

Can low-cost sensors be used for informational PM-2.5 monitoring in Oregon?

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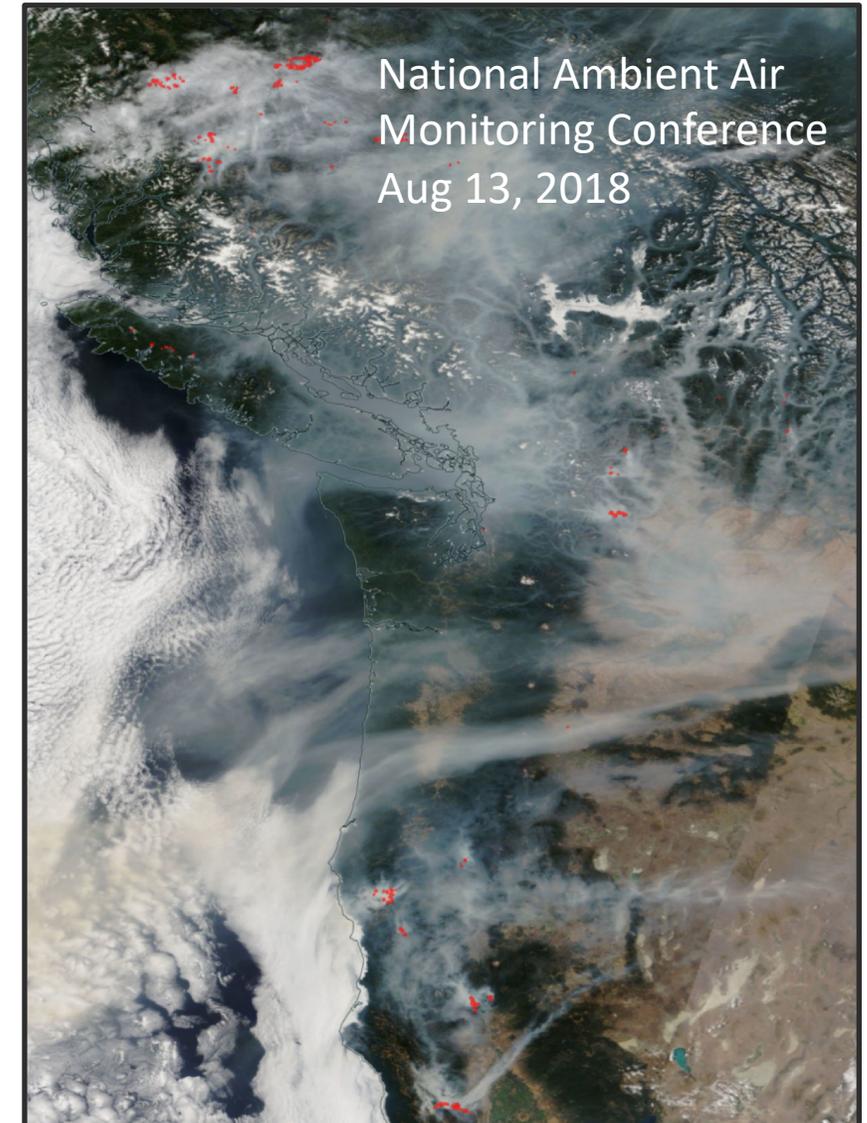
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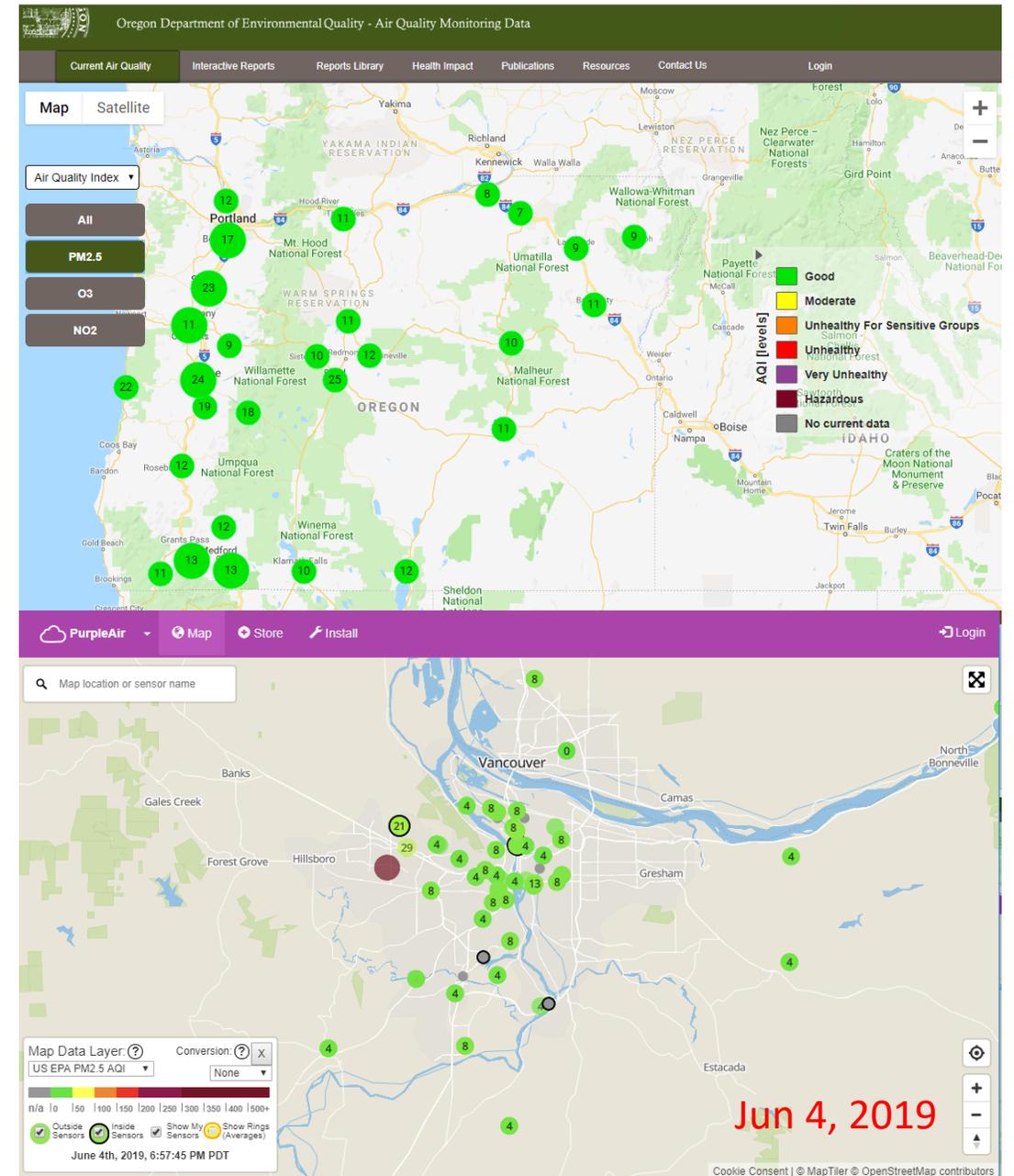
Acknowledgment: Phillip Orlando at Portland State University



Oregon DEQ's PM-2.5 Monitoring

- Existing PM-2.5 network
 - Federal Reference Method
 - ~ \$20k-35k for 1-site per year
 - Federal Equivalent Method
 - Informational-level monitoring (eg. Air Quality Index)

- Can low-cost sensors be used to expand PM-2.5 monitoring in Oregon?

