2019 AIVC Workshop

Evaluation of Low-Cost IAQ Monitors

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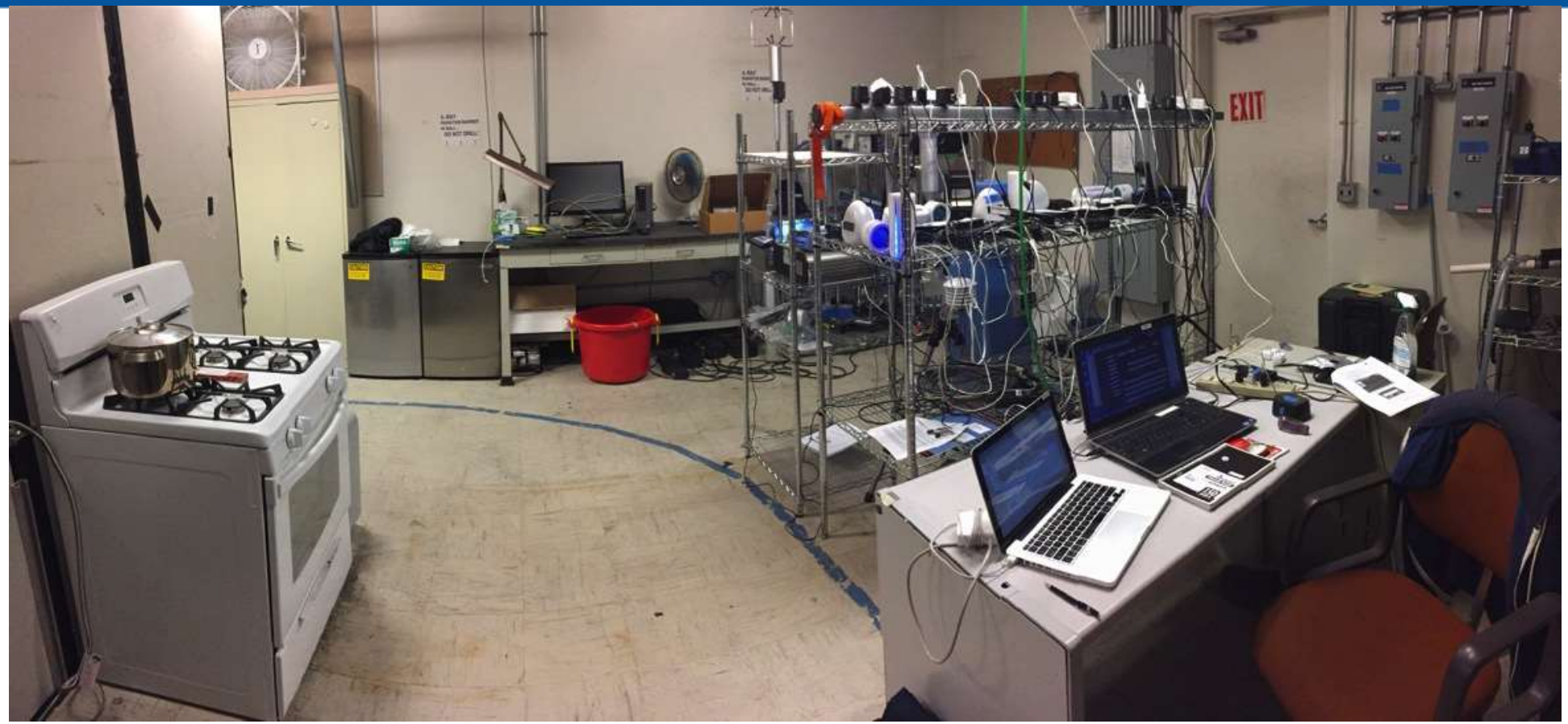
Objectives

1. Can these low cost devices detect events?
   - At least well enough to do something?
     - Turn on ventilation system or air filtration
     - Shelter in place
2. Are they OK for long term chronic assessments at lower concentrations?
   - Ventilation system control
   - Health assessments
3. Are they consistent unit to unit?
4. Do they still work after a year? Five years? Ten years?

Focus on Particles – only contaminant of concern with a low-cost option

LBNL Lab Testing



Sources

Burned incense, candles and cigarettes

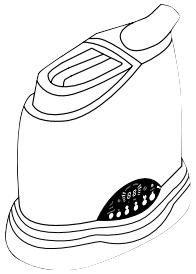




Heated pots of water, an oven, a hair dryer, and an electric burner

Cooked green beans, bacon, pancakes, toast, and a pizza, and heated canola oil



Released AZ test dust, shaked a dust mop, and operated an ultrasonic humidifier using unfiltered tap water

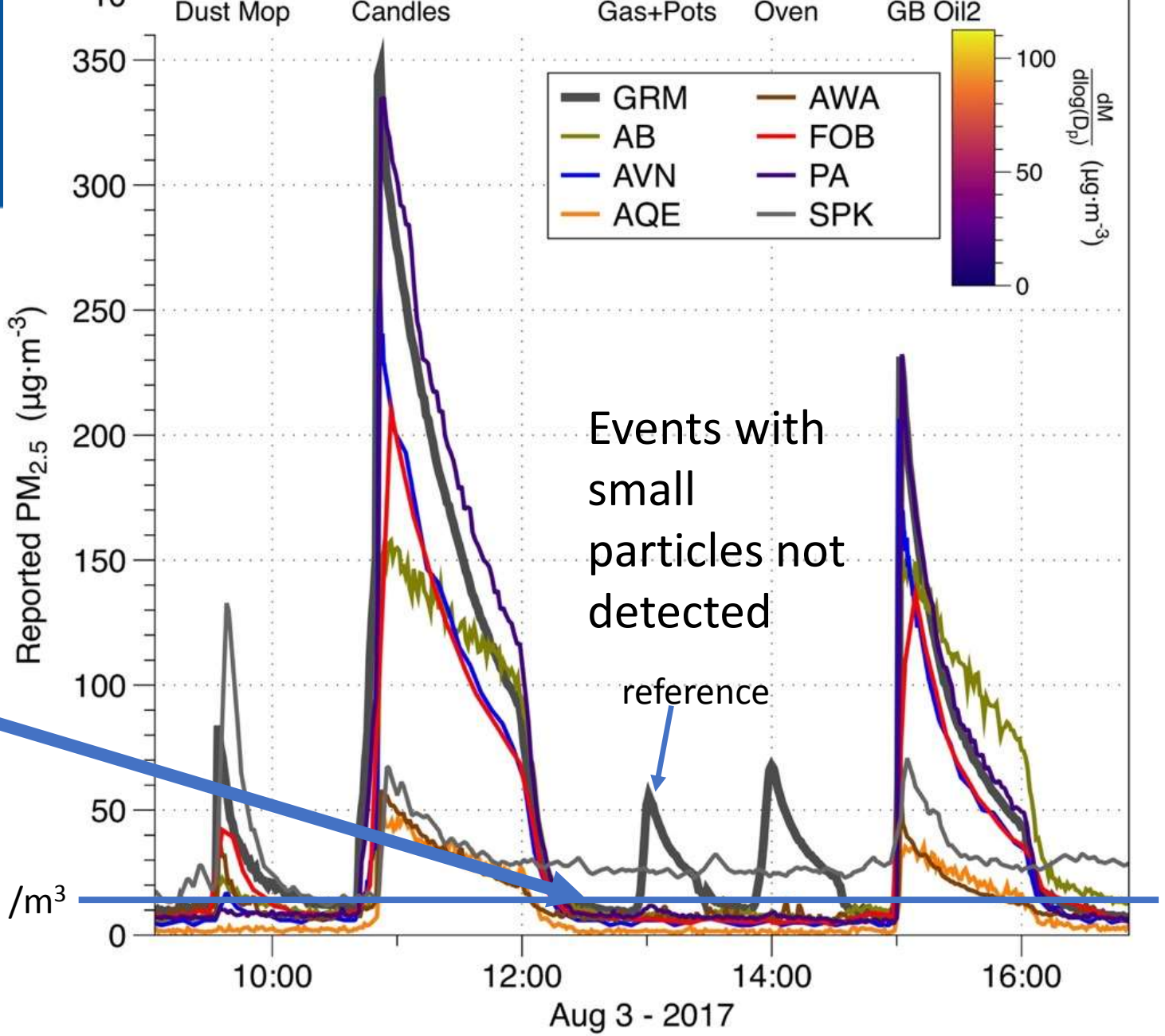
LBNL testing – low cost monitors

Air beam	Air Visual Node	Air Quality Egg	AWAIR	Foobot	Purple Air	Speck
						

These use mass-produced particle sensors that cost $10 to $35

All based on light scattering – no ultrafine particle detection

Example Events



Big % errors at low concentrations

CalEPA limit = 12 ⌈g /m^3
WHO and Canada:
10 ⌈g /m^3

LBNL Study Conclusions

Four consumer monitors detected most sources and semi-quantitatively measured all **large** sources of $PM_{2.5}$.

