Dust, Low-Cost Sensors, and a Few Lessons Learned

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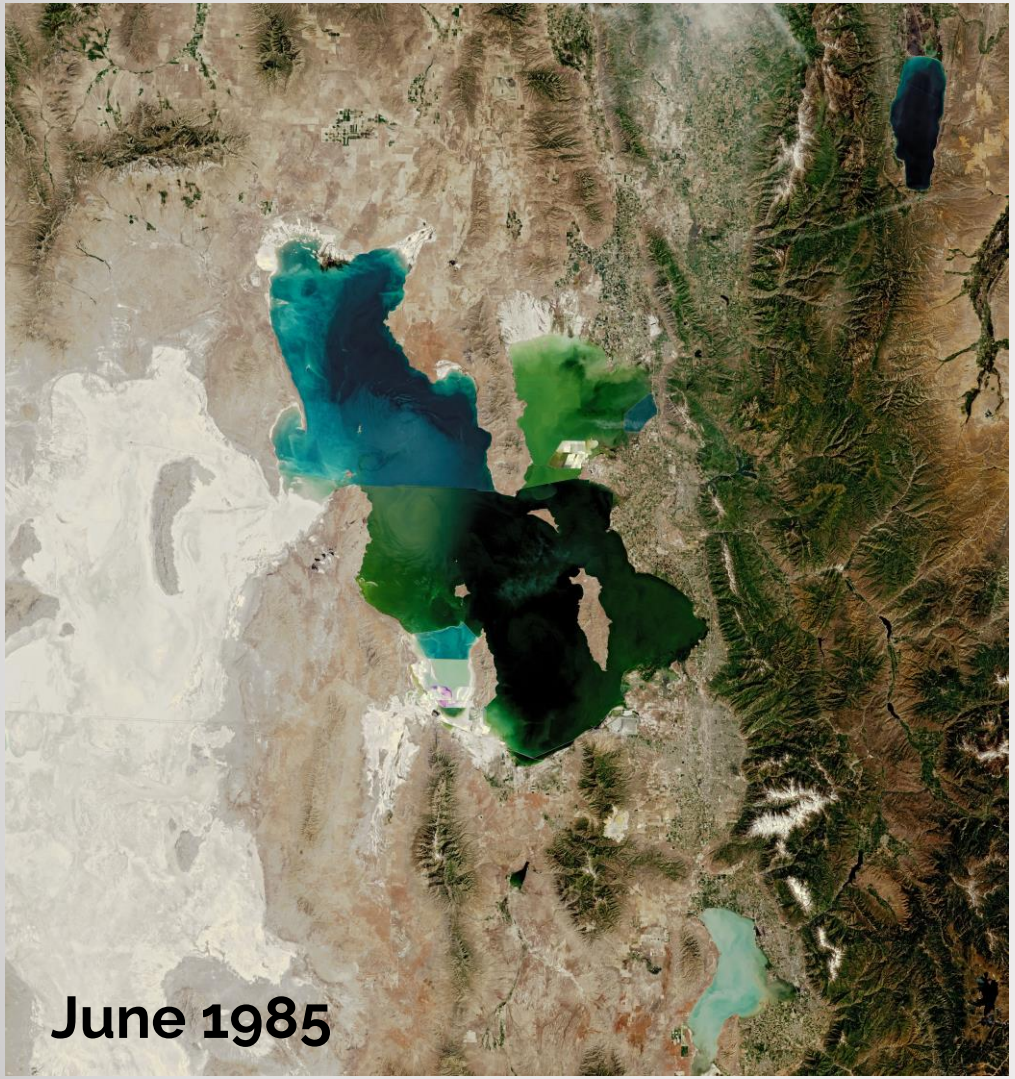
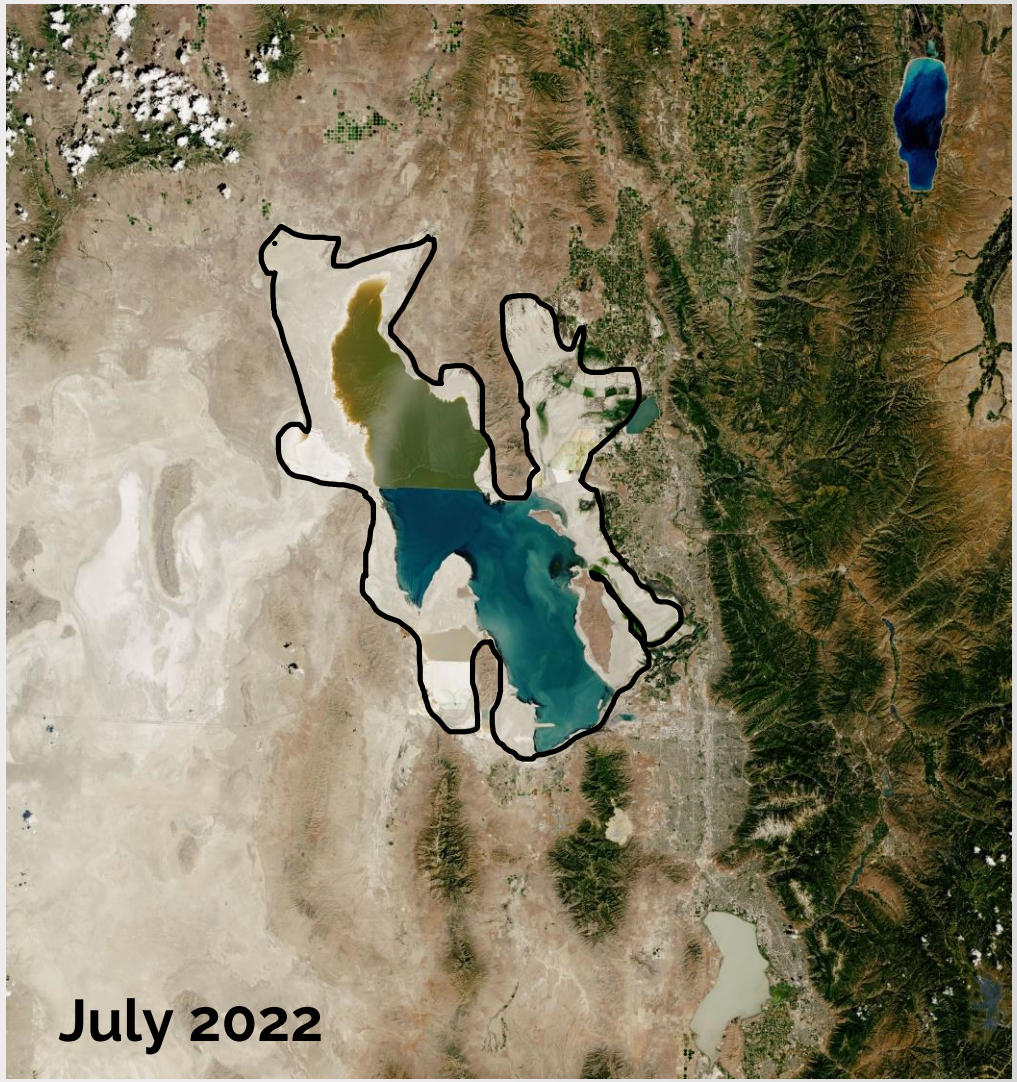
Challenges

