Results and Lessons Learned from Using Low-Cost PM Sensors to Detect Ambient $PM_{2.5}$ and PM_{10}

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for

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Sonoma Technology, Inc.

Outline

- 4 studies
  - PM_{10} coal dust
  - $PM_{2.5}$ winter PM conditions
  - PM_{10} windblown dust
  - $PM_{2.5}$ wildfire smoke
- Lessons learned

1. Study – Coal Dust (PM_{10})

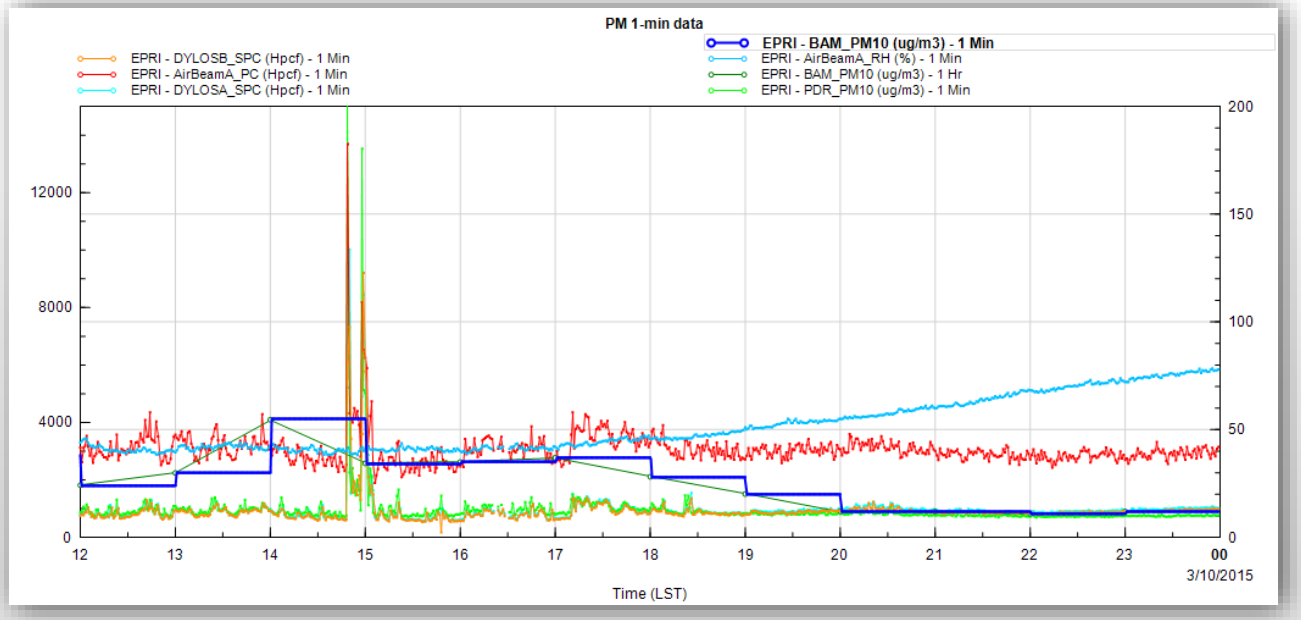
- Objective
  - Determine whether sensors can detect and quantify fugitive PM_{10} from coal piles
  - Identify sensor limitations and technical challenges
- Study
  - 2-month study in warm climate
  - Weather station

Equipment	
Reference Instrument	MetOne BAM-1020 PM_{10} Thermo PDR-1500
Sensors	Dylos AirBeam

Sponsor: Electric Power Research Institute (EPRI)

1. Results – Coal Dust (PM_{10})

- 17 events were identified
  - Short in duration (a few minutes)
  - Concentrations were 2–5 times higher than background
- 37 of 1,392 hours (2.7%) were impacted by windblown dust events