PA

FOB

AB

AVN

Two consumer monitors detected many sources but not quantitatively.

AWA

AQE

One monitor was not informative.

SPK

Consumer monitors not suitable to detect & control ultrafine particles or control to IAQ standards.

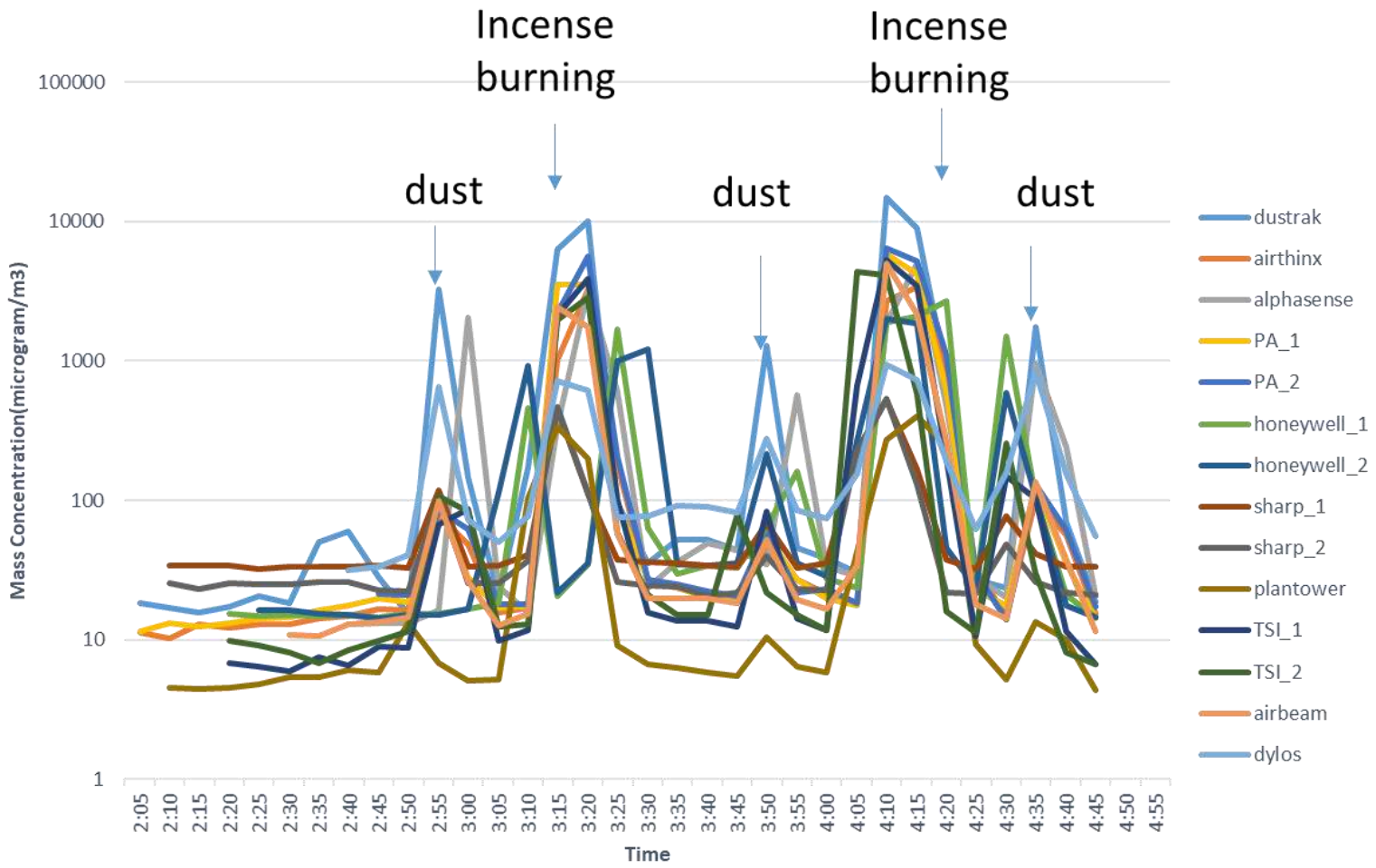
Note that this is an evolving technology: at least on device (AWAIR) has upgraded sensor since these tests

Ohio State Study: Lab and Field

Bare sensors: Honeywell HPM, Sharp GP2Y1010AU0F, Plantower PMS5003, Shinyei PPD71

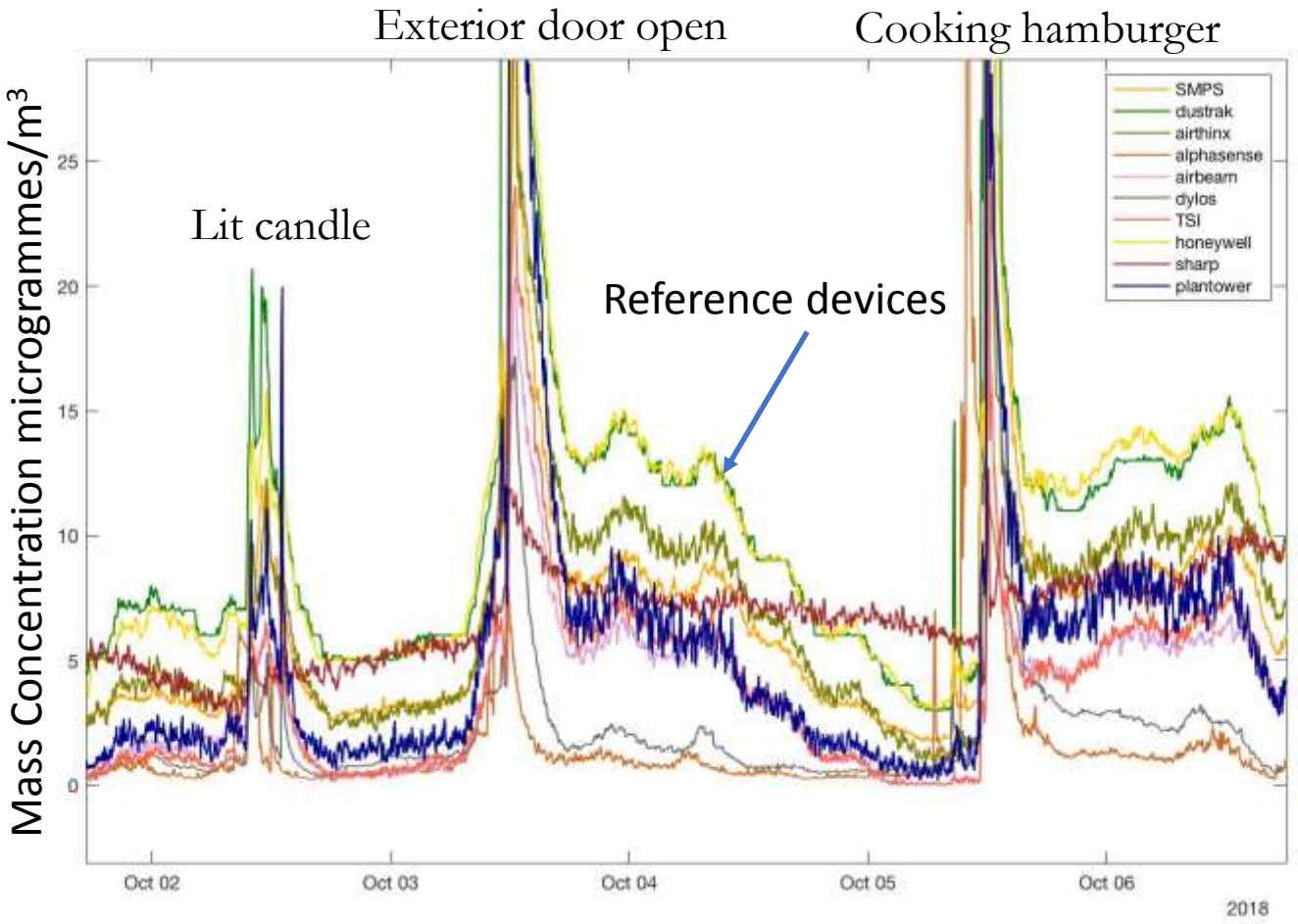
Integrated monitors: Foobot, AirBeam2, Dylos DC1100 PRO, AirThinx, Purple Air II, Tsi Blue Sky, Alphasense OPC-N2

