



PurpleAir Sensors: Perspectives and Challenges

Highlighting the work of EPA ORD

NACAA Spring Membership Meeting

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EPA Research

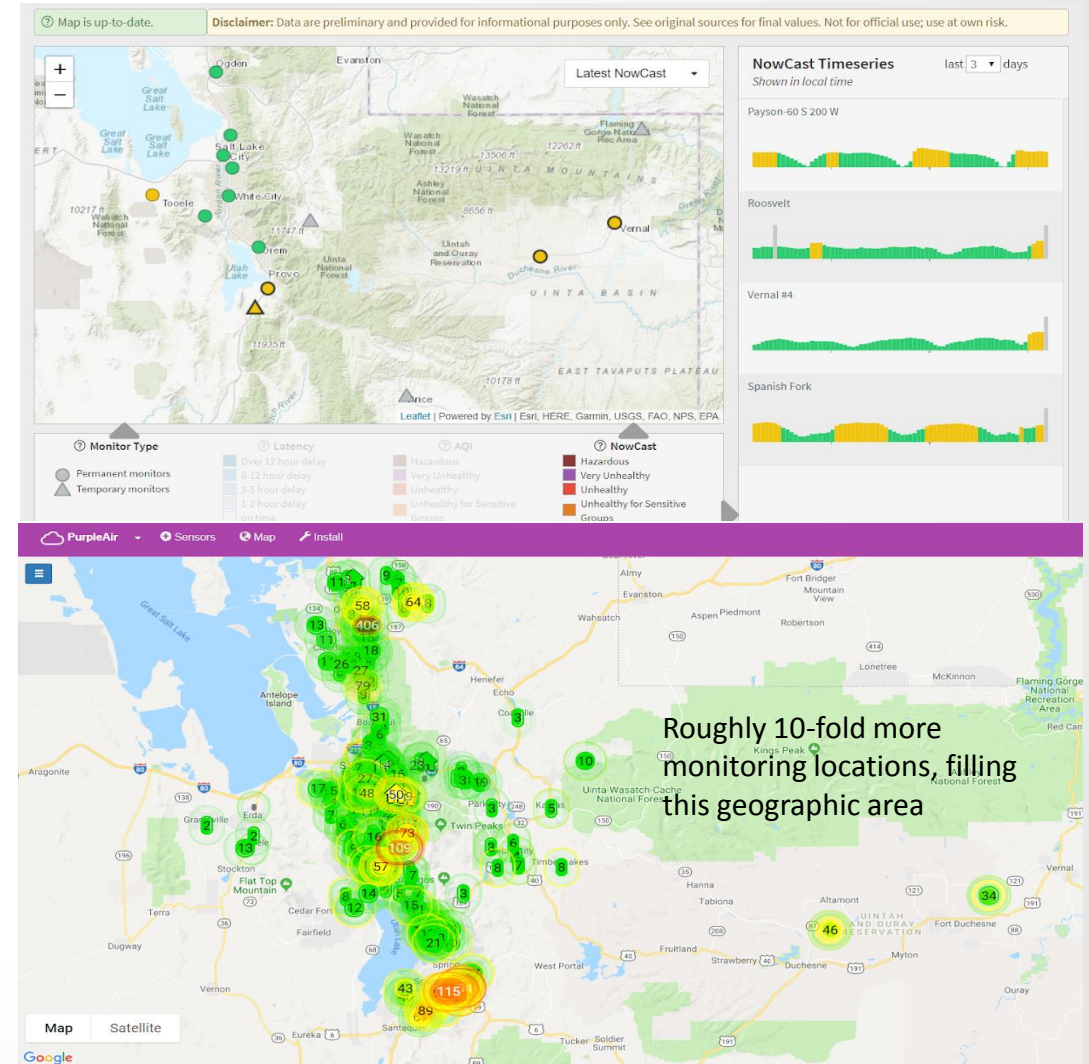
SPEAR (Sensor Performance, Evaluation and Application Research) Program

- Project Goals
 - Discover, evaluate, develop, apply and communicate new & emerging air quality sensor technologies to meet a wide range of stakeholder needs (citizen science to regulatory officials)
- Research Questions
 - What are the capabilities of emerging next generation air measurement (NGAM) technologies and their potential to meet current & future air quality monitoring needs?
 - How can EPA best support sensor developers and the user community?
 - What other data and technologies are needed to help understand and interpret sensor data?
 - How can EPA apply the knowledge gained to issues of concern to EPA and their clients/partners/stakeholders?