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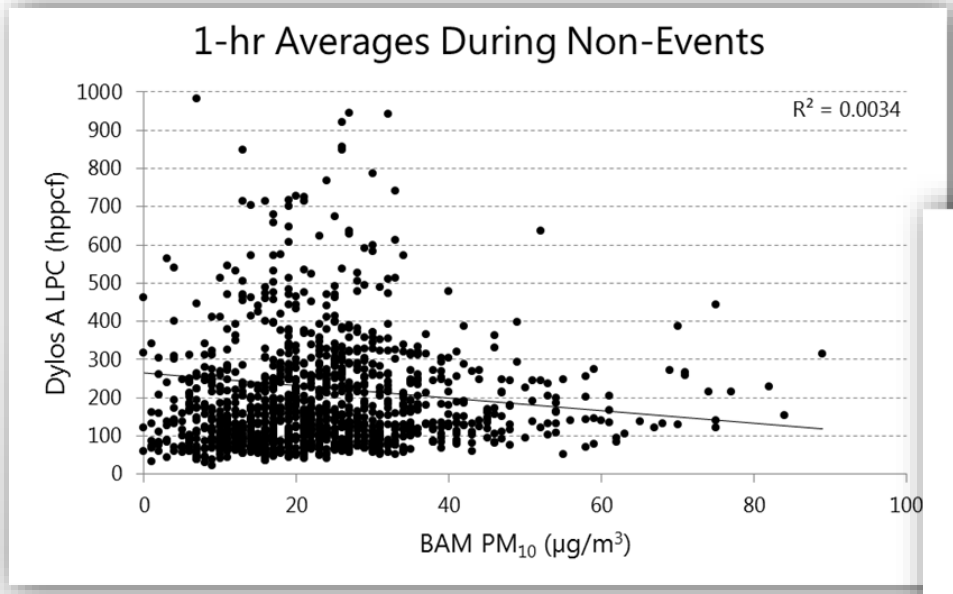
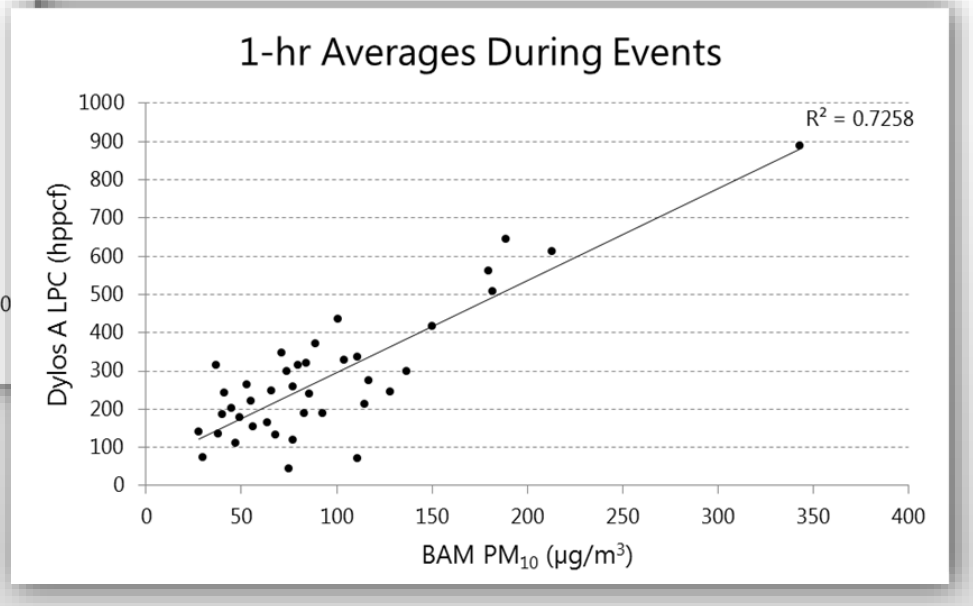
1. Results – Coal Dust (PM_{10})

Dylos had good correlation with the BAM for events; weak correlation for all data





2. Study – Winter ($PM_{2.5}$)

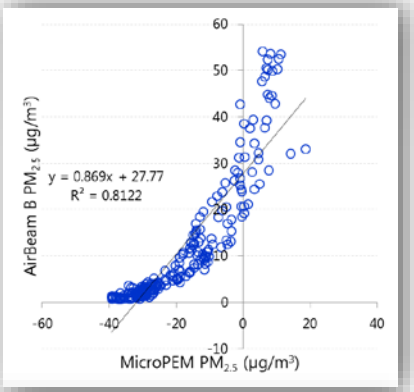
- Objective
  - Examine the use of low-cost PM sensors for answering questions about Tribal air quality
  - Conduct intercomparison study and mobile sampling
- Study
  - 8-month study in northern Minnesota (Oct-June)
  - Outdoor exposure

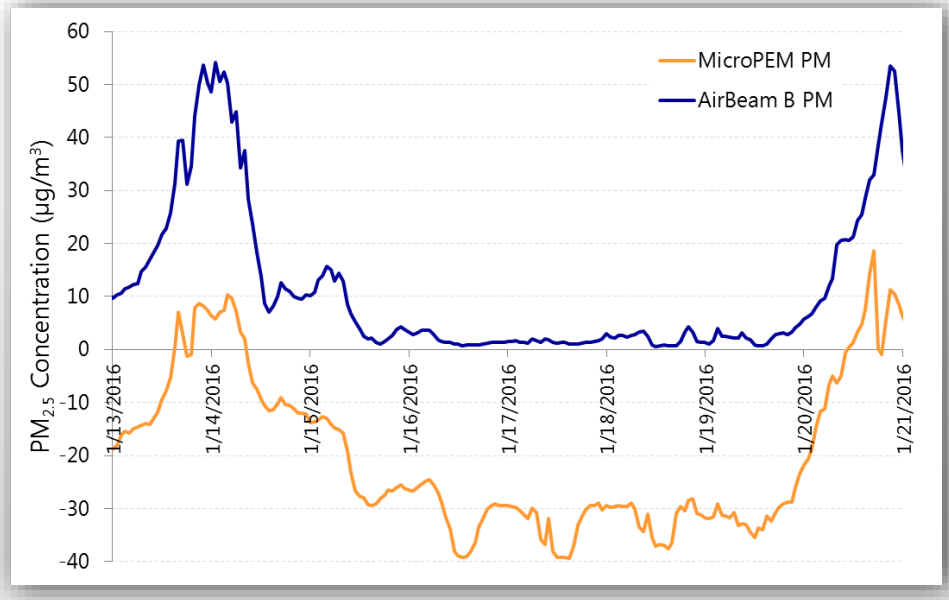
Equipment	
Reference Instrument	FRM – $PM_{2.5}$ (1-in-6 day)
Sensors	AirBeam MicroPEM

