



DEPARTMENT OF  
**ECOLOGY**  
State of Washington

# Particle Sensors in the WA Ambient Air Monitoring Network

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WA Dept. of Ecology, Air Quality Program

June 2023

# Air Quality Dot Map Web & Mobile App

*Now including PM sensors!*

Interactive Map | Smoke Forecast | Burn Bans | Reports | FAQ | Information | About us | Contact us

Air Quality Index ▾

ALL

PM2.5

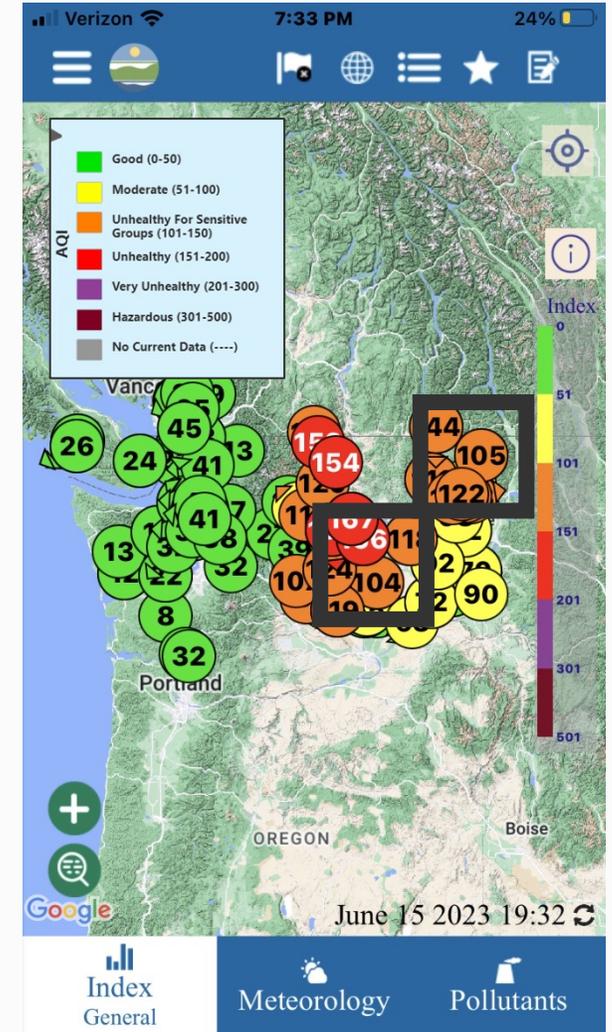
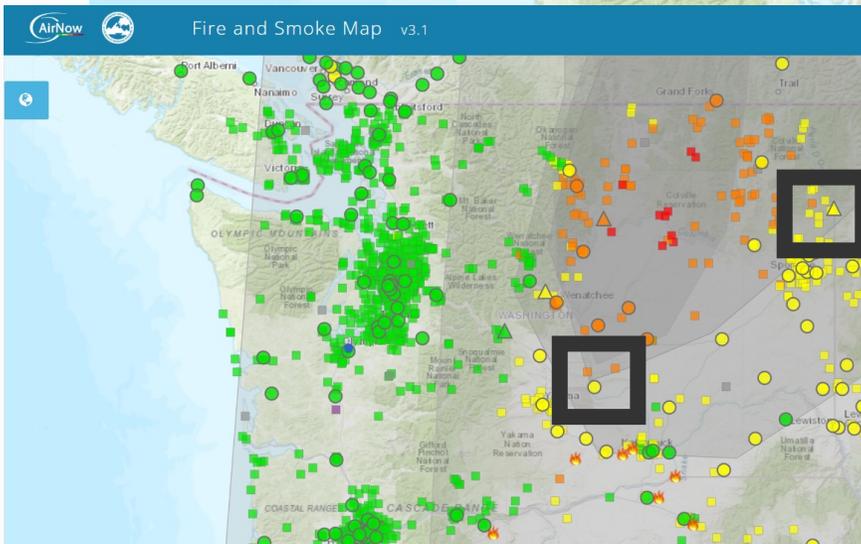
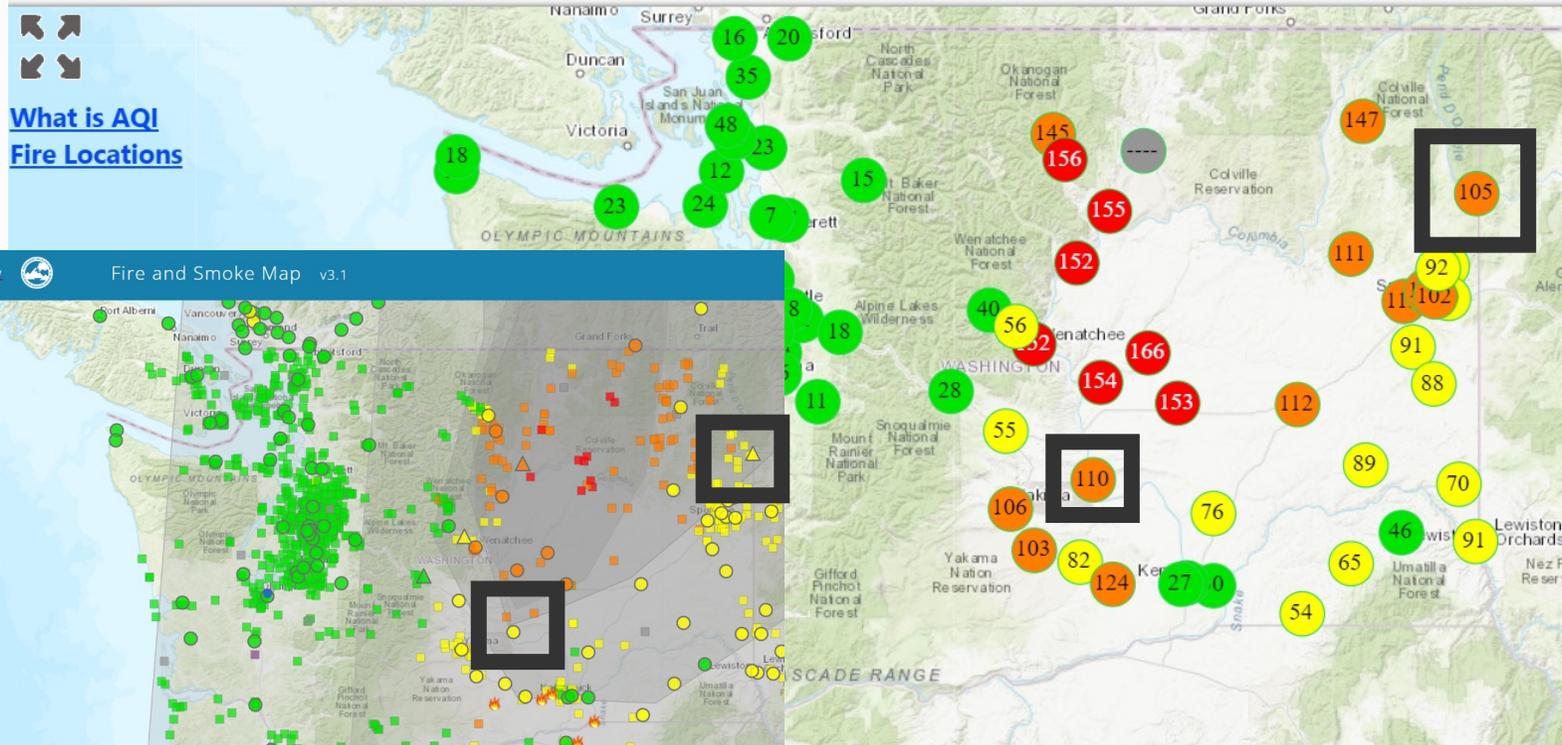
O3

