



# 2018 Dry Climate Home Performance Forum

Is a \$200 IAQ (Particle) Monitor Good Enough to Keep You Safe?

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# Acknowledgements

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Simon Walker helped with experiments and data downloads.

Dr. Yang-Seon Kim weighed filters for gravimetric measurements.

# Consumer Grade Monitors

AB



PM, T, RH

1 sec

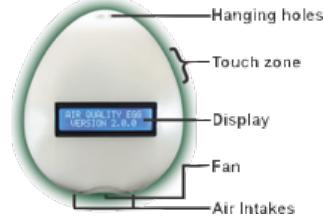
AVN



PM<sub>2.5</sub>, PM<sub>10</sub>, CO<sub>2</sub>,  
T, RH

10 sec – 15 min

AQE



PM, T, RH

1 min

AWA



PM, CO<sub>2</sub>, VOC,  
T, RH,

10 sec – 5 min

FOB



PM, CO<sub>2</sub>, VOC,  
T, RH,

5 min

PA



PM<sub>1.0</sub>, PM<sub>2.5</sub>, PM<sub>10</sub>,  
T, RH

80 sec

SPK

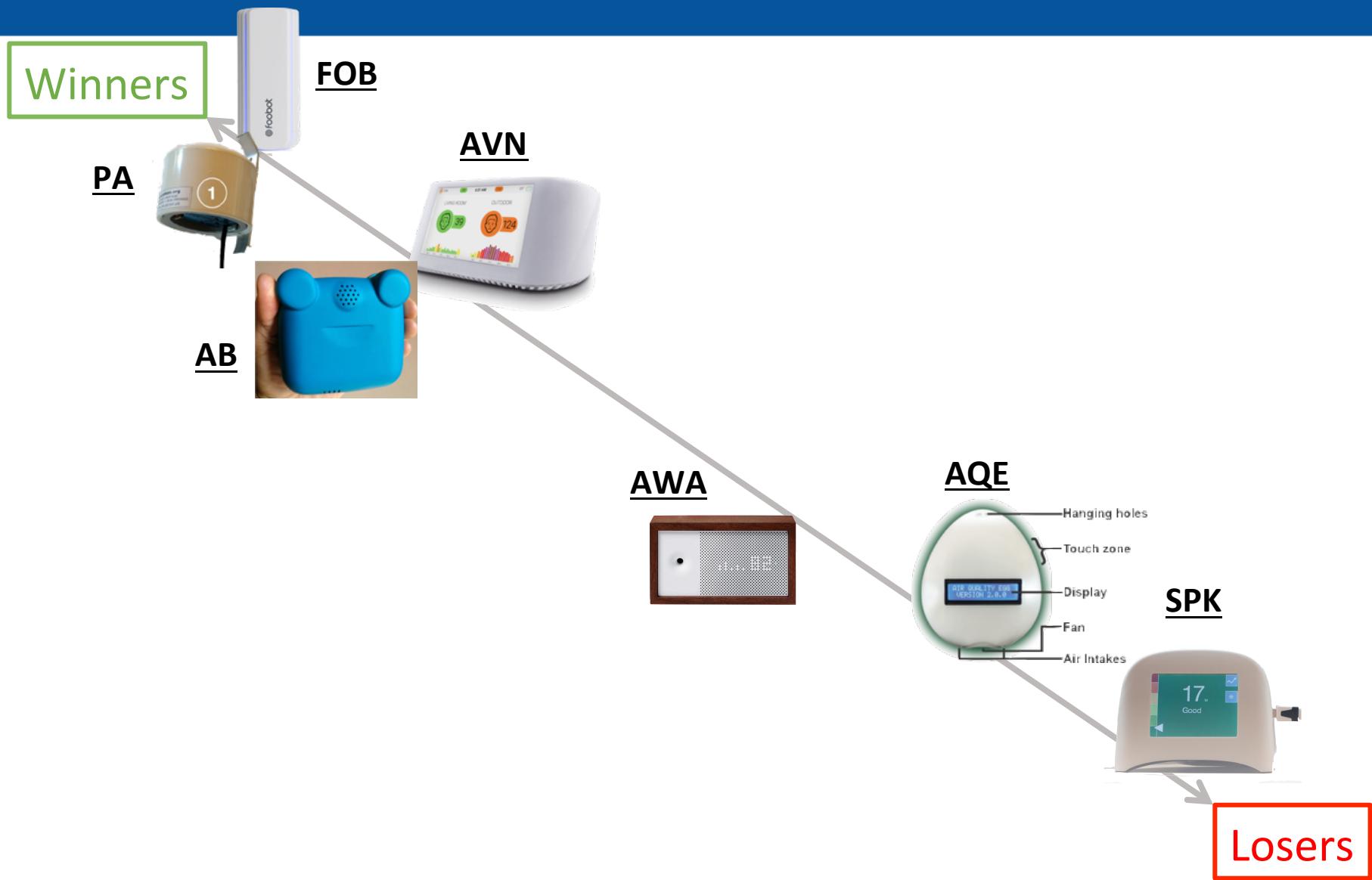


PM, # particles  
T, RH

1 min

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

# Results



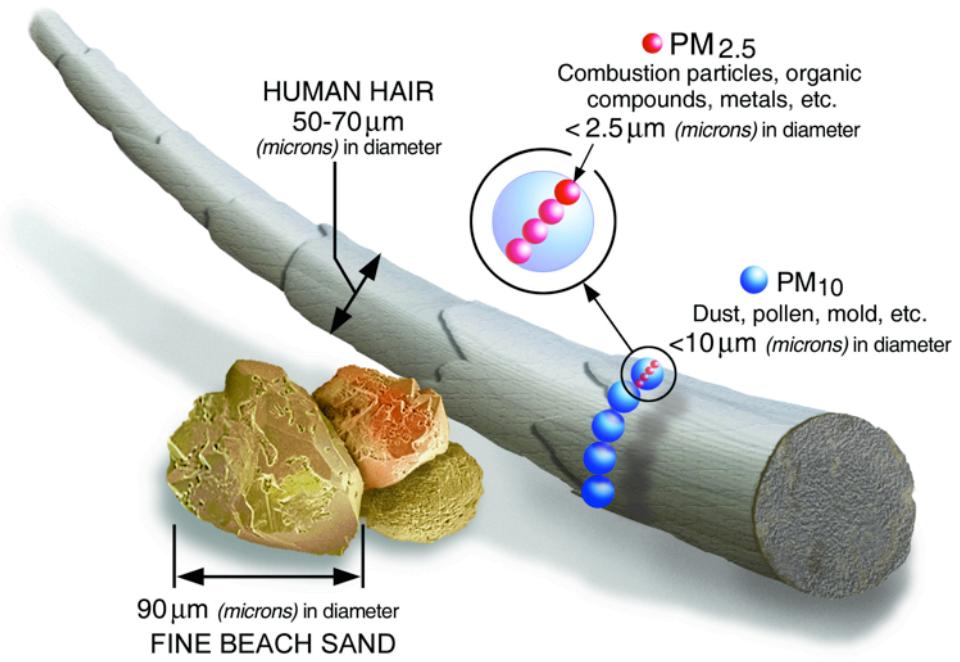
# Focus on Fine Particulate Matter (PM<sub>2.5</sub>)

Higher ambient PM<sub>2.5</sub>

...causes increased cardiovascular morbidity and mortality;

...is associated with and likely causes respiratory illness.<sup>1</sup>

In-home exposure to PM<sub>2.5</sub> causes more health damage than any other non-biological air pollutant.<sup>2</sup>



[www.epa.gov/pm-pollution/particulate-matter-pm-basics#PM](http://www.epa.gov/pm-pollution/particulate-matter-pm-basics#PM)

PM<sub>2.5</sub> detection can enable control by ventilation or filtration.

1. EPA, *Integrated Science Assessment for Particulate Matter*. Washington, DC: U.S. Environmental Protection Agency; 2009.
2. Logue, *Environ Health Perspect*. 2012;120:216-222.

# PM<sub>2.5</sub> Benchmarks

Standard	Annual mean µg/m <sup>3</sup>	24-h mean µg/m <sup>3</sup>
US Ambient Standard (2012)	12	35
WHO Guideline Values (2005)	10	25
Canadian Ambient Standard 2015	10	28
Canadian Ambient Standard 2020	8.8	27

# Reference PM<sub>2.5</sub> Measurements

- U.S. federal reference method (FRM) is gravimetric: specifies pump, inlet, filter, and weighing procedures
  - Designed for 24h int.
  - Too noisy for indoors.
- Alternative gravimetric sampling equipment designed for indoor spaces
  - Integrated
  - \$1500
- Federal equivalent methods (FEM)
  - Tapered Element Oscillating Microbalance
  - Beta attenuation
  - Specialized optical methods



1h or less  
\$10-25K  
per unit

# Research PM Monitors

- Optical scattering devices developed for occupational health, used for residential research.
- Cost \$4-10K for analyzer; \$500 for OEM sensor unit.