Motivation

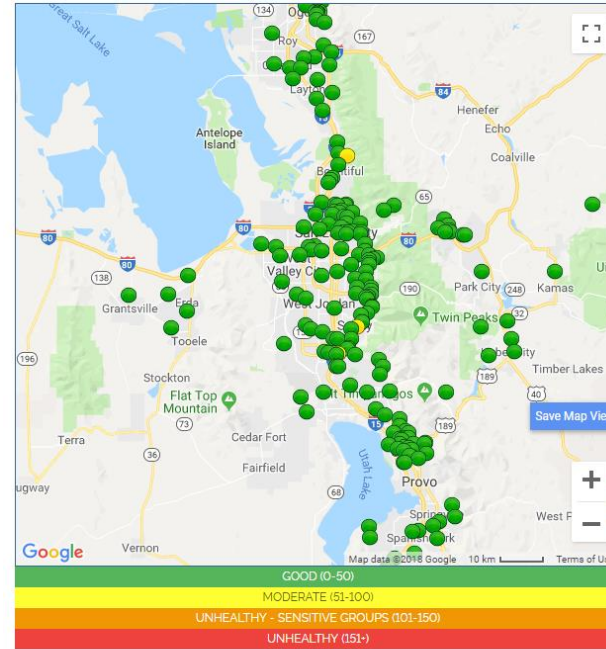
- There are more than 6000 publicly reporting PurpleAir sensors worldwide
 - Plus more streaming privately
 - Outnumber the regulatory monitors
- In some cases, this data is out-competing AirNow for Air Quality information
 - Distrust in government
 - Data is close and perceived to be more representative of local exposure





Motivation

- PurpleAir data is being reported by new organizations, weather apps, and more.
- The US EPA Air Quality Index (AQI) is being misapplied when communicating the data
 - Data are not corrected for accuracy issues before display/AQI application
 - High frequency data is assigned an AQI – this is not at the same time base as is used by the USEPA AQI
 - Gives perception that sensor data and regulatory data are of equal quality



*Note: The AQI (Air Quality Index) shown here are from a wide variety of sensors, each with their own strengths and weaknesses. KSL is not responsible for inaccurate information.

Screenshot from 10/24 - <https://www.ksl.com/?nid=1314>

PurpleAir data was the primary data set being shown by a local news channel, and the public was pointed to it for air quality information by a local library.

Footnote text:
“The AQI (Air Quality Index) shown here are from a wide variety of sensors each with their own strengths and weaknesses. KSL is not responsible for inaccurate information.”

PurpleAir is not the only sensor manufacturer displaying an AQI message for sensor data.





Research Questions

- How does the accuracy of PA sensors vary?
 - Across the US?
 - Over time?
 - Are there specific factors that contribute to the variation - particle size/size distribution, pollutant mixture, concentration level, environmental conditions, and other factors?
 - Which factors influence aging?
- What indicators or methods could be used to quality assure PA sensor data?
 - What are necessary data cleaning procedures – systematic treatment of data, removing artifacts, data adjustment?
 - What observations indicate sensor failure/malfunction?
 - What are recommendations for collocation frequency and methods?

EPA Projects

1. Evaluation in RTP
2. Phoenix as a Test bed for Air Quality sensors (P-TAQ)
3. Long-Term Performance Project (LTPP)
4. Wildfire Smoke



RTP Evaluation (Oct. 2017-Mar. 2018)

- **Field collocation is essential**
- Sensors are precise
 - Good agreement between sensors
 - Channels A and B are highly correlated
- Sensors are not accurate
 - Better agreement with FEM $PM_{2.5}$ than PM_{10}
 - Overestimates $PM_{2.5}$ by factor of about 1.6
 - Estimate of PM_{10} closer in this climate (0.86-1.06)
- Results are consistent with AQ-SPEC and others
 - Is linear correction enough? – RH, PM_c
- Comparison of sensors within the same device may indicate failure, blockage, or need for power cycling but do not indicate age or potential outlier data