NO2

SO2

CO

PM10



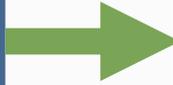
Smoke event - June 16, 2023

# WA Ecology PM Sensor Uses

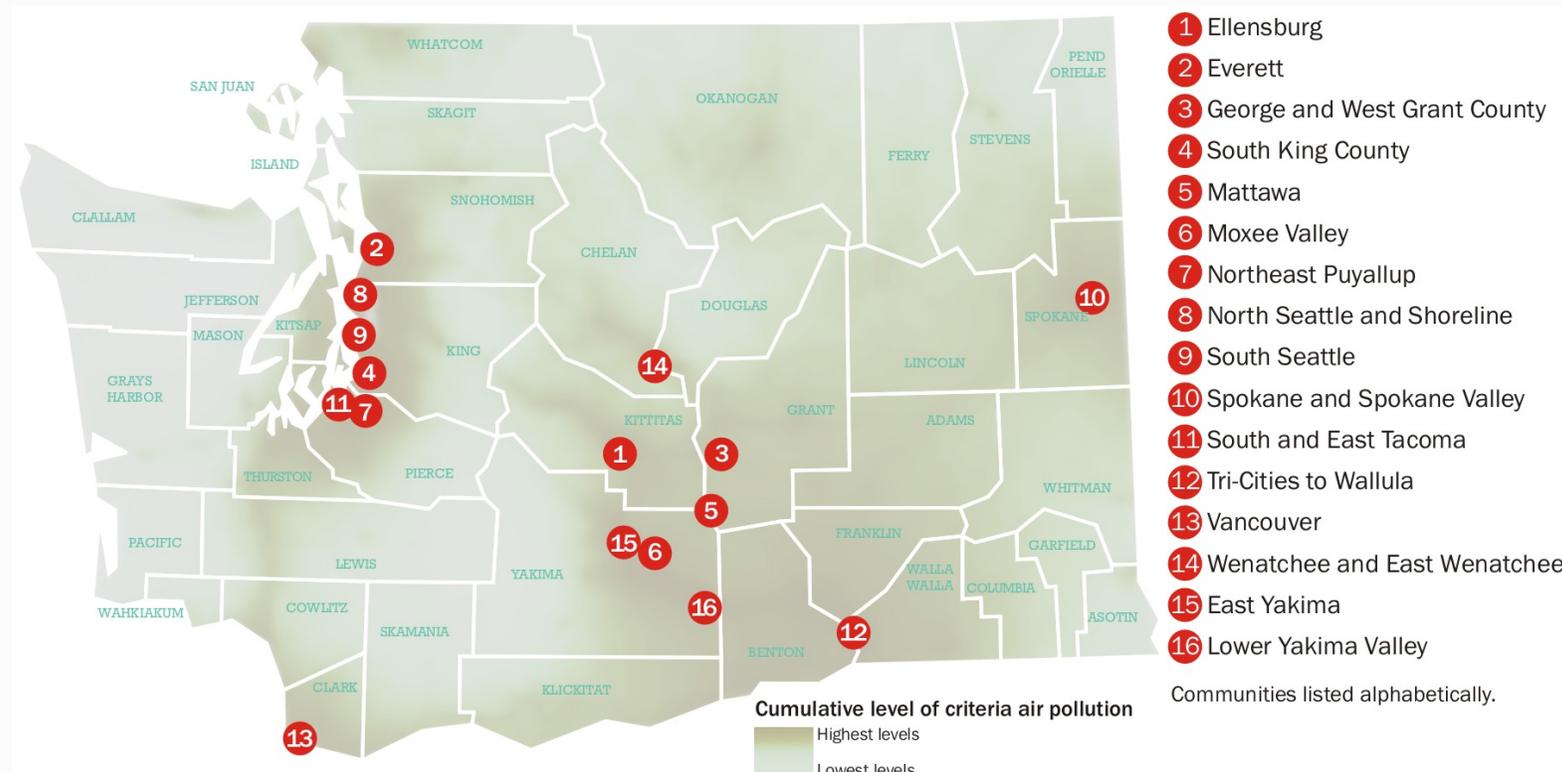
- Sensors fill need for low-cost, portable, and easily deployable PM monitoring.
- Applications include:
  - Temporary monitoring of smoke from wildland fires
  - Surveys or saturation studies of unmonitored areas
  - Monitoring to aid in smoke management decisions
  - Increased monitoring in communities overburdened by air pollution (Section 3 - Climate Commitment Act)