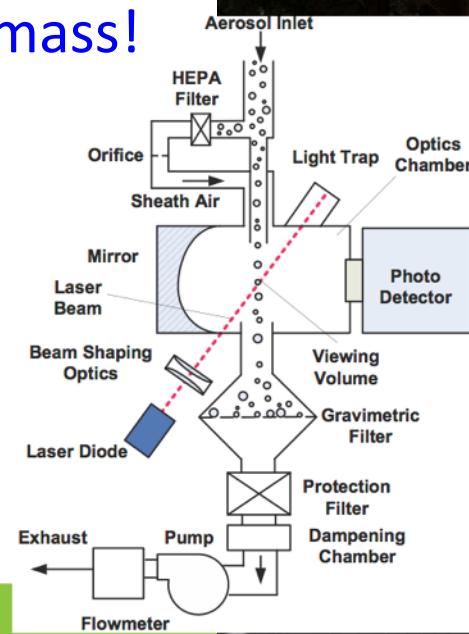
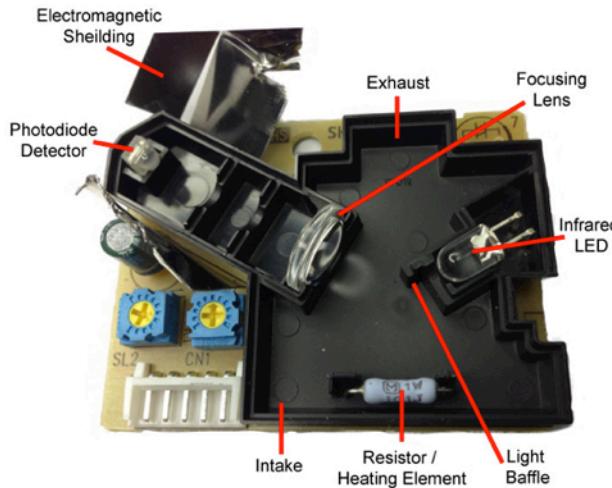


# Scattering Light

The intensity of scattered light depends on:

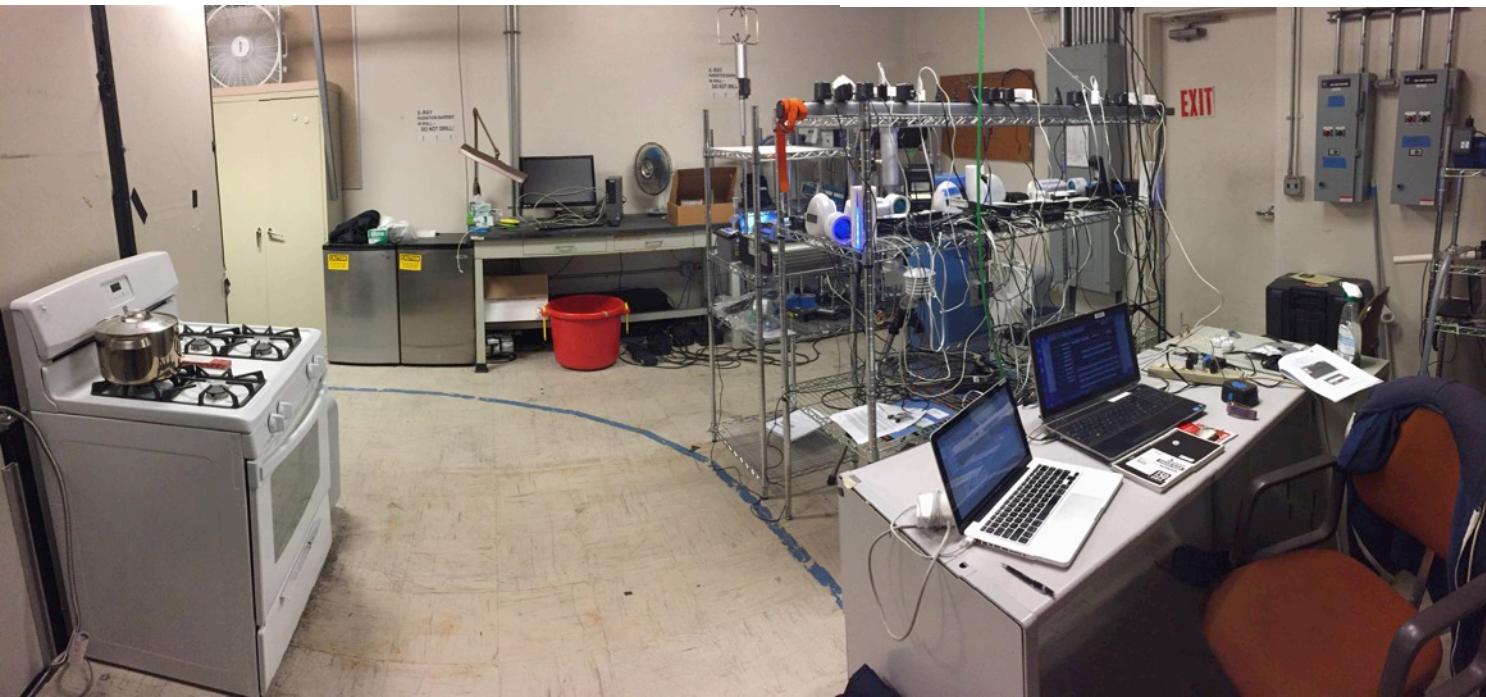
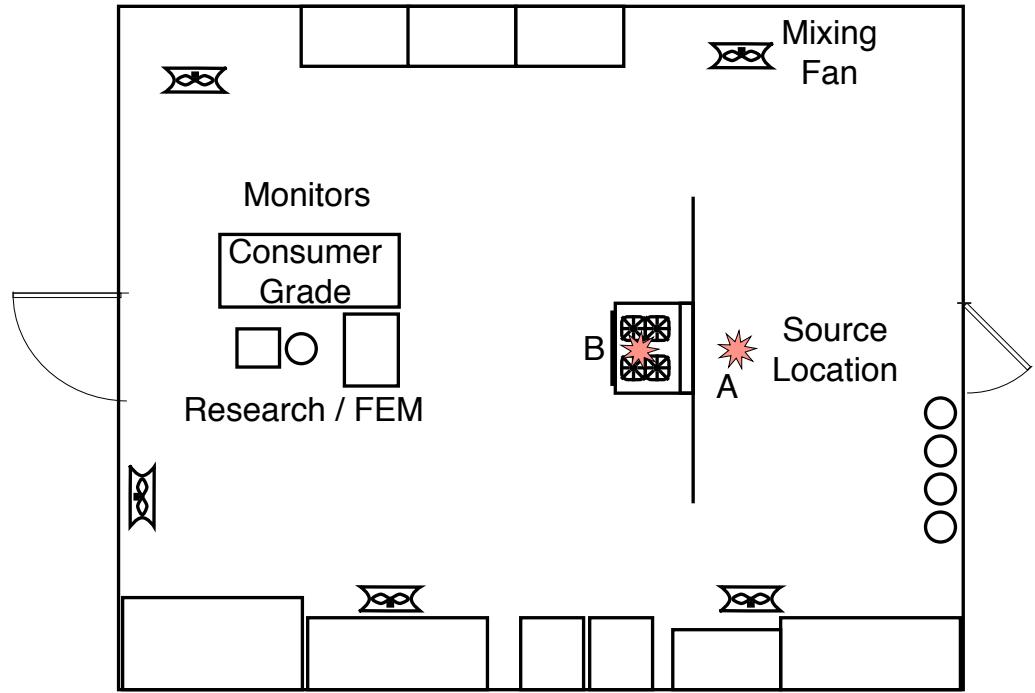
- Light wavelength
- Detection angle
- Particle size
- Refractive index

Approximately linear with mass!



# Room Setup

450 ft<sup>2</sup>  
~126 m<sup>3</sup>



# Reference & Research Instruments

## FDMS-TEOM (FEM)



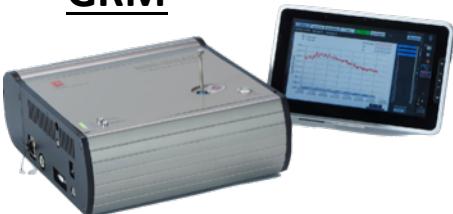
5 min\*

## 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 mm

“True” PM<sub>2.5</sub> estimated using FDMS to get mass and GRM to get time-resolution