OHIO State Lab Results



Most events detected – some better than others

Ohio State Field Results

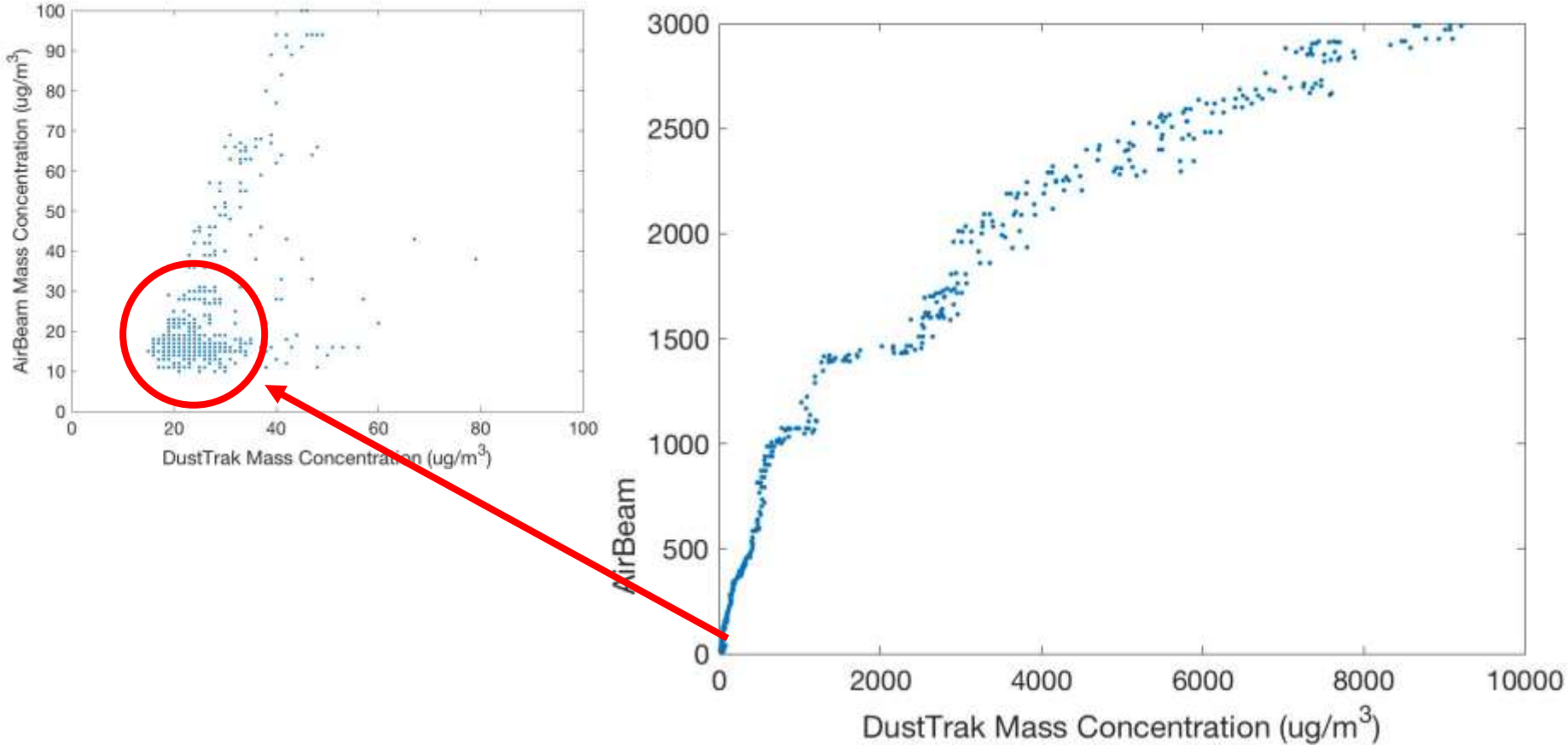


Events mostly detected

Poor at low concentrations

Ohio State Lab Results

- Poor correlation at low concentration – much better at high concentration
- OK for event detection, maybe not for chronic exposure