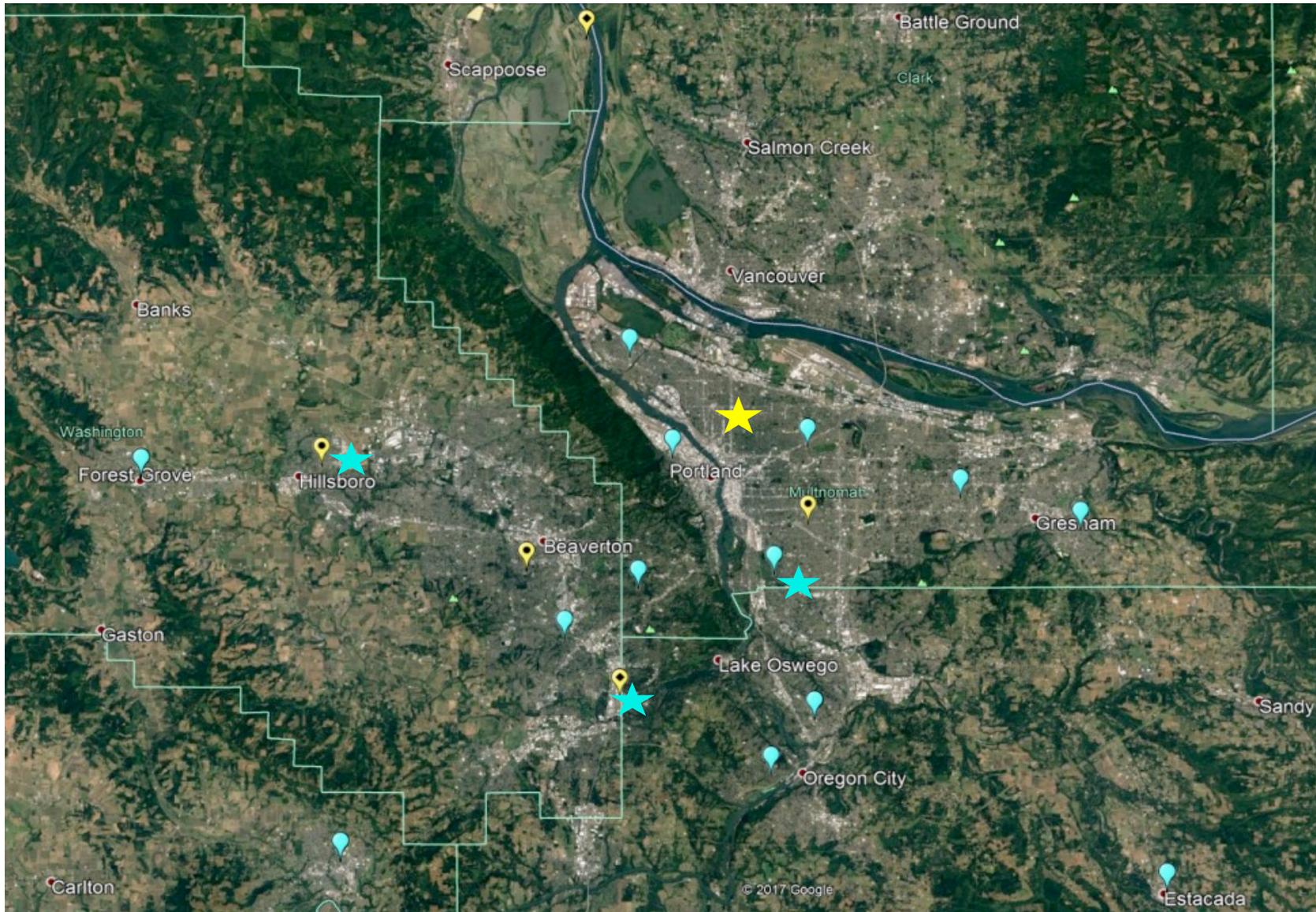


Project Background

Air quality sensors are in the early stages of technological development, as their accuracy and the value of their measurements are still being evaluated. Currently, the quality of data generated is unknown and the EPA has not approved them for comparison to federal air quality standards. Nonetheless, this new generation of low-cost, highly portable air quality sensors opens an exciting opportunity for people to use this technology for a wide range of applications beyond traditional regulatory monitoring. These include research, personal exposure monitoring, increased coverage, improved spatial and temporal resolution, source identification, emergency protection, education and community engagement. Oregon DEQ and many other groups are conducting research to learn more about these technologies.

Project Background

- We see air monitoring evolving from the regional to the neighborhood scale. Low cost sensors already make that possible, and the networks are growing rapidly. This can provide many benefits to regulatory agencies, but we need to focus our efforts to find ways to engage, educate, and empower our citizens.
- DEQ regularly receives questions/complaints about how its air quality data differ from low-cost sensors being installed by the public.



Key:

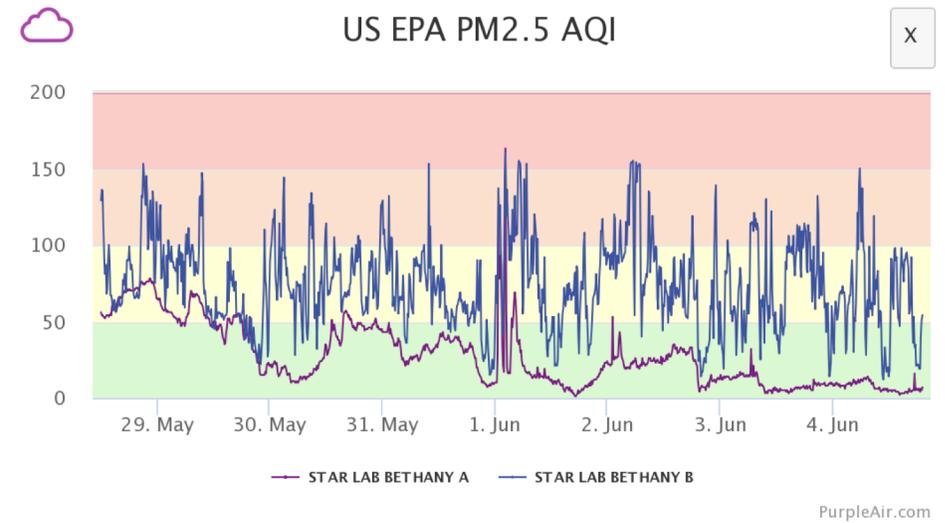
Yellow – Existing monitors, Blue – New Monitors, Star – Air Toxics

Low-cost sensor performance is often unknown

- South Coast/EPA/academic papers
 - Suitable for advisory/ambient PM monitoring
- Particular concerns
 - Drift
 - Spikes
 - Sensitivity to environmental conditions/siting
 - Aspiration effects
 - Data completeness
 - Longevity
- Integrative measures
 - Are they useful?
 - Do data meet Oregon's data quality objectives?



California's South Coast AQMD



Why build a low-cost PM sensor package at DEQ?

- Expand PM-2.5 monitoring using an approach that is consistent with existing methods in Oregon
 - Measurement approach
 - Use existing IT and AQM network infrastructure
- Provide publicly-owned near real-time data
- Provide data of known quality (e.g., traceable)
- Data should meet DEQ data quality objectives

Oregon DEQ data quality objectives

- Data completeness $\geq 75\%$

<https://www.oregon.gov/deq/FilterDocs/aqmlowcost.pdf>

<https://www.oregon.gov/deq/FilterDocs/aqmtargets.pdf>

- Air Quality Index data should be within $\pm 20\%$ FRM Data



State of Oregon Department of Environmental Quality

Air Quality Monitoring Performance Targets¹

Application	Pollutants	Precision & Accuracy ²	Examples	Supporting Documentation
Regulatory or compliance monitoring, Air toxics monitoring ³	Ozone, PM _{2.5} , CO, NO ₂ , SO ₂ , Lead, VOCs, HAPs ³	$\pm 10\%$	Filter-based FRM ⁴ sampler, Continuous FEM ⁵ PM monitor, FEM ozone analyzer, EPA laboratory protocols	40 CFR parts 50, 53, and 58, National Air Toxics Trend Station Technical Assistance document
Supplemental monitoring, Special studies, Real-time Air Quality Index	Ozone, PM _{2.5} , H ₂ S, VOCs, Meteorology	$\pm 20\%$	Nephelometer, E-BAM, H ₂ S monitor for odors, Calibrated met station, Sensor-based with quality control and validation	Organization's approved quality assurance plan or sampling analysis plan
Area and source surveys, Screening; Fenceline monitoring, Personal exposure	Ozone, PM _{2.5} , NO ₂ , VOCs, Meteorology	$\pm 30\%$	Calibrated sensors, Home met station	EPA Air Sensor Toolbox
Information, Education, Community monitoring	Ozone, PM _{2.5} , NO ₂ , CO, VOCs and others	$\pm 50\%$	Low-cost sensors, Personal monitors	South Coast AQMD Air Quality Sensor Performance and Evaluation Center

¹ This document is for informational use only. DEQ makes no claim, warranty or guarantee of instrument performance when operated by users for their specific applications.

² These guidelines are likely to evolve as technology and science advance.