Mass reading scattering devices

## PDR



20 sec

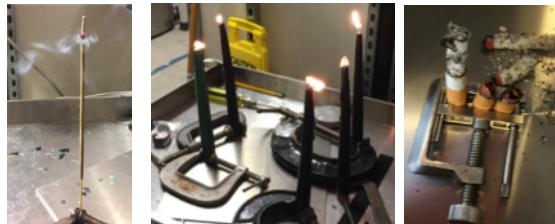
## BT



1 min

# Sources

Burned incense, candles and cigarettes

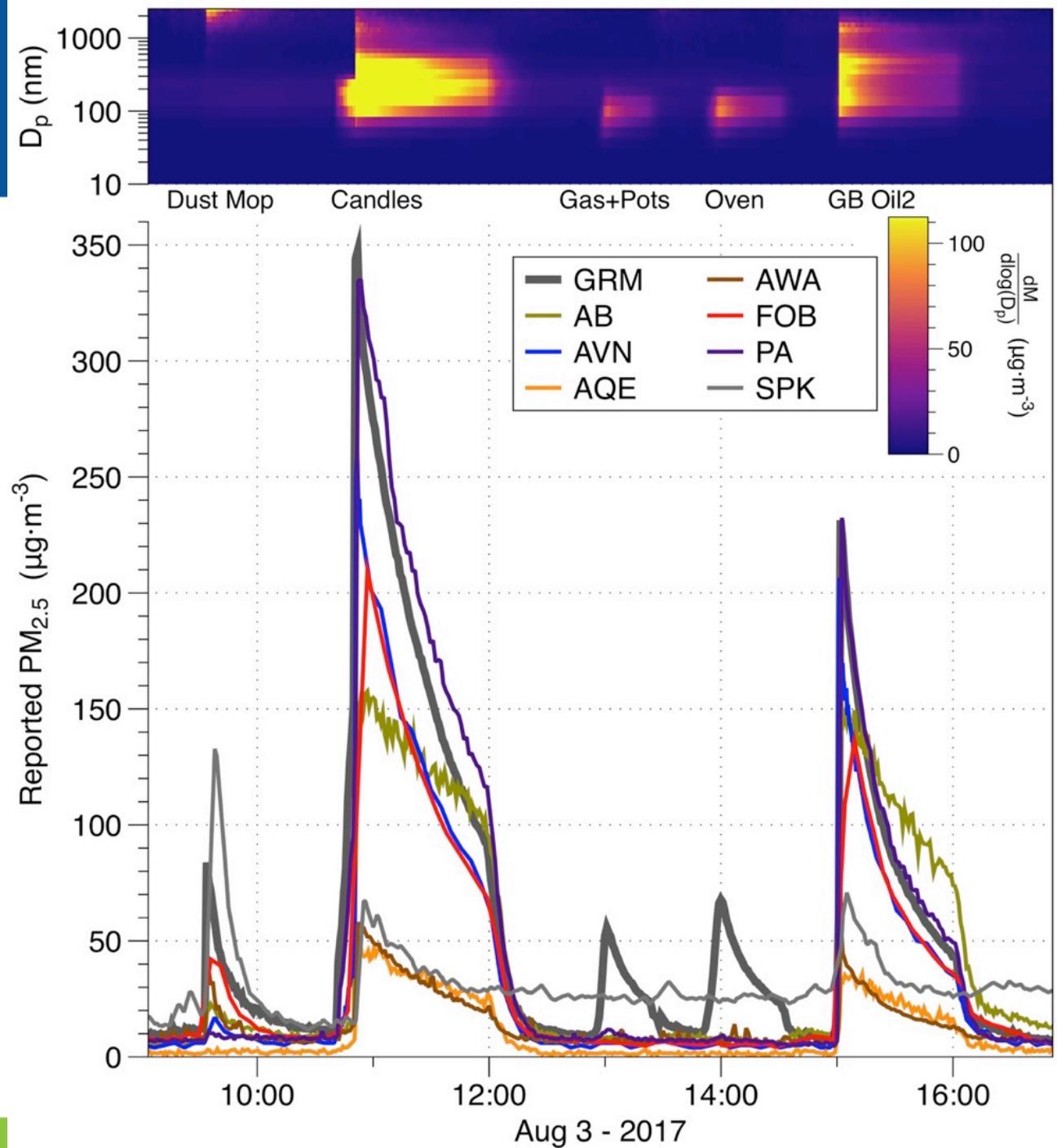


Cooked green beans, bacon, pancakes, toast, and a pizza, and heated canola oil

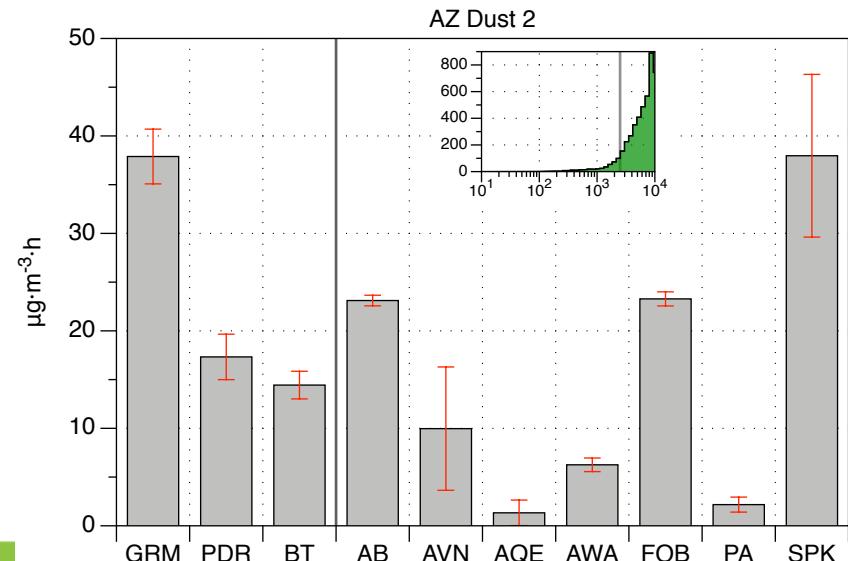
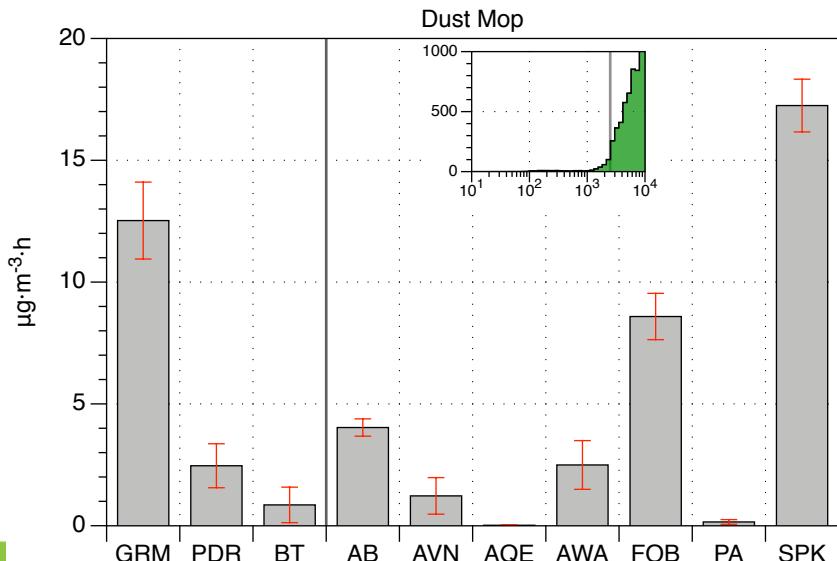
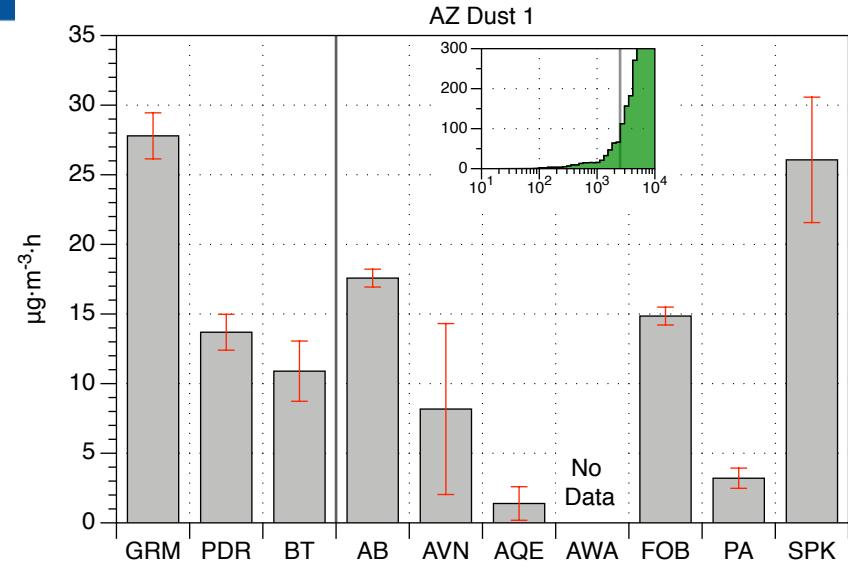
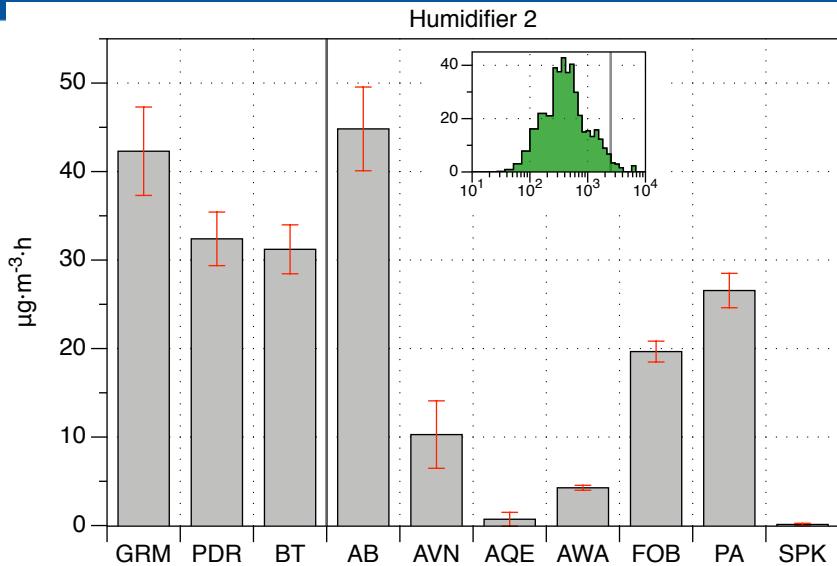


Released AZ test dust, shaked a dust mop, and operated an ultrasonic humidifier using unfiltered tap water

