Apples to Apples vs Apples and Oranges: A Perspective on Tiered Lab vs Field Testing of PM Instruments

Edmund Seto
University of Washington

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SCHOOL OF PUBLIC HEALTH
UNIVERSITY of WASHINGTON

What we want…

- PM sensor that
  - Is low(er) cost
  - Easy to setup
  - Works anywhere, everywhere
  - Works across a wide range of size, composition, concentrations
  - Not affected by environmental conditions
  - High correlation with reference instrument
  - Low maintenance

Maybe this magical PM sensor doesn’t exist?!

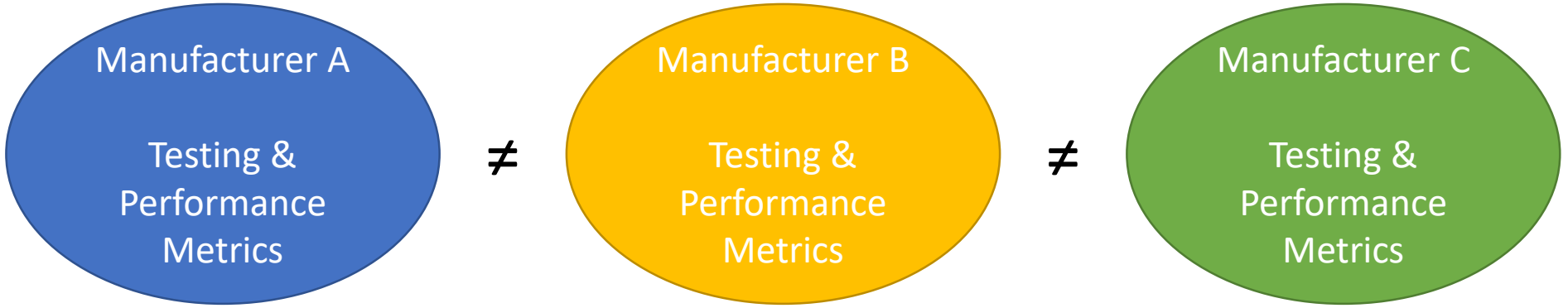
PM specific challenges that affect structure and scope of testing/certification programs

- Variations in PM composition can affect PM measurement
- Environmental conditions (such as humidity) affect PM measurement
- Thus, real-world performance of a sensor depends on the use case

- An end-user would like to know
  - What sensor should I choose?
  - How is it likely to perform for my particular usage scenario?

Challenge selecting sensors from Manufacturers

Verifiable Manufacturer Performance Testing and Specifications?

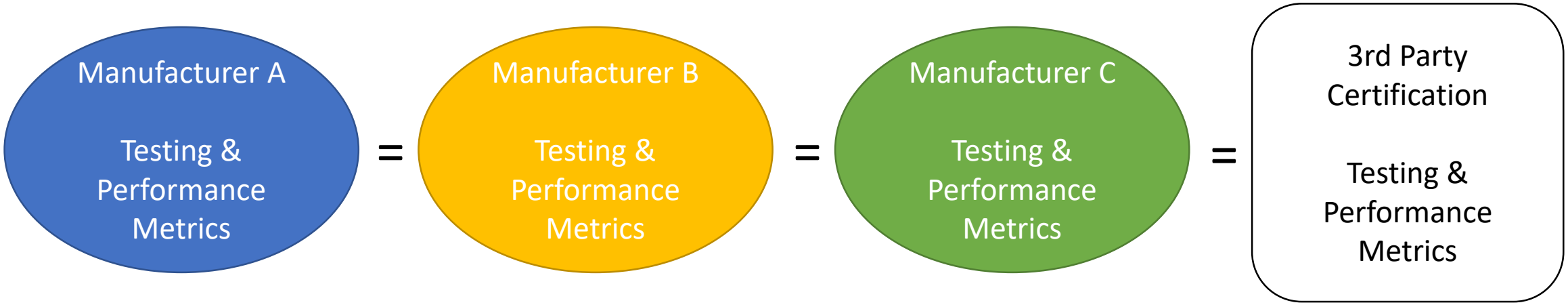


Without a standardized testing protocol and recommended performance measures, it is very difficult to select sensors for subsequent field use.