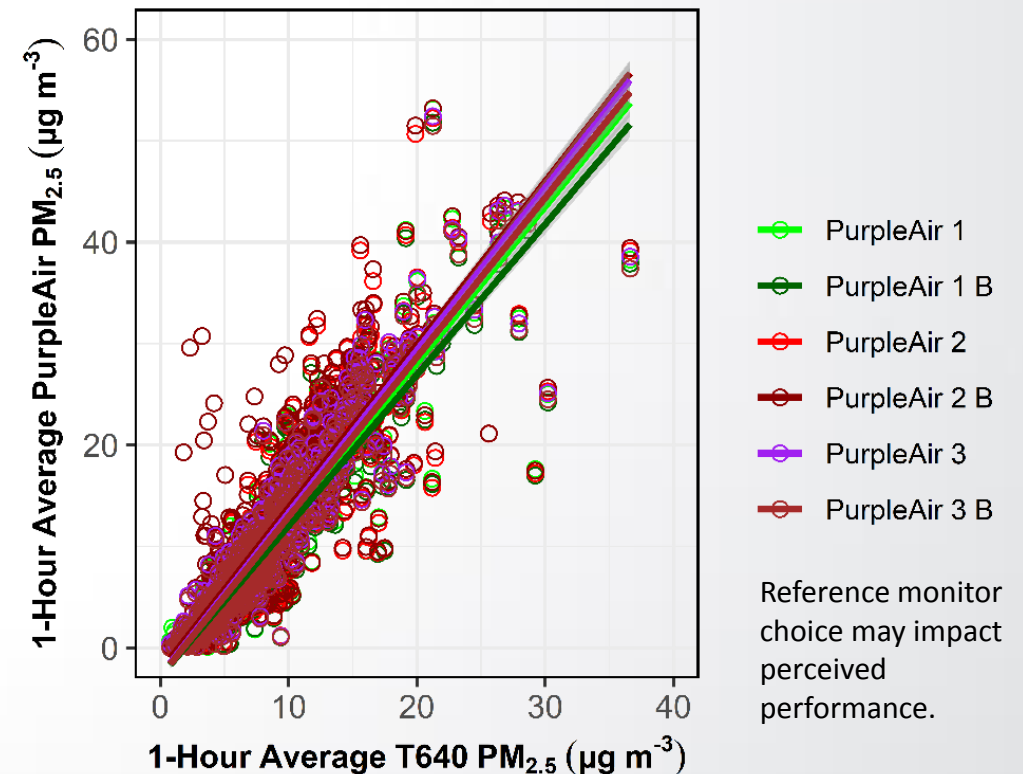
Project Lead: Andrea Clements

PurpleAir 1a $y = 1.54x - 2.80$ $r^2 = 0.84$

PurpleAir 2a $y = 1.63x - 2.82$ $r^2 = 0.83$

PurpleAir 3a $y = 1.60x - 2.69$ $r^2 = 0.89$

PurpleAir vs T640 1-Hour Averaged $PM_{2.5}$





Phoenix P-TAQ (Nov. 2018 – Mar. 2020)

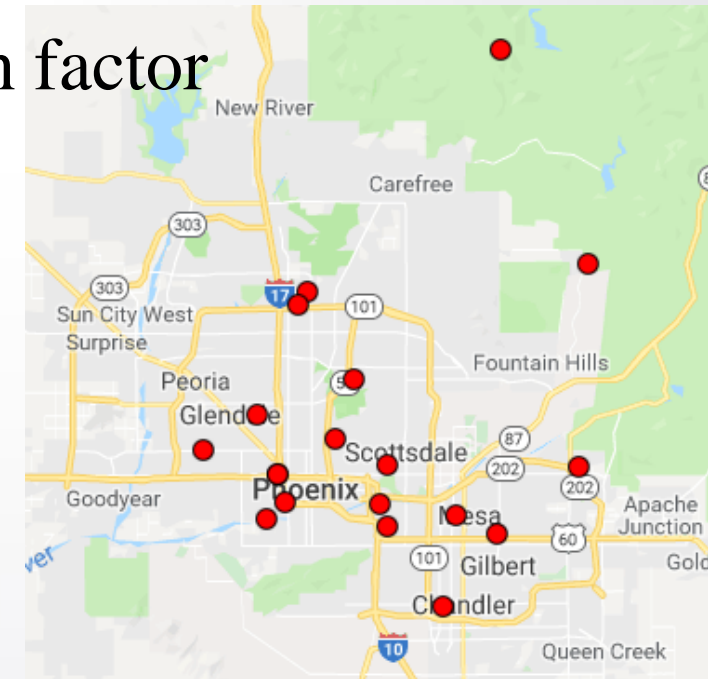
Project Lead: Sue Kimbrough

Phase 1 – Pilot (Nov. 2018 - May 2019)

- Study PurpleAir performance in new, **extreme environment**
 - Low humidity, high temperature, and high PM₁₀ concentrations
- Evaluate sensor performance against collocated reference monitors
- Sensor degradation, reproducibility, and local correction factor

Phase 2 – (May 2019-Mar. 2020)

- Is PurpleAir suitable to supplement monitor network?
- Calibration of non-collocated PurpleAir sensors
- Optimal density and use of PurpleAir sensors

