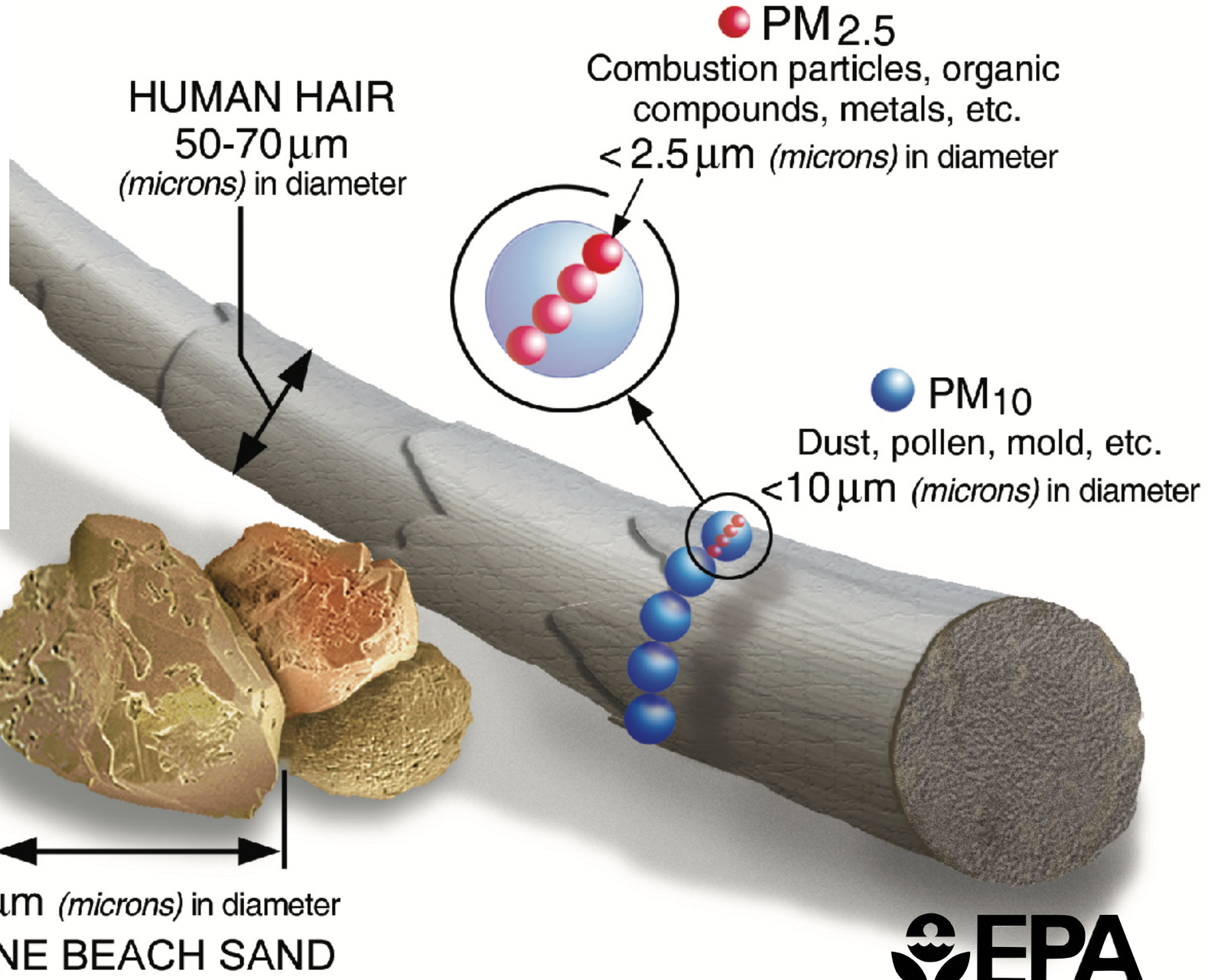

Pollen
Textile fibers
Hair
Spores
Talcum powder
Bacteria
Combustion
Viruses
Molecules
10^{-3}
10^{-2}
10^{-1}
1
10^{1}
10^{2}
Particle Size (µm)


HUMAN HAIR
50-70 µm
(microns) in diameter
PM2.5
Combustion particles, organic compounds, metals, etc.
< 2.5 µm (microns) in diameter
PM10
Dust, pollen, mold, etc.
<10 µm (microns) in diameter
90 µm (microns) in diameter
FINE BEACH SAND
EPA

Knowing PM levels is important

Particle Pollution (PM)	PM2.5	primary	1 year	12.0 µg/m3	annual mean, averaged over 3 years
		secondary	1 year	15.0 µg/m3	annual mean, averaged over 3 years
		primary and secondary	24 hours	35 µg/m3	98th percentile, averaged over 3 years
	PM10	primary and secondary	24 hours	150 µg/m3	Not to be exceeded more than once per year on average over 3 years

https://www.epa.gov/criteria-air-pollutants/naaqs-table

Exposure Limit	Limit Values
OSHA Permissible Exposure Limit (PEL) - General Industry See 29 CFR 1910.1000 Table Z-1 (PNOR) and 29 CFR 1910.1000 Table Z-3 (Inert or Nuisance Dust)	15 mg/m3 (50 mppcf*) TWA
American Conference of Governmental Industrial Hygienists (ACGIH) Guideline	10 mg/m3 TWA (inhalable particles)
CAL/OSHA PELs	10 mg/m3 TWA

https://www.osha.gov/dts/chemicalsampling/data/CH_259640.html

AQI— **A**ir **Q**uality **I**ndex

AQI Score	Category	$PM_{2.5}$ Value $\mu g \cdot m^{-3}$
0-50	Good	0 - 12
51-100	Moderate	12.1 - 35.4
101-150	Sensitive	35.5 - 55.4
151-200	Unhealthy	55.5 - 150.4
201-300	Very Unhealthy	150.5 - 250.4
>301	Hazardous	> 250.5