# Climate Commitment Act Expanded PM<sub>2.5</sub> Monitoring

Characterize community-scale  
pollution patterns



Use data to act to reduce air pollution  
inequities



Map of overburdened communities highly impacted by air pollution

# Ecology's SensWA PM<sub>2.5</sub> Sensor



Exterior

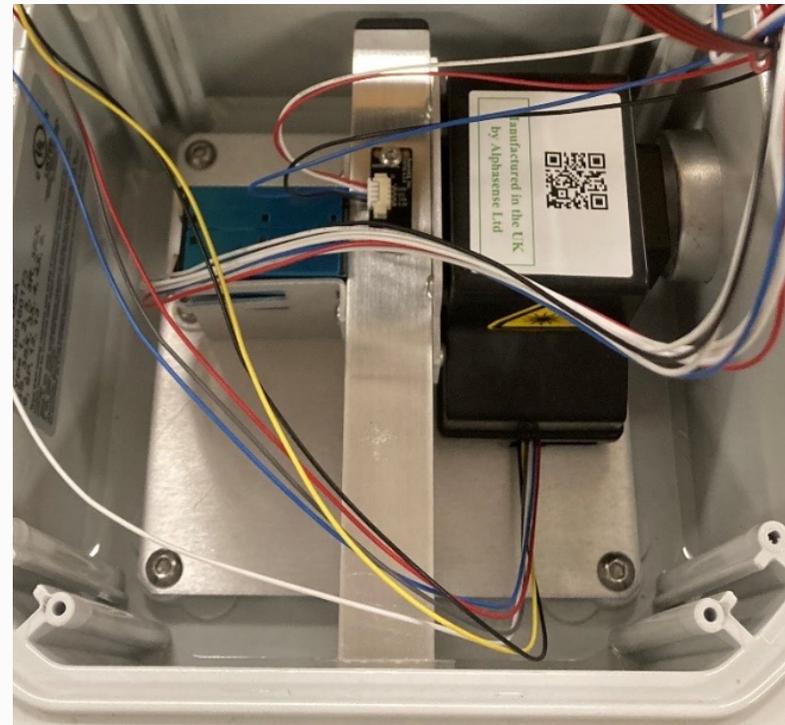


Interior

# QuantAQ Modulair-PM $PM_{10}$ Sensor



Exterior



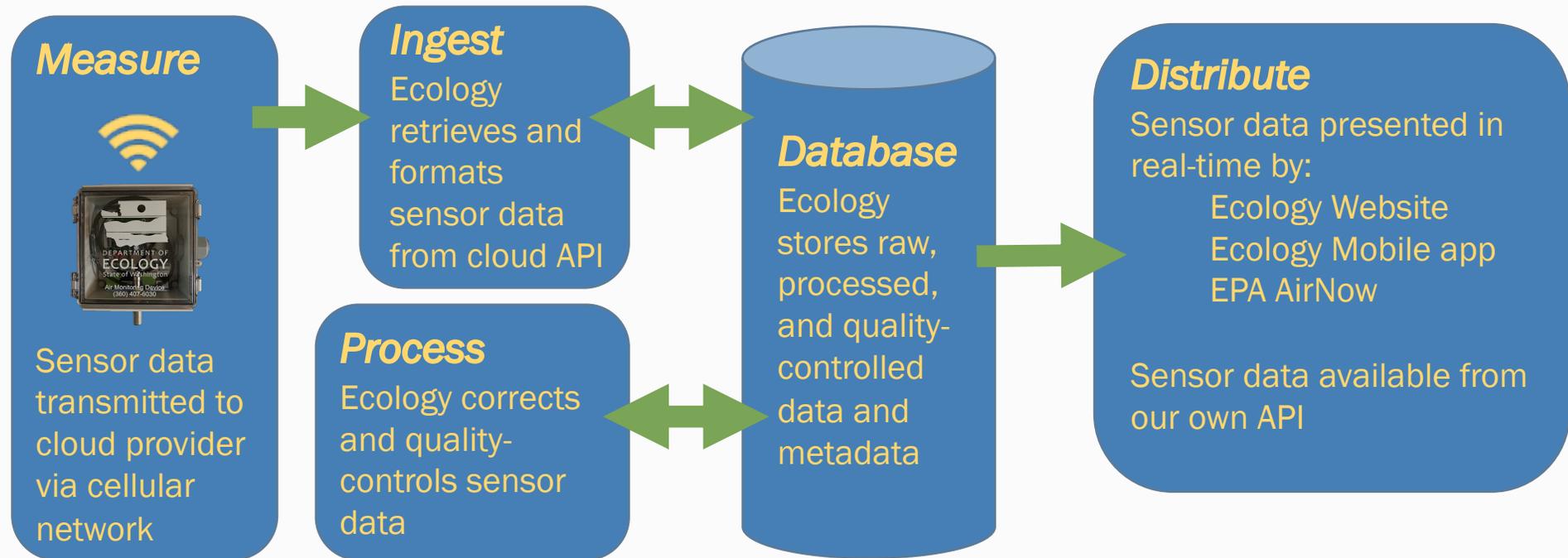
Interior

# PM Optical Measurements

- Nephelometer (PM<sub>2.5</sub>)
  - Measures ensemble particle light scattering
  - Convert to mass concentration based on assumed mass scattering efficiency