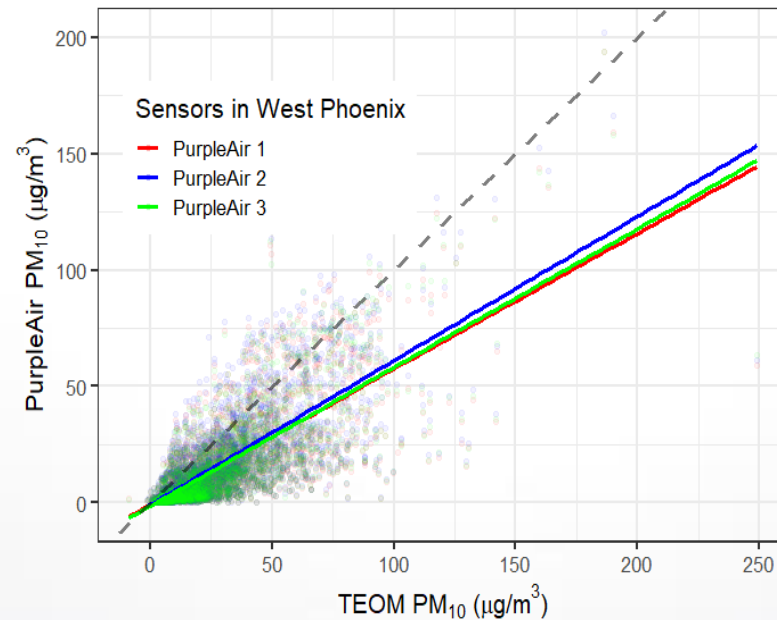
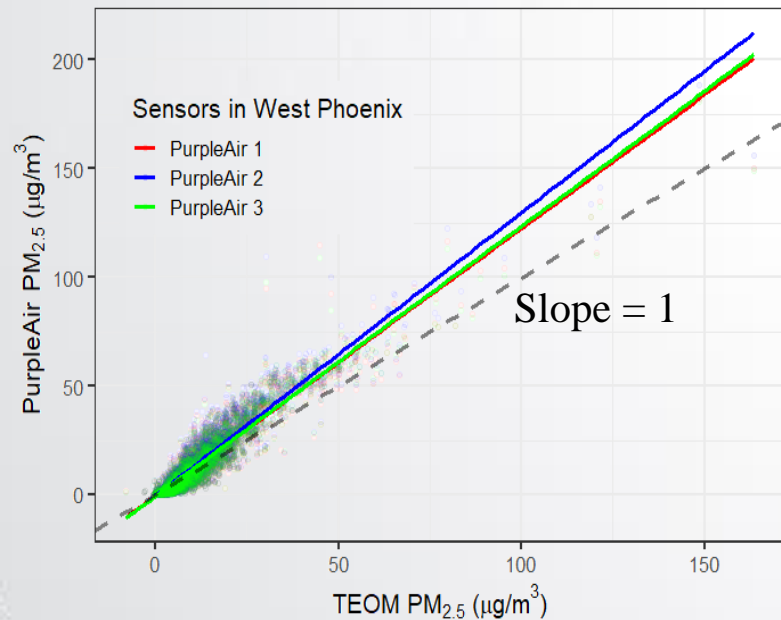
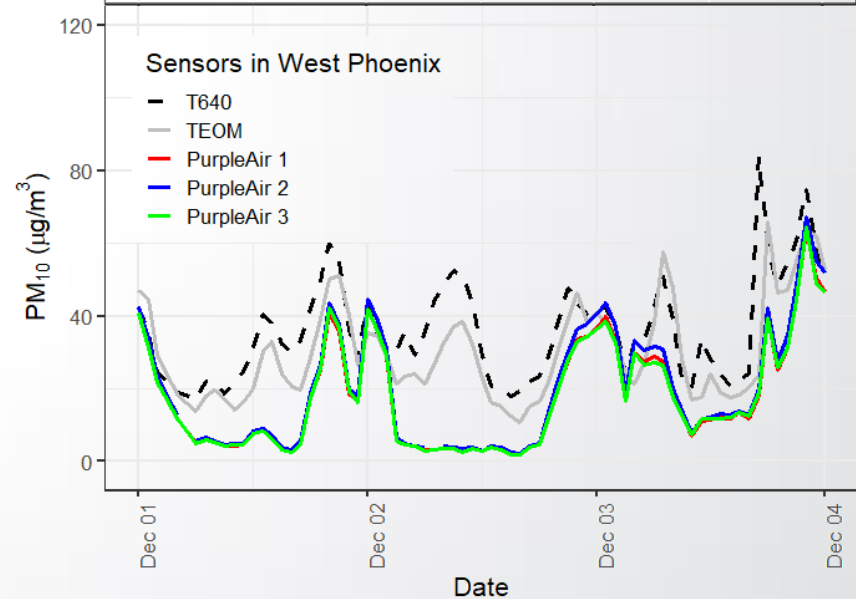
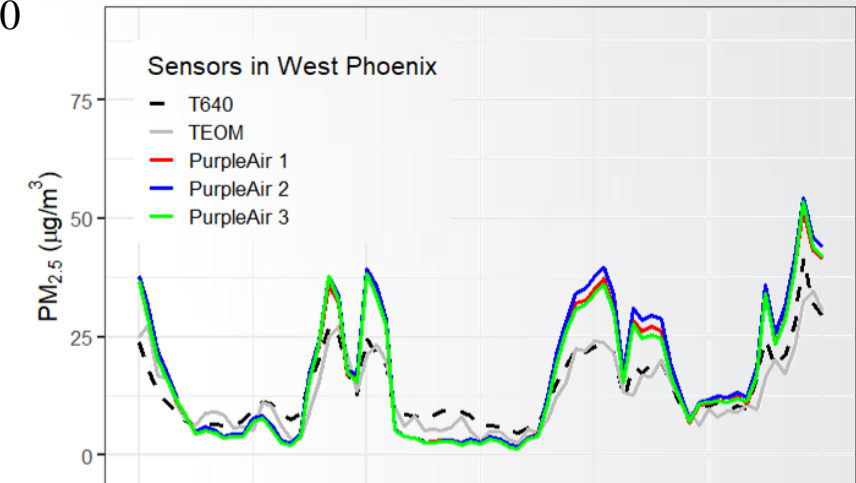




P-TAQ Pilot (Nov. 2018 – Apr. 2019)

- Hourly PurpleAir PM_{2.5} data correlates much better than PM₁₀
- PurpleAir over-estimates PM_{2.5}, underestimates PM₁₀