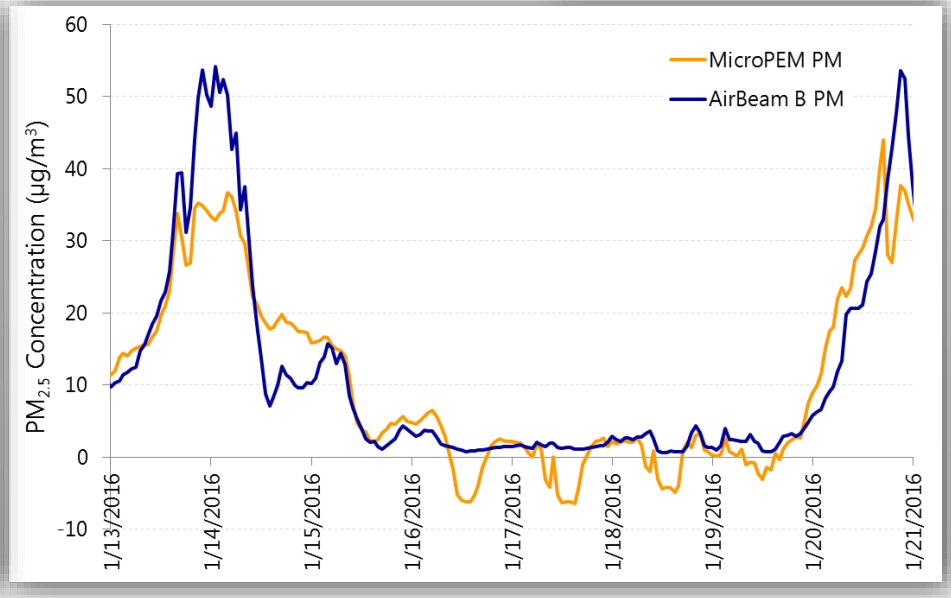
Sponsor: U.S. EPA and Leech Lake Band of Ojibwe

2. Results – Winter ($PM_{2.5}$)

- The MicroPEM and AirBeam B are well correlated during most time periods between calibration/zeroing
- The MicroPEM was difficult to zero properly and exhibited significant baseline shifts between calibration/zeroing







Sponsor: U.S. EPA and Leech Lake Band of Ojibwe

2. Results – Winter ($PM_{2.5}$)

Good correlations (R^2) between 24-hr sensor measurements on FRM sample days for AirBeam and bias-corrected MicroPEM

	FRM 1	FRM 2	MicroPEM	AirBeam A	AirBeam B
FRM 1	1.00	-	-	-	-
FRM 2	0.93	1.00	-	-	-
MicroPEM	0.01[uc] 0.96[bc]	0.01[uc] 0.89[bc]	1.00	-	-
AirBeam A	NA	NA	NA	NA	-
AirBeam B	0.83	0.85	0.01[uc] 0.95[bc]	NA	1.00

[uc] Uncorrected MicroPEM $PM_{2.5}$ data
[bc] Bias-corrected MicroPEM $PM_{2.5}$ is well correlated with the FRMs

Sponsor: U.S. EPA and Leech Lake Band of Ojibwe

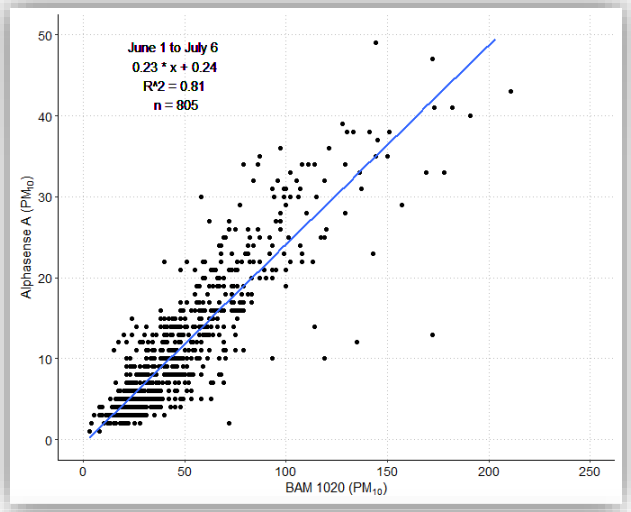
3. Study – Windblown Dust (PM_{10})