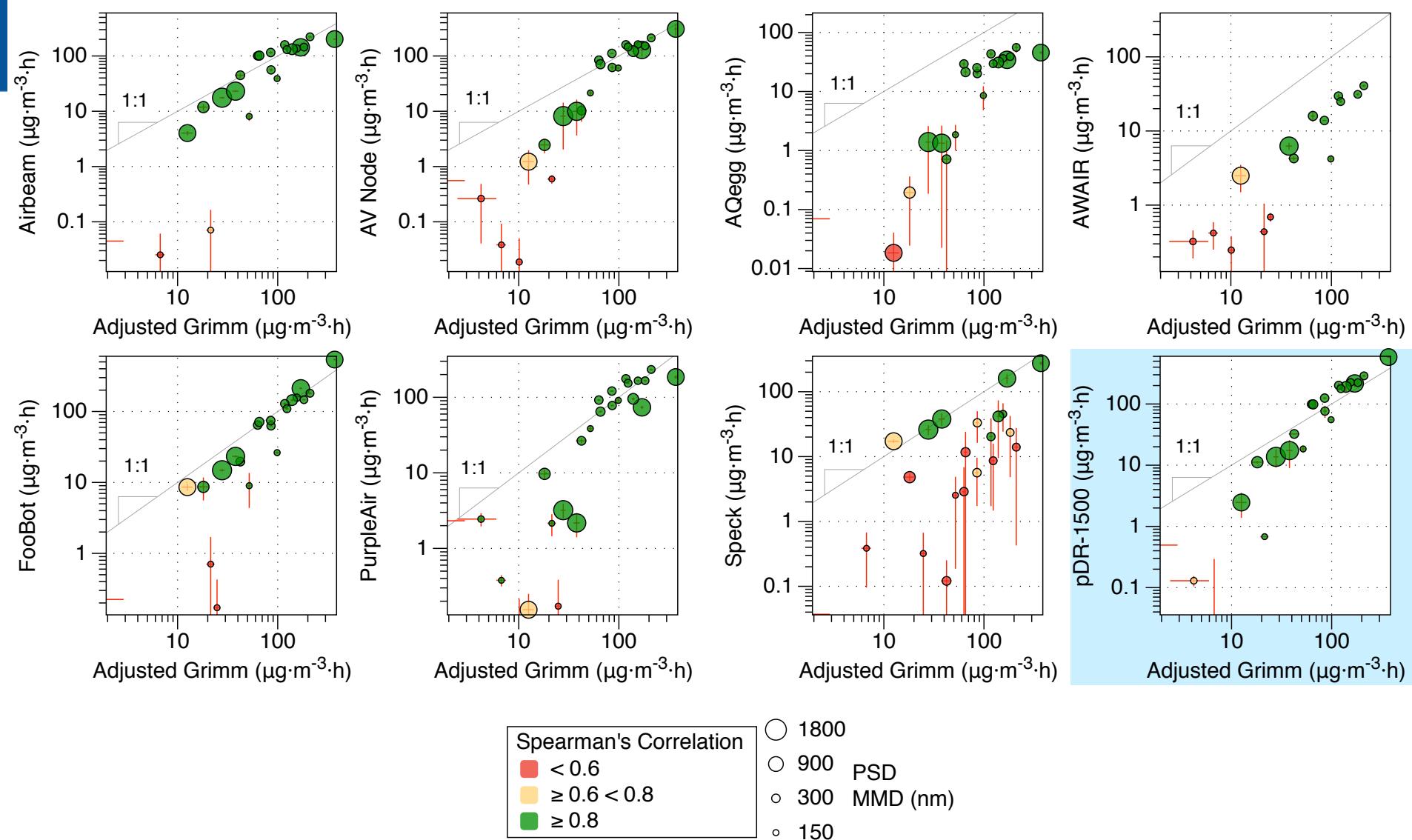
# Example Data



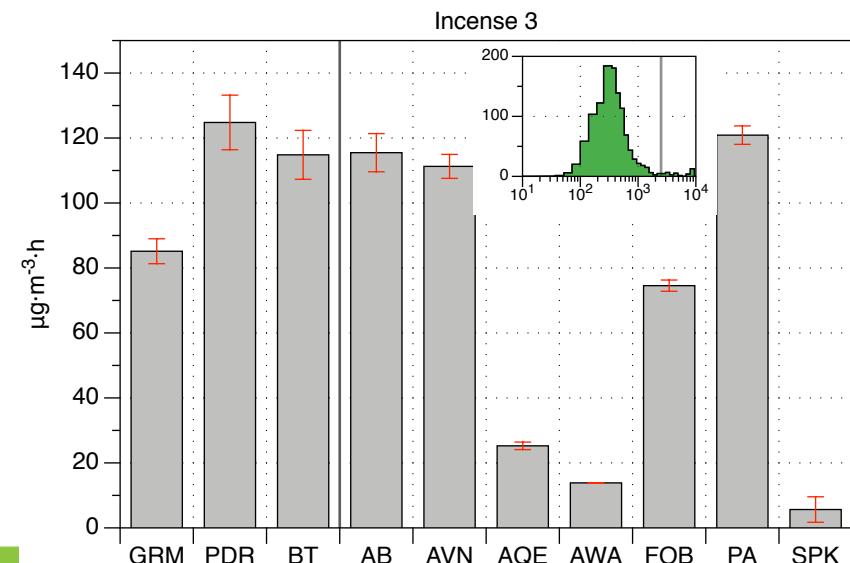
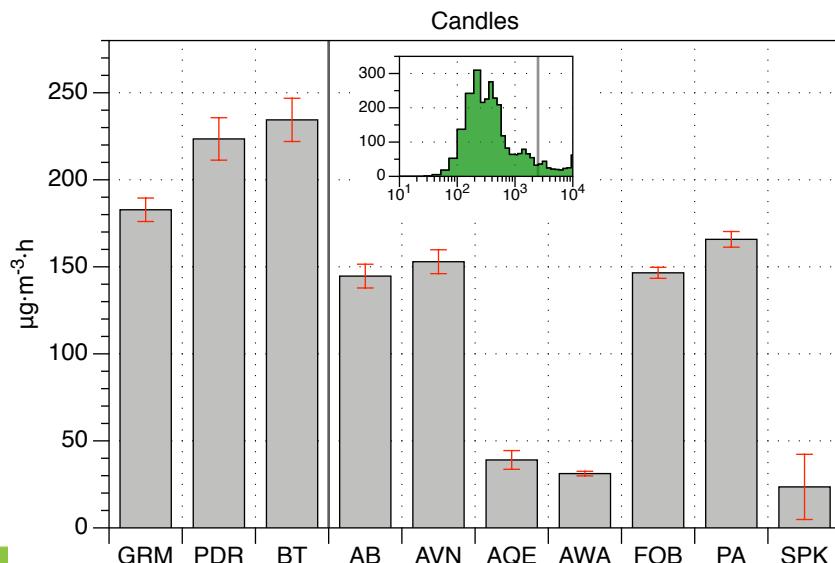
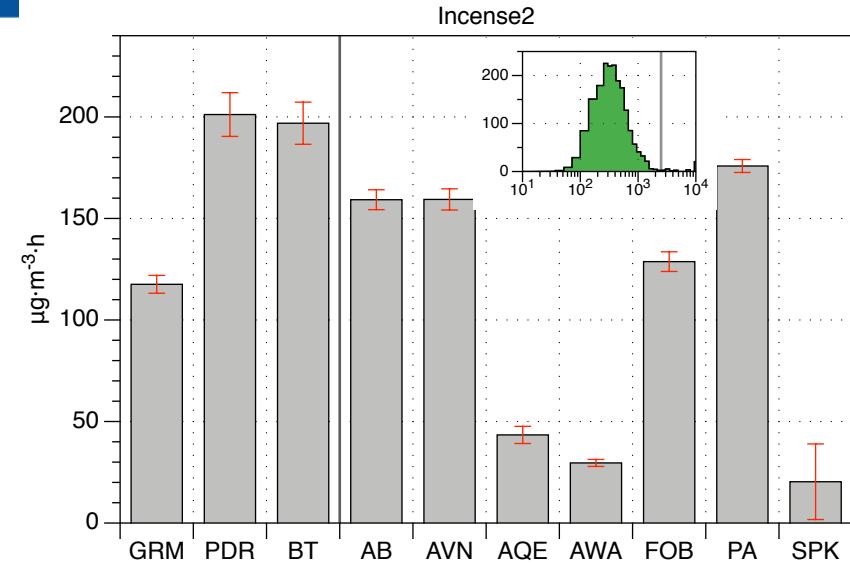
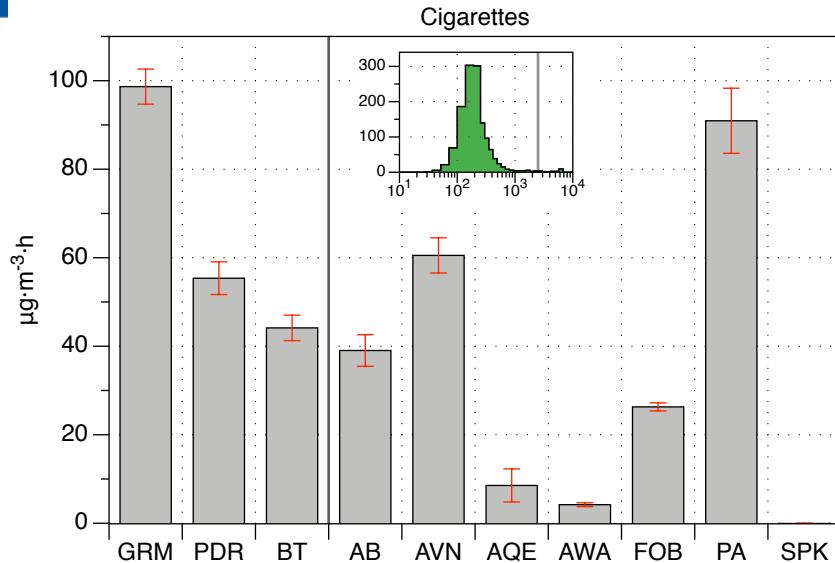
# Unfiltered Humidifier and Dust