- Arid/semi-arid lands are increasing
- Regulatory measurements of PM_{10} are sparser than $PM_{2.5}$
  - EPA has 1,370 active $PM_{2.5}$ (particulate matter less than 2.5 μm in diameter) sites versus 800 active PM_{10} (particulate matter less than 10 μm in diameter) sites
- PM_{10} is more spatially heterogenous than $PM_{2.5}$
- Low-cost sensors are effective at complementing reference measurements, especially for $PM_{2.5}$
- Many low-cost PM sensors are ineffective at measuring dust
- Dust can adversely affect $PM_{2.5}$ correction factors that are based on co-locations with federal reference or federal equivalent methods

The “Great” Salt Lake





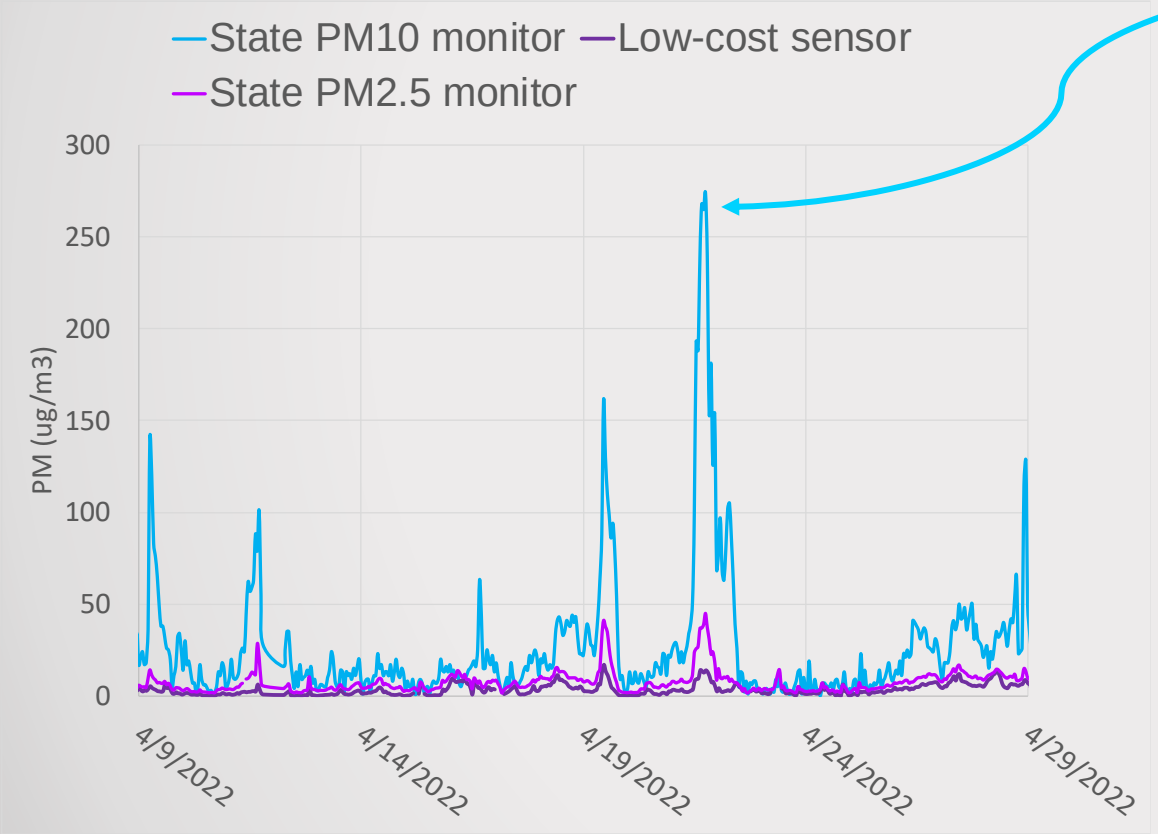
Salt Lake City, October 20, 2017

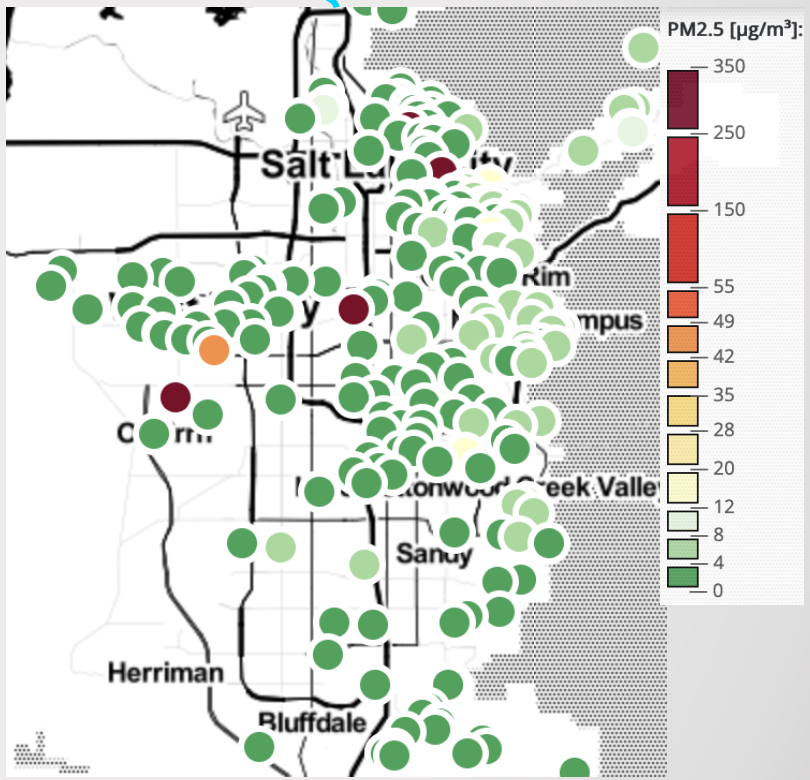
Low-cost sensors & dust

- Most low-cost particulate matter (PM) sensors are ineffective at measuring dust. * In spite of:
  - manufacturer claims
  - some studies showing high correlations with reference measurements of PM_{10}
- Is there anything better?
- Is there any way to make use of the existing measurements that are relatively ineffective at dust?
- How does dust affect co-located calibration factors?