³ Hazardous air pollutants or air toxics

⁴ Federal Reference Method

⁵ Federal Equivalent Method

Designing the Oregon DEQ PM sensor package

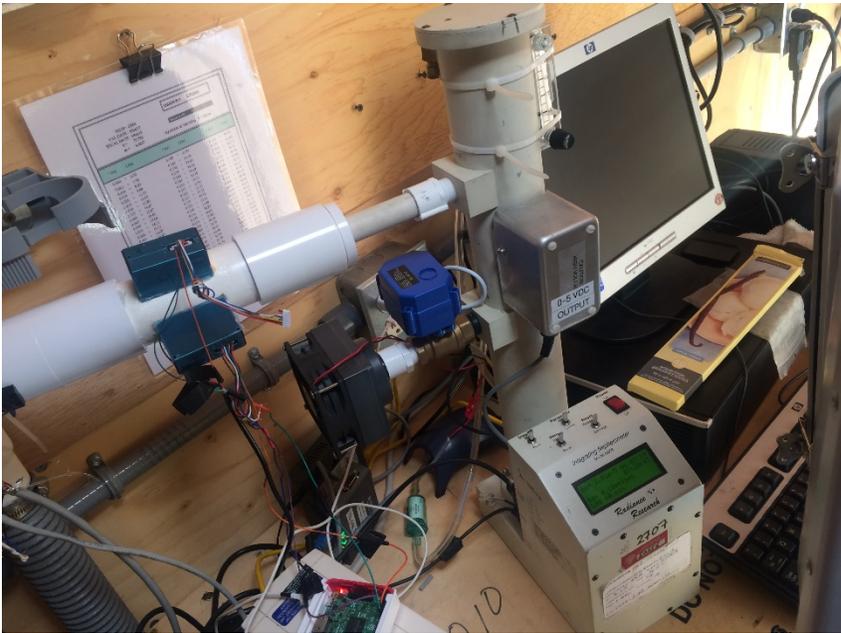
- Sensor selection – Background Research:
 - South Coast AQ SPEC/EPA/academic papers
- Data of known quality
 - Tracking sensor & performance
 - Identify drift & confirm sensor operation
 - Known data pipeline
 - Quality assessment
- Measurement technique
 - Optical PM measurements (composition, RH...)
 - Reduce environmental impacts on sensor
 - Ability to zero
- Provide communities with real time data
 - Cellular communication
 - Community work



2 Parts

Part 1: Inline with Nephelometer (Met One M903)

Examine Plantower sensor performance across Oregon

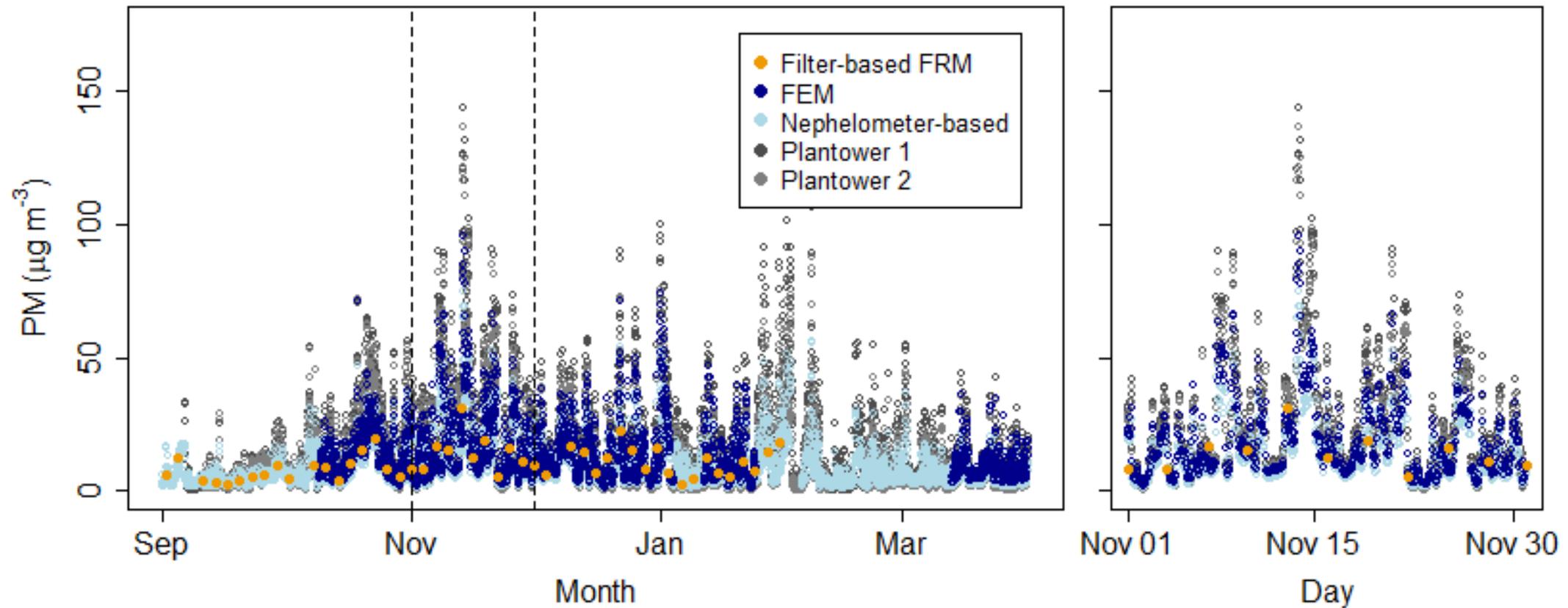


Part 2: Sensor Package

Stand-alone package for use in Oregon

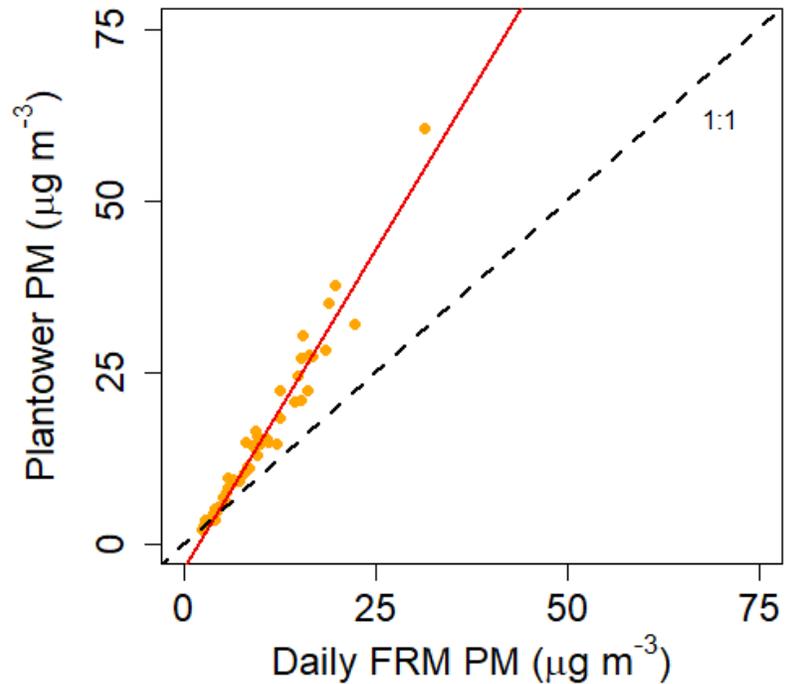


Part 1: Plantower PMS5003ST Vs. Nephelometer Performance

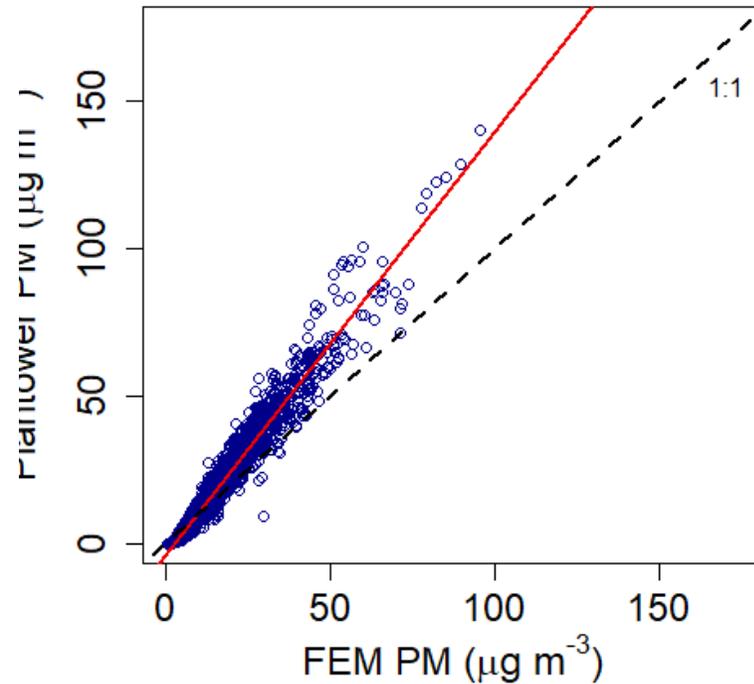


Plantower PMS5003ST comparison with co-located reference and informational-level monitors