There are also values for PM_{10}, O_3, CO, SO_2, and NO_2

This is based on a 24hr average. If conditions are changing 3hr averages are allowed

There will be lags and steps in the reported values

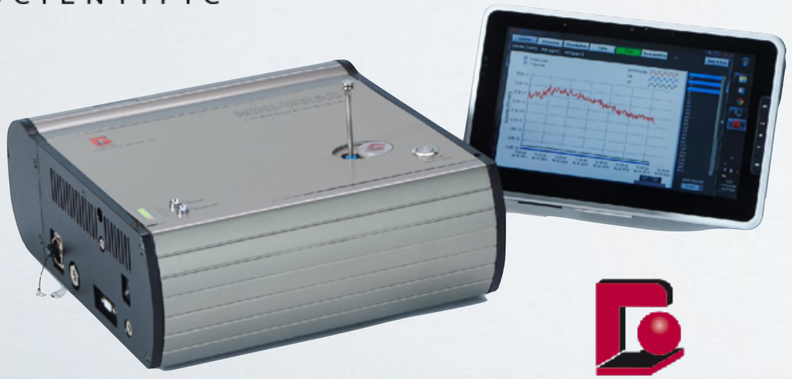
EPA

Looked ~~cool~~ bad, was it? This day no, but the next very

Instruments / Devices Span a Spectrum of Costs and Uses

FRM / FEM - ~$30k

ThermoFisher SCIENTIFIC



GRIMM
a brand of DURAG GROUP

Research IH - ~$7k

Consumer <$300

Sensor ~$25

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OPTICAL SENSING USING MIE-SCATTERING

Used by all of the current consumer devices, and most of the research instruments

Mass is proportional the scattering of the light

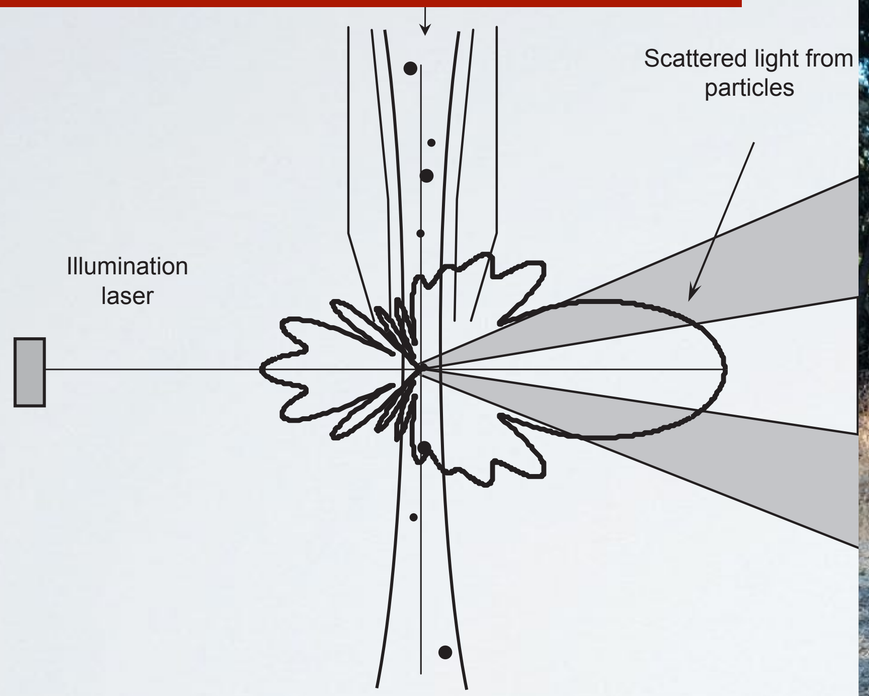

Fig. 1. Schematic diagram of a conventional optical particle spectrometer.

The response is a function of the mass, density, particle size, and optical properties. Source specific calibrations!