- Objective
  - Can low-cost PM sensors detect dust events?
  - How precise are the sensors?
  - Are they reliable?
  - Can they provide sufficient warning time?
- Study
  - 3-month springtime study
  - School in eastern Santa Barbara County

Equipment	
Reference Instrument	MetOne BAM 1020 (FEM for PM_{10}) GRIMM 11-R (Particle counts) MetOne E-BAM (PM_{10})
Sensors	AirBeam (3 units) Alphasense OPC-N2 (3 units)

Sponsor: Santa Barbara County Air Pollution Control District

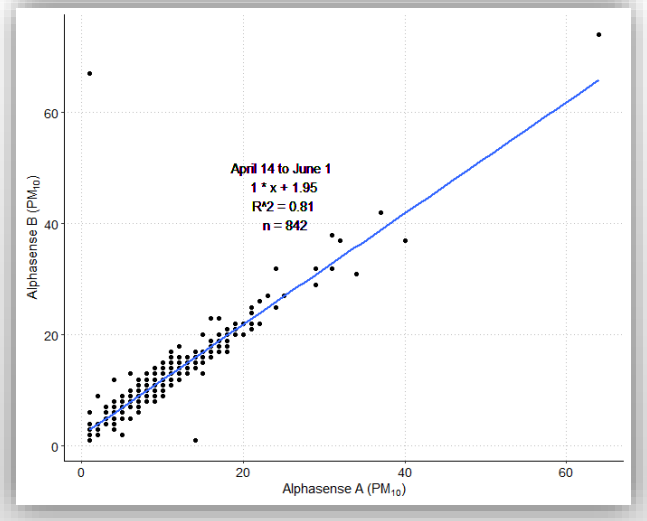
3. Results – Windblown Dust (PM_{10})