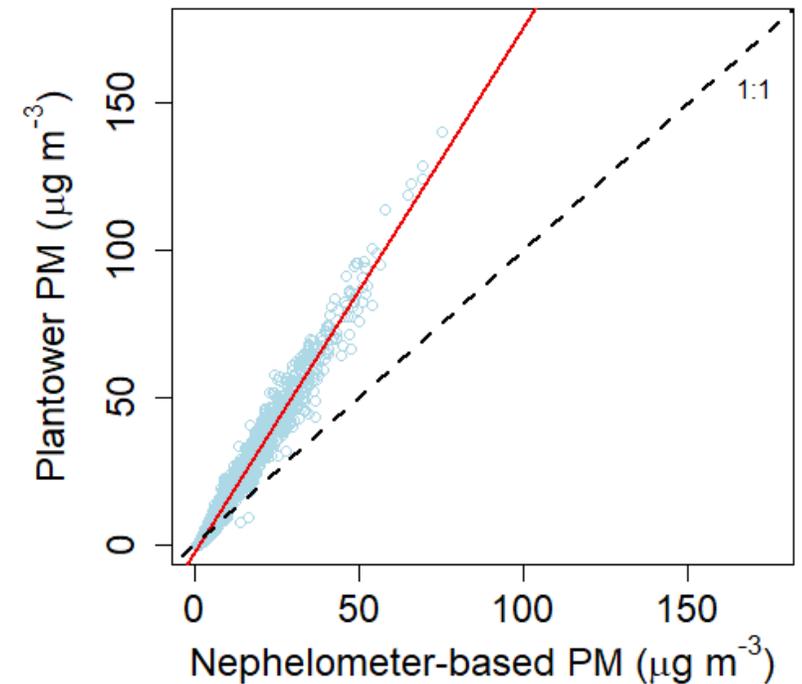
Plantower PM-2.5 = 1.86 * FRM PM - 3.33
 $R^2 = 0.96$



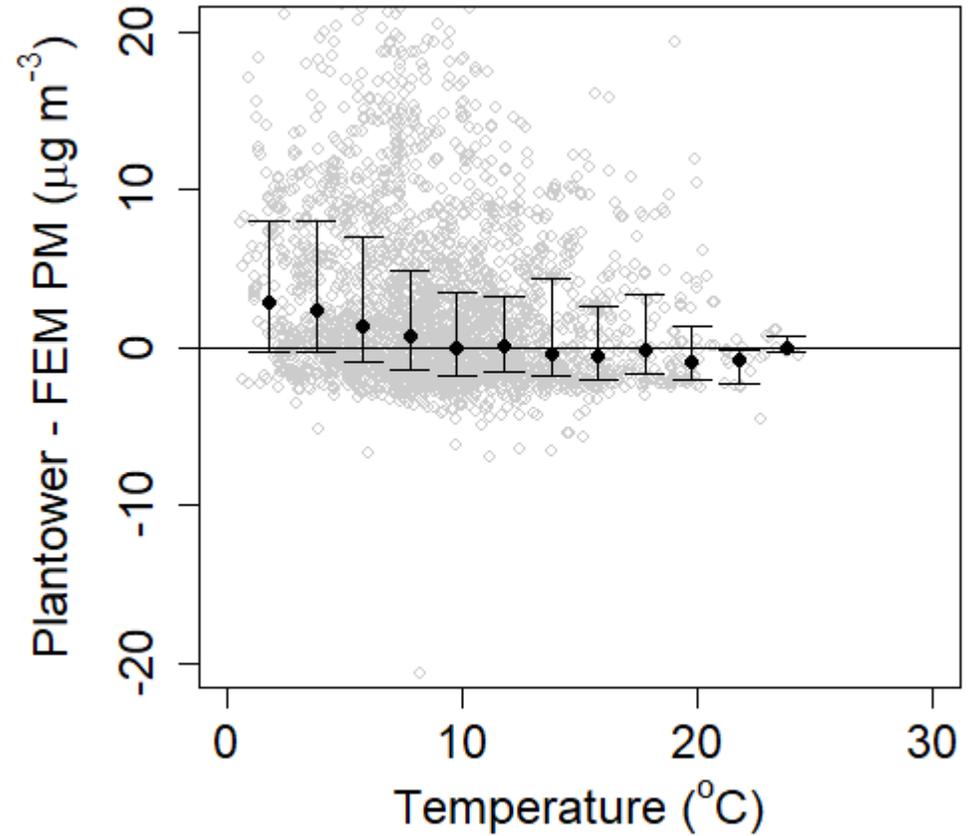
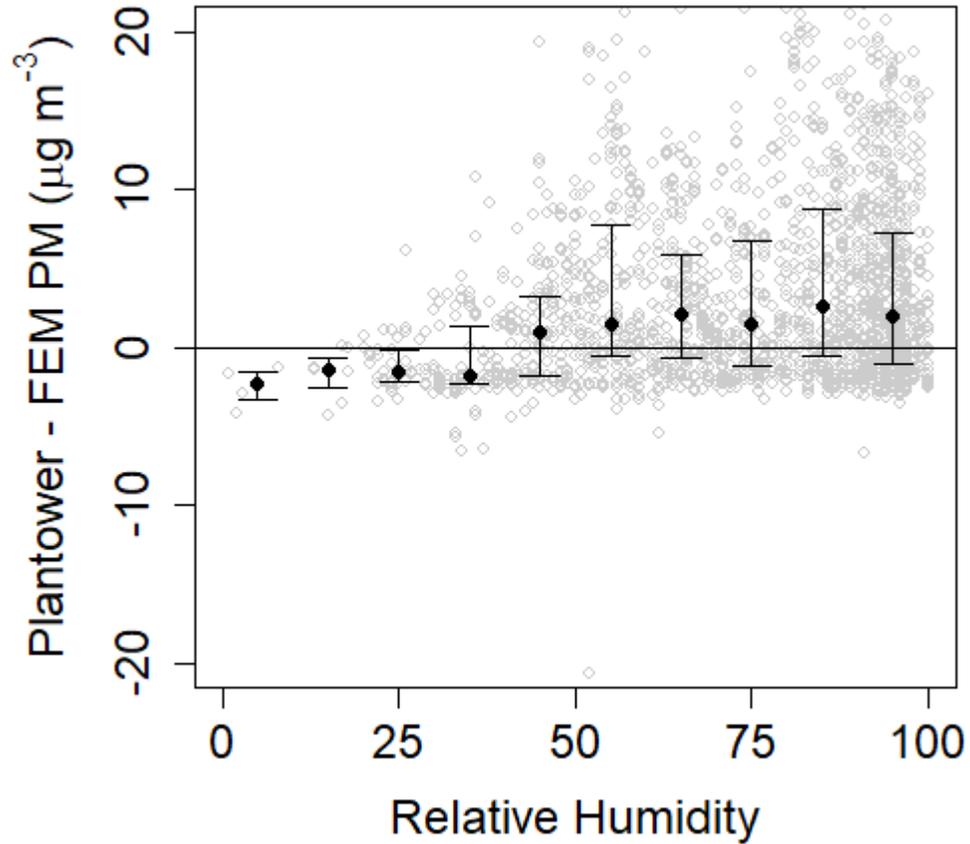
Plantower PM-2.5 = 1.44 * FEM PM - 3.70
 $R^2 = 0.96$