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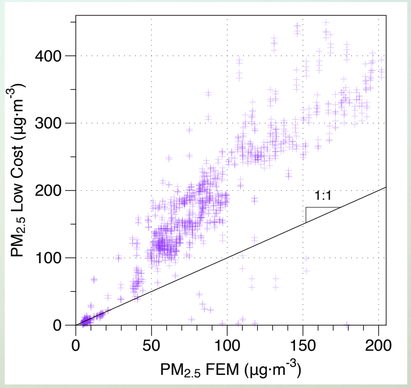
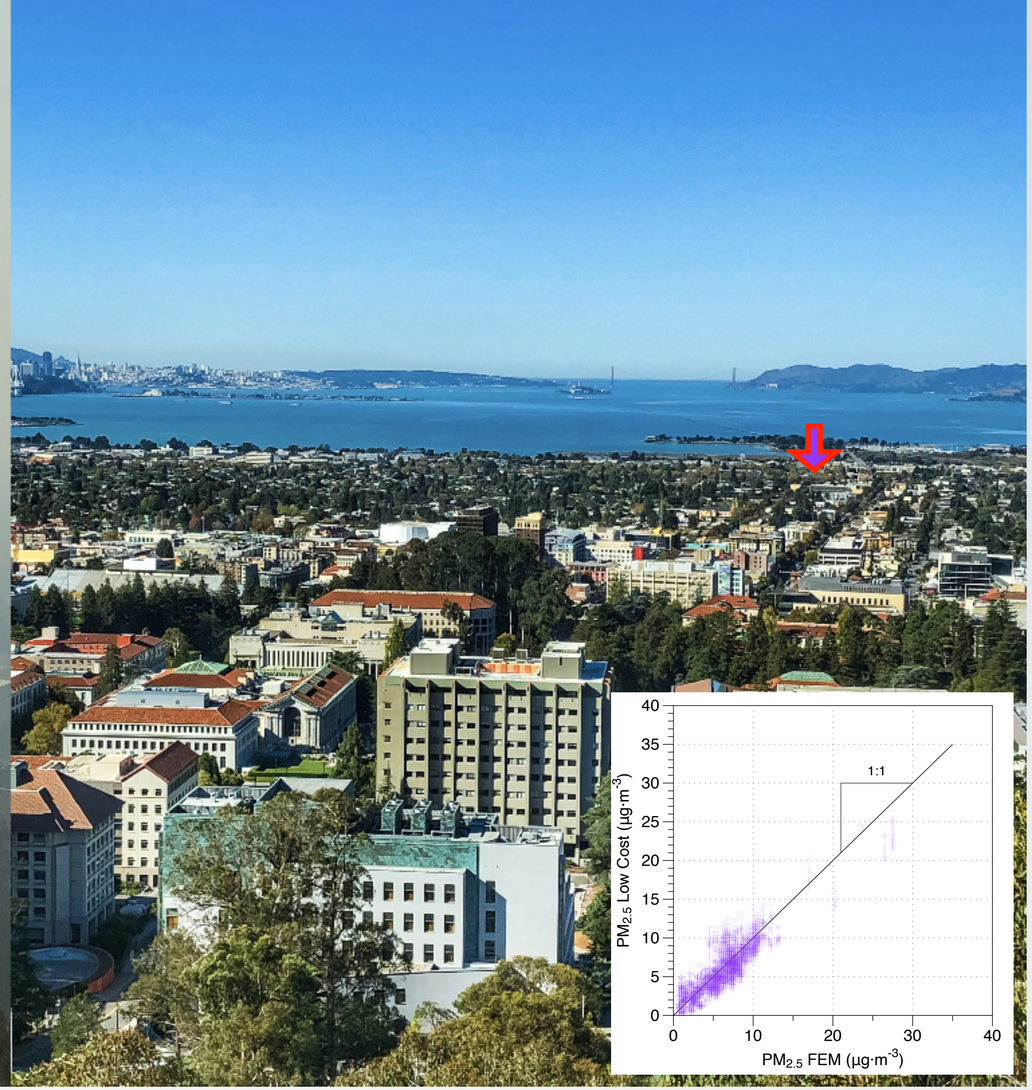
Lets look at some wildfire data





The smoke from the Camp fire outside Paradise, CA impacted ~13 million people for almost two weeks starting 8-Nov 2018

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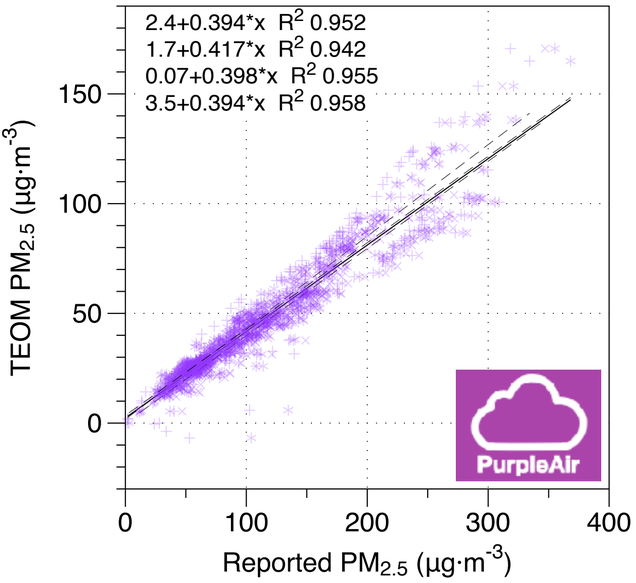