*Kuula et al. 2019; Ouimette et al. 2022; Kaur et al. 2022

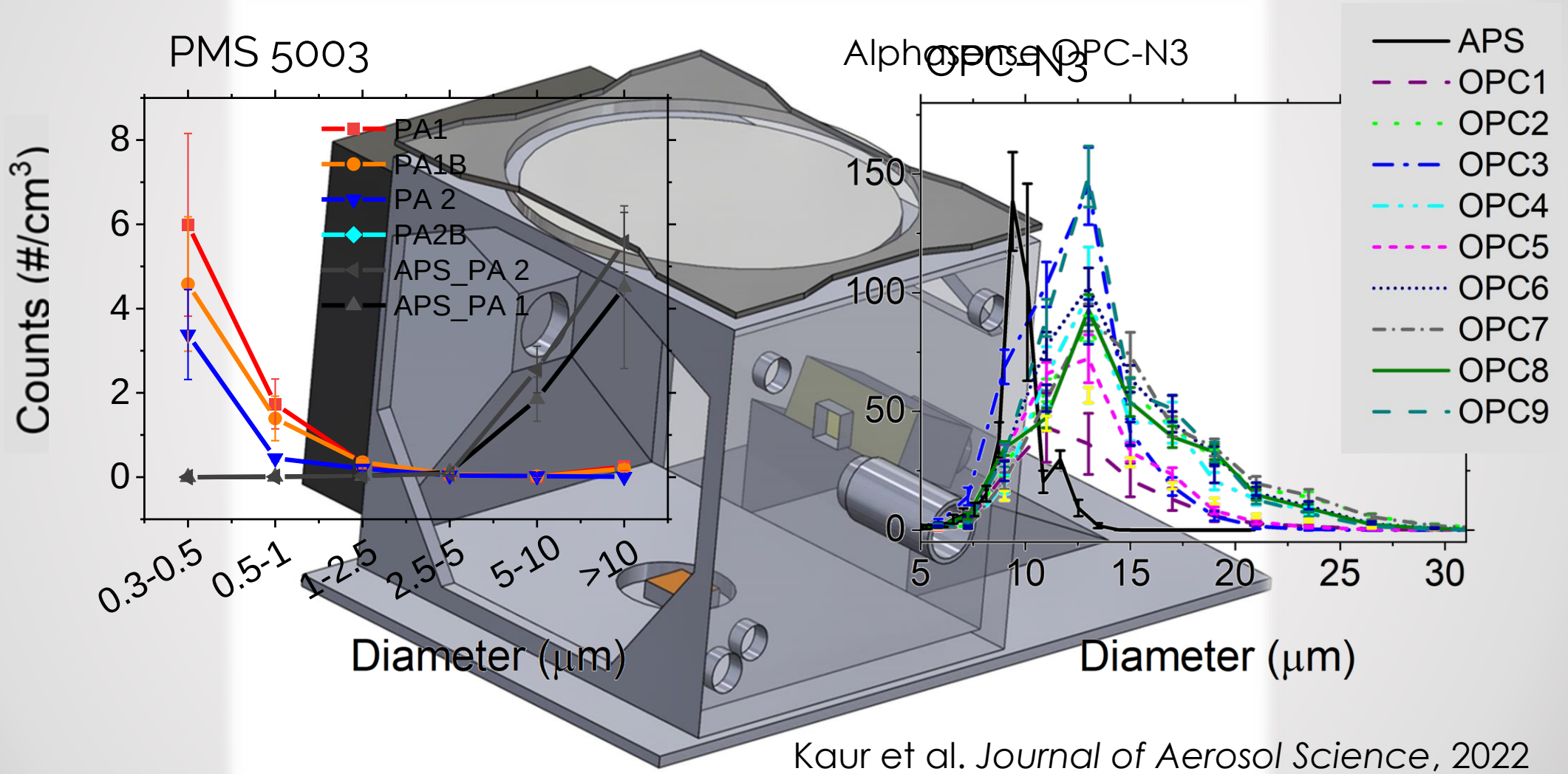
Low-cost sensors underestimate particulate matter (PM) levels during dust events





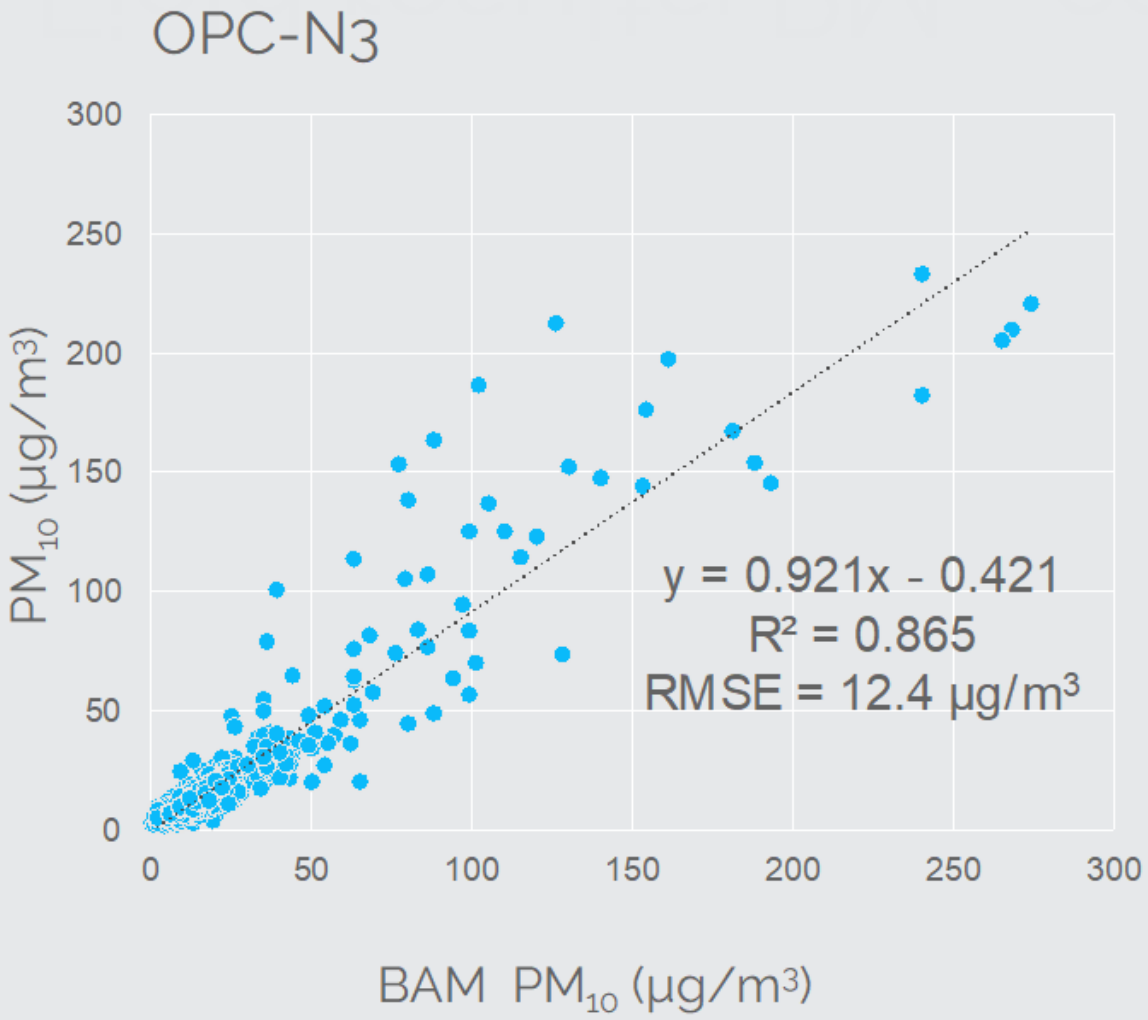
Salt Lake City 4/21/22 5 pm
Sensors from AQ&U, PurpleAir, and Tellus
Aqandu.org