Plantower PM-2.5 = 1.79 * FEM PM - 2.38
 $R^2 = 0.98$



Plantower PM-2.5 Humidity-Temperature Dependence

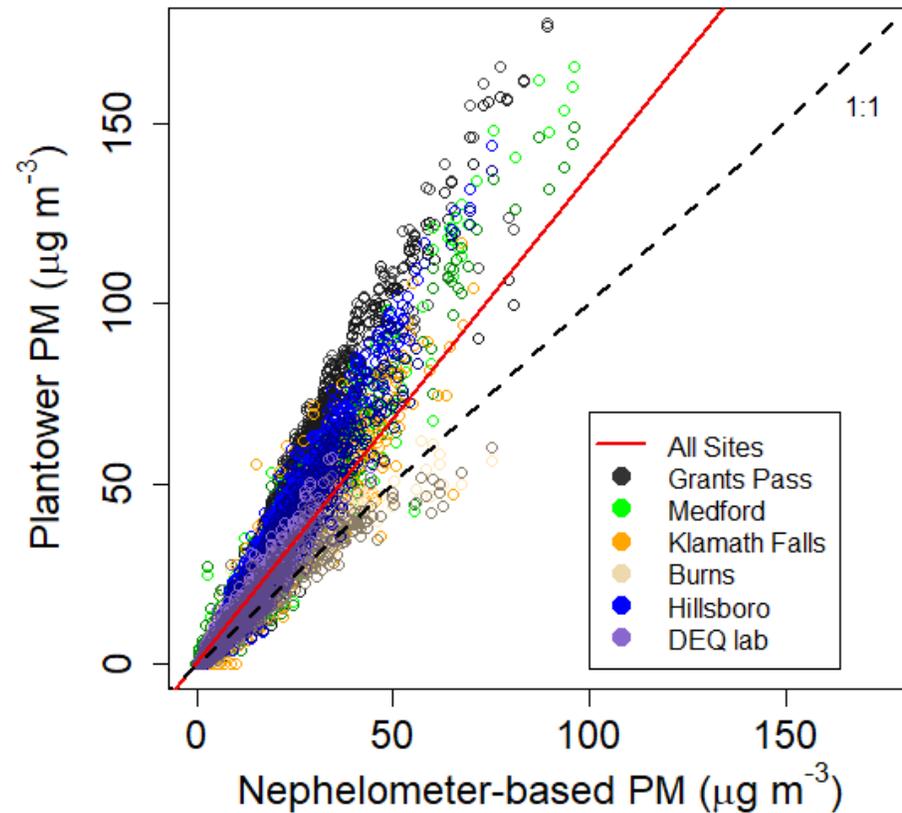


Sensor-Site Regressions

All sites combined:

$$\text{Plantower PM} = 1.35 * \text{Nephelometer-based PM} + 0.35$$

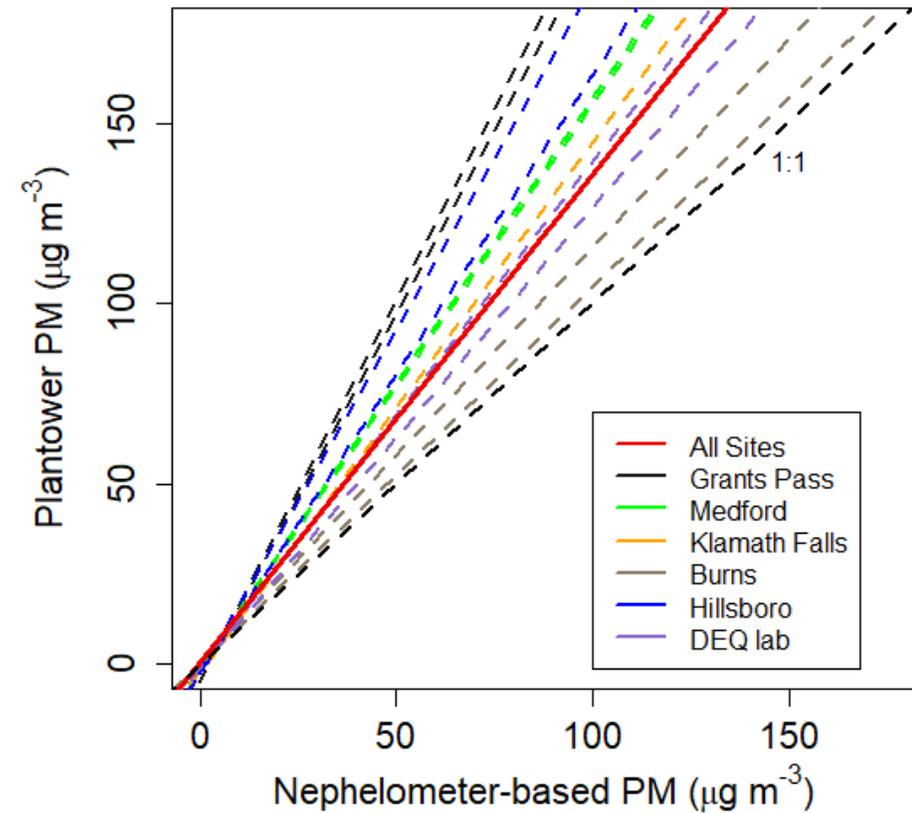
$$R^2 = 0.61$$



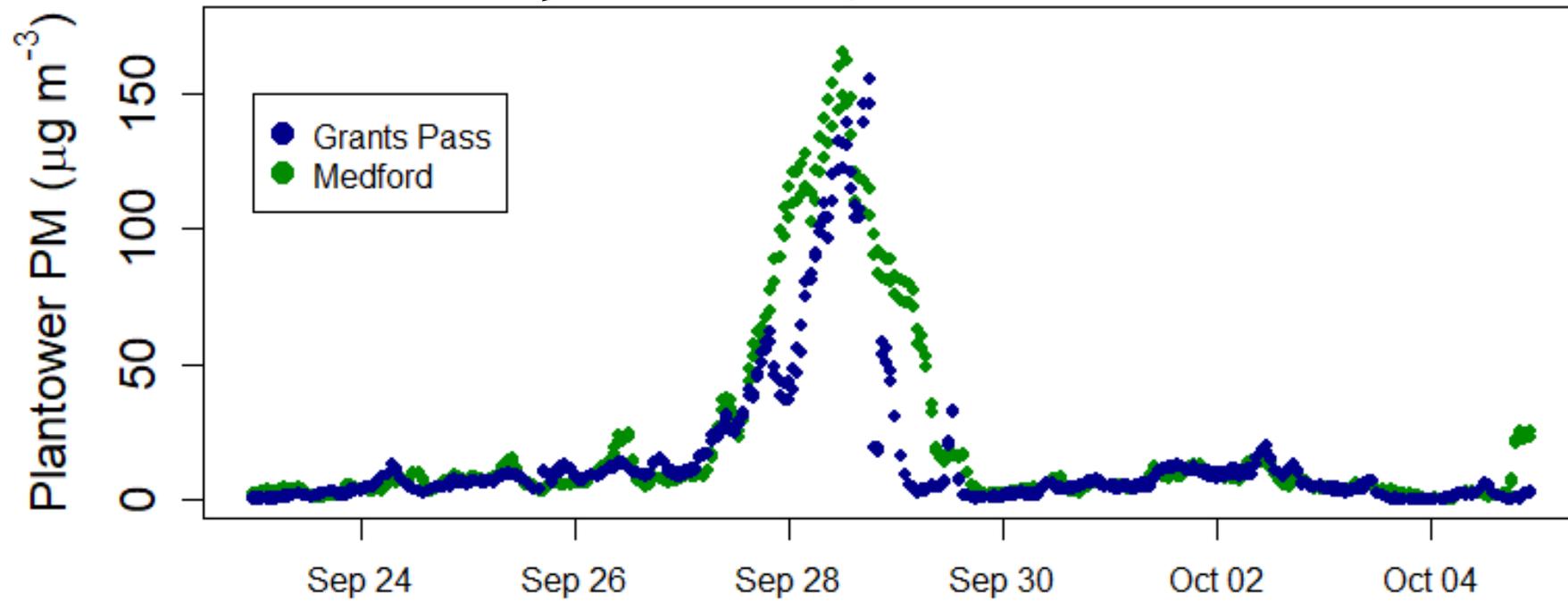
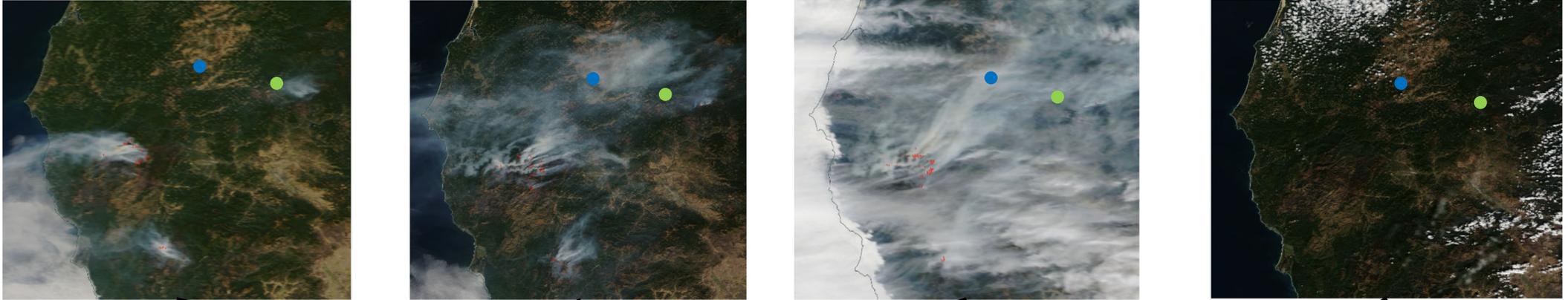
Site specific:

Slope range: 1.04 (Burns) - 2.11 (Grants Pass)