6 March 2018

Assessment of low-cost particulate matter and VOC sensors

Laure MOURADIAN

Sensors tested at CETIAT

AWAIR
PM, VOCs, CO_2

LASER EGG
PM

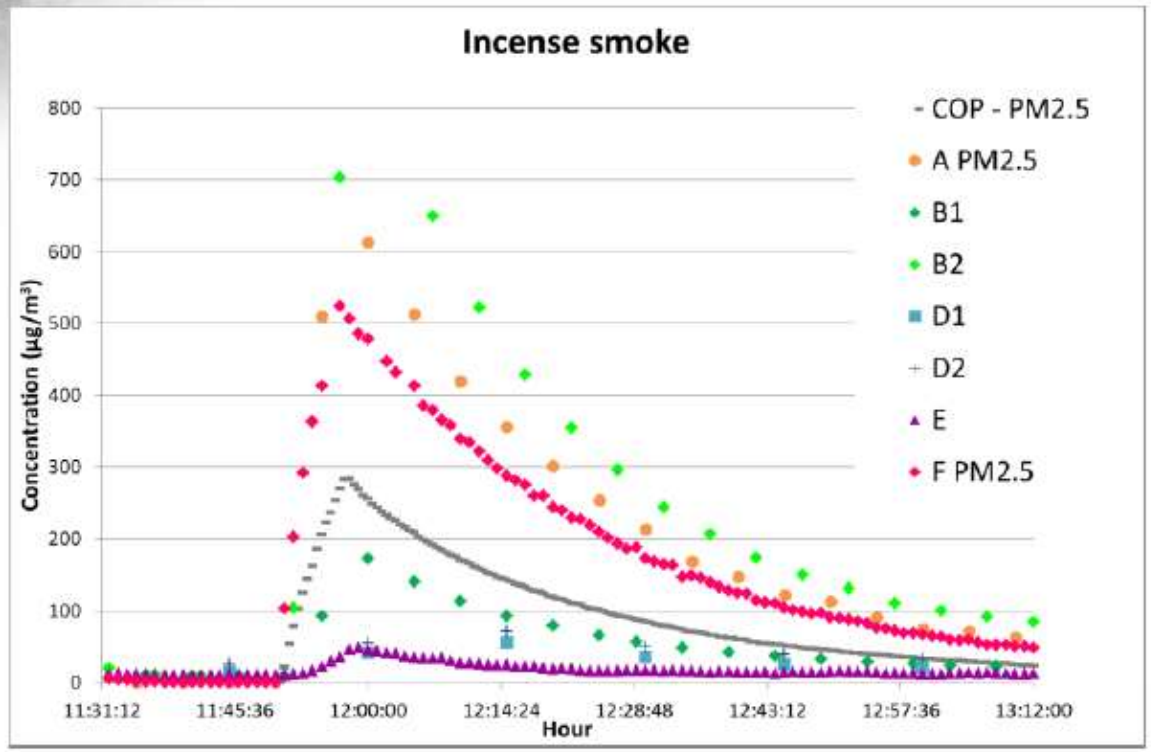
SPECK
PM

AERECO
PM

UNI-T
PM, VOCs

FOOBOT
PM, VOCs

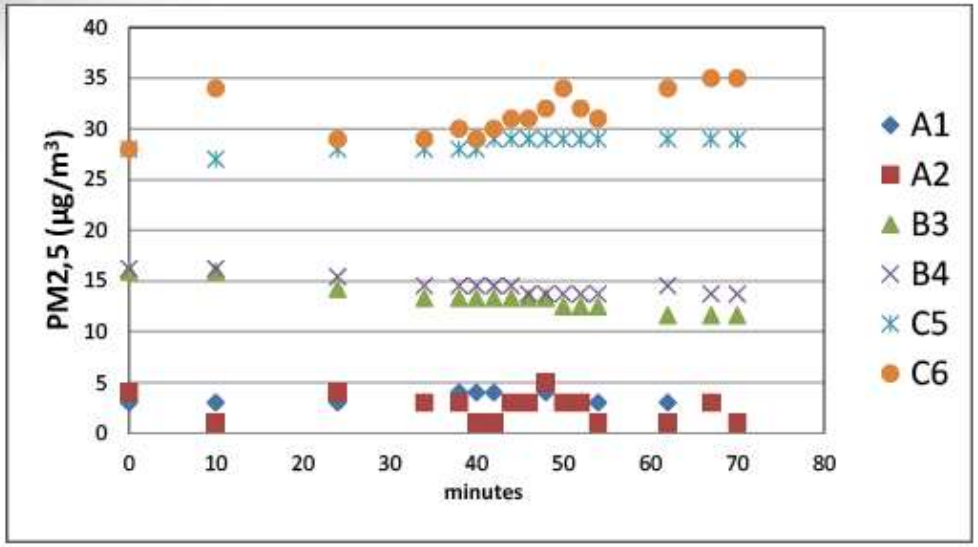
Sensor response to incense smoke



All devices responded to strong particle emitting event

But some a lot more than others

Measurement at low level of particles



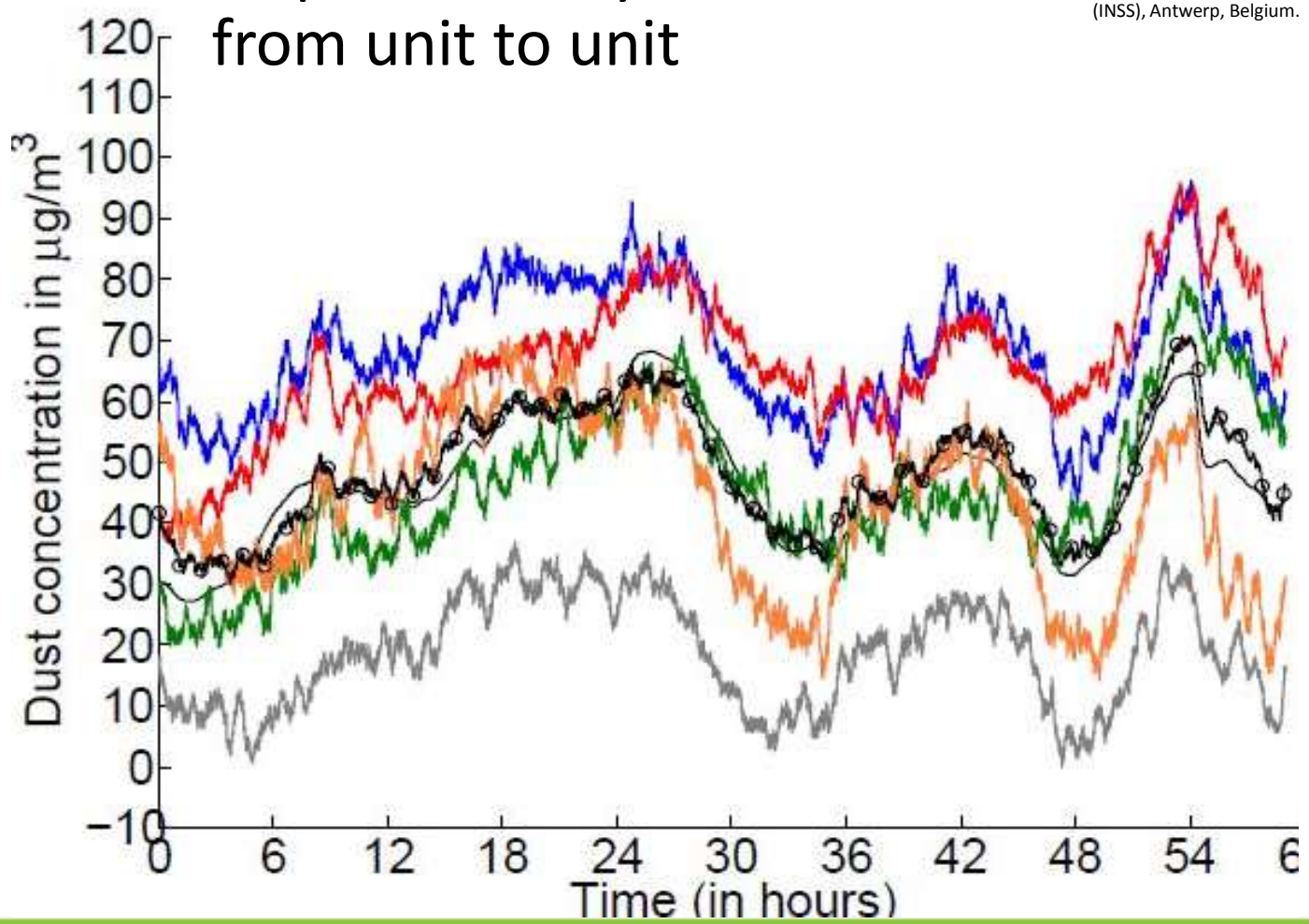
With no particle generation background levels have large range relative to health-related thresholds at about 10 microgrammes per cubic meter

CETIAT Summary

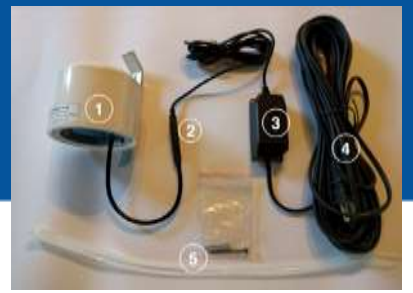
- Most devices can detect events
  - But not quantitatively
- Not good at low concentrations
- OK for events, but not for chronic exposure