- Low-cost PM sensors (PM<sub>2.5</sub>)
  - Function as a mini-nephelometer
- Particle Counter (PM<sub>10</sub>)
  - Sizes and counts individual particles via light scattering
  - Converts to mass concentration based on assumed particle density

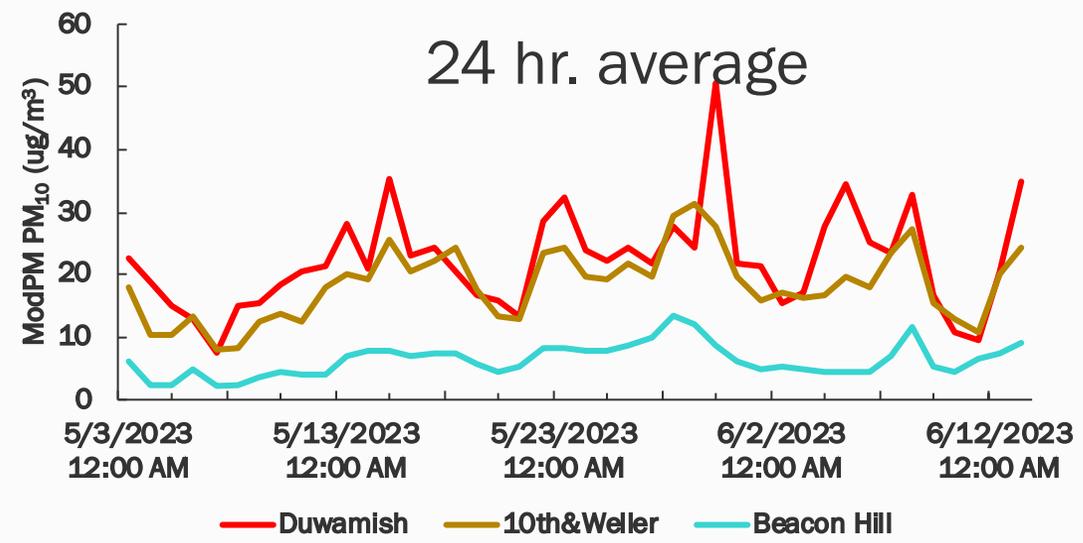


# SensWA PM<sub>2.5</sub> Sensor Data Flow



# Seattle PM<sub>10</sub> Sensors

Uncalibrated  
May '23 - Present



	24-hr ModPM PM <sub>10</sub> (BAM PM <sub>2.5</sub> ) (ug/m <sup>3</sup> )		
	Duwamish	10th & Weller	Beacon Hill
Min.	7.5 (2.5)	8.0 (4.0)	2.2 (2.3)
Max.	50.6 (9.6)	31.3 (12.1)	13.42 (9.6)
Avg.	22.2 (6.1)	18.4 (8.2)	6.37 (5.5)
STD	8 (2.0)	5.6 (2.2)	2.6 (1.8)