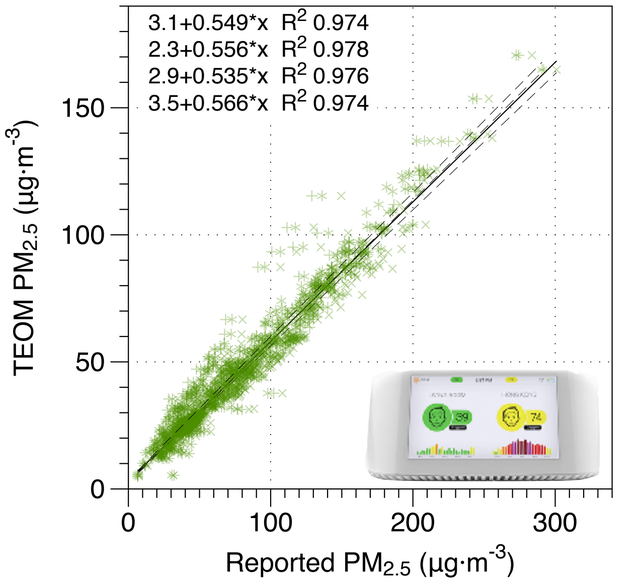

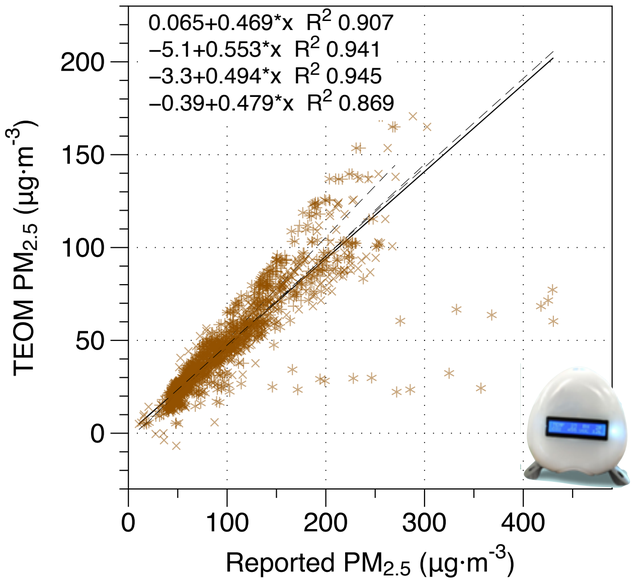

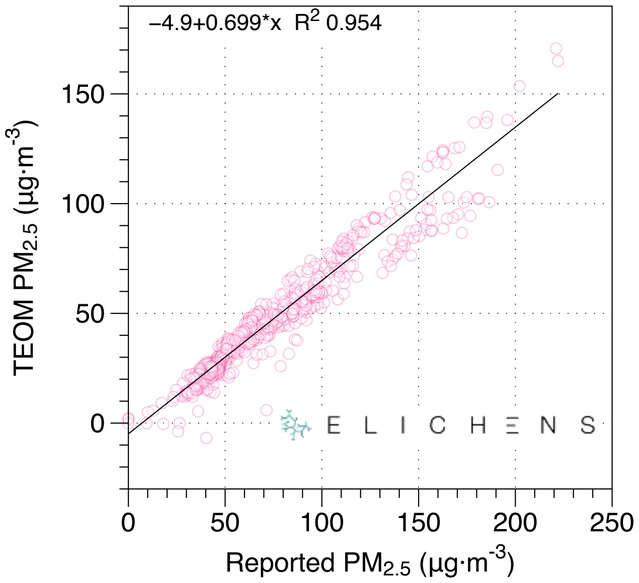

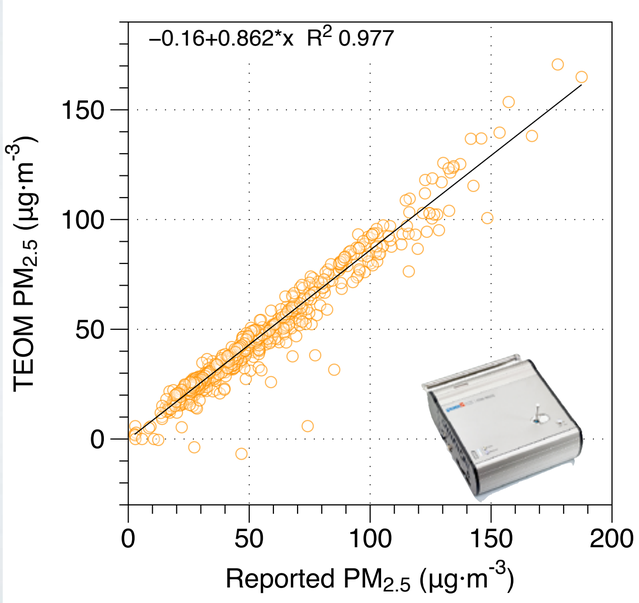

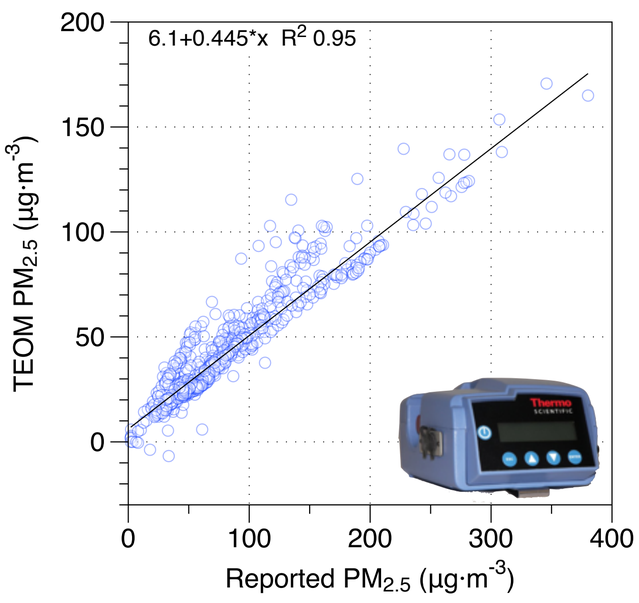

Well correlated, with a few issues

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What did we learn about the response to wildfire smoke

All of the optical devices (low-cost and research grade) over report on wildfire smoke