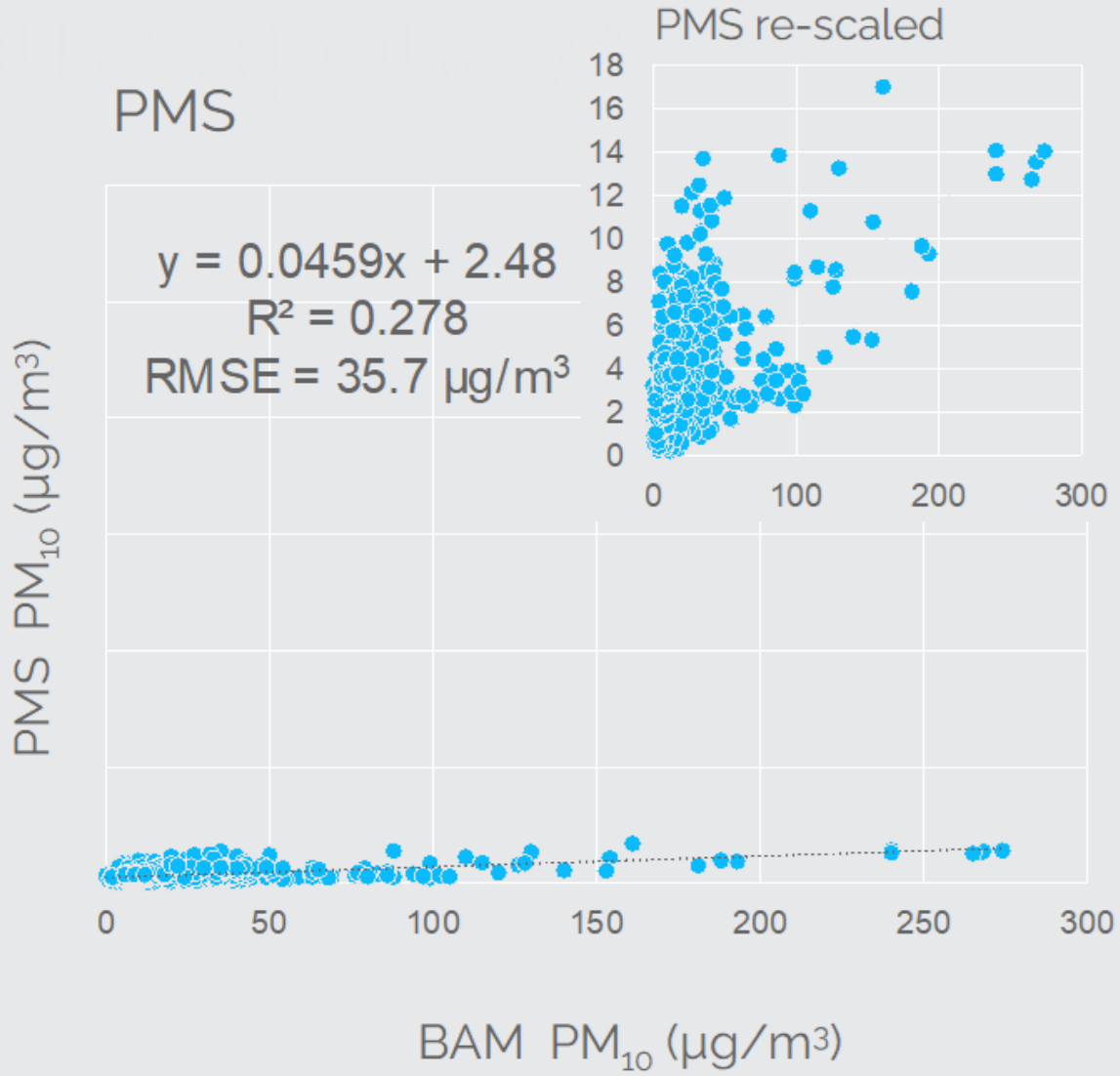
Is there anything better? Size selectivity to monodisperse PM_{10}