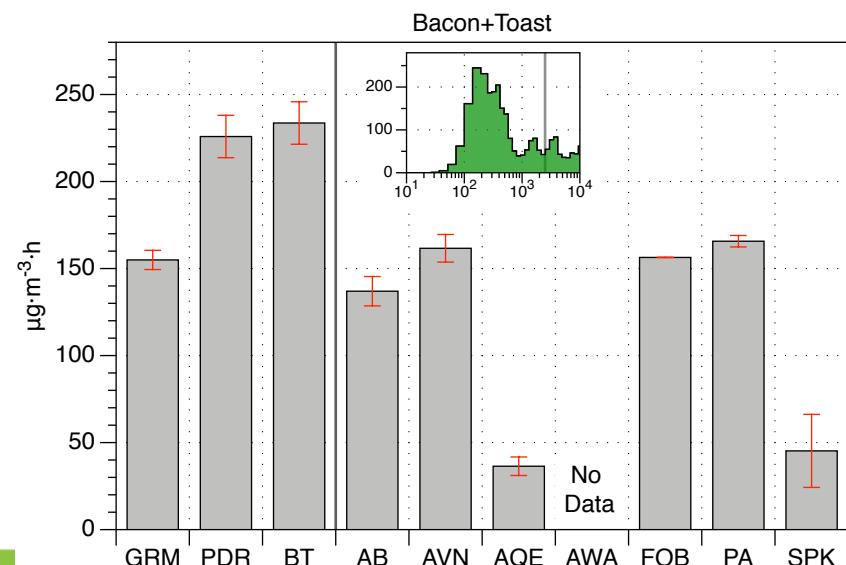
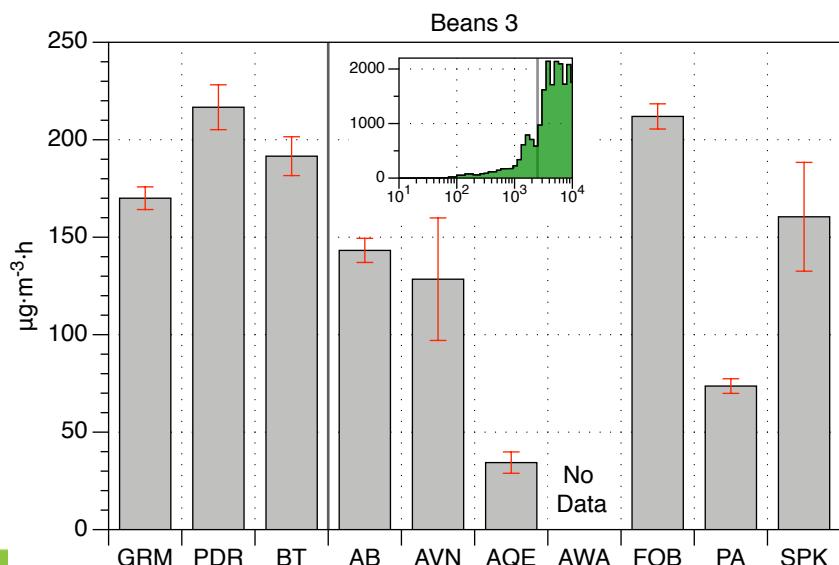
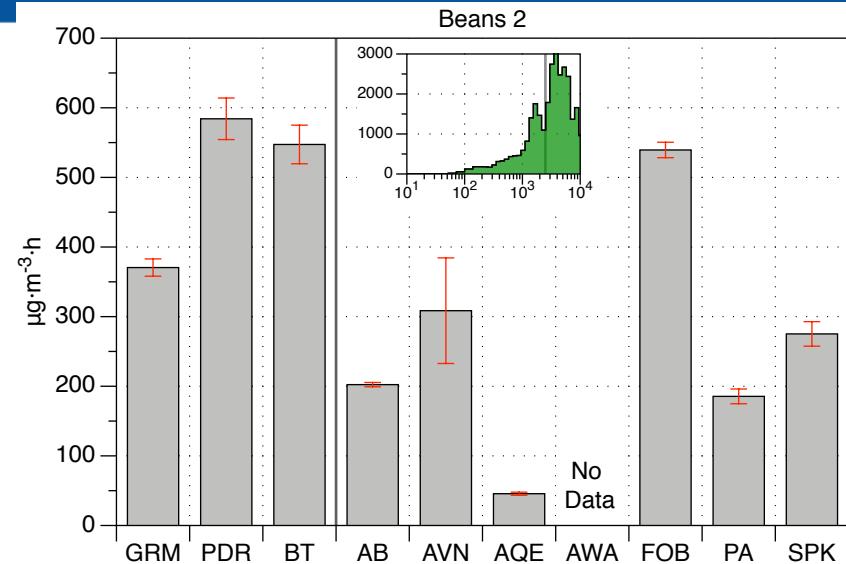
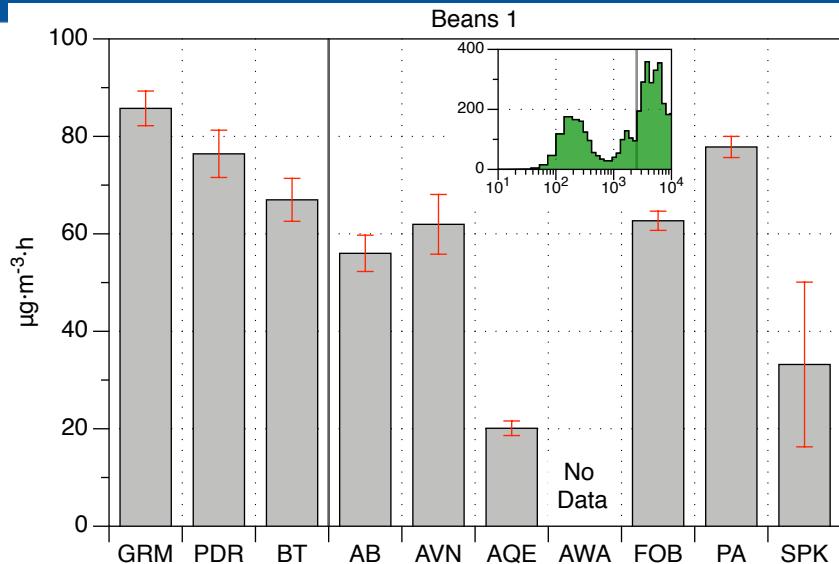
# Results