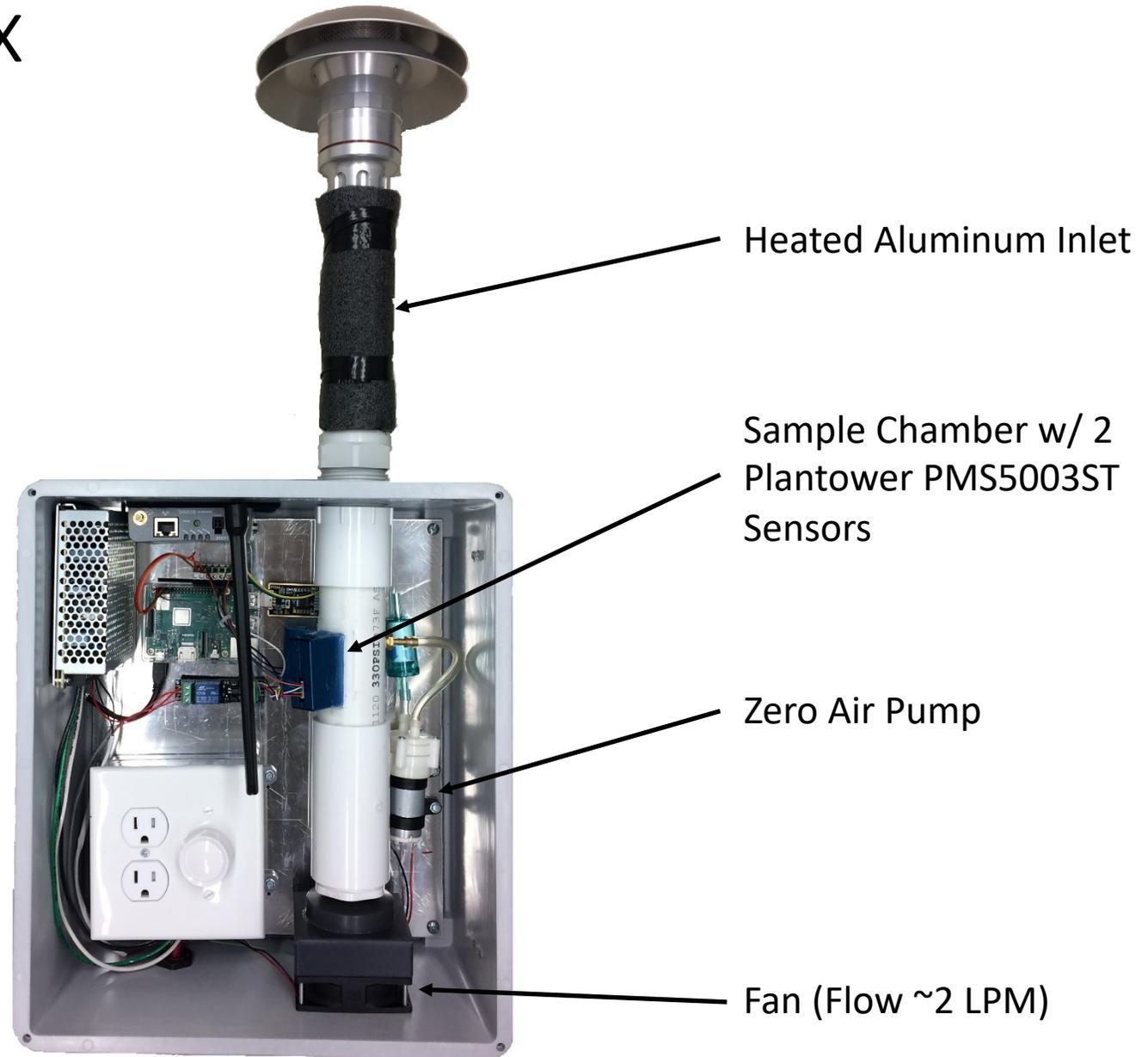
R^2 range: 0.91 (Burns) - 0.98 (Hillsboro)