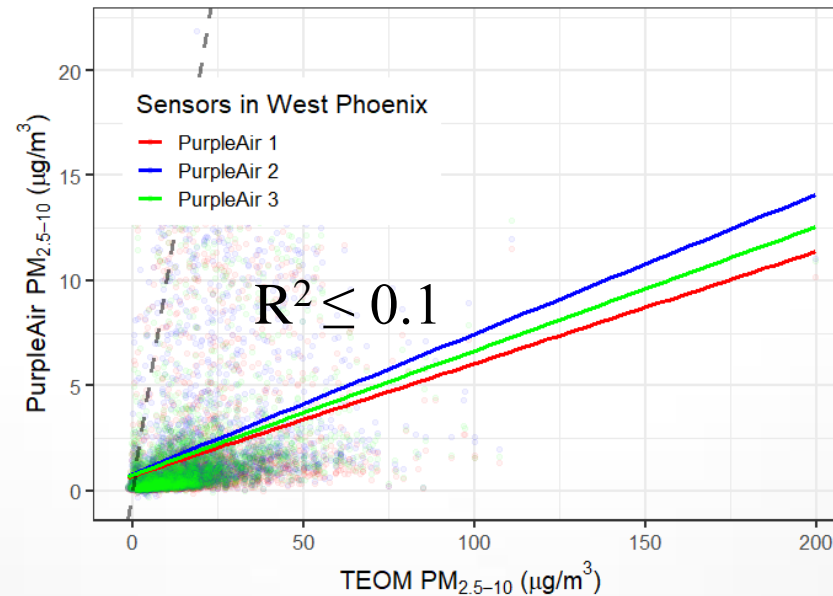
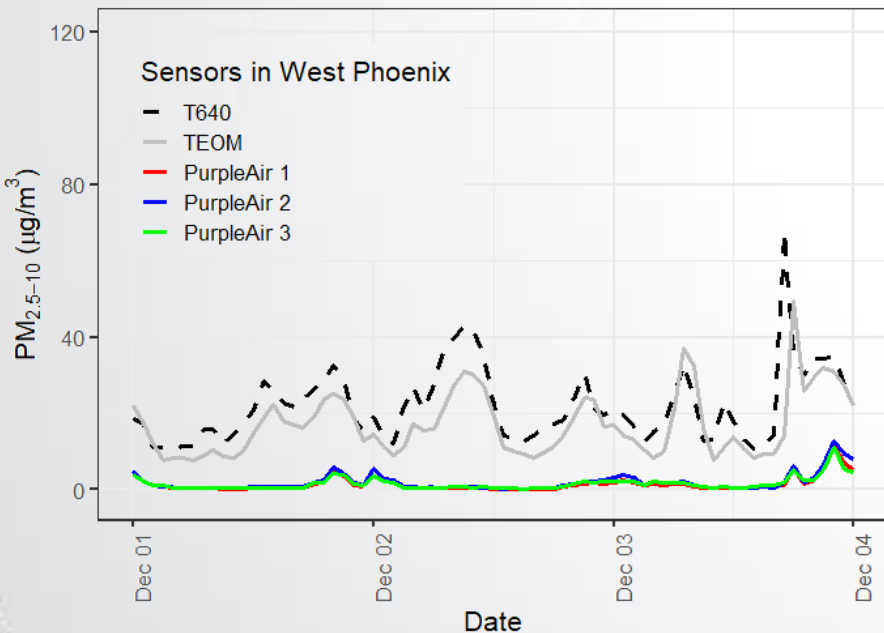
Sensor	PM _{2.5}		PM ₁₀	
	R ²	Regression	R ²	Regression
PurpleAir 1	0.88	$y = 1.2x - 0.5$	0.52	$y = 0.6x - 0.8$
PurpleAir 2	0.88	$y = 1.3x - 0.5$	0.52	$y = 0.6x - 0.7$
PurpleAir 3	0.89	$y = 1.2x - 0.8$	0.54	$y = 0.6x - 1.4$





P-TAQ Pilot (Nov. 2018 – Apr. 2019)

- Hourly PurpleAir PM_{2.5} data correlates much better than PM₁₀
- PurpleAir over-estimates PM_{2.5}, underestimates PM₁₀
 - PM₁₀ simply scales the PM_{2.5} concentration – not a reliable measurement
 - PM_{2.5-10} events are not detected by PurpleAir



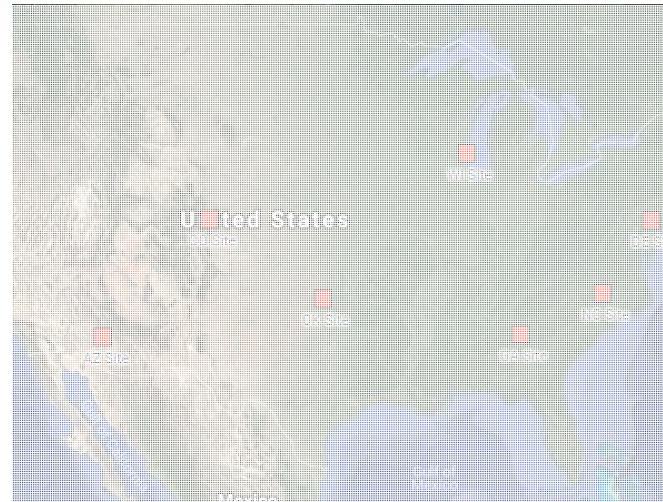
PurpleAir
sensors
should not be
used for PM₁₀