Kaur et al. *Journal of Aerosol Science*, 2022

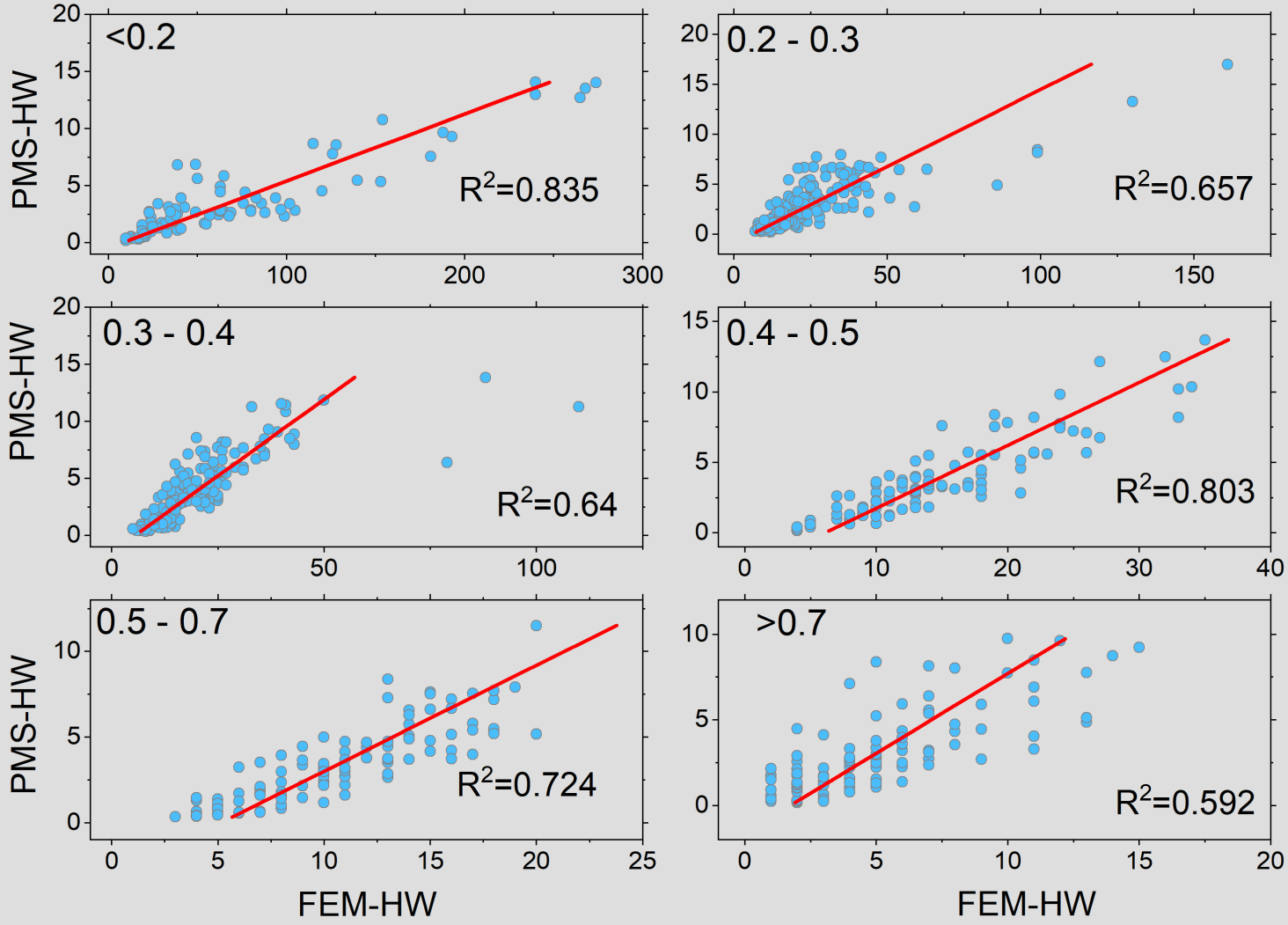
OPC-N3 and PMS vs. FEM PM_{10}





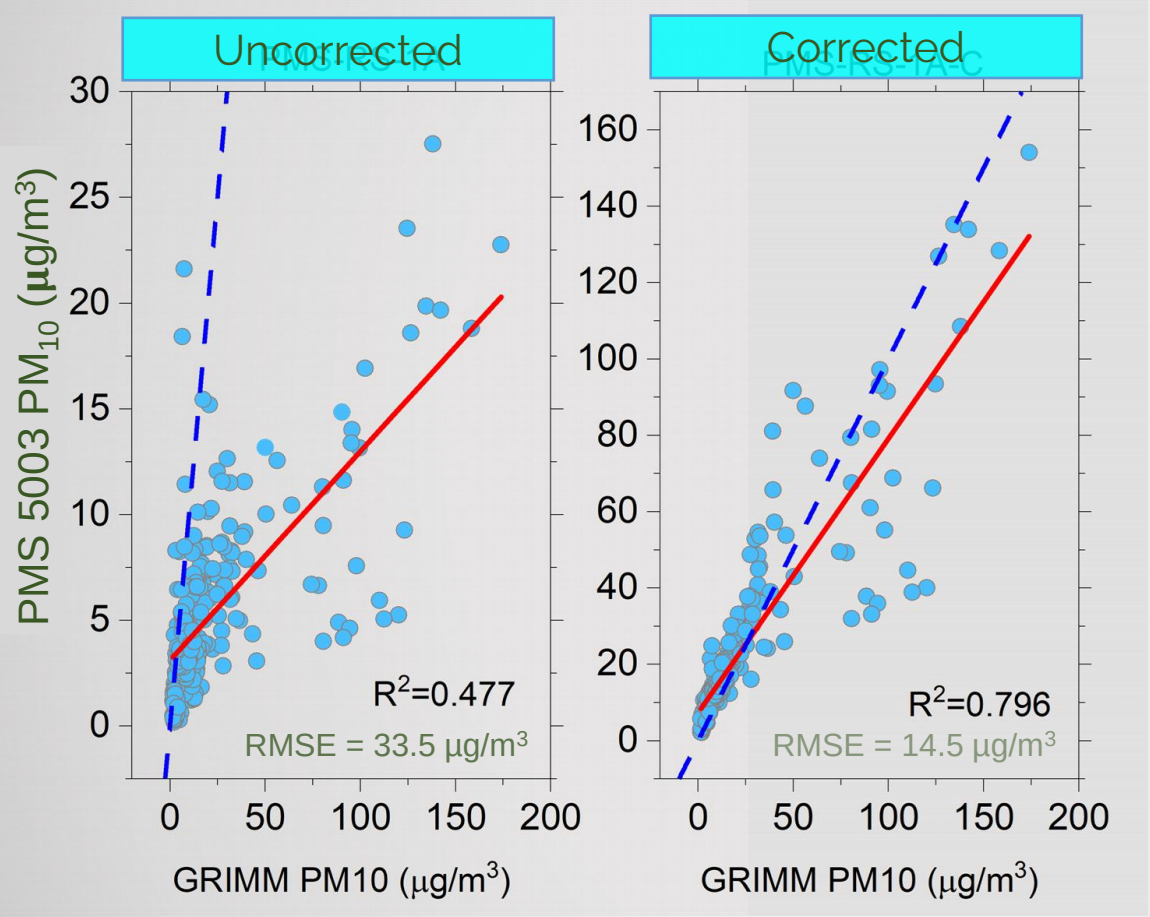
Kaur and Kelly, *Atmos. Measurement Techniques*, 2022

What if we bin the low-cost sensor concentrations?