**Duwamish = Industrial**  
**10<sup>th</sup> & Weller = Near-road**  
**Beacon Hill = Residential**

# Sensor Calibration: PM<sub>2.5</sub> & PM<sub>10</sub>

- Collocation-correction process replaces traditional calibration
- Collocation with Beta Attenuation Monitor (BAM)
- Collocate in community to monitor
- Correct to account for unique sources and aerosol composition

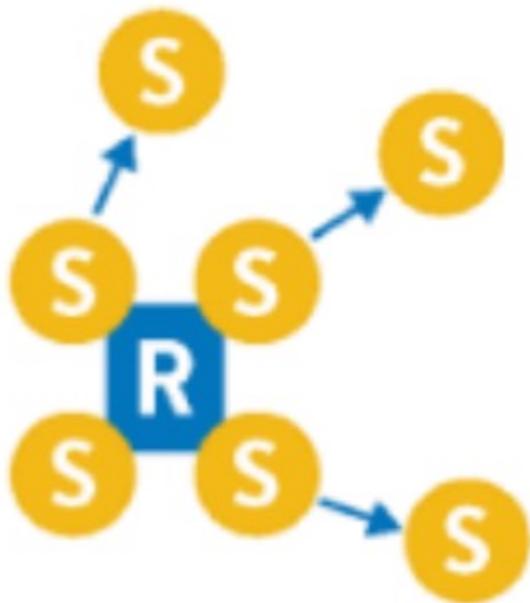


**ModPM & BAM PM10**  
Spokane-Broadway



**SensWA & BAM PM2.5**  
Spokane-Broadway