Long-term performance project (LTPP)

Study Design:

- 6 air sensors
- Some PM only some multipollutant
- 7 air monitoring stations across the US
 - NC, GA, DE, AZ, CO, OK, WI
- 1-year of measurements beginning in June 2019
- Comparison with similar reference monitors across sites



Sites across the US

Project Lead: *Andrea Clements*



AQY - Aeroqual



PurpleAir



ARISense -
Aerodyne Research



Ramp - SenSit



Maxima -
Applied Particle Technology



Clarity Node -
Clarity Movement Co.



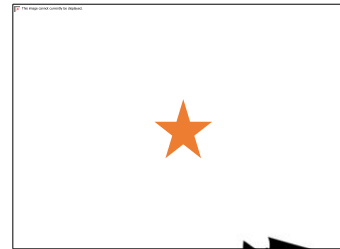
LTPP - US Performance PurpleAir

Design:

- Leverage projects already underway by air monitoring agencies
- 12 partner air monitoring agencies and ~50 collocated Purple Air sensors across the US

Objectives:

- Draw broader conclusions about the performance of Purple Air sensors
 - Different climates
 - Extreme events
- Explore methods of Quality Assuring (QA) and adjusting data from distributed sensors



Collocation sites
in 10 states - AK,
AZ, FL, GA, OK,
VT, NC, CA, WI, IA



Partners from 10 states



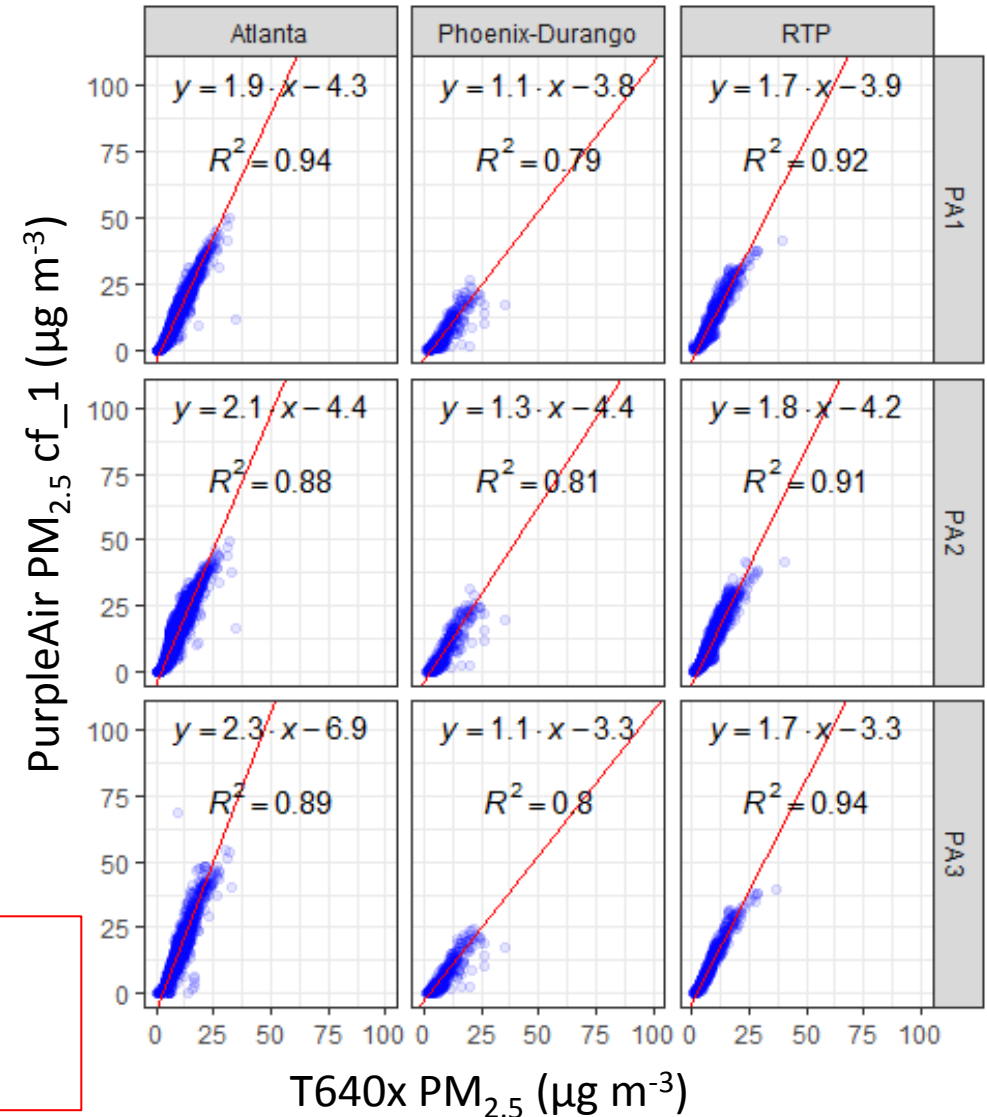
LTTP - US Performance PurpleAir

Preliminary PurpleAir findings

- Good precision between sensors as similar slopes are observed for replicate sensors at same site.
- Accuracy is variable - field collocation is essential as relationships in different parts of the country vary
 - Slope ~2.1 Atlanta
 - Slope ~1.7 in RTP
 - Slope ~1.2 Phoenix