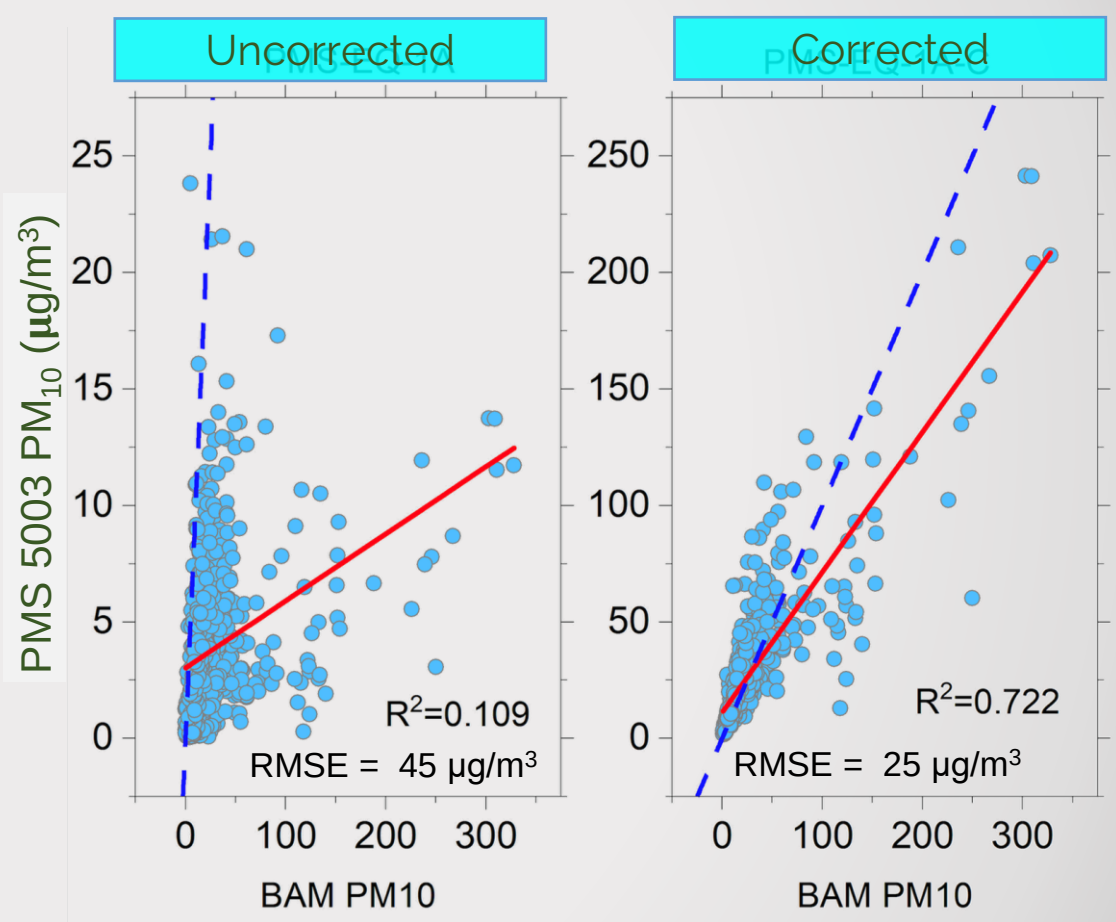


- $PM_{2.5}/PM_{10}$ ratio correction factor for each size bin.
- Apply these factors at our two other locations.
- .