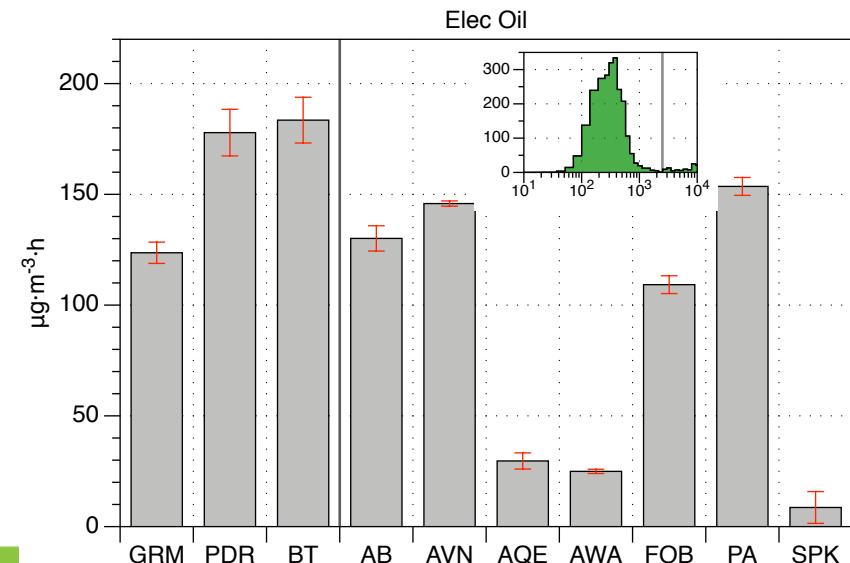
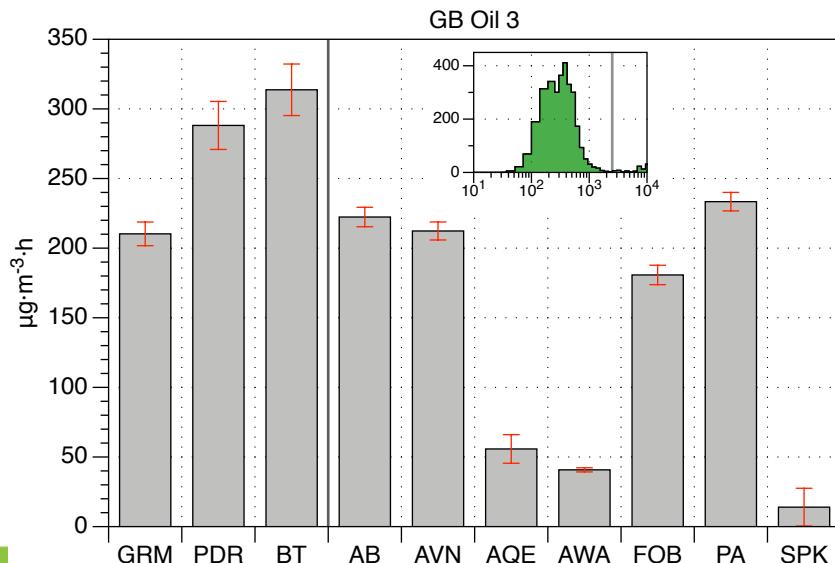
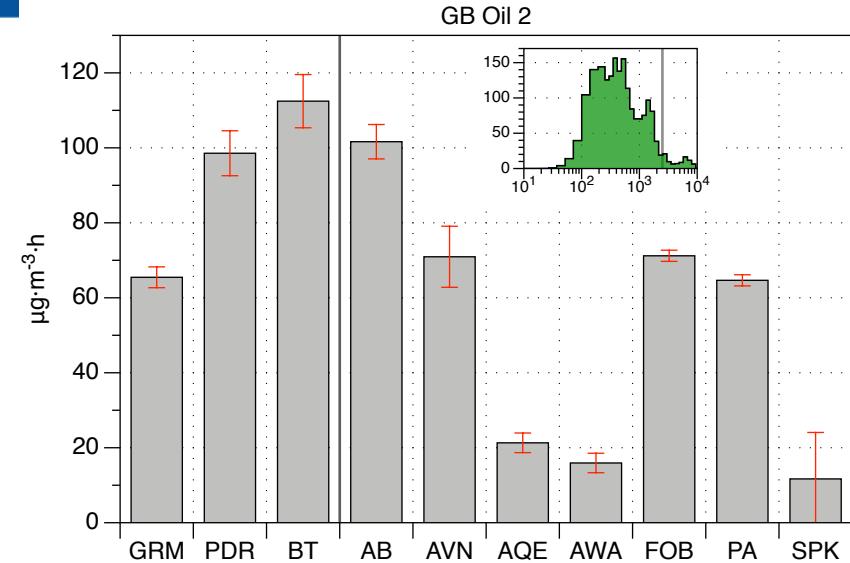
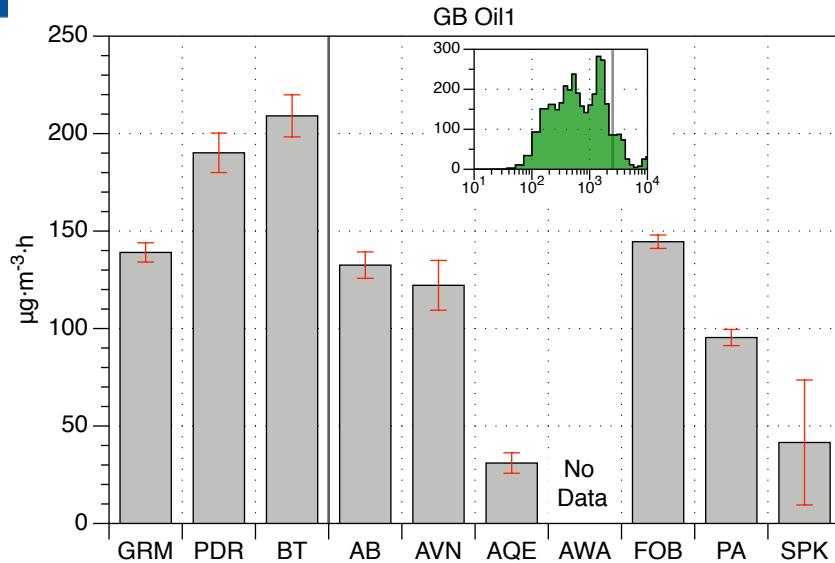
# Recreational Combustion



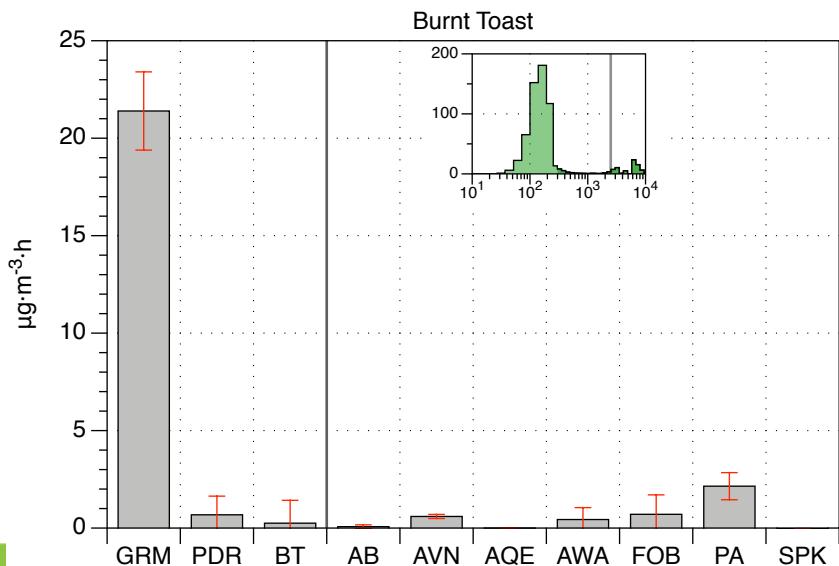
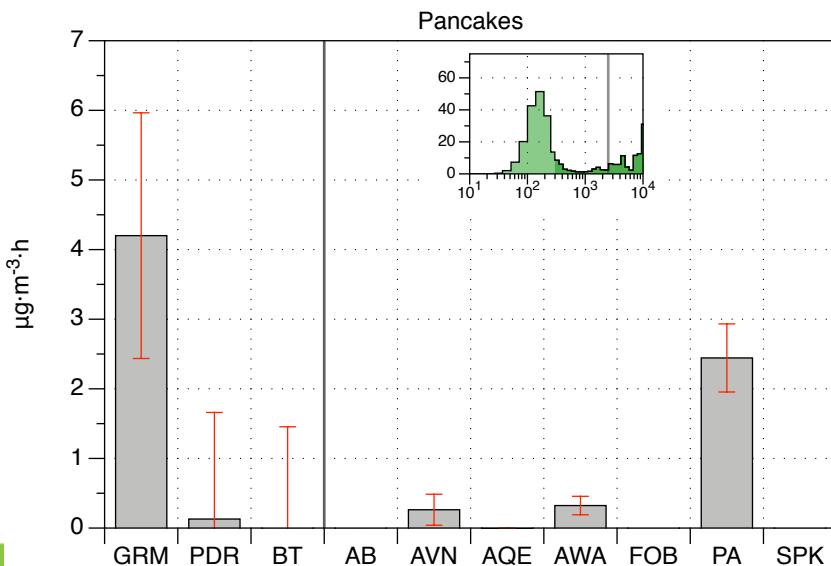
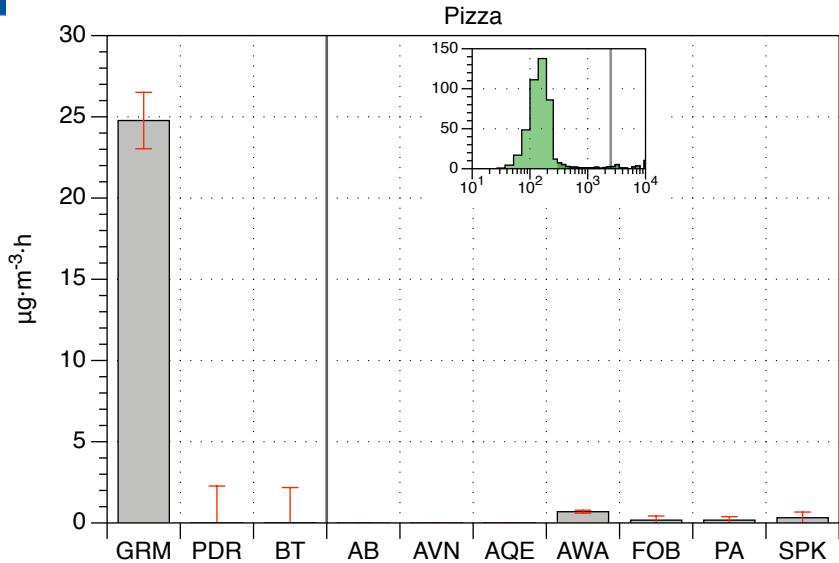
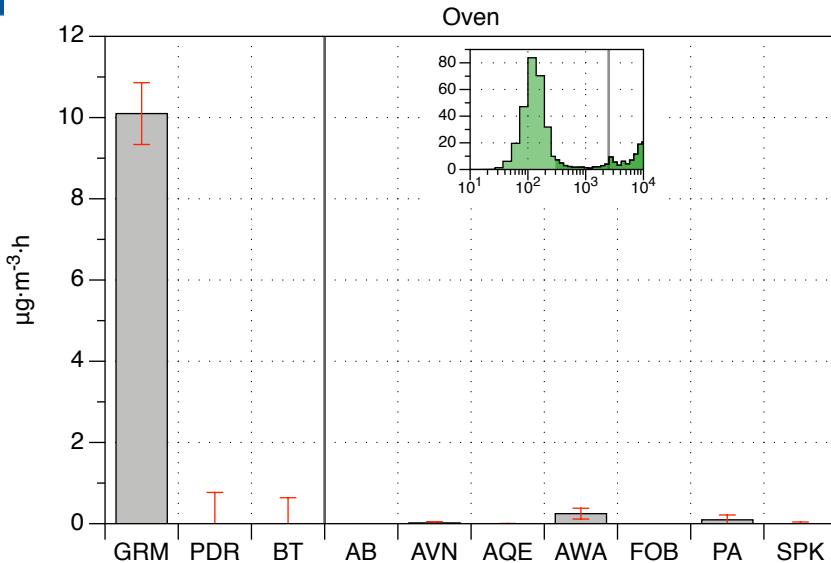
# Stir-Frying and Frying + Toasting