Consistency

5 Specks – very inconsistent from unit to unit



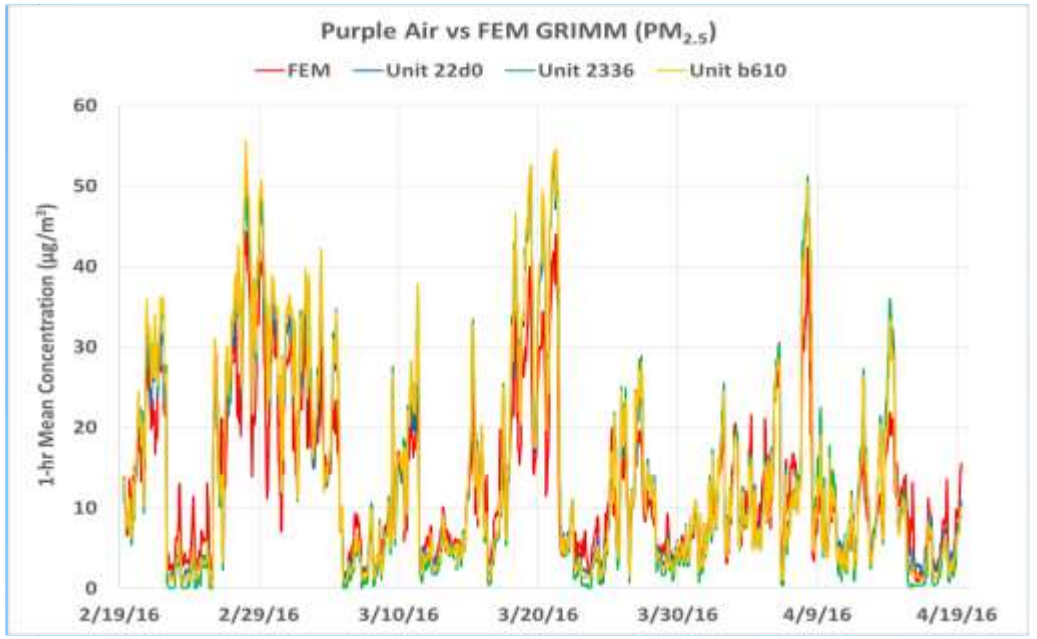
Budde, M., Busse, M., and Beigl, M. (2012). Investigating the Use of Commodity Dust Sensors for the Embedded Measurement of Particulate Matter. Paper presented at the Ninth International Conference on Networked Sensing Systems (INSS), Antwerp, Belgium.

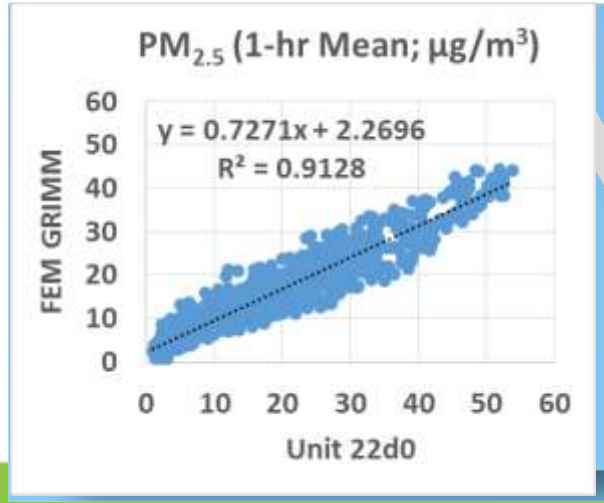


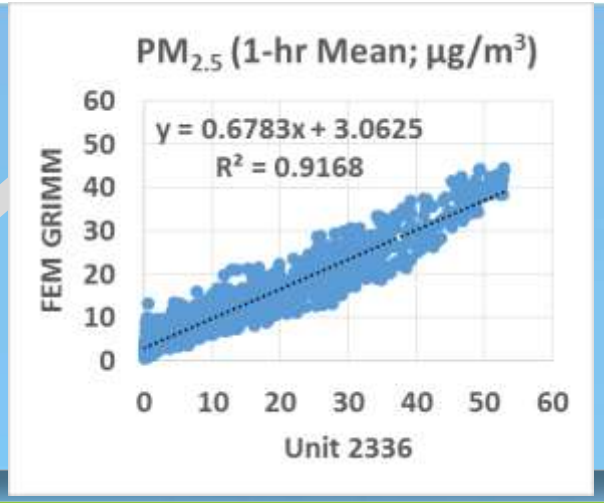
PurpleAir

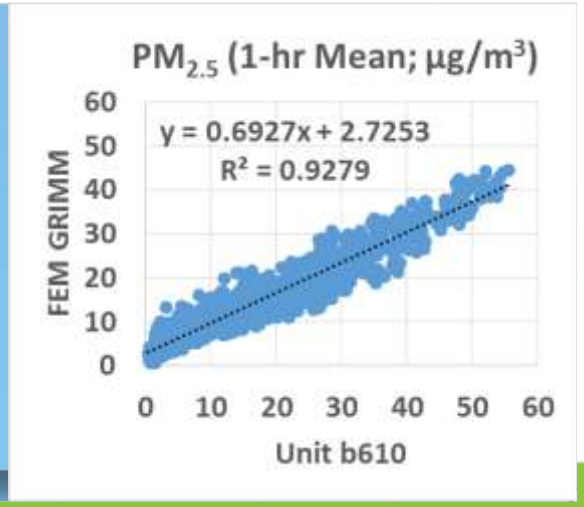
AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Consistent results
Little unit to unit variability
Close to reference calibration