Applying PM-ratio calibration to the PMS PM_{10}



Residential site

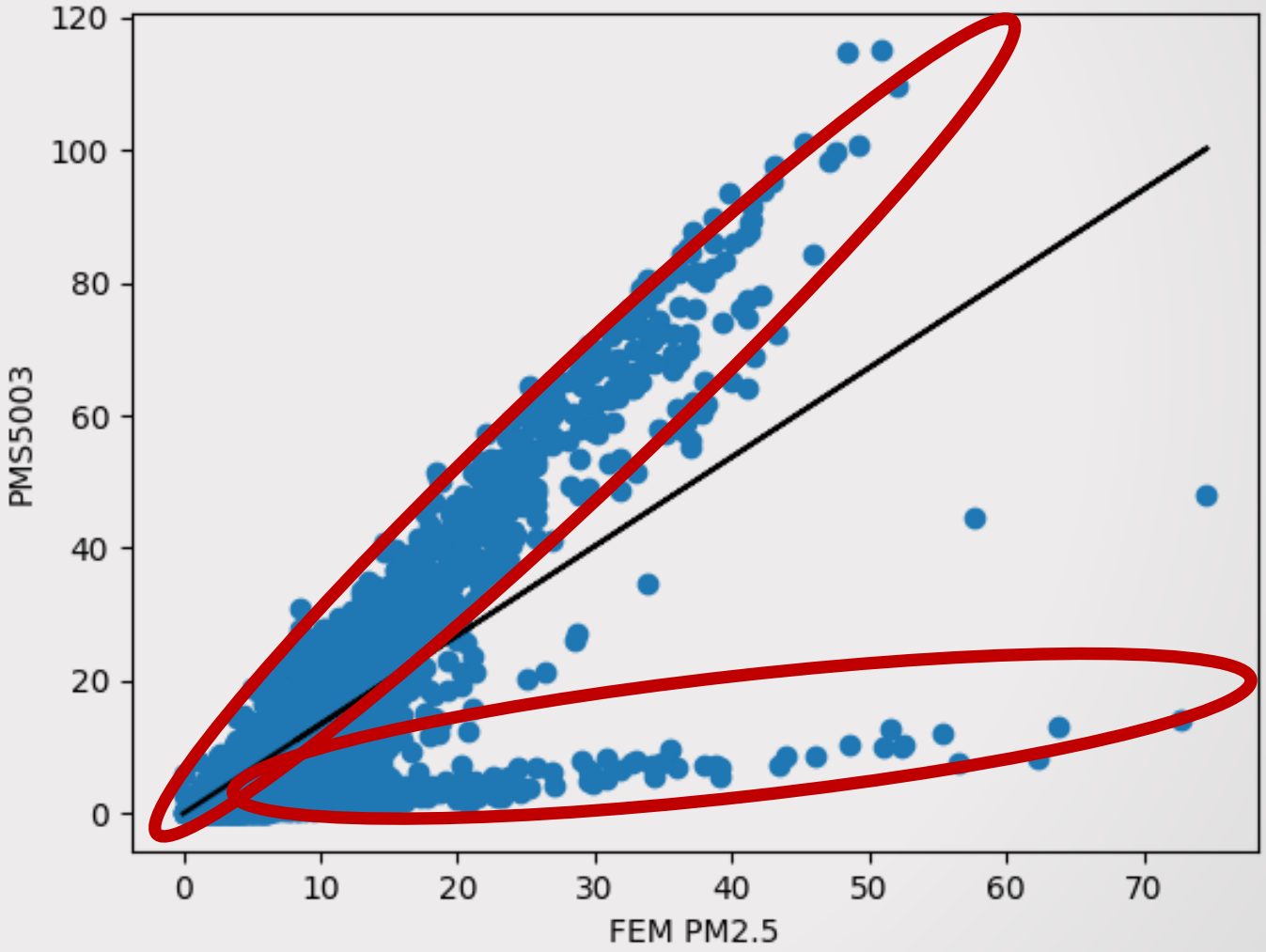


EQ monitoring site

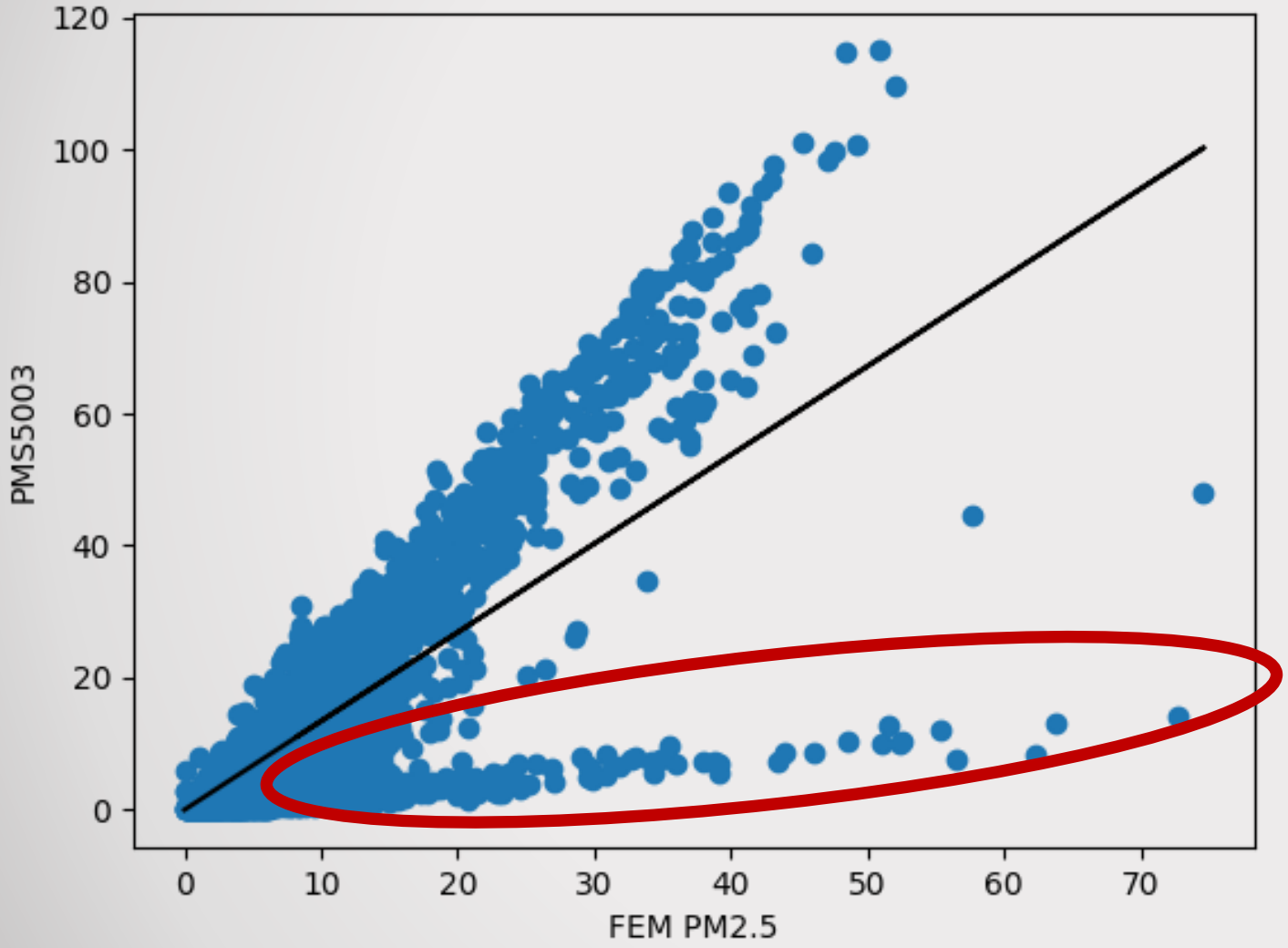
Kaur and Kelly, *Atmos. Measurement Techniques*, 2022

Effect of dust on PMS $PM_{2.5}$ calibration factors

- Jan 2022- Oct 2022
- Avg. of 4 PMS sensors
- PMS sensors highly correlated
- Two populations apparent