Red line=
linear
regression

1-hr comparisons across 3 sites



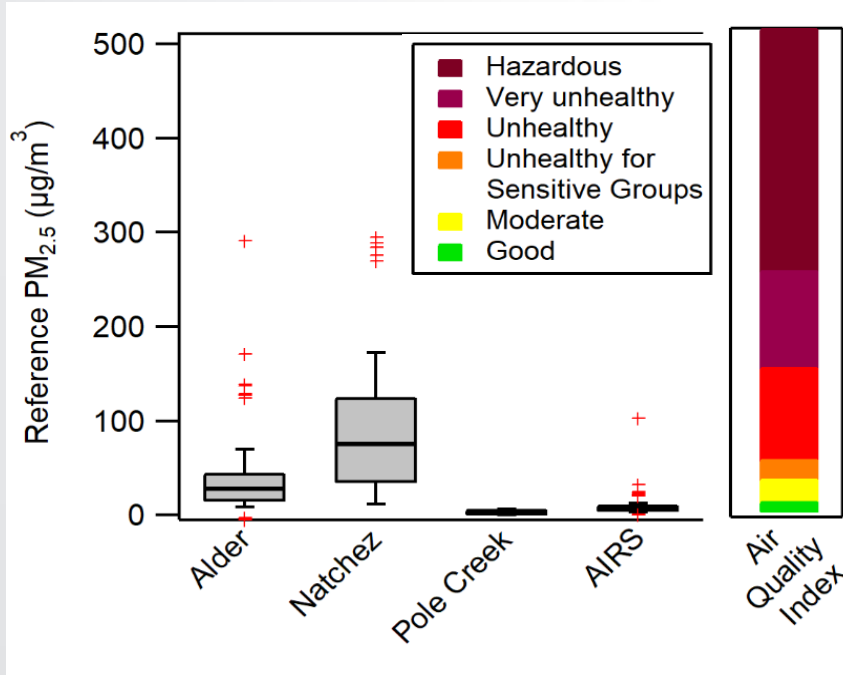


PM sensors for wildfire smoke

Project Lead: Amara Holder

Evaluated low to mid-cost PM_{2.5} sensors to augment ambient monitoring networks during wildfire smoke events:

- PurpleAir PAII-SD (PM₁, PM_{2.5}, PM₁₀)
- Aeroqual AQY (PM_{2.5}, O₃, NO₂)
- SenSevere RAMP (PM_{2.5}, CO, CO₂)