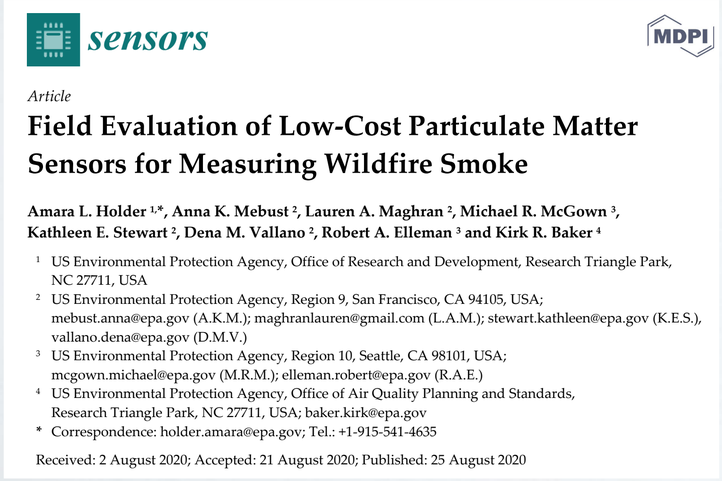
Over reporting by a factor of two is common

Know your data

It is usually wrong, but it is often correctable

Holder, A. L., Mebust, A. K., Maghran, L. A., McGown, M. R., Stewart, K. E., Vallano, D. M., et al. (2020). Field Evaluation of Low-Cost Particulate Matter Sensors for Measuring Wildfire Smoke. Sensors, 20(17), 4796–17. http://doi.org/10.3390/s20174796

Delp, W. W., & Singer, B. C. (2020). Wildfire Smoke Adjustment Factors for Low-Cost and Professional PM2.5 Monitors with Optical Sensors. Sensors, 20(13), 3683–21. http://doi.org/10.3390/s20133683



sensors

MDPI

Article

Field Evaluation of Low-Cost Particulate Matter Sensors for Measuring Wildfire Smoke

Amara L. Holder [1,*], Anna K. Mebust [2], Lauren A. Maghran [2], Michael R. McGown [3], Kathleen E. Stewart [2], Dena M. Vallano [2], Robert A. Elleman [3] and Kirk R. Baker [4]

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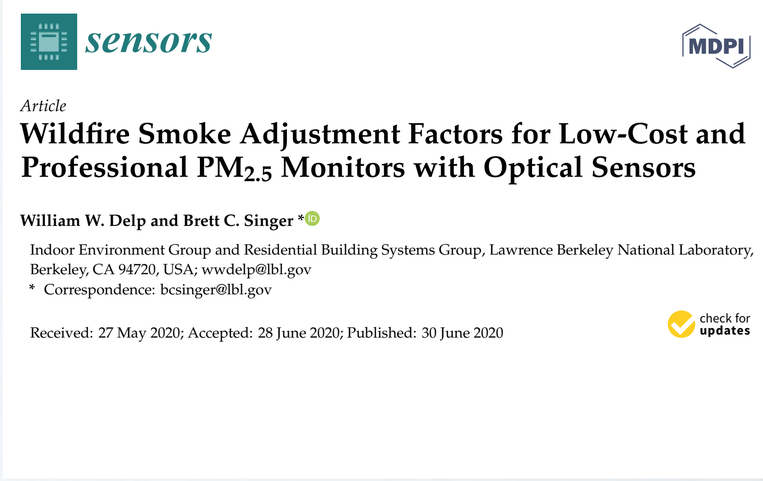
Received: 2 August 2020; Accepted: 21 August 2020; Published: 25 August 2020



sensors

MDPI

Article

Wildfire Smoke Adjustment Factors for Low-Cost and Professional $PM_{2.5}$ Monitors with Optical Sensors

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Received: 27 May 2020; Accepted: 28 June 2020; Published: 30 June 2020