Alphasense A vs. BAM

Hourly PM_{10} measurements

R^2 = 0.81



Alphasense A vs. Alphasense B

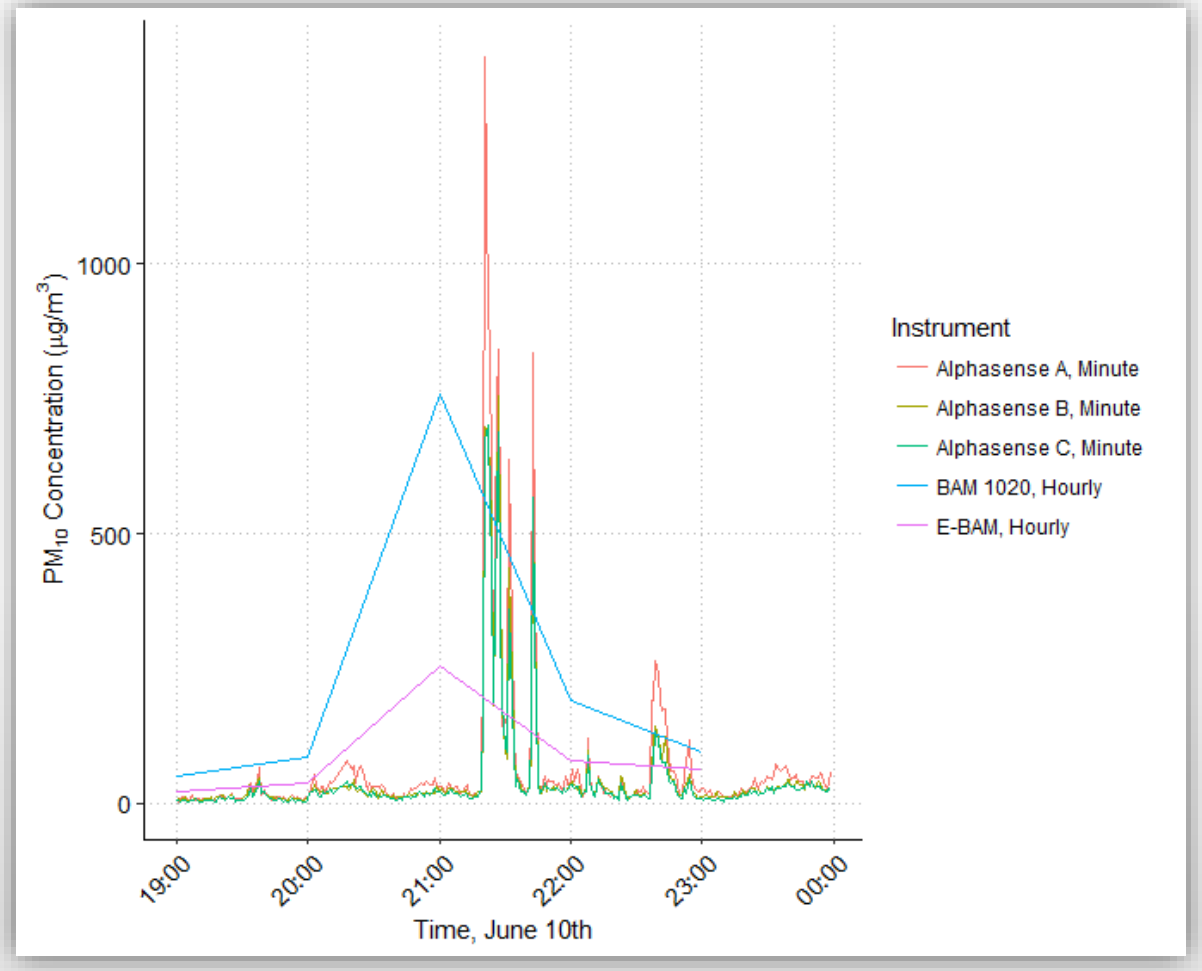
Hourly PM_{10} measurements

R^2 = 0.81

BAM = 1*x + 1.95

Sponsor: Santa Barbara County Air Pollution Control District

3. Results – Windblown Dust (PM_{10})



Early Detection

Alphasense A measures a peak at 21:21, for a lead time of 39 minutes over the FEM instrument.

Note: BAM reported at begin hour but not available until after the hour

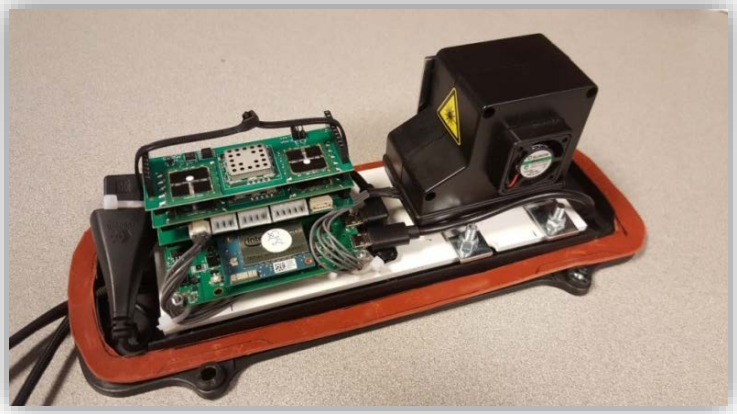
4. Study – Wildfire Smoke ($PM_{2.5}$)

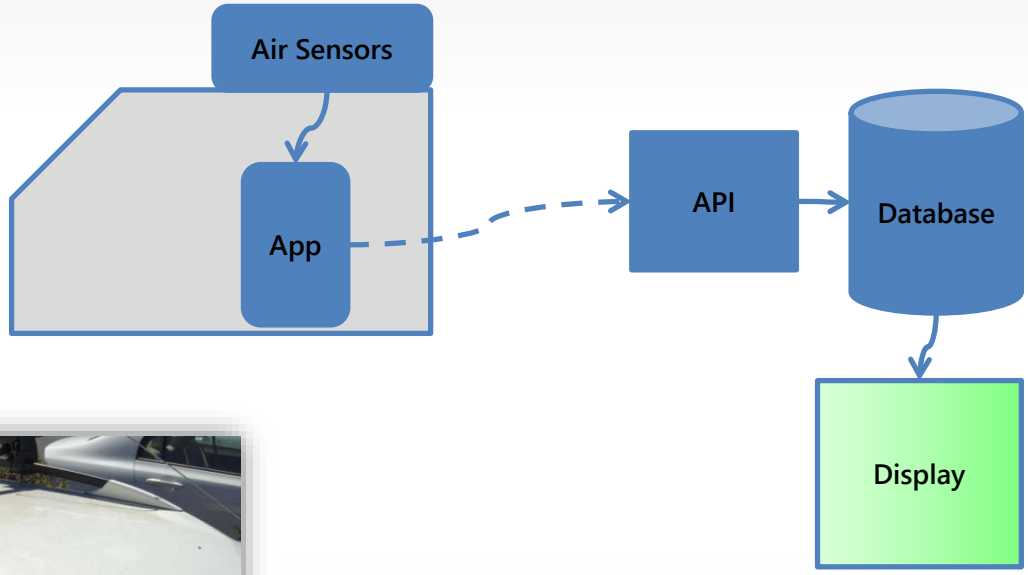
- Objective
  - Determine whether low-cost PM sensors can detect wildfire smoke
  - Explore mobile/stationary monitoring
  - Demonstrate real-time communications
- Study
  - PM sensors, quick-mount, real-time communications, website for viewing
  - Preliminary testing in summer 2016
  - Planned for fall 2016