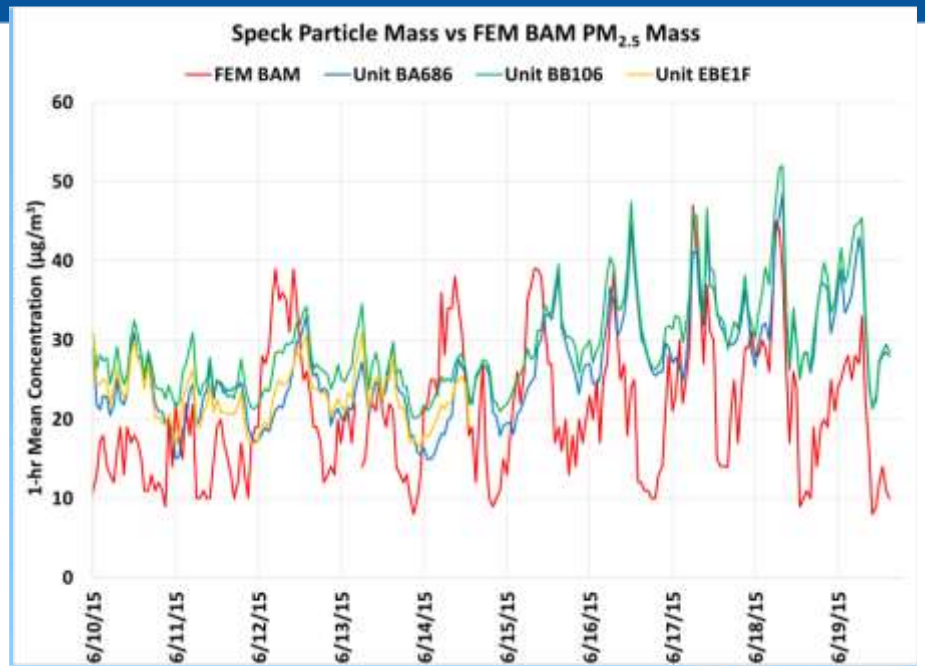


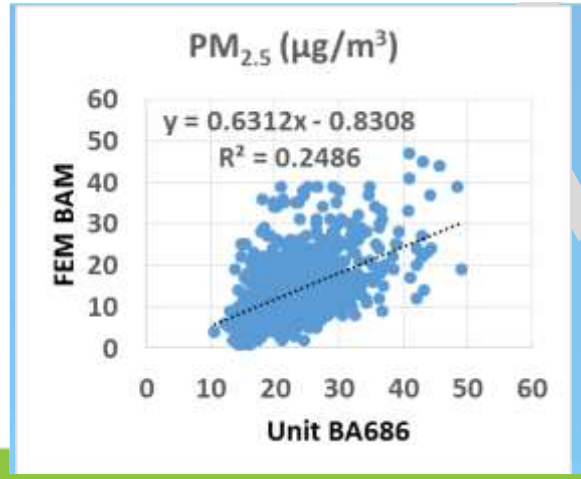


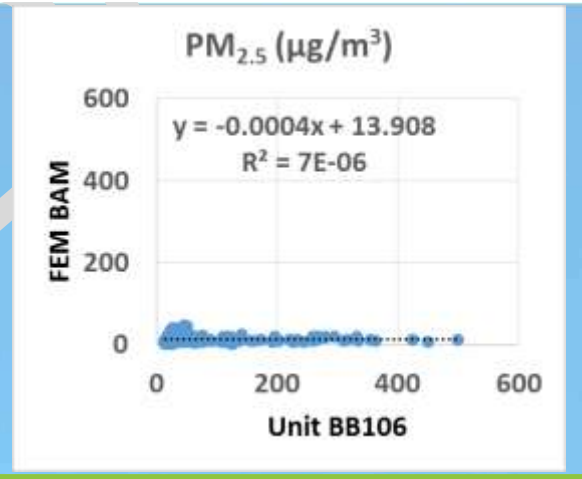
Speck V2.0

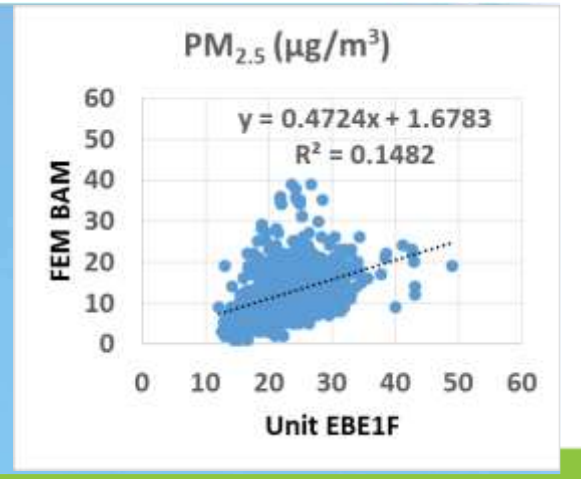
AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Very inconsistent results unit to unit
-Poor correlation with reference









Glasgow School of Art

J. Sens. Sens. Syst., 7, 373–388, 2018
https://doi.org/10.5194/jsss-7-373-2018

JSSS Journal of Sensors and Sensor Systems Open Access

Field evaluation of a low-cost indoor air quality monitor to quantify exposure to pollutants in residential environments

Alejandro Moreno-Rangel[1], Tim Sharpe[2], Filbert Musau[2], and Gráinne McGill[2]
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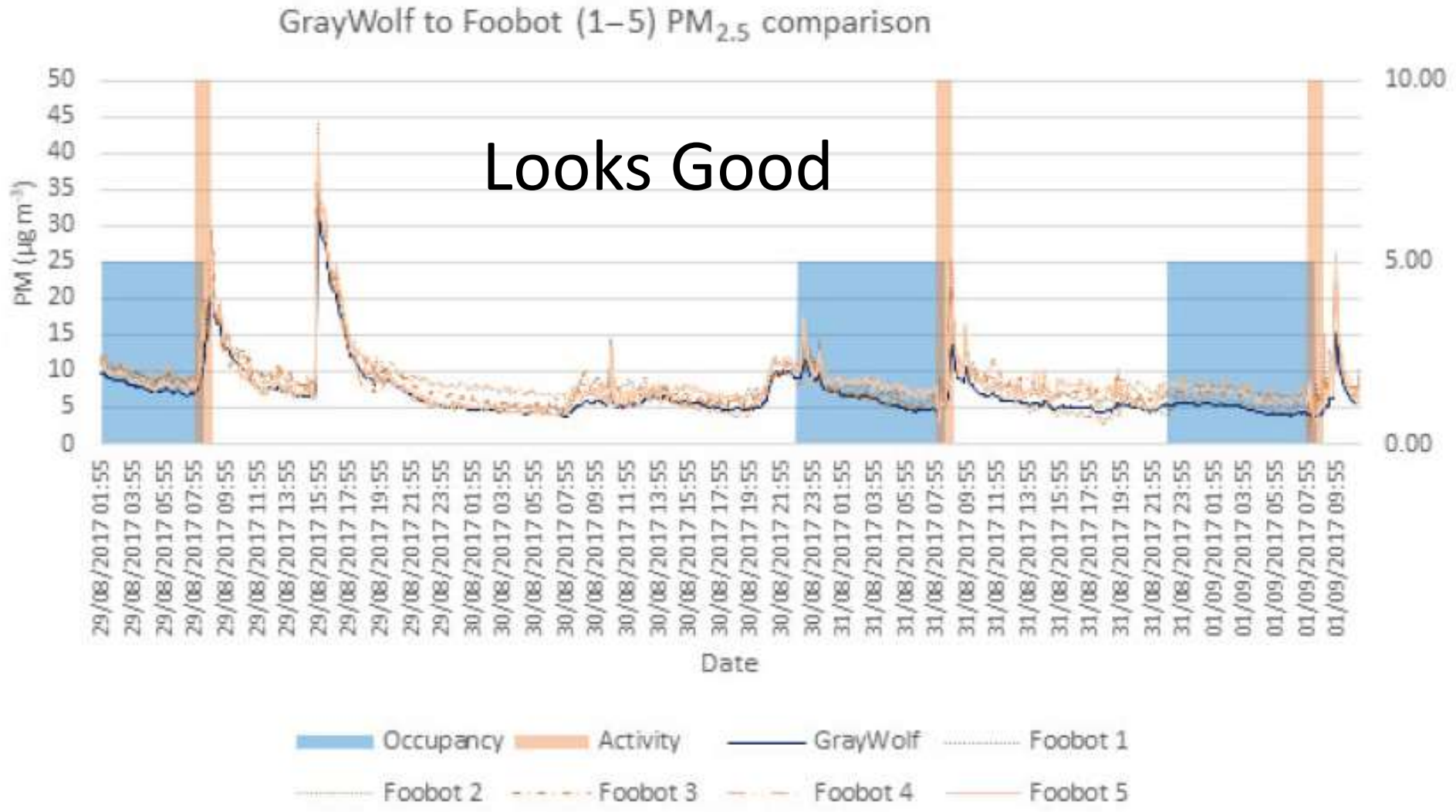
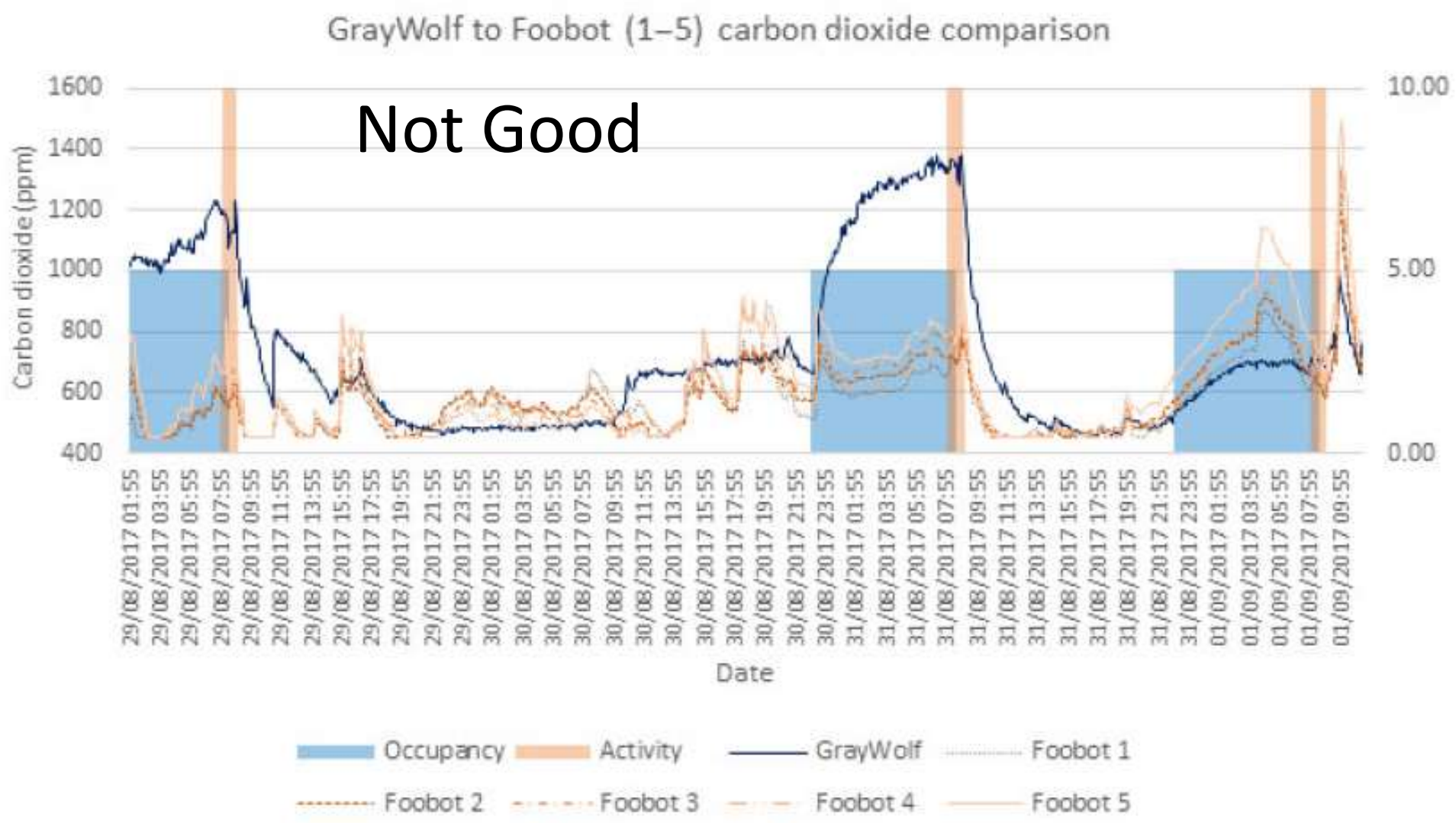
[2]Mackintosh Environmental Architecture Research Unit, The Glasgow School of Art, Glasgow, G1 6DE, UK