Apples to Apples Testing: Should we have standardized testing conditions, e.g., in lab conditions that manufacturers can document performance, and 3rd parties can verify?

Tier 1: Apples to Apples Testing

Verifiable Manufacturer Performance Testing and Specifications



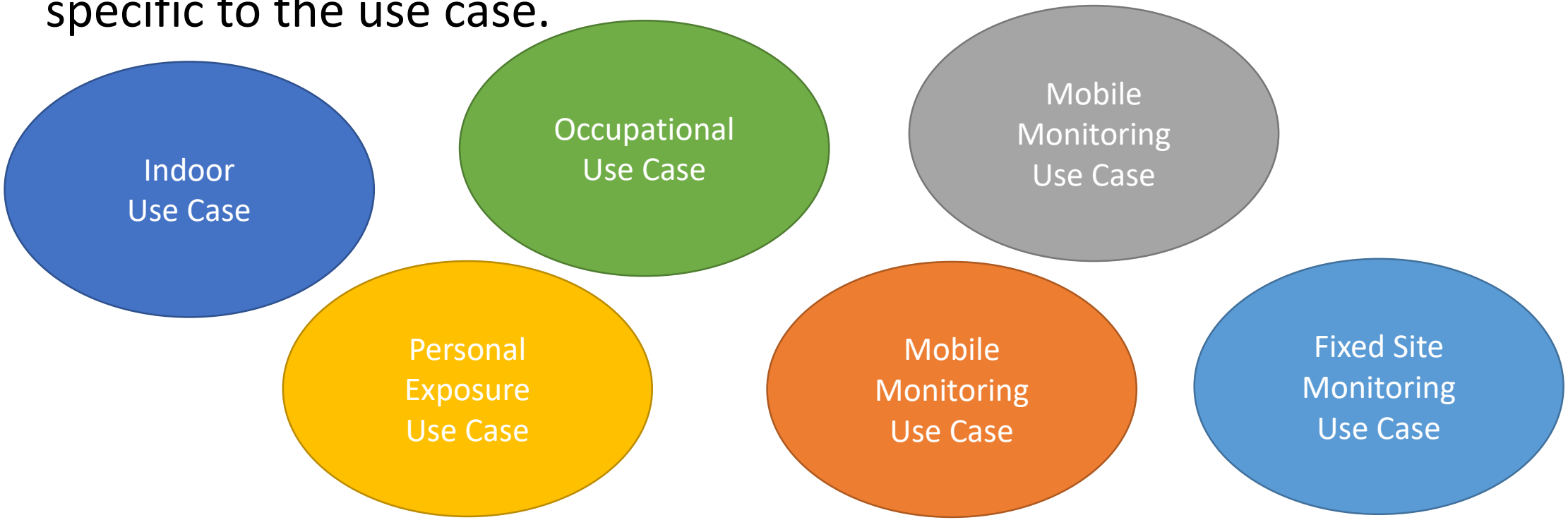
Standardized testing protocol and recommended performance measures

- Specific aerosol composition (Arizona Road Dust?)
- Specific temp and humidity
- Specific range of concentrations
- Specific reference instrument/method
- Specific metrics should be reported (LODs, LOQ, correlation, bias, RMSE, sensor to reference plot with 1:1 line, Bland-Altman plot, sensitivity at different particle sizes, between sensor variations, etc.)