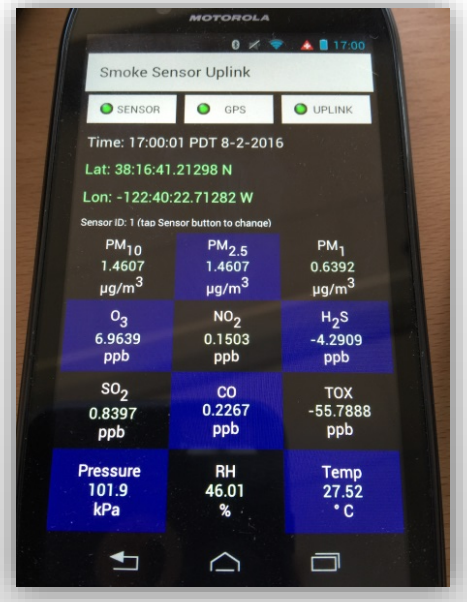
Equipment	
Reference Instrument	None
Sensors	Alphasense OPC-N2 Spec sensors with Intel Briza system

Sponsor: U.S. Forest Service

4. Study – Wildfire Smoke ($PM_{2.5}$)







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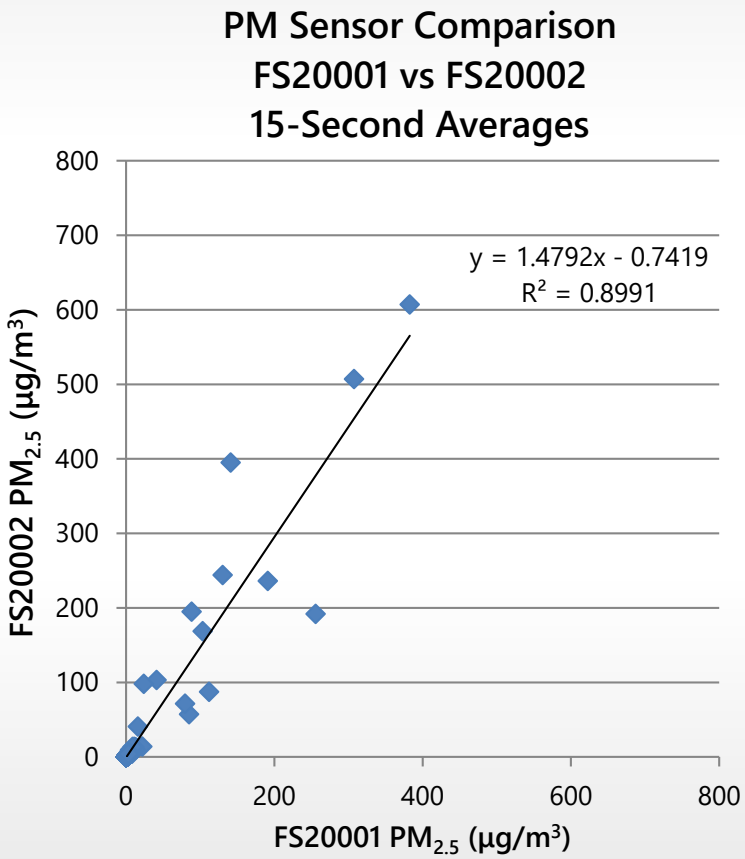
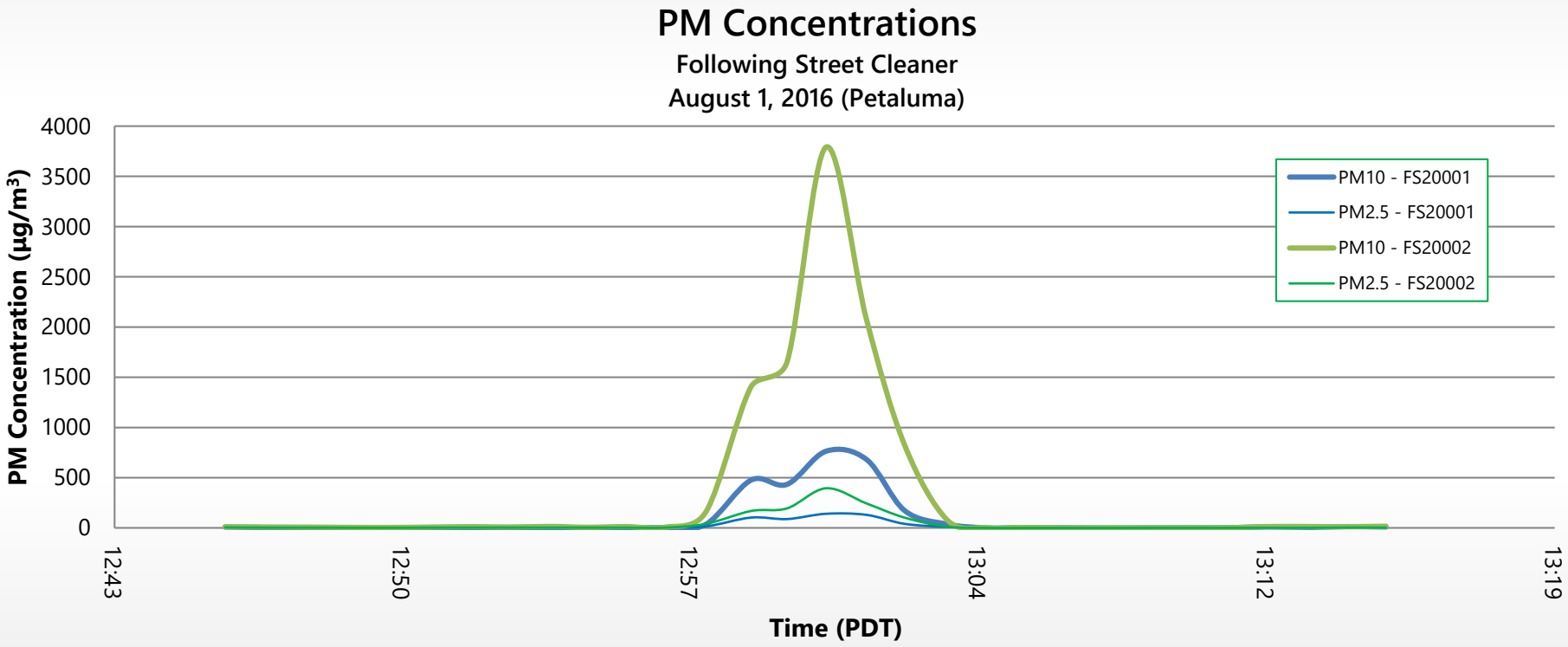