check for updates

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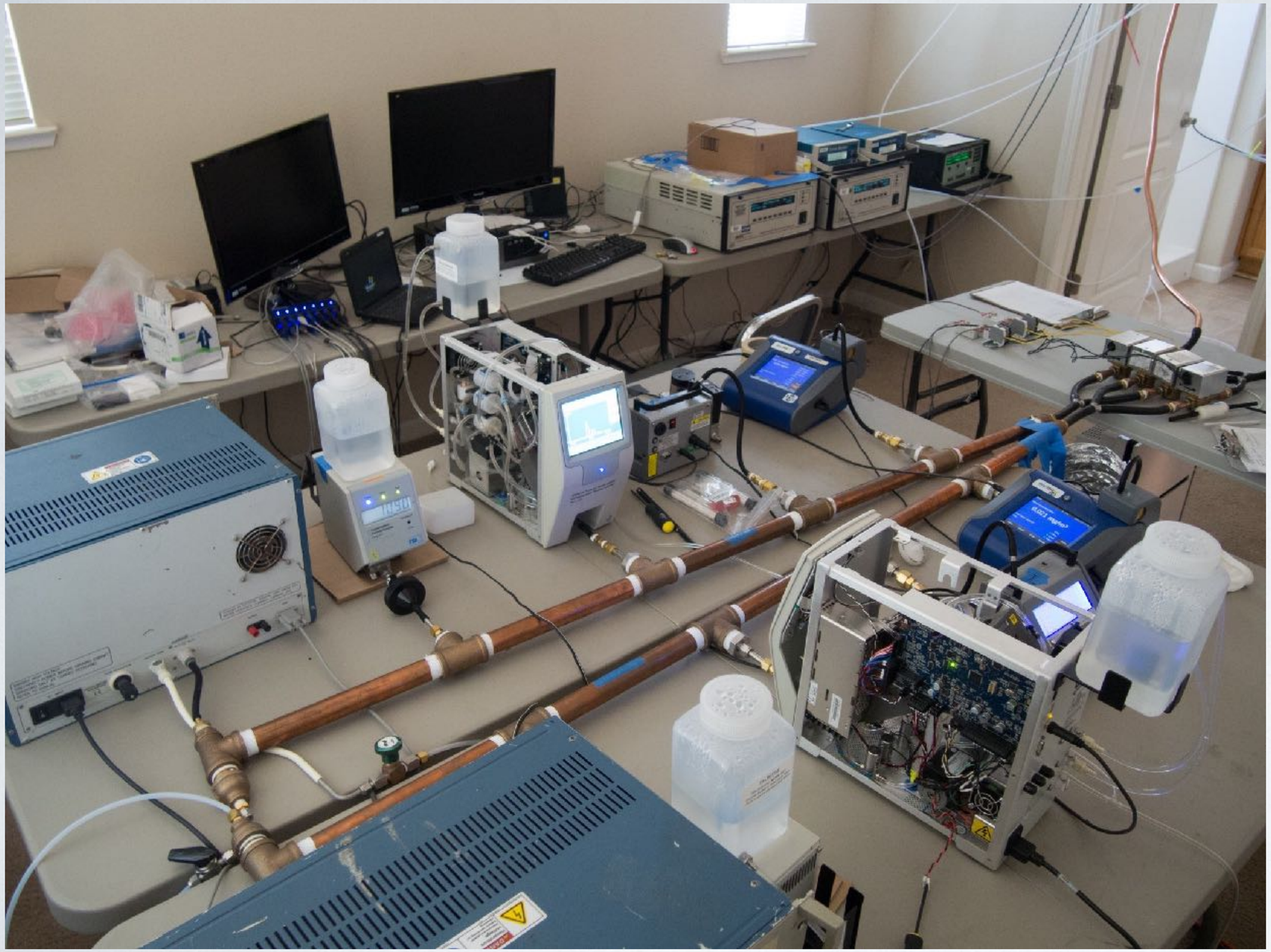


2015 No cool consumer devices

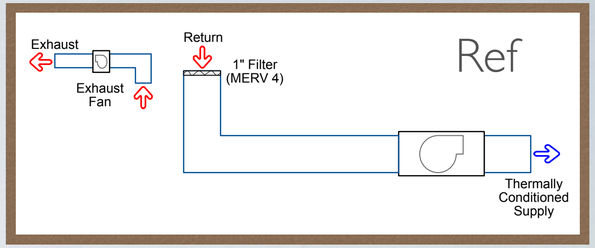
ARB project looking at ventilation in new construction. Specifically near roadway.

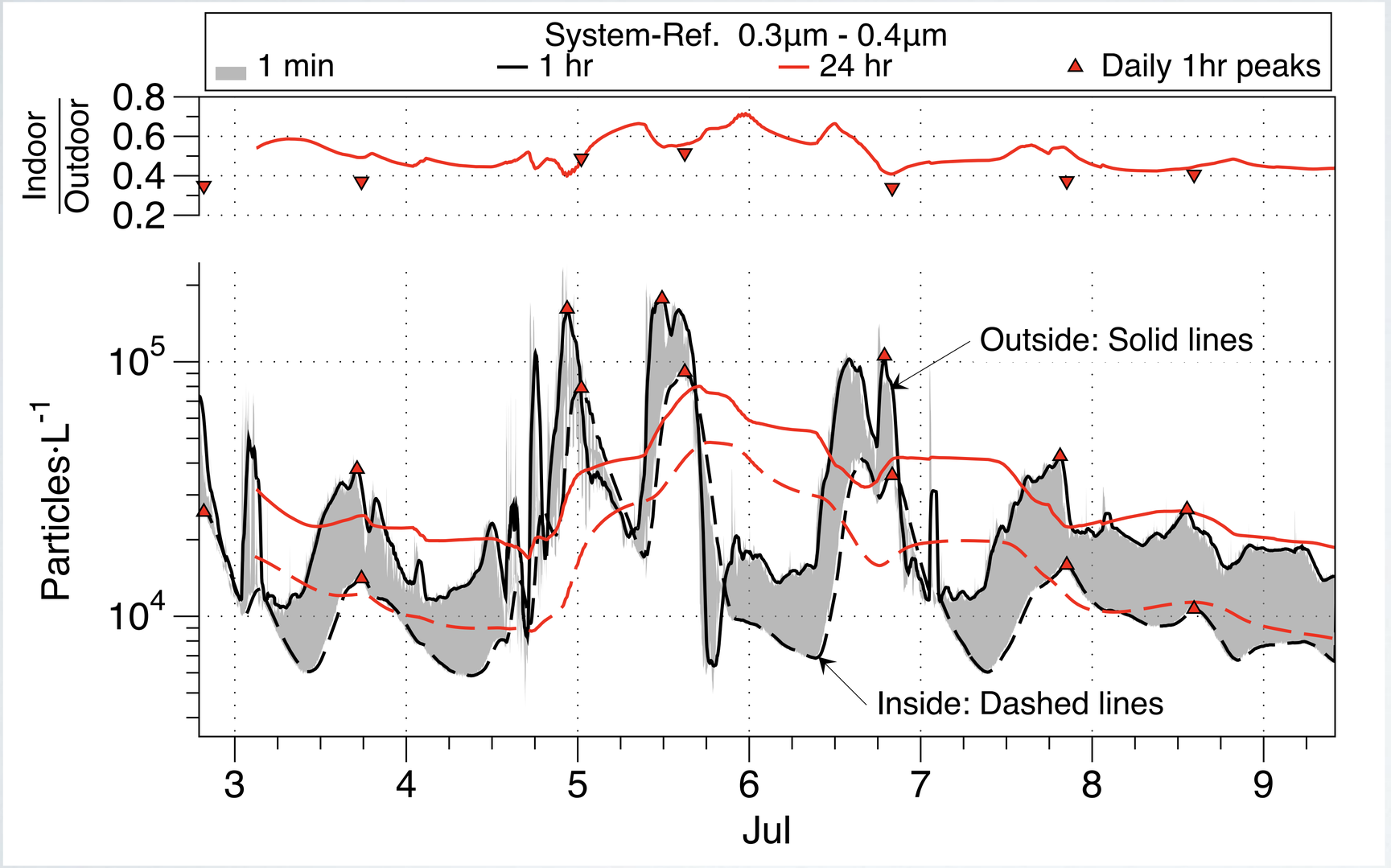
$300K in instruments managed by 3 PhDs in an unoccupied house