Probably best carried out in a lab, exposure chamber, highly reproducible results

However, Tier 1 results may be misleading

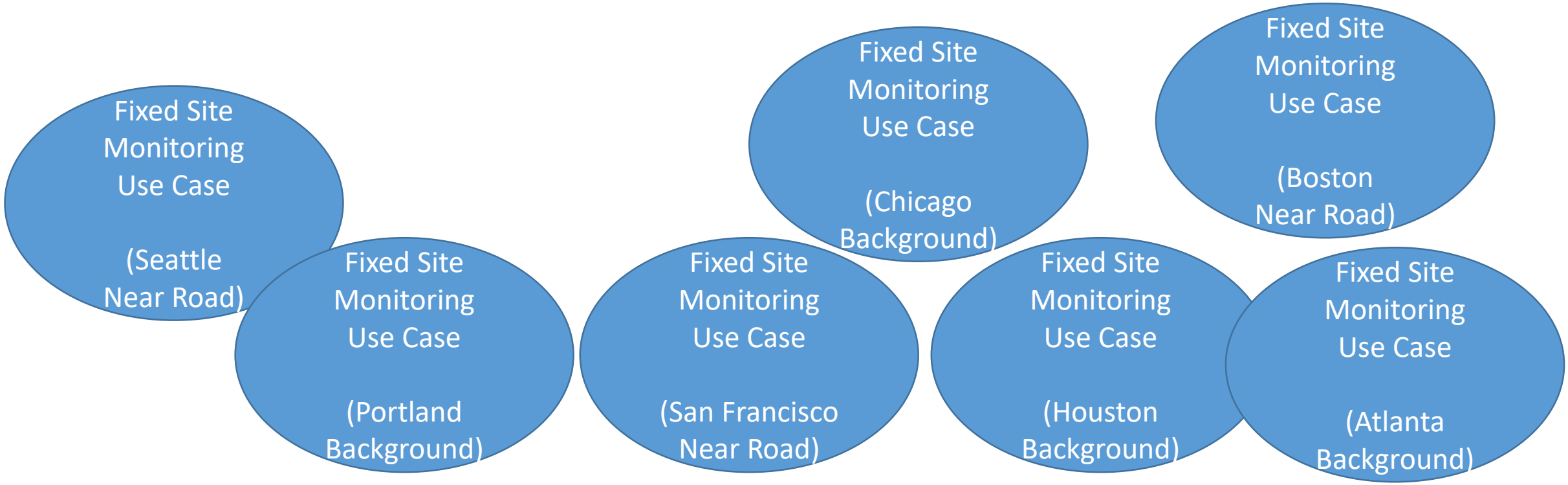
- Real-world isn't always Arizona Road Dust in a standard exposure chamber.
- Hence, there's a need for real-world performance testing that's specific to the use case.



Tier 2: Apples and Oranges Testing

Developing a recommended protocol/process

- Use case → DQOs/DQIs → Template QAPP for QA/QC → Systematic data reporting/sharing of results for a sensor



Correlation good, Calibration better!

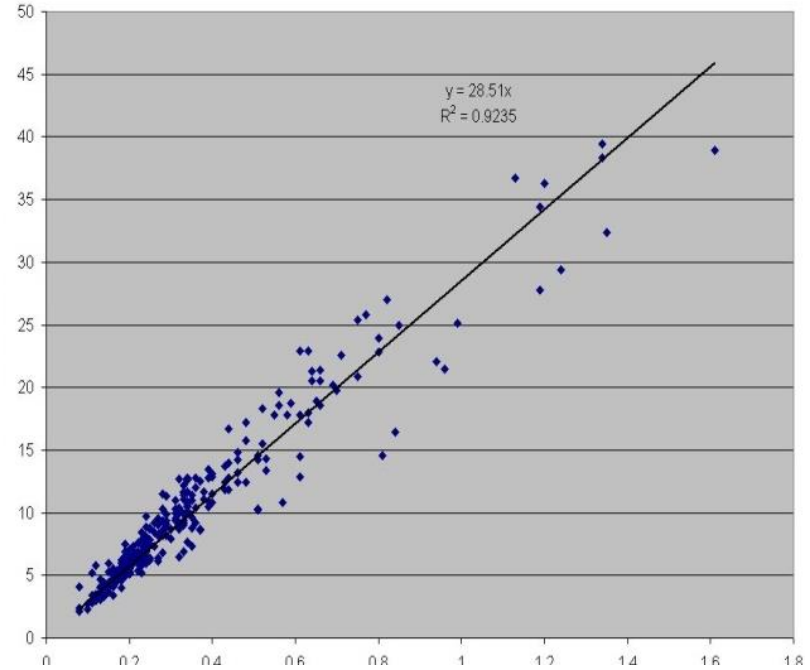
Again, because real-world performance varies, using a sensor that has been shown to correlate well in the lab or in a particular field setting, does not mean the absolute concentrations measurements can be trusted in another scenario.