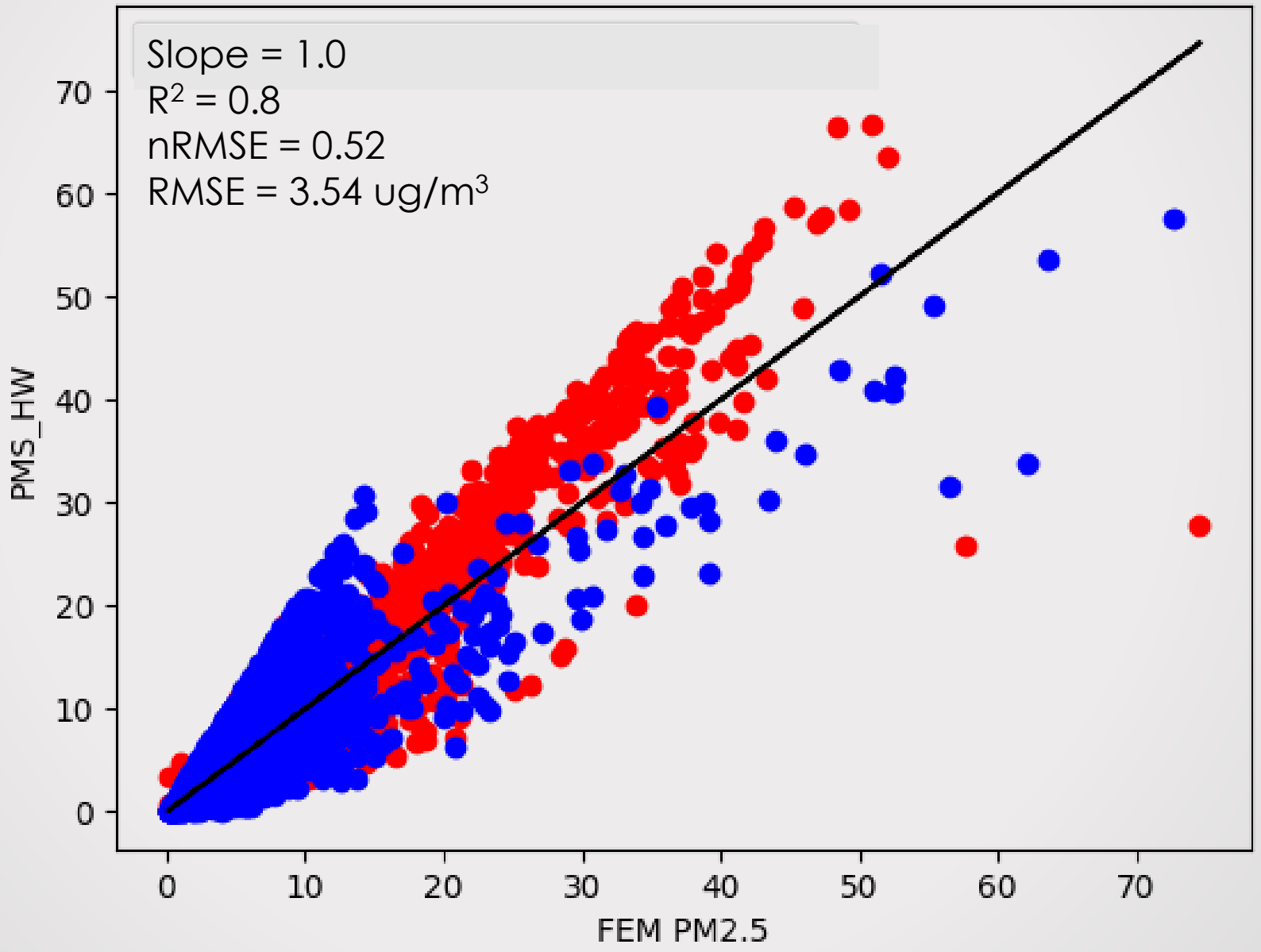


Separating the effect of dust on $PM_{2.5}$ calibration factors



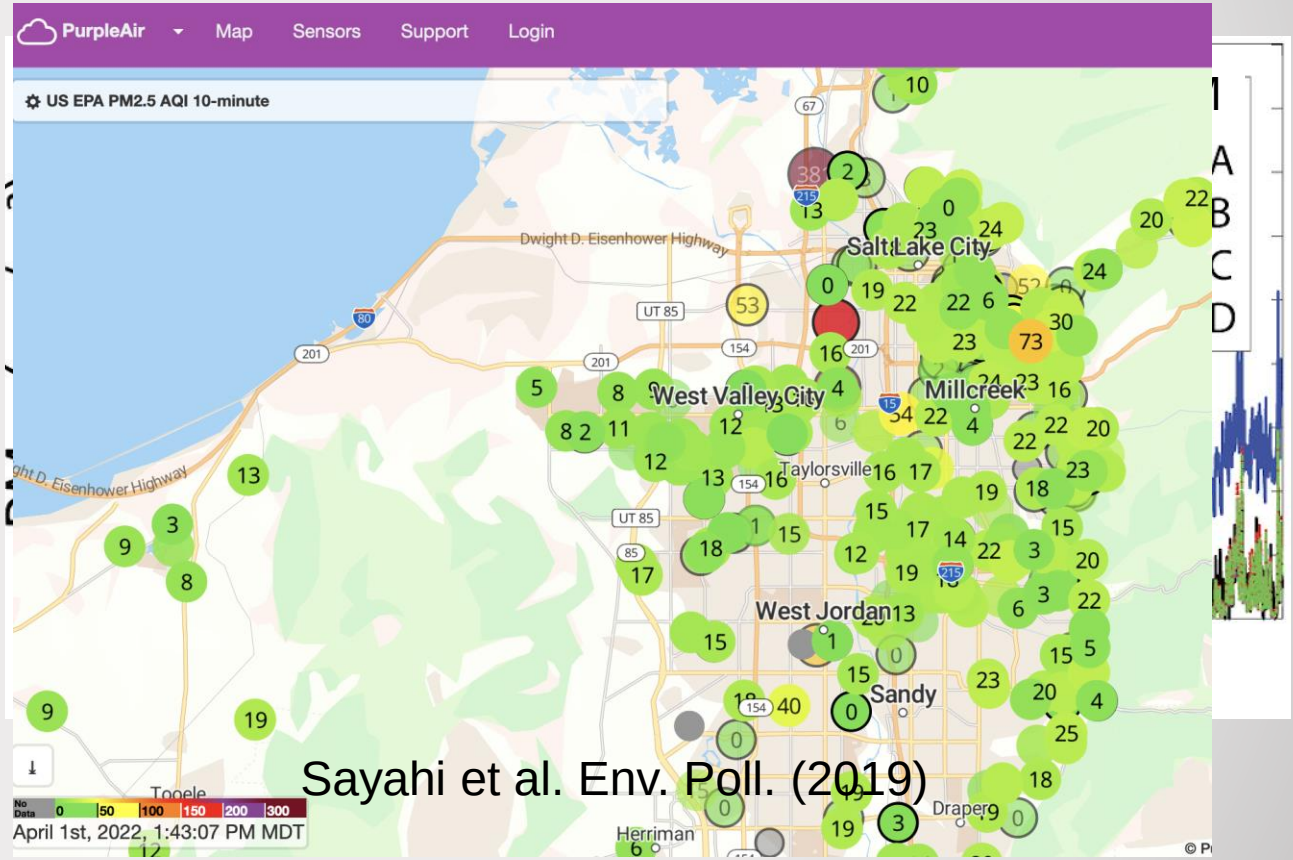
- Find all measurements when $PM_{2.5}$ PMS/FEM ratio < slope
- Create histogram of $PM_{2.5}$ PMS/FEM
- Look for local minima
- Where to get PM_{10}
- Work in progress

After correction



A Few Lessons Learned

- Drift screening
- Outlier screening
- Calibration/correction
- Managing a network (not low-cost)
  - Only a fraction of low-cost sensors are actually deployed
  - WiFi only devices can be challenging for organizations



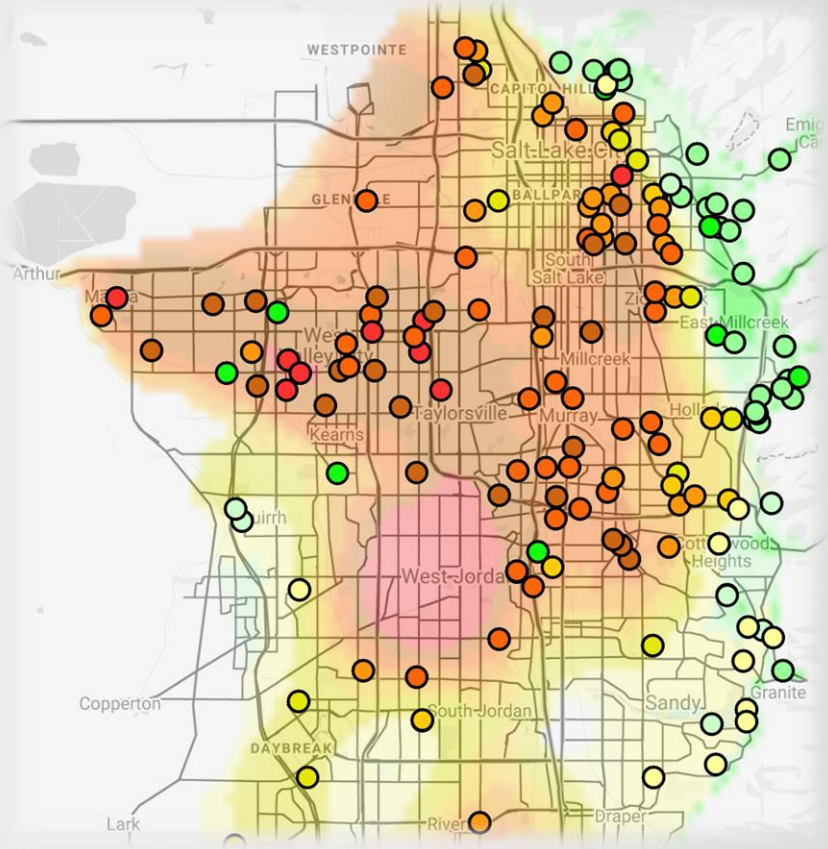
Sayahi et al. Env. Poll. (2019)

PurpleAir April 1, 2022

Data integration

- After correction and screening
- Integrate to help users make sense of imperfect measurements
- We use Gaussian Process model with optimized co-variates for time, space, and elevation.
- Validation with leave-one-out cross validation

Kelly et al. *Environ. Sci. Technol.* (2021)



Salt Lake City 12/22/21 8 am
Sensors from AQ&U, PurpleAir, and Tellus,
Visualization from Tellus.

Conclusions

- Many low-cost PM sensors are ineffective at measuring PM_{10}.
- The OPC-N3 is a promising tool for measuring PM_{10} (at a significantly higher price).
- $PM_{2.5}/PM_{10}$ ratio-based correction could cost-effectively provide spatially resolved PM_{10} estimates.
- Dust can bias correction factors co-located correction factors.
- Quality assurance is important: outlier and drift screening, correction factors, and data integration.

Thanks

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