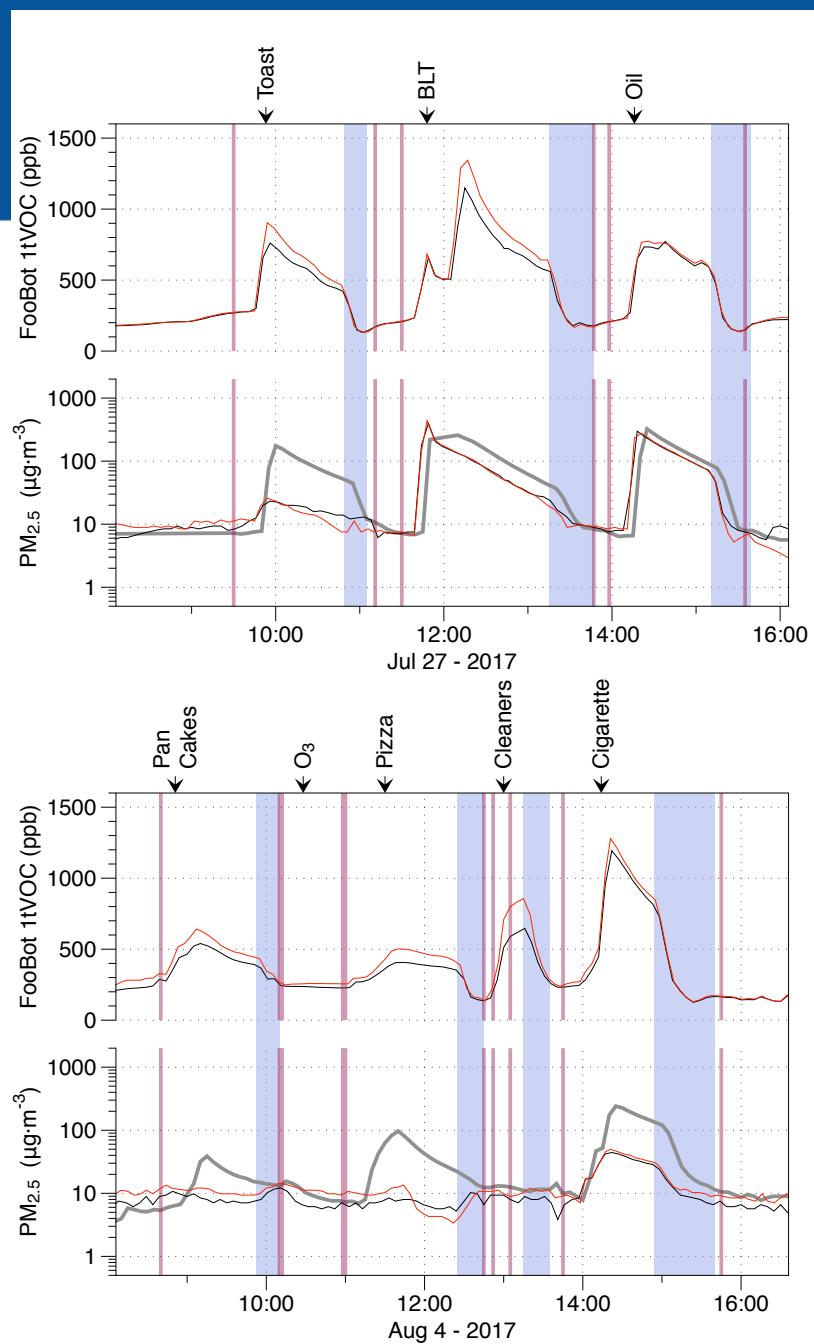
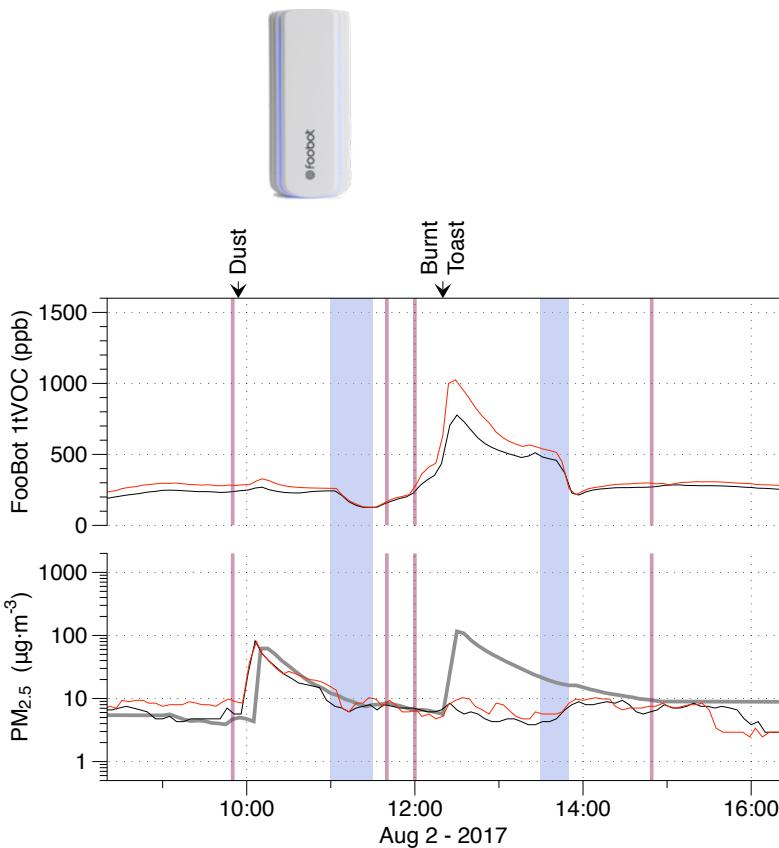
# Heating Oil on Gas or Electric Burners



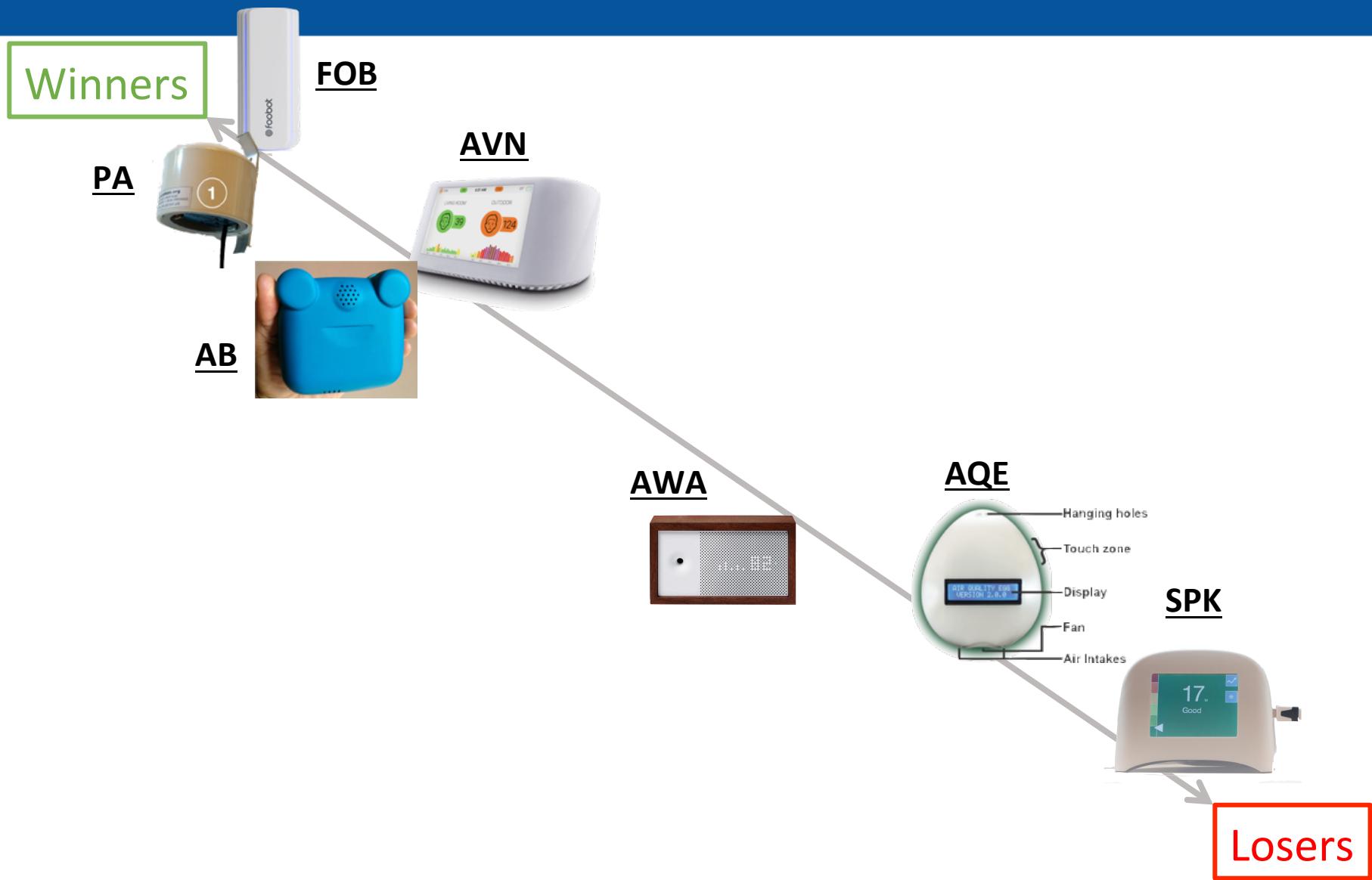
# Cooking that Emits Mostly <0.3 um Particles



# VOC sensor detected cooking events with only small particles



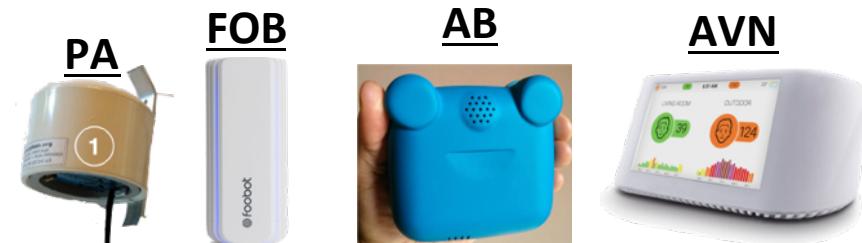
# Results



# Conclusions

Four consumer monitors detected most sources and quantitatively measured all large sources of PM<sub>2.5</sub>.