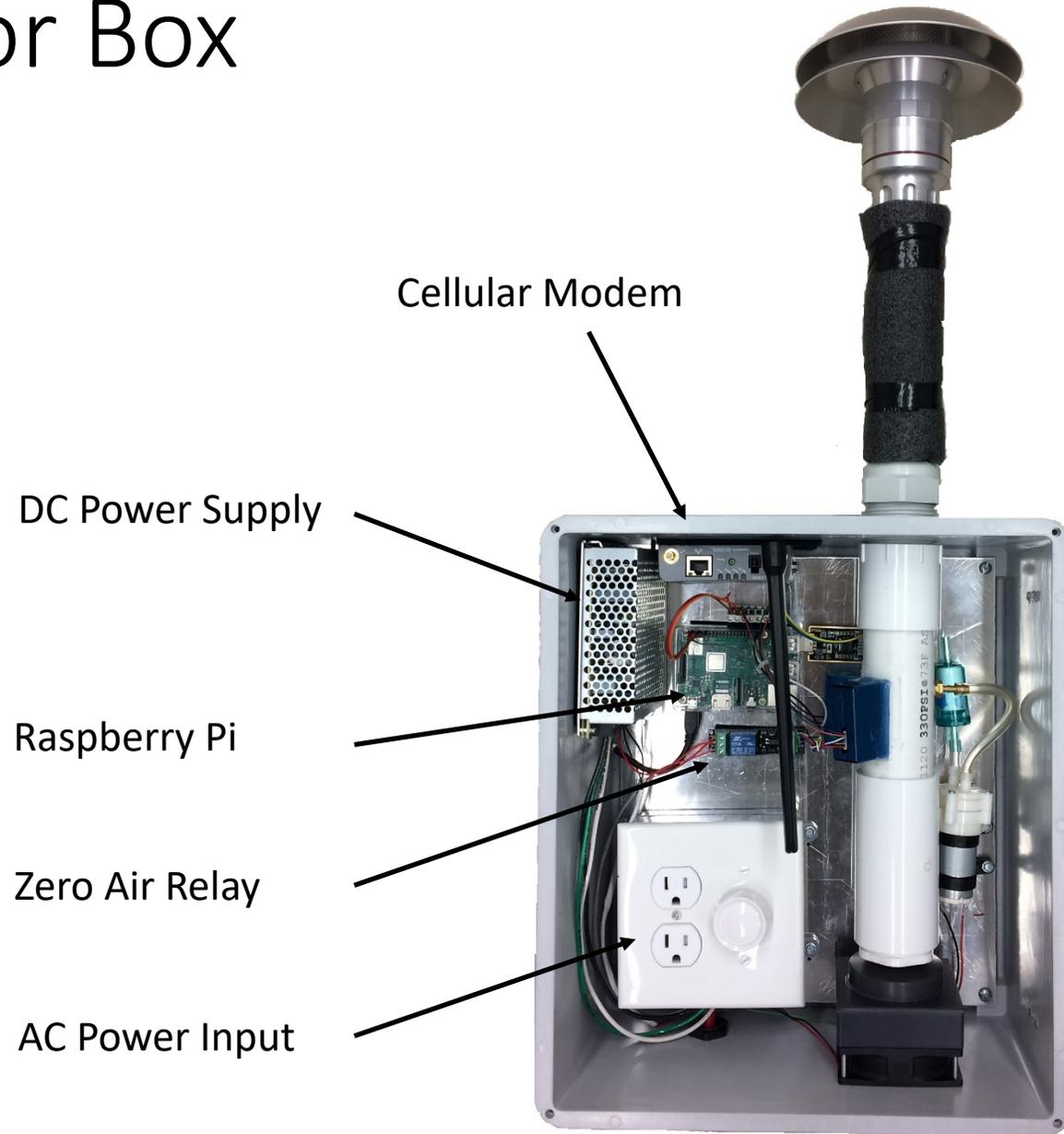
2018 Southern Oregon Fires



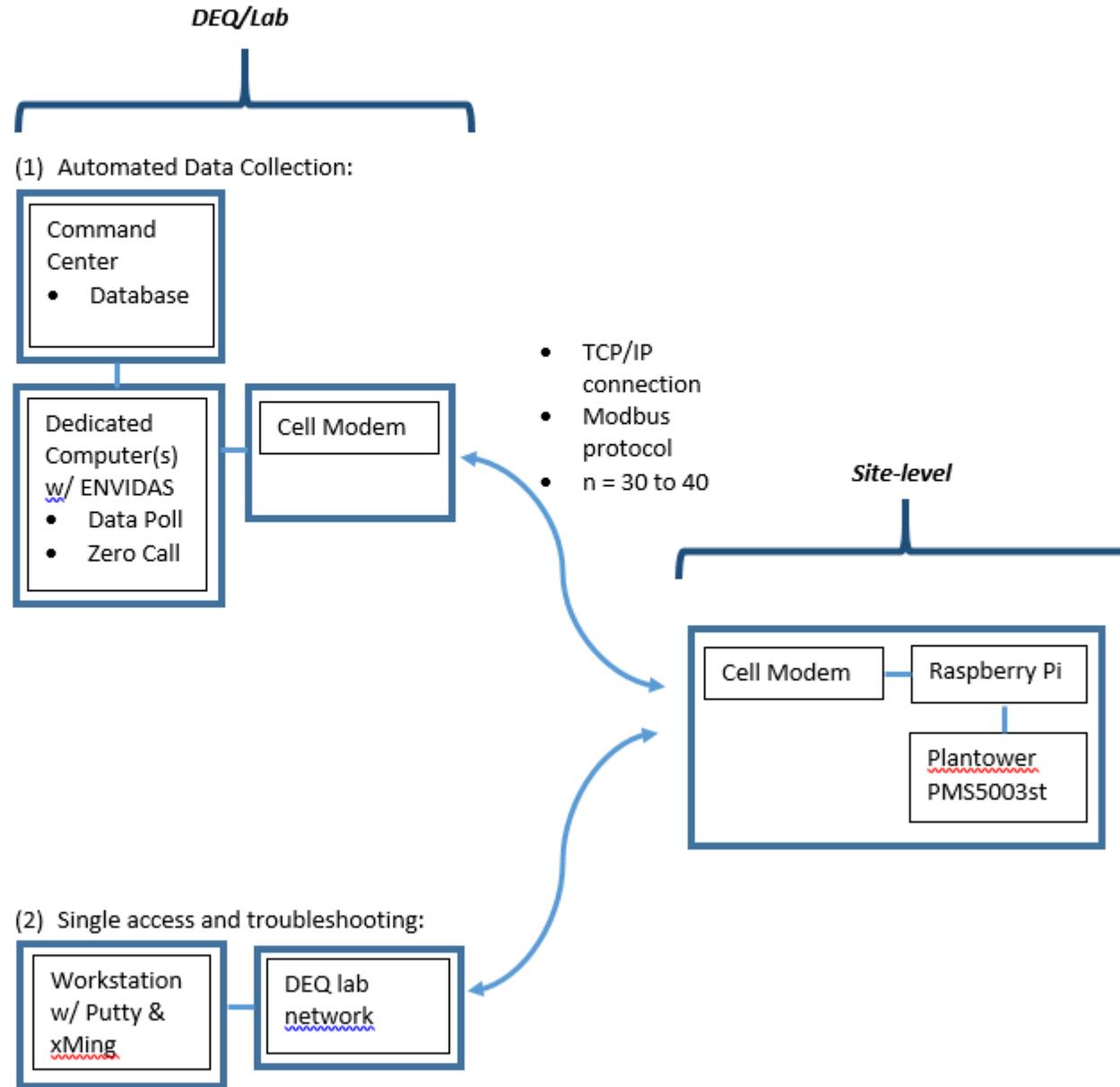
Part 2: Sensor Box



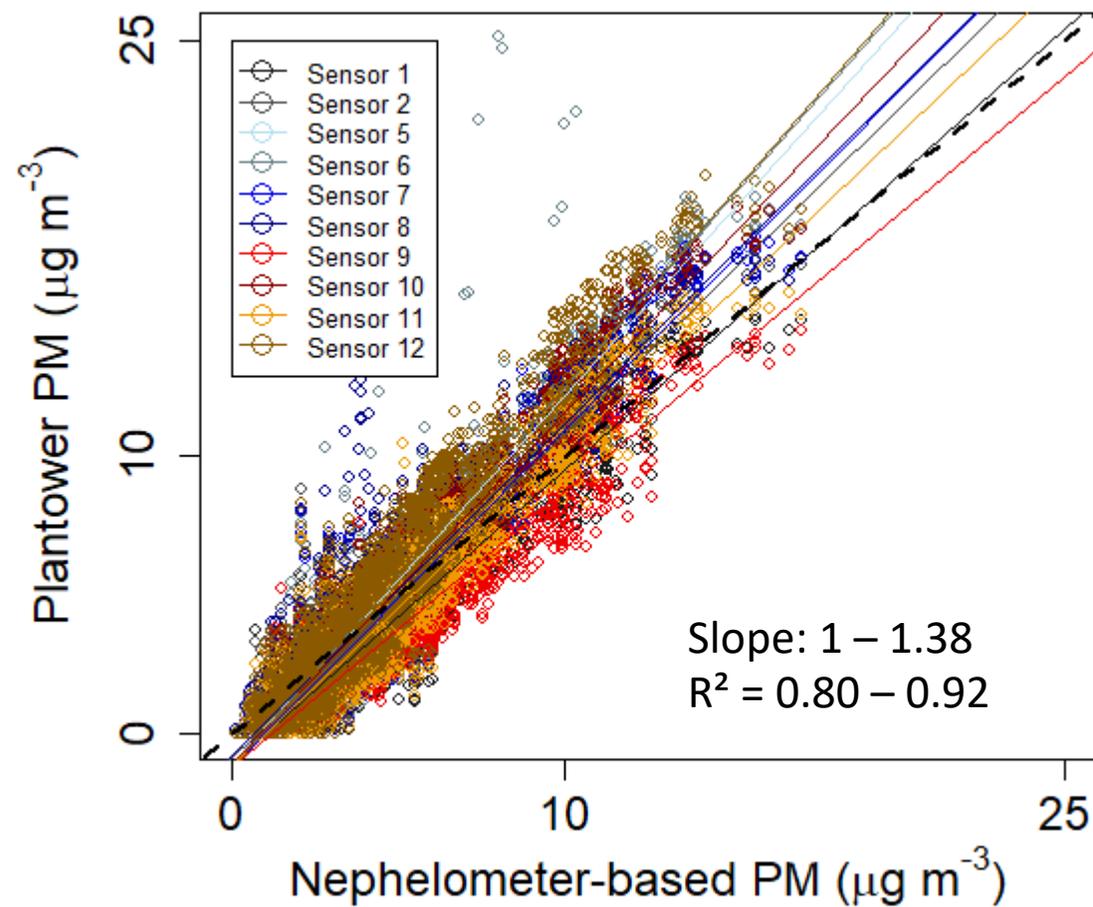
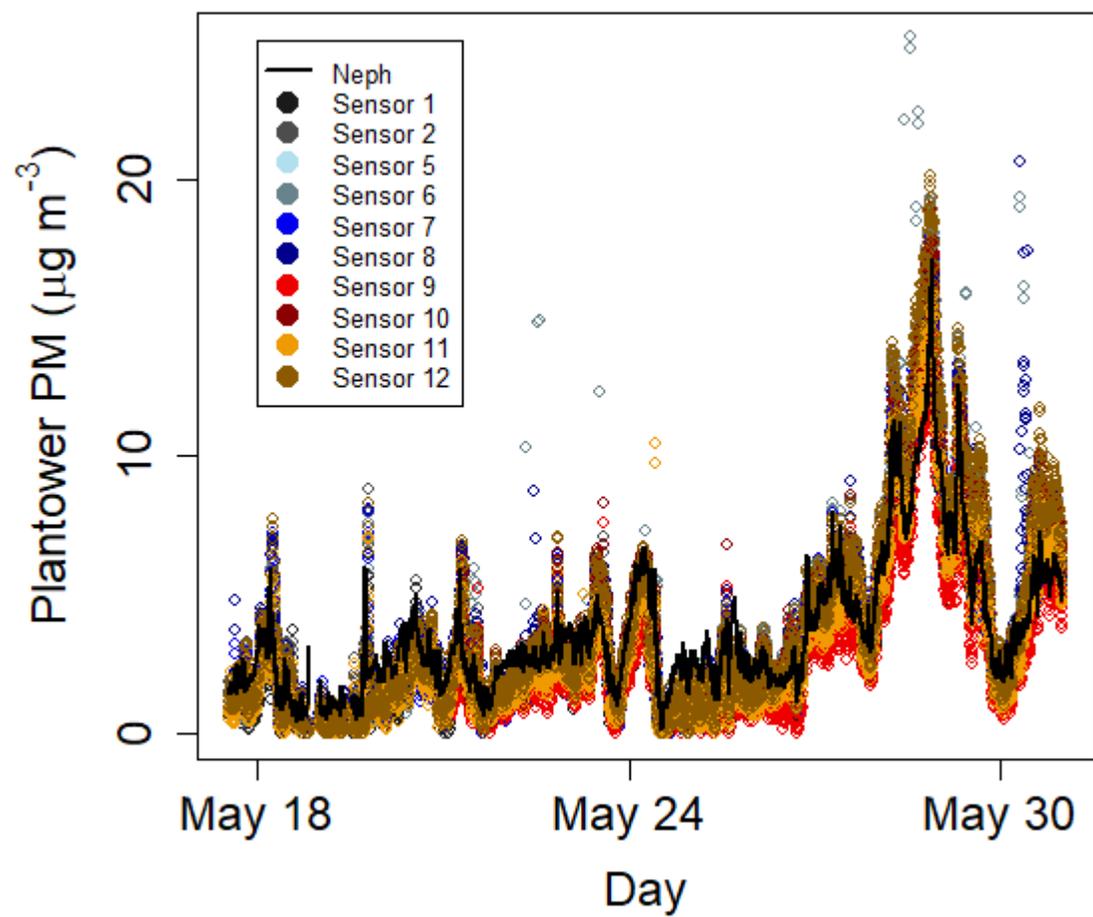
Sensor Box