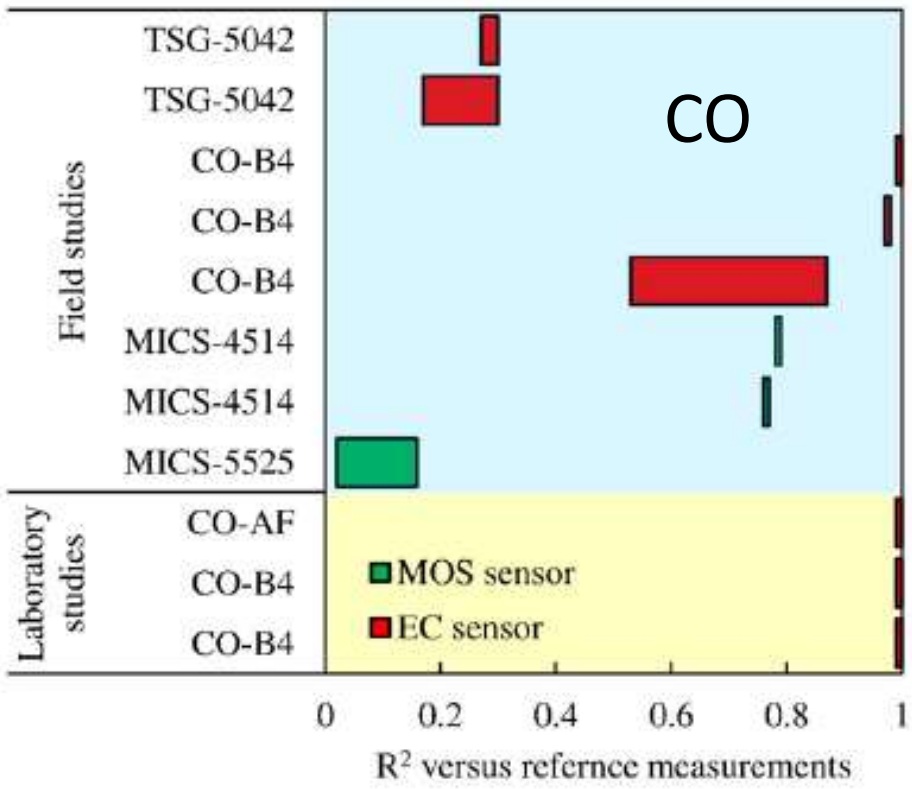
Foobot particle measurements



Foobot CO_2 measurements



Sensing other stuff - CO



Bad

Good

MOS – Metal oxide semiconductor

EC – Electro-chemical

In the field cross-sensitivities – hard to calibrate out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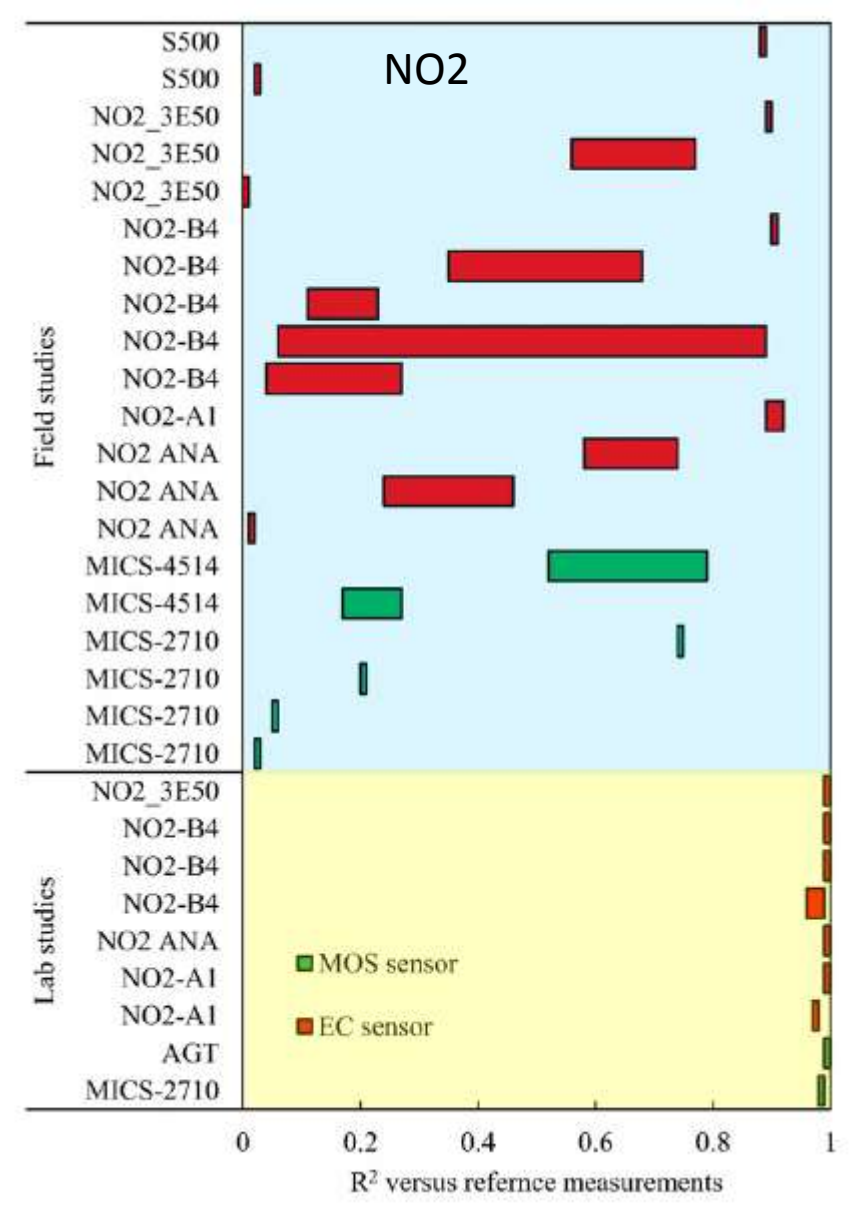
Review