Smoke from a BBQ restaurant

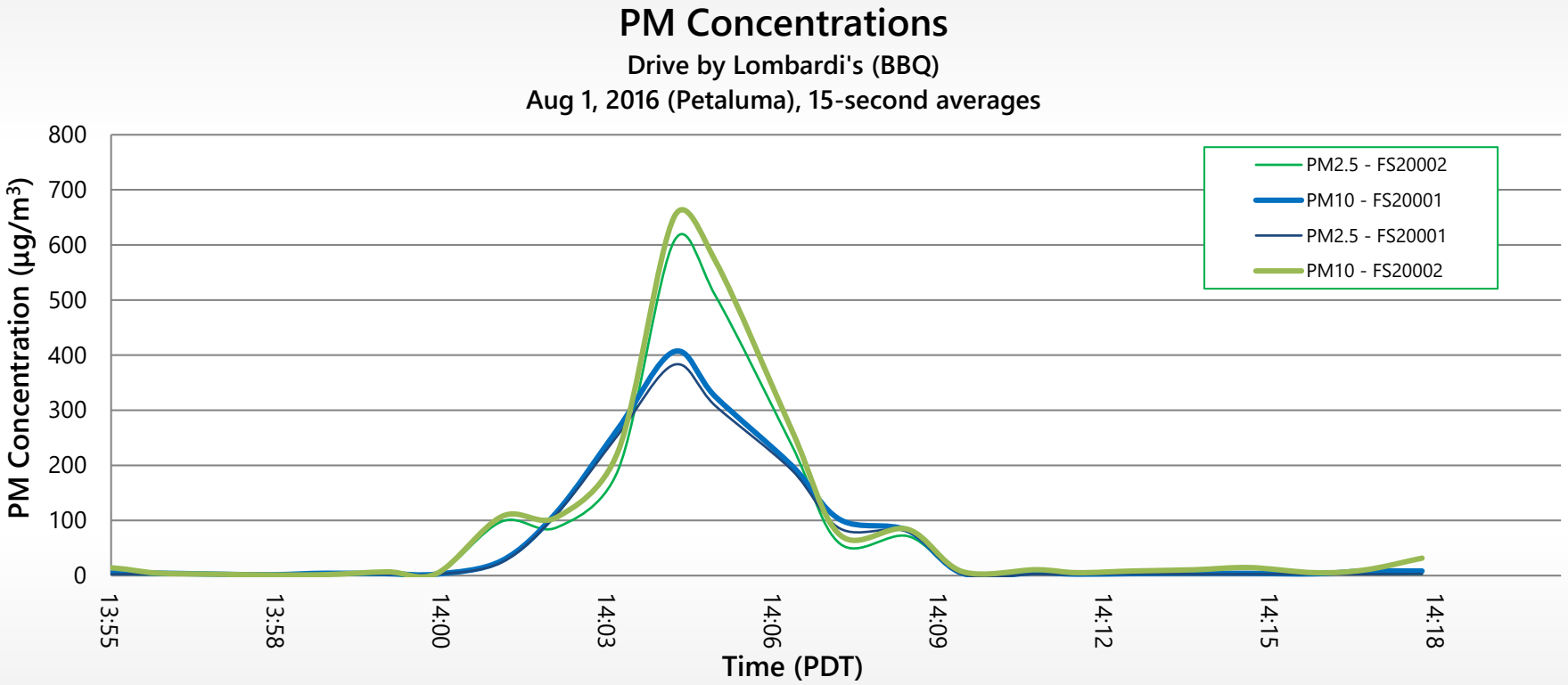
Sponsor: U.S. Forest Service

4. Results – Wildfire Smoke ($PM_{2.5}$)



Notes: PM from street cleaner
Low $PM_{2.5}/PM_{10}$ ratios (about 12-20%)
FS20001 reading lower