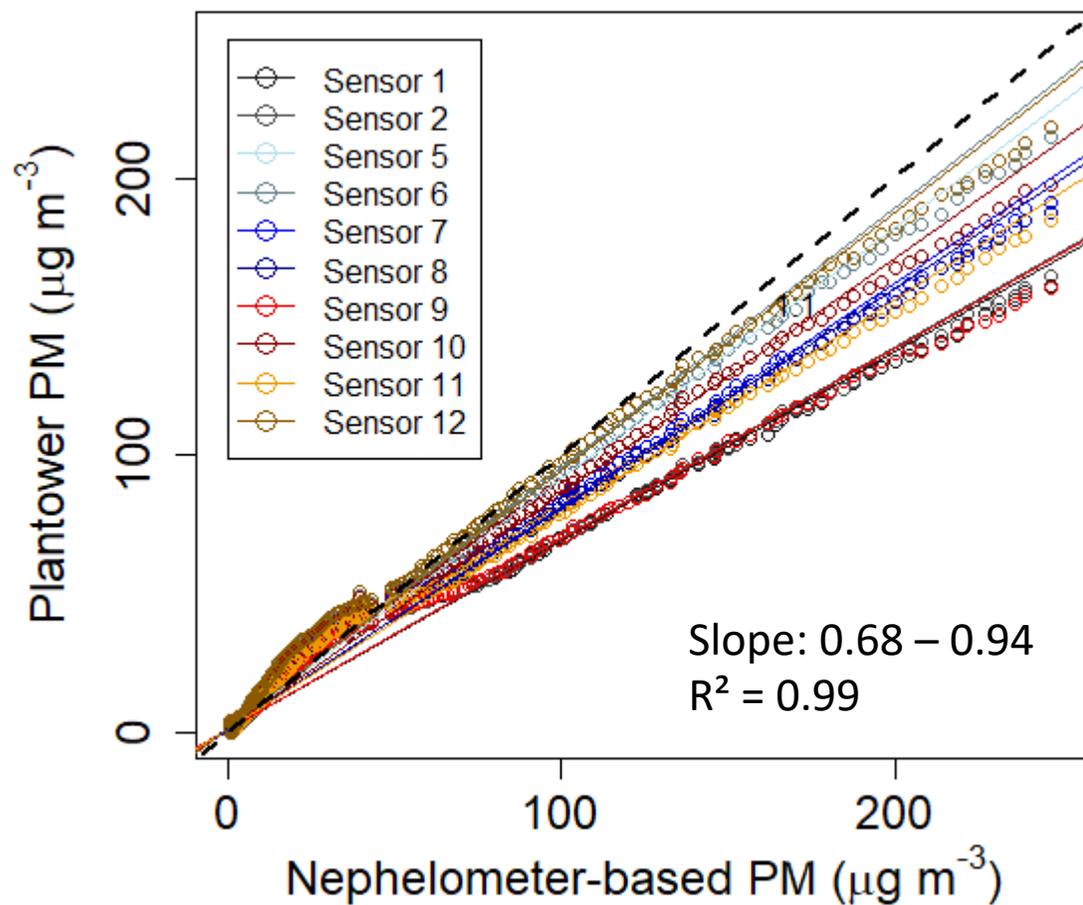
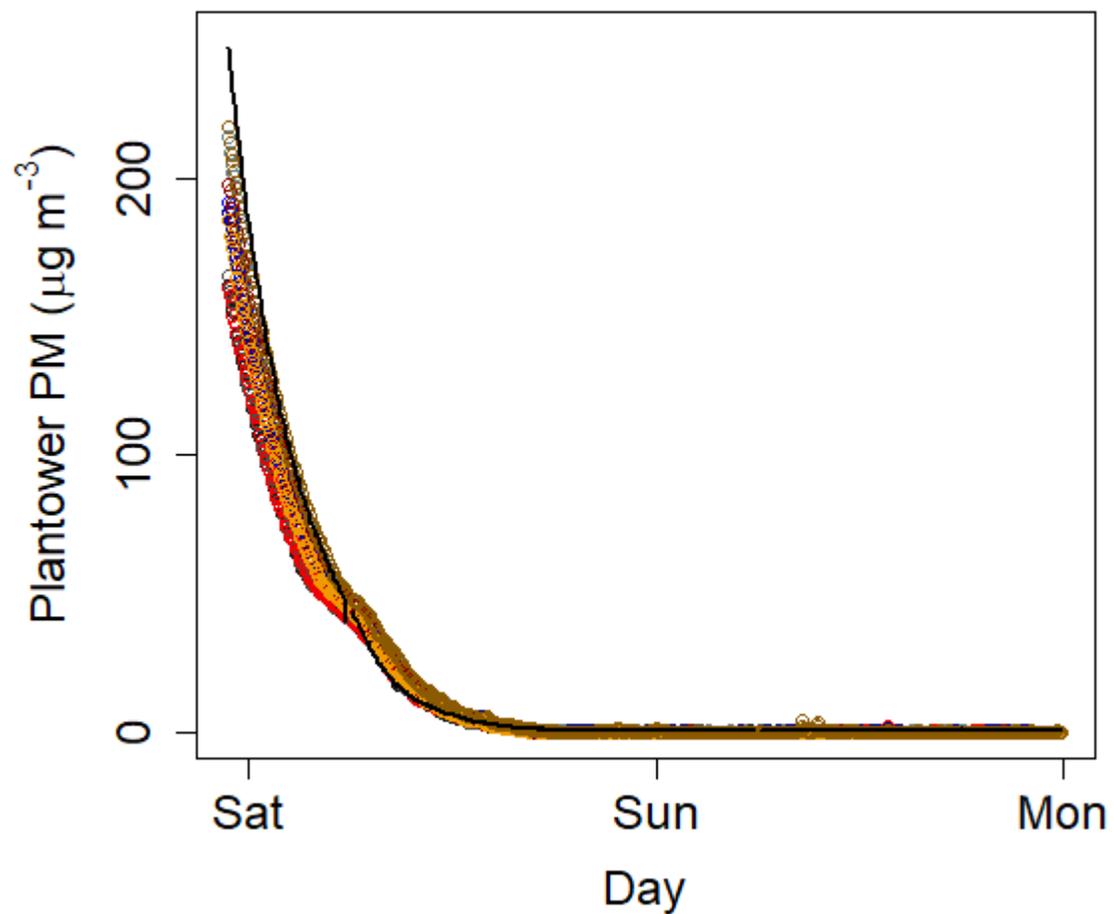
Data Flow



Group-test



Smoke-test



Conclusions

- Oregon DEQ built a low-cost sensor package
 - Aim was to provide informational-level PM data to the public
 - Plantower sensor showed good agreement with FRM/FEM/Nephelometer-based PM measurements
 - Will help expand spatial and temporal PM monitoring in Oregon
 - Legitimate use cases (e.g., Observed wildfire smoke)
- DEQ's sensor package
 - Strategy for identifying & mitigating low-cost sensor limitations (eg. Drift, environmental artifacts, etc.)
 - Consistent with existing informational-level PM monitoring in Oregon
 - Provide publicly-owned real-time data
- Including low-cost sensors for PM monitoring at Oregon DEQ
 - Careful consideration of data quality objectives
 - Network-level maintenance/QA (ongoing)
 - Community outreach (ongoing)

Future direction:

- Current focus
 - Refine sensor box
 - Determine site & sensor specific corrections
 - Address network-scale challenges (eg. Maintenance, data QA)
 - Community building/sensor hosting
 - Explore use for PM monitoring during field burning
- Long-term possibilities
 - Incorporate other pollutants/meteorology
 - Validate/improve PM forecasting models
 - Feedback/collaboration from the larger community