As part of Tier 2 testing, co-location experiments with a reference instrument in the field can help determine if there is:

- An offset in concentration
- Slope greater or less than 1, or non-linearity comparing sensor to reference
- Noise at the low or high ends of relevant concentrations
- Environmental interferences
- Degradation in performance over time

Example of Calibration: Integrating Nephelometer in WA State

Norm Ahlquist and Bob Charlson with an early integrating nephelometer. UW Photo by William Eng, circa 1966

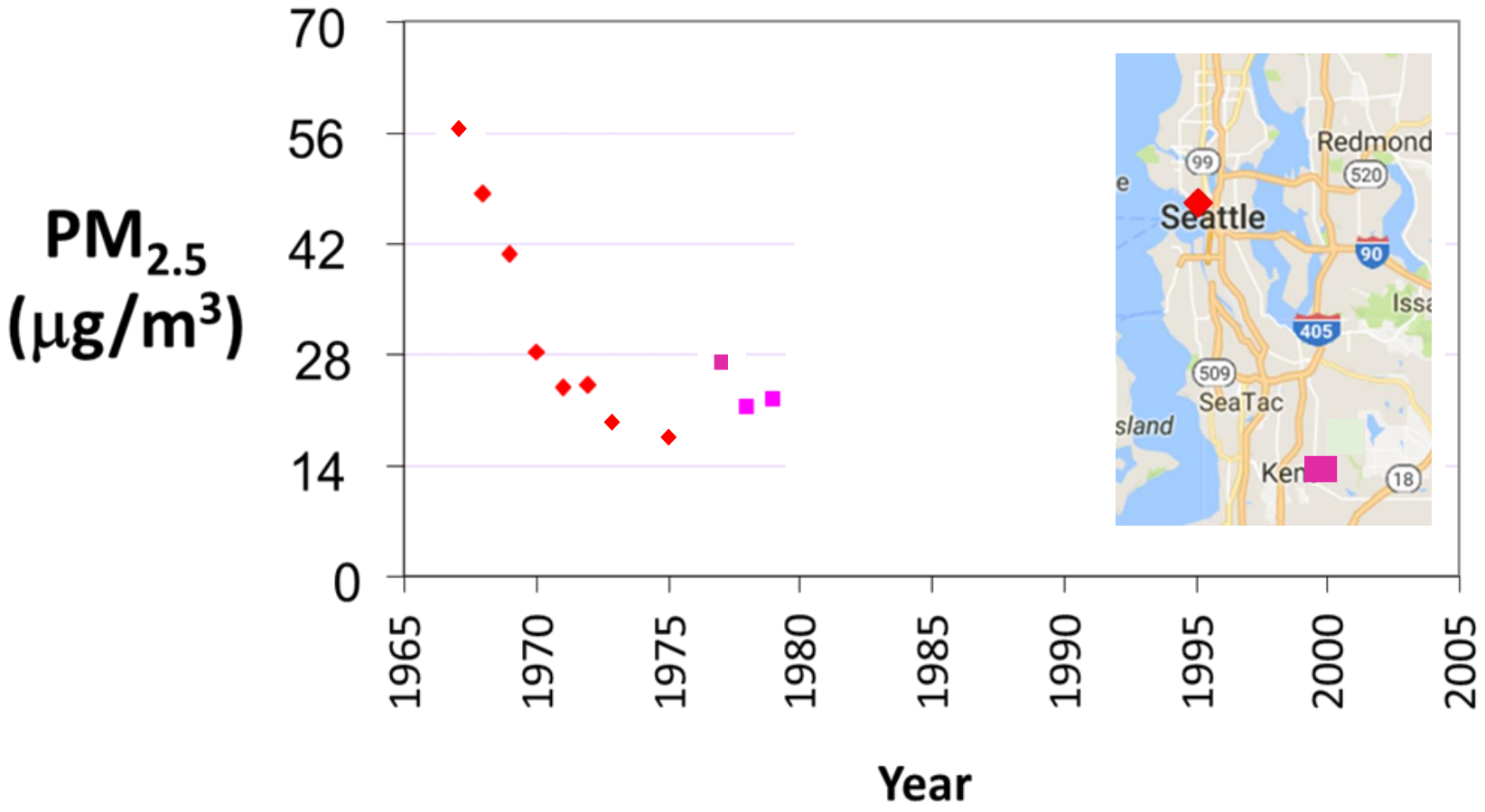


$PM_{2.5}$ vs neph in 1990s

Credit: Tim Larson, UW

Estimated $PM_{2.5}$ Annual Averages*

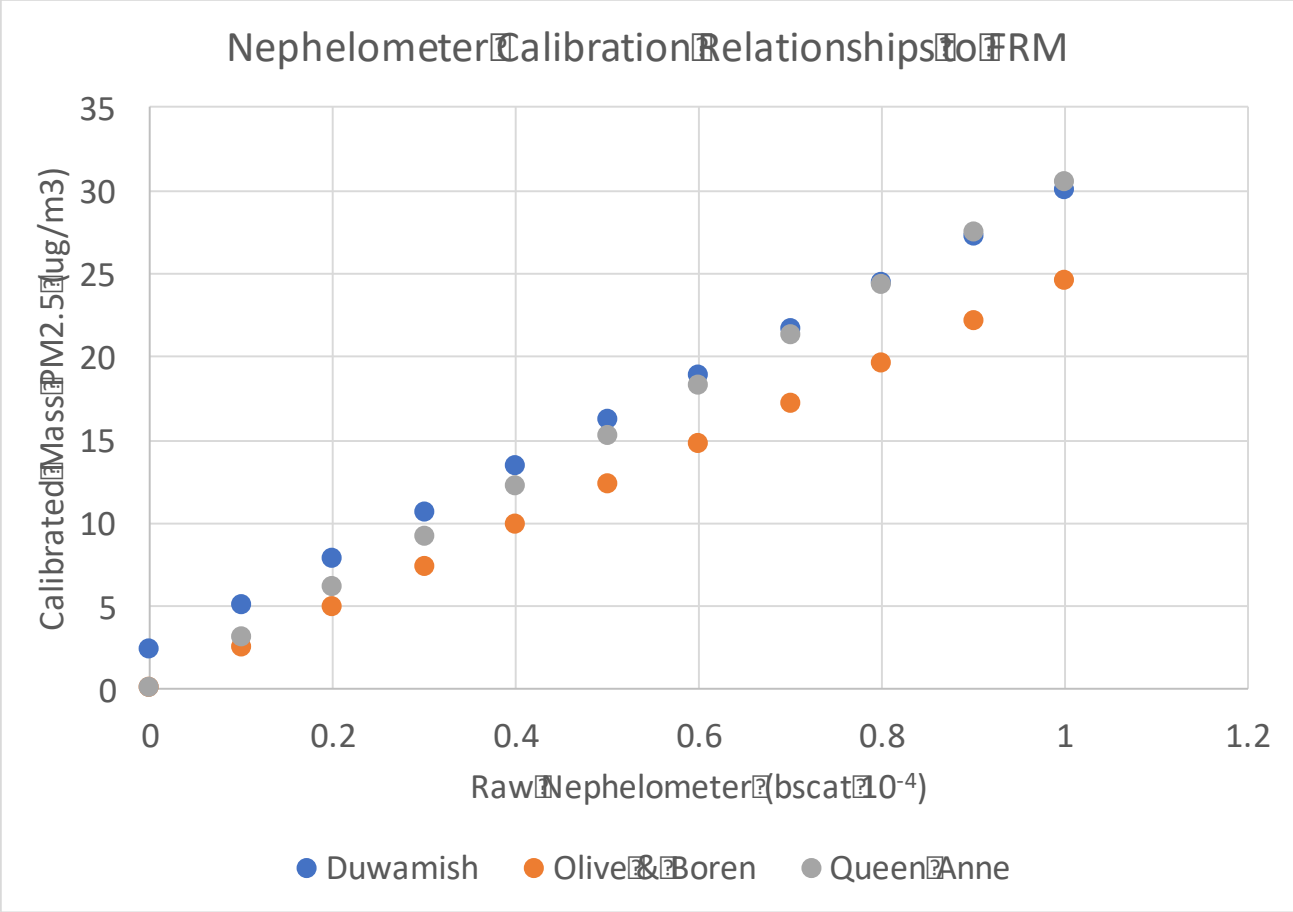
Seattle, WA



*based on light scattering readings

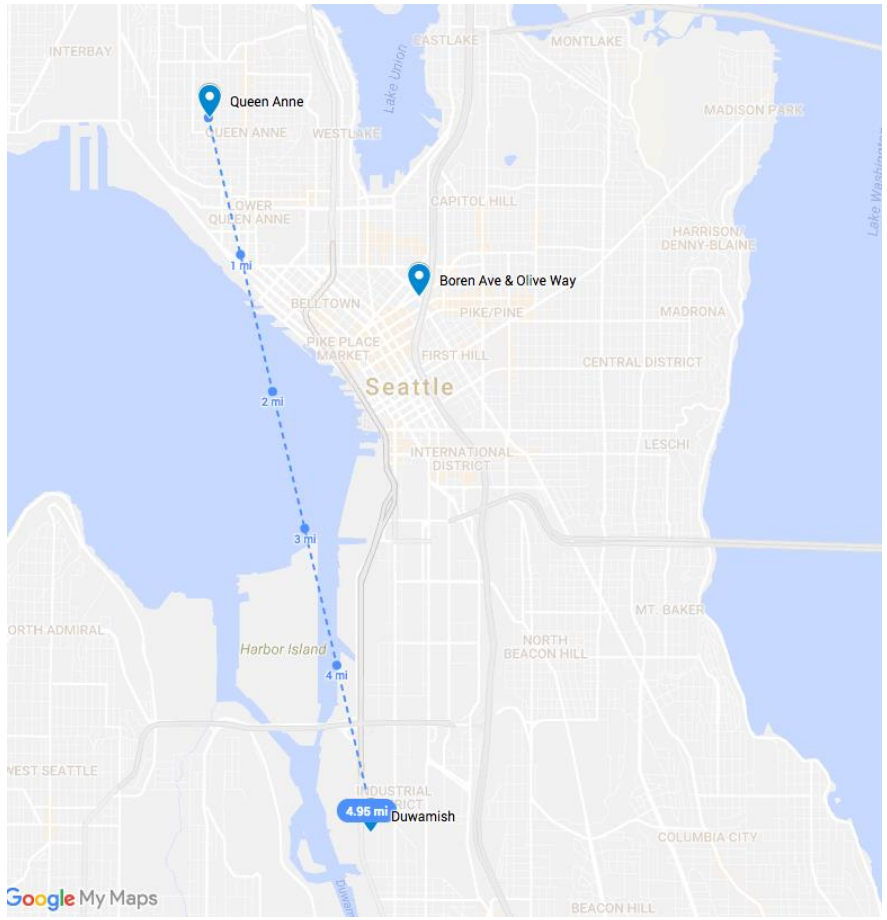
Credit: Tim Larson, UW

Site-specific calibrations for each nephelometer



R^2= 0.90 R^2= 0.81 R^2= 0.75

Monitors 5 miles apart



PSCAA follows 40 C.F.R. § 58 Appendix A requirements for quality assurance and quality control. Co-location, fit site-specific regression models.

Credit: Data from PSCAA

Summary

- There may be value in a tiered testing approach
  - Tier 1: Verifiable Manufacturer Testing
  - Tier 2: Use Case-Specific Testing Protocols, with Systematic Sharing of Performance Results

Thanks!