End-user perspective of low-cost sensors for outdoor air pollution monitoring

Aakash C. Rai [a], Prashant Kumar [a,b,*], Francesco Pilla [c], Andreas N. Skouloudis [d], Silvana Di Sabatino [e], Carlo Ratti [f], Ansar Yasar [g], David Rickerby [d]

Sensing other stuff – NO_2



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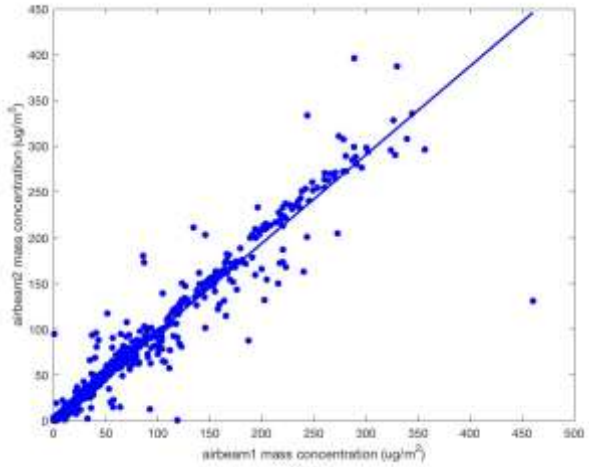
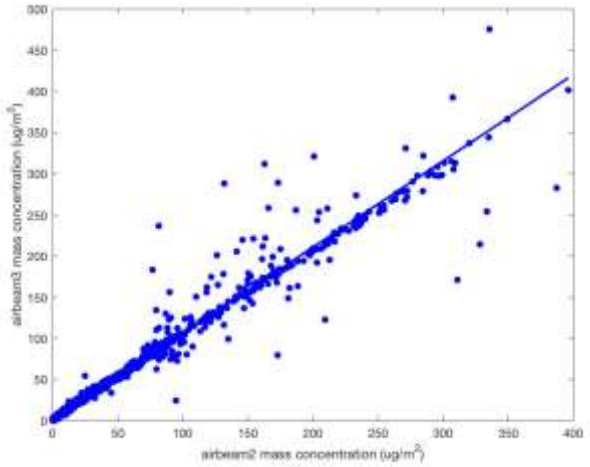
Summary

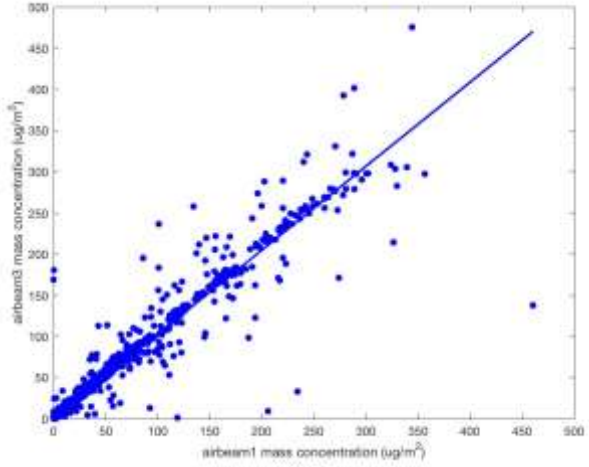
- Choose carefully – some devices much better than others
- Good ones OK for event sensing – less so for chronic exposure
- PM current focus – other contaminants even harder to measure consistently

Questions

Consistency: Ohio





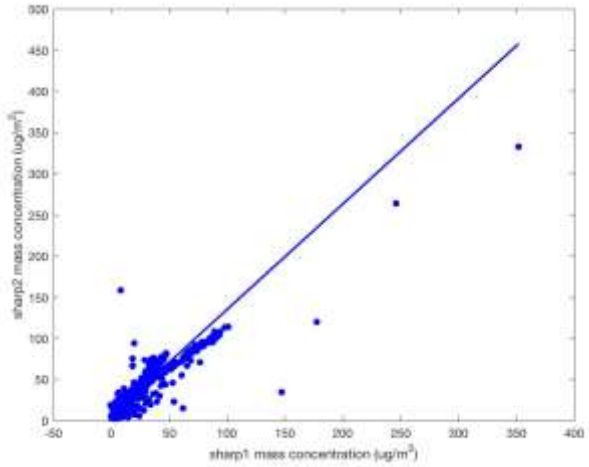


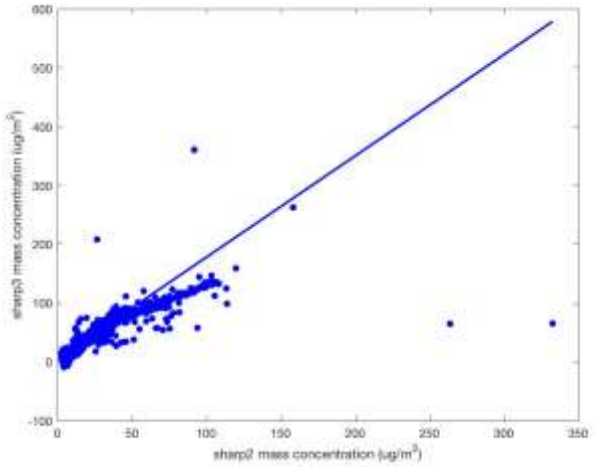
Airbeam2

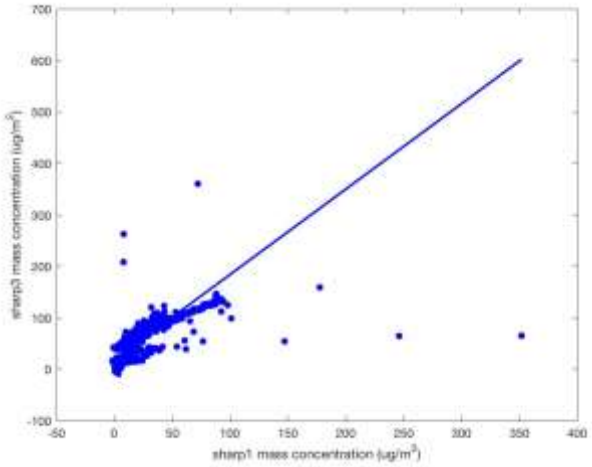
- ~34,000 1-min-averaged data
- Slopes between 0.96 to 1.04
- $R^2 > 0.94$

Consistently good

Consistency: Ohio







<u>Sharp GP2Y</u>

- ~30,000 1-min-averaged data
- Slopes range from 1.3 to 1.7
- R^2 are 0.64 (TL), 0.28 (BL), and 0.85 (TR)

Not Consistent

LBNL testing – low cost monitors

	Air beam	Air Visual Node	Air Quality Egg	AWAIR	Foobot	Purple Air	Speck
							
	PM	PM2.5 PM10	PM	PM	PM	PM1 PM2.5 PM10	PM, count
	T	T	T	T	T	T	T
	RH	RH	RH	RH	RH	RH	RH
		CO_2		CO_2	CO_2		
				VOC	VOC		
Sampling Time	1 s	10 s – 15 min	1 min	10 s-5 min		80 s	1 min

These use mass-produced particle sensors that cost $10 to $35
All based on light scattering – no ultrafine particle detection

Reference & Research Instruments

FDMS-TEOM (FEM)

5 min*

PEM + Pump

~1 hr

GRM

1 min

Sophisticated optical particle spectrometer coupled with an electrical mobility analyzer provides 41 bins from 10 nm up to 35 μm

Mass reading scattering devices

PDR

20 sec

BT

1 min