Metric was I/O Indoor / Outdoor ratio

Key aspect we used the same instrument for in / out measurements

Example data showing mediocre performance





~50% reduction in the 0.3 - 0.4 µm size bin (good surrogate for the wildfire smoke)

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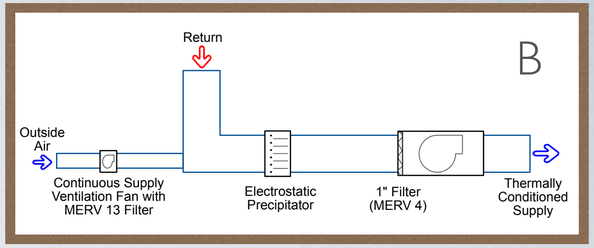
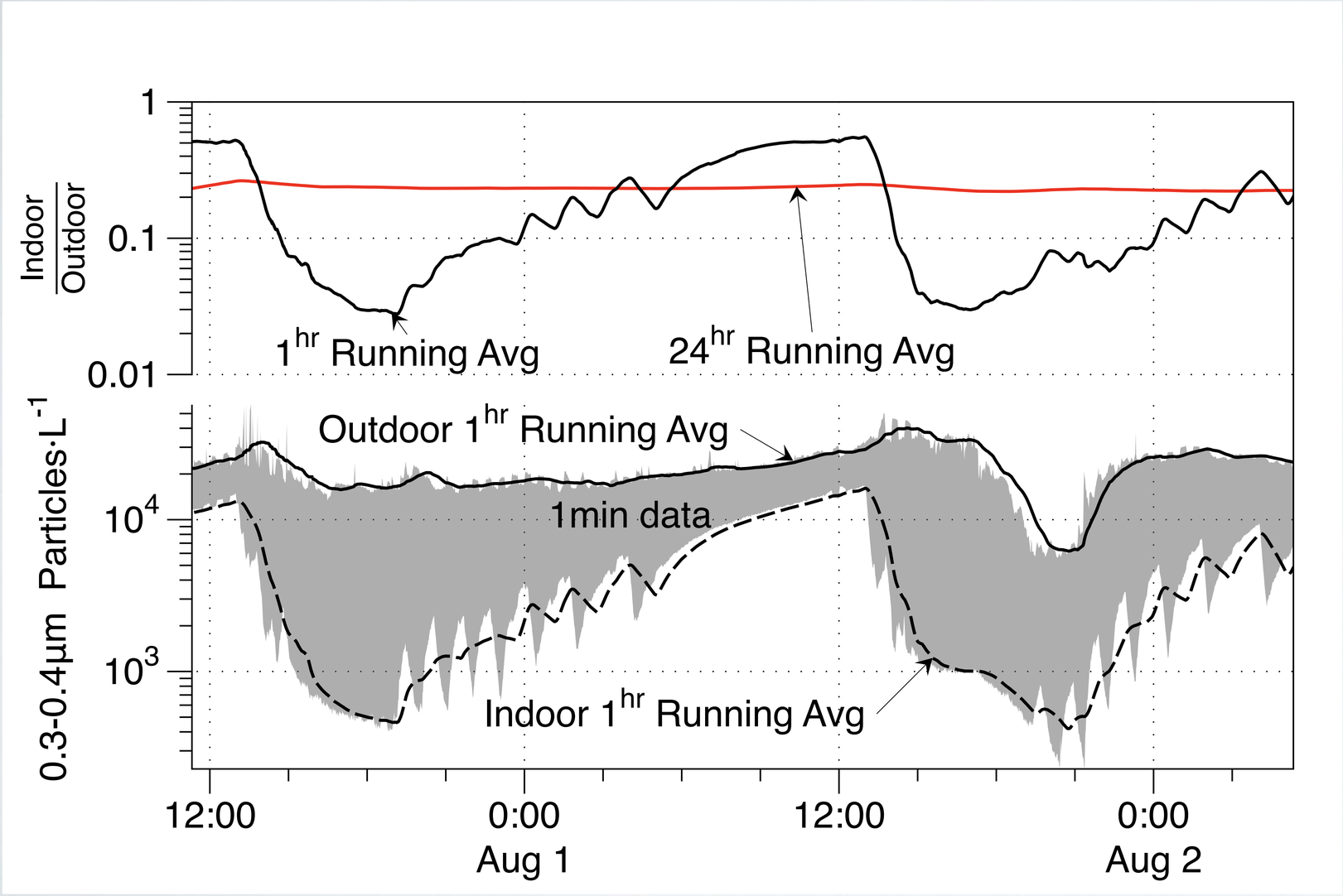
Example data showing mixed performance