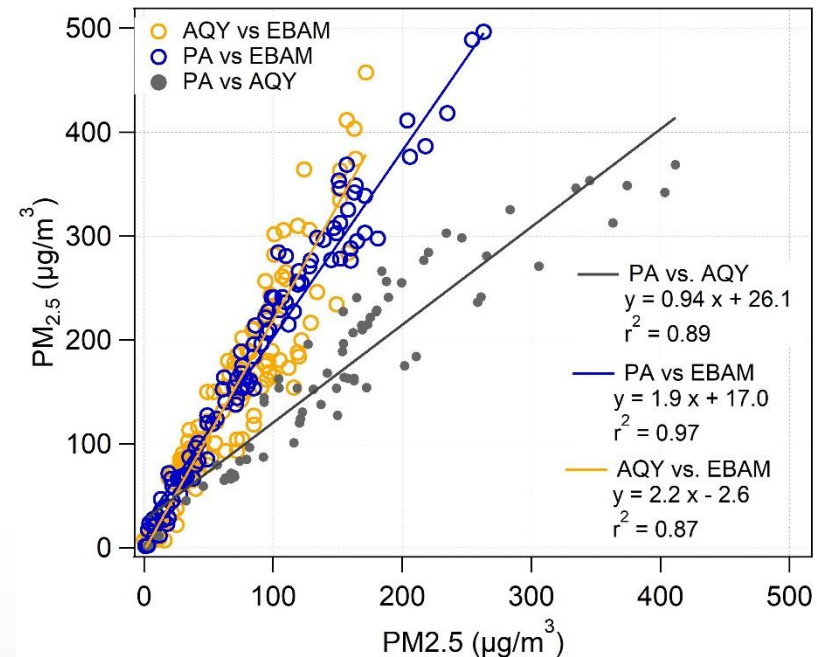
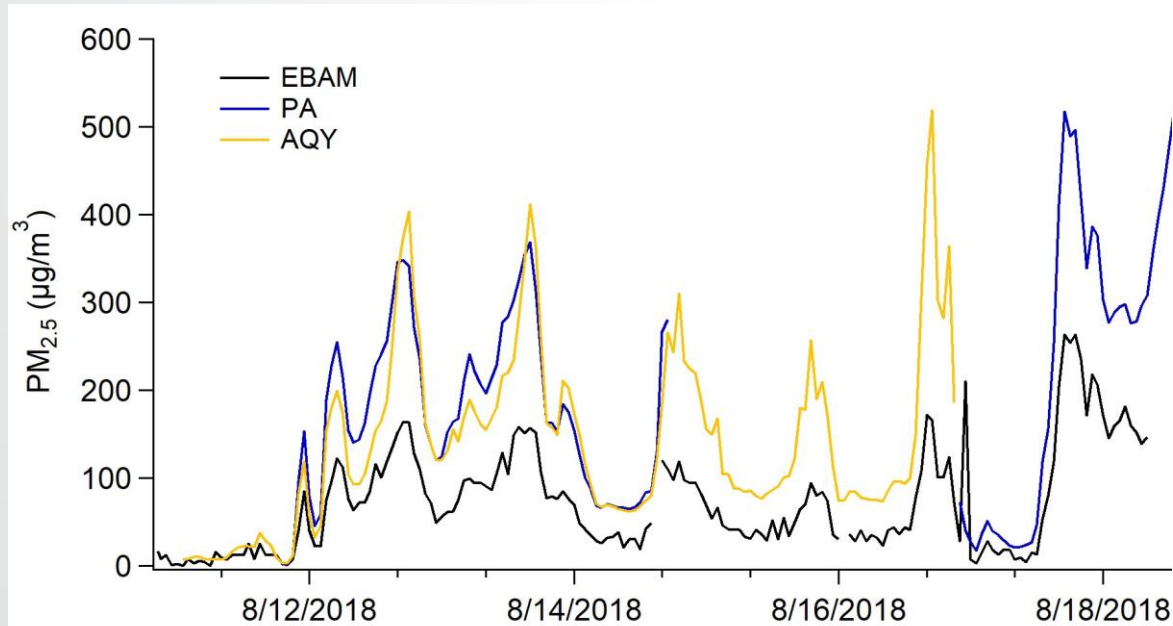


Fire/Measurement Location	Sensors	Reference
EPA ambient monitoring site (RTP, NC)	AQY, PA, RAMP	T640
Natchez Fire (Happy Camp, CA)	AQY, PA	E-BAM
Bald Mt – Pole Creek Fire (Price , UT)	AQY, PA	E-SAMPLER
Alder Fire (Springville, CA)	RAMP	BAM
(Pinehurst, CA)	AQY, PA, RAMP	BAM
(Camp Nelson, CA)	RAMP	E-BAM



PM sensors for wildfire smoke

- All PM sensors were highly correlated ($r^2 > 0.8$) with reference instruments at elevated PM concentrations
- PM sensors generally reported 1.5 – 2X higher than BAMs at elevated concentrations, but were in better agreement at lower concentrations
- Correction for RH and T improve comparison as does using the PurpleAir CF data





Potential collaboration with PurpleAir

*Project Leads: Gayle Hagler
Andrea Clements*

- Goals:
 - Supporting collaboration and information sharing between the parties
 - Exchange of air quality data – current and historical
- Potential Collaboration Type - Memorandum of Understanding (MOU)
- Potential work EPA may pursue
 - Research on quality assurance methods for PA data
 - If methods produce data of sufficient quality, EPA may explore the use of the data in research studies and applications
 - Model evaluation
 - Data fusion
 - Data visualization
 - Development of research and informational applications
- A formal agreement is currently under legal review and discussion by both parties. If a final agreement is signed, the signed version will be shared.



Acknowledgments

Thanks to all contributors:

- EPA eval: A. Clements, T. Conner, S. Reece, M. Srivastava (Jacobs), J. Rice, R. Williams
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- LTPP: A. Clements, K. Barkjohn, I. VonWald, C. Johnson (Jacobs), partner agencies
- EPA-Aeroqual CRADA: R. Duvall, G. Henshaw (Aeroqual)
- Wildfire: A. Holder, B. Mitchell, A. Mebust, D. Vallano, L. Maghran, K. Stewart, R. Elleman, M. McGown.

Partner air monitoring organizations:

- Phoenix: Maricopa County Air Quality Department - B. Davis, H. Patel, I. Domsy, R. Pope
- LTPP: Maricopa County Air Quality Department, Wisconsin Department of Natural Resources, Colorado Department of Public Health and Environment, Oklahoma Department of Environmental Quality, Delaware Department of Natural Resources, Georgia Department of Natural Resources, Iowa Department of Natural Resources, San Luis Obispo County Air Pollution Control District, EPA Region 4, Sarasota County Government, Quapaw Nation, Vermont Department of Environmental Conservation, Alaska Department of Environmental Conservation, Forsyth County Office of Environmental Assistance and Protection, Mojave Desert Air Quality Management District, Antelope Valley Air Quality Management District

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