→ Appear suitable to manage IAQ.



Two consumer monitors detected many sources but not quantitatively.

AWA



One monitor was not informative.

SPK



Results should be verified in homes.

- What fraction of PM<sub>2.5</sub> detected?
- How durable are the devices?

Consumer monitors not suitable to detect & control ultrafine particles.

# Questions?

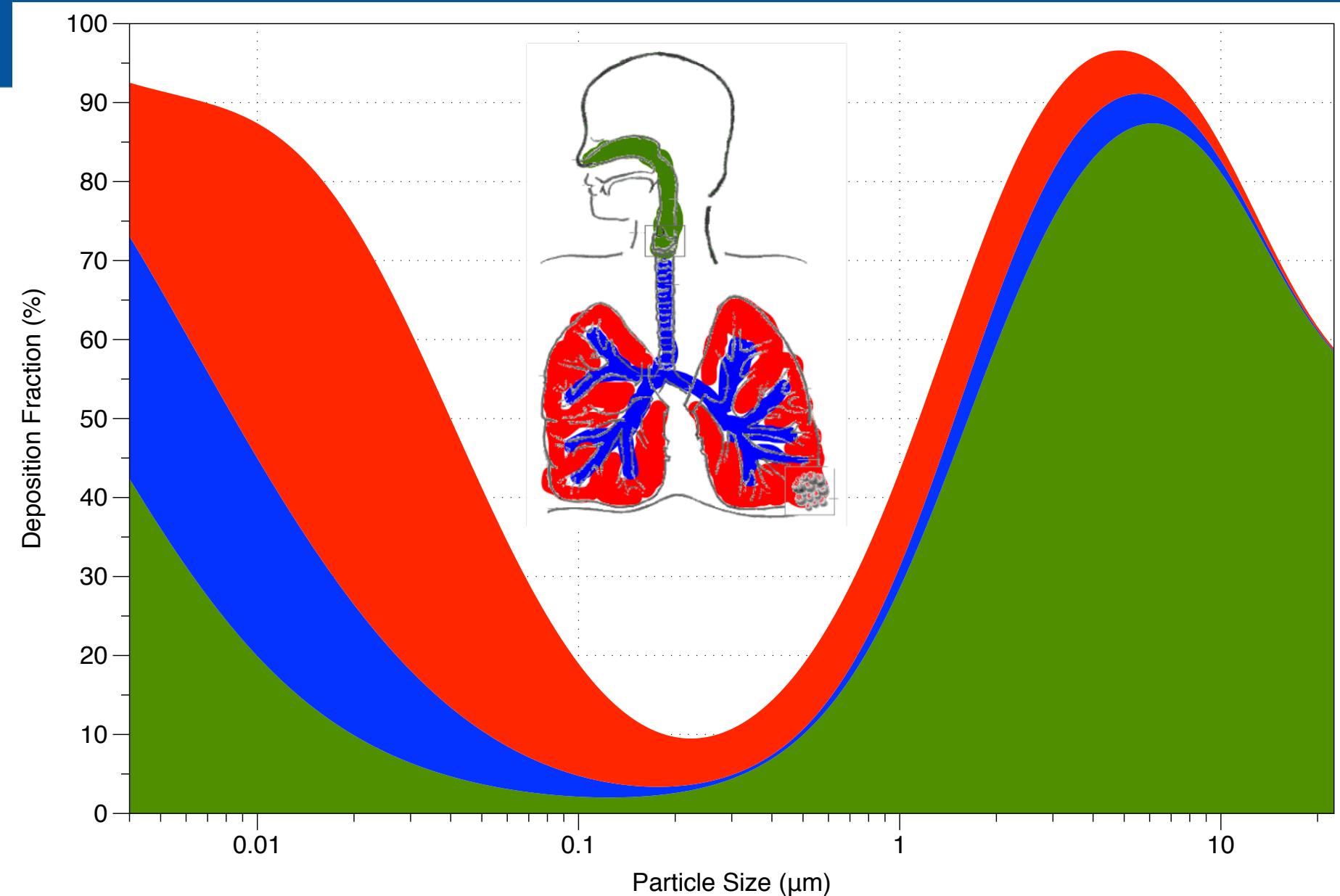
Woody Delp

[wwdelp@lbl.gov](mailto:wwdelp@lbl.gov)

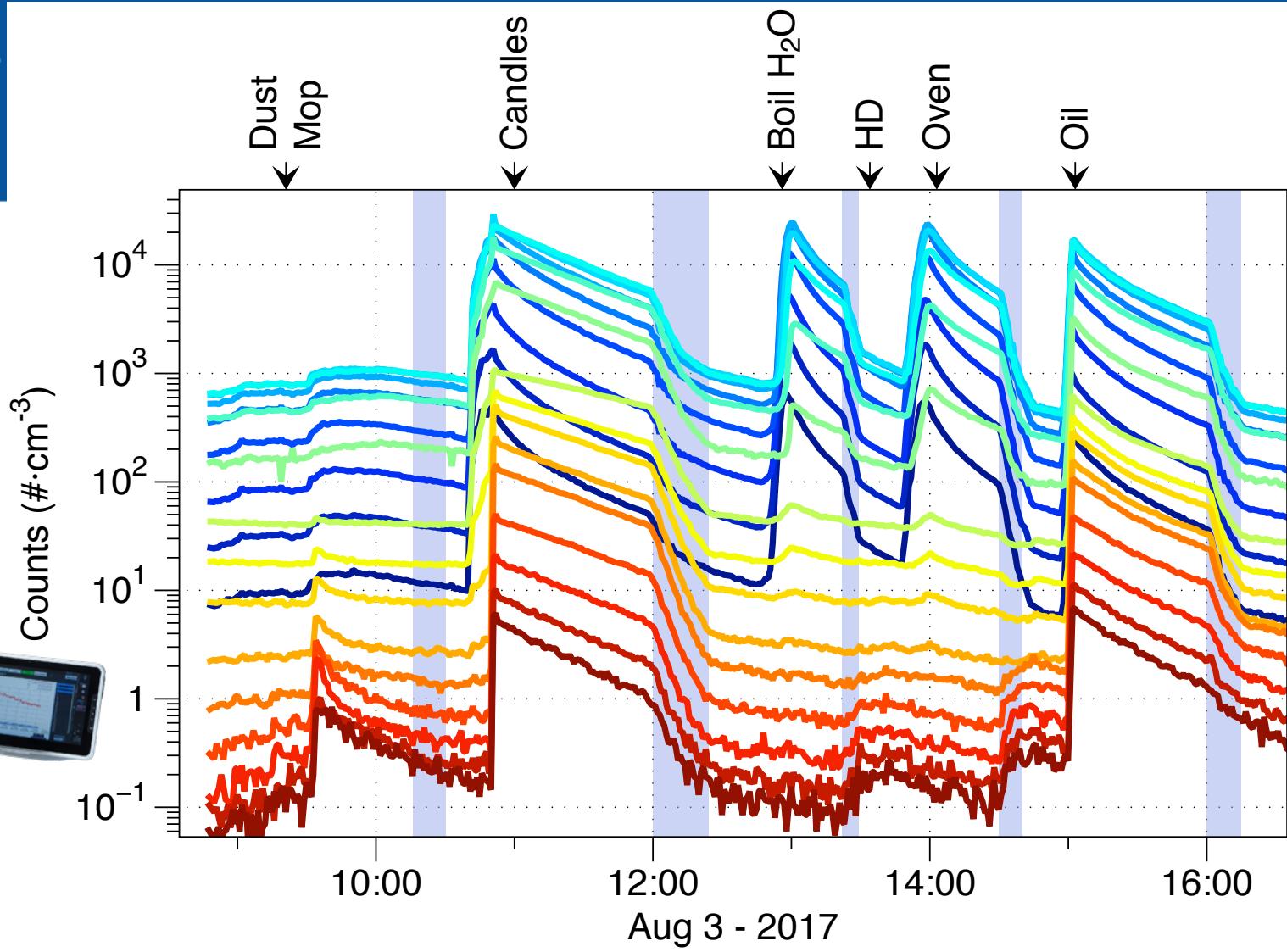
Brett C. Singer

[bcsinger@lbl.gov](mailto:bcsinger@lbl.gov)

# Size Matters for Particles



# Example Data



Channel  
nm

10	37	139	352	679
14	52	193	414	800
19	72	253	488	943
27	100	298	576	