Only provided filtration when the unit was on with the 'stat

95+% reduction when the AC was running, otherwise less than 50%

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What can a sophisticated consumer do?

Don’t panic!

If you monitor inside compare it to the best of your ability to a like instrument outdoors

If miles away from the fire, concentrations are pretty consistent and smooth in the greater Bay area, and the EPA AirNow sight provides useful information. Try to use 'corrected' data when possible.

https://fire.airnow.gov/

Ideally take the same instrument outside. We want to find out the correction factor for the current fire. (It is likely to be reading high by the factor of 2)

If it is bad outside shut your doors and windows

This will likely yield ~50% reduction in values

If you have a forced air system, turn the fan to 'ON' (rather than 'AUTO')

This further reduces the values, the actual amount depends on the size of the system and the quality of the filter

Use a good portable room air cleaner that is large enough for the space

AHAM VERIFIDE Independently Tested. Consumer Trusted.

CADR - Clean Air Delivery Rate

https://ahamverifide.org

DIY filter / fans can help

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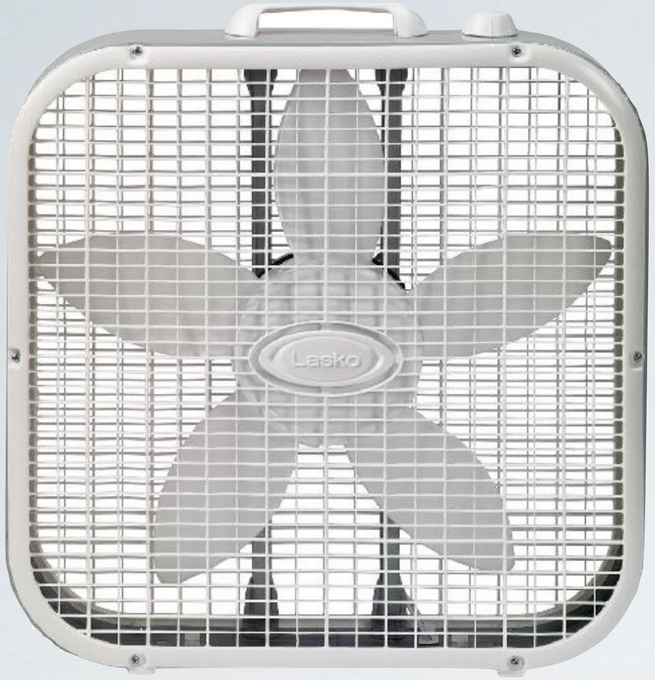

3-speed fan, high 2,500 cfm

3-speed fan, high 2,163 cfm

medium 1,900 cfm

low 1,463 cfm

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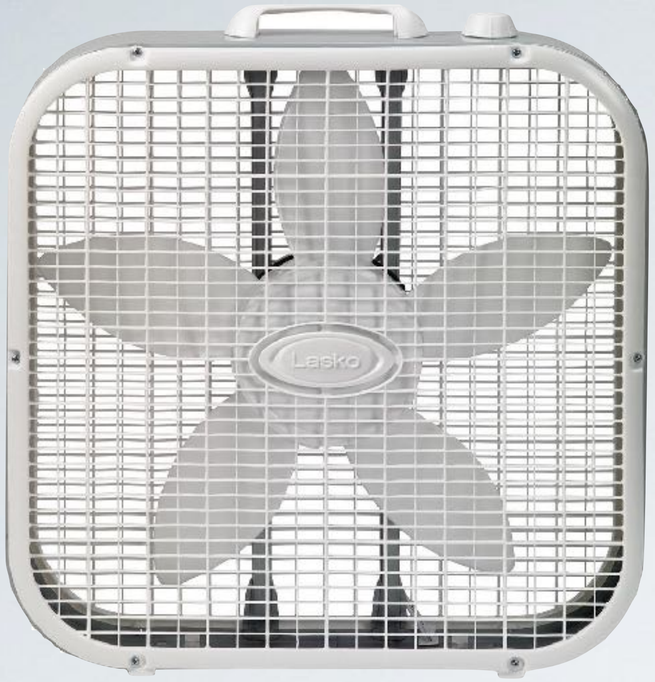
Assembled ‘product’



+

Spd	Flow (cfm)		CADR* (cfm)
High	205	η 65%	132
Med	122		79
Low	83		54

One is quieter than the other

CADR	Power
233cfm	77W
132cfm	~100W

Summary

Most low cost monitors are likely to over report wildfire smoke by a factor of 2.

Indoor outdoor measurements should use the same instrument, or at least be corrected

Indoors will only be half as bad as outside, and it is fairly easy to get to a 90+% improvement.

End

Very easy to blow past these numbers with indoor sources