4. Results – Wildfire Smoke ($PM_{2.5}$)



Notes: PM from BBQ smoke
High $PM_{2.5}/PM_{10}$ ratios (about 80 to 95%)
FS20001 reading lower

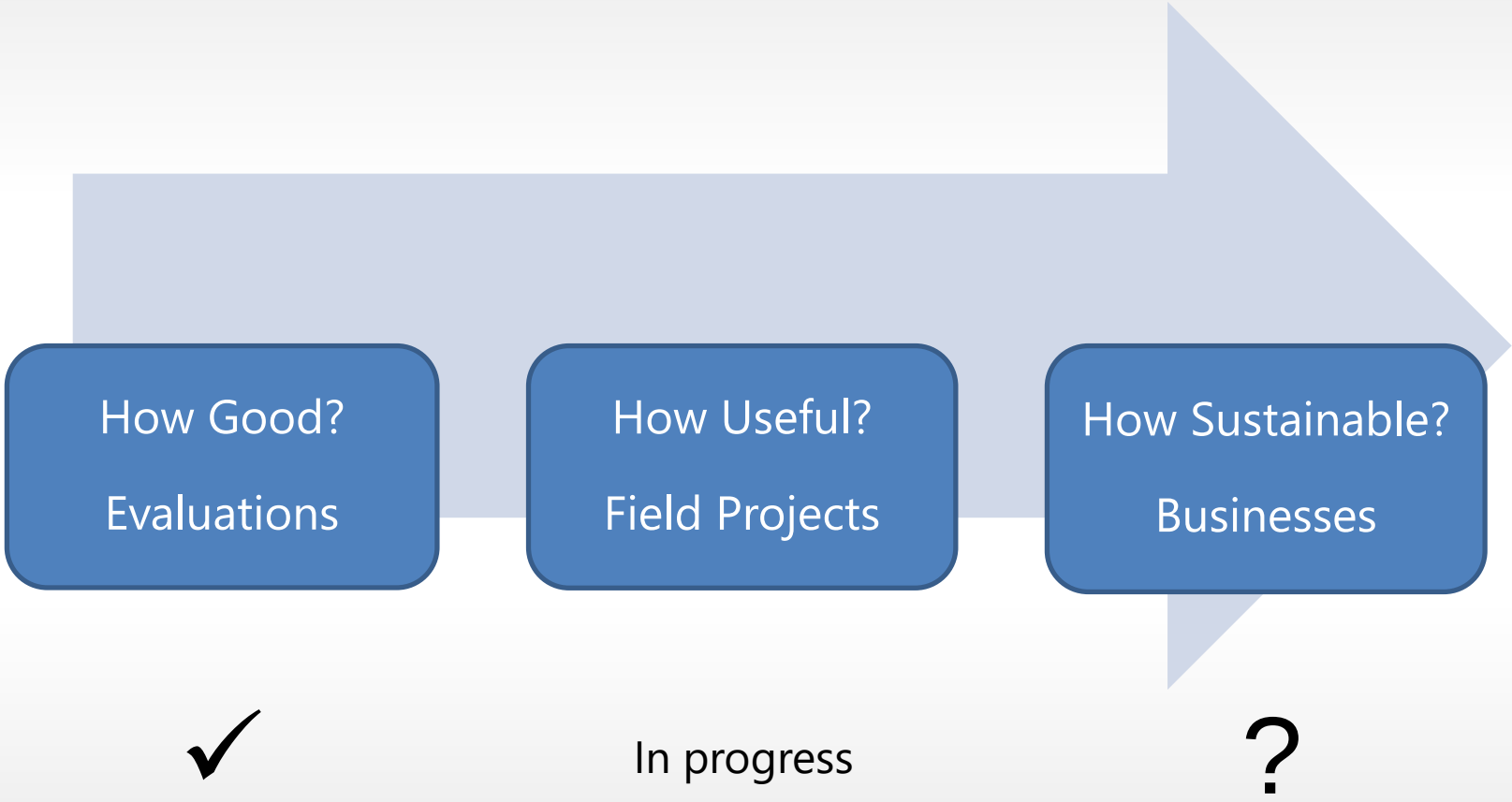
Lessons Learned

- Sensors
  - Rapid changes; versioning issues with firmware
  - Drift, calibration requirements, and “soiling” issues
  - Hardware issues
- Data logging
  - Data acquisition systems don’t always handle sensors
  - Time standards
- Communications
  - Critical for high data availability
  - More challenging/costly

Lessons Learned

- Data management
  - More challenging than FEM instrument (60 to 3600 times more data and more uncertainty)
- Cost
  - Projects cost much more than one sensor
  - Operations and data management are more intense

Path Forward



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