# Continuous Subset Collocation Strategy



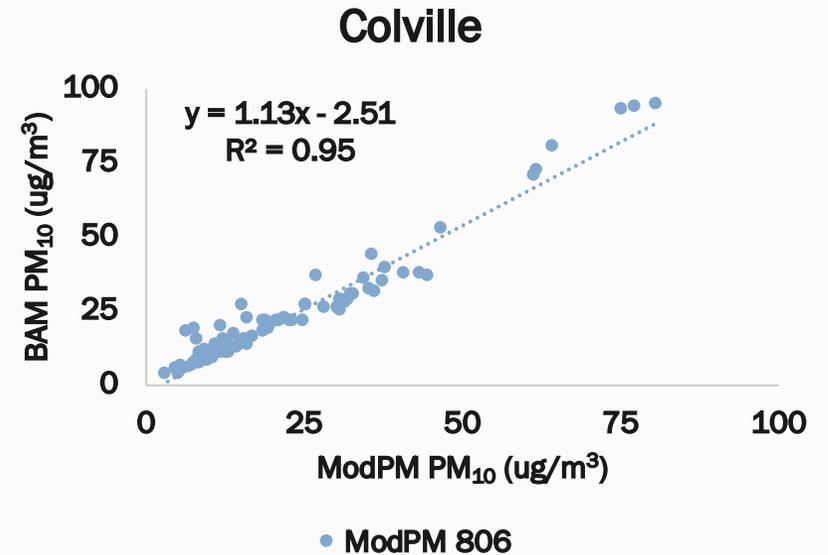
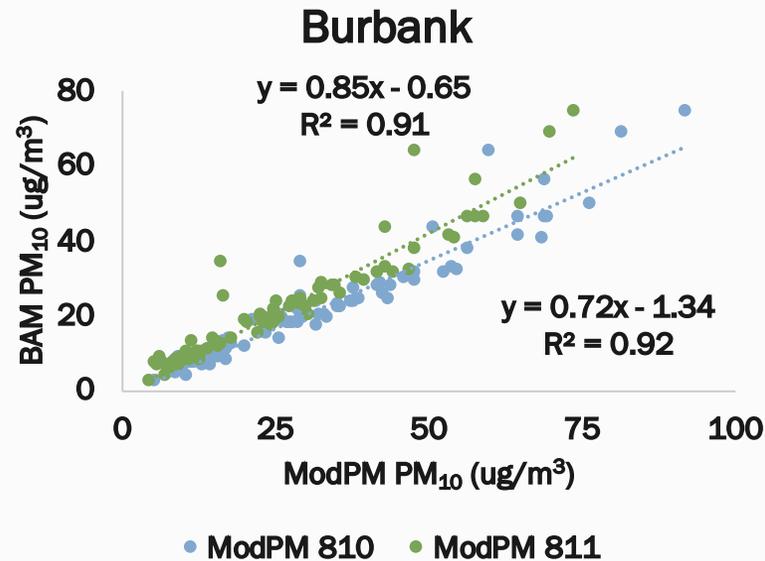
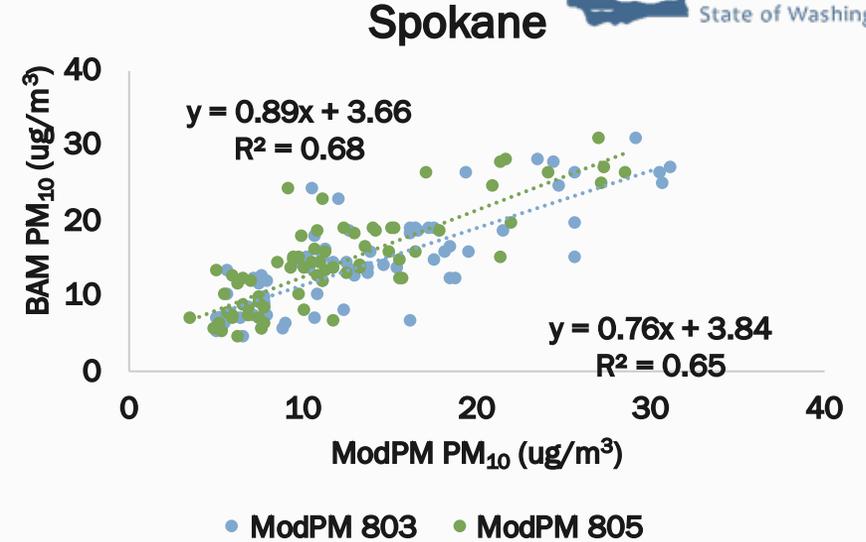
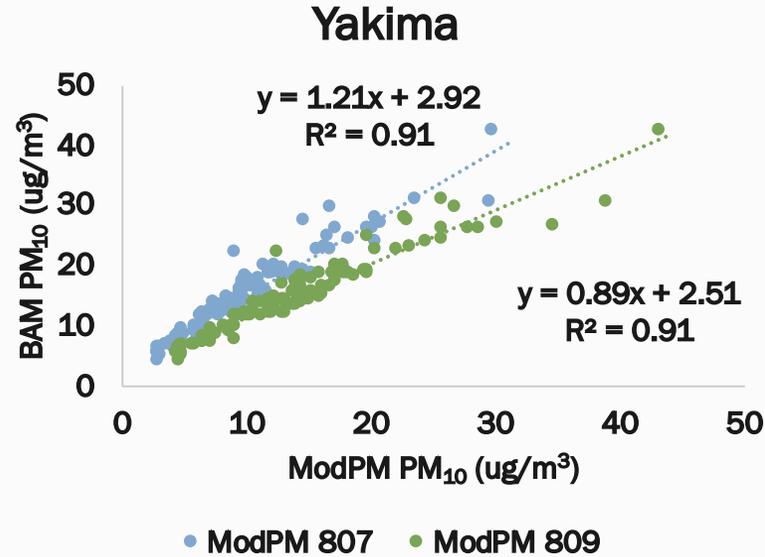
## Key

**S** sensor

**R** reference  
instrument

- Adapted from EPA's Enhanced Air Sensor Guidebook (Dec. 2022)
- Collocate all sensors first with BAM for >30-day period (*in progress*)
- Satellite sensors deployed in surrounding area
- Sensor(s) continuously collocated
- Satellite sensors collocated for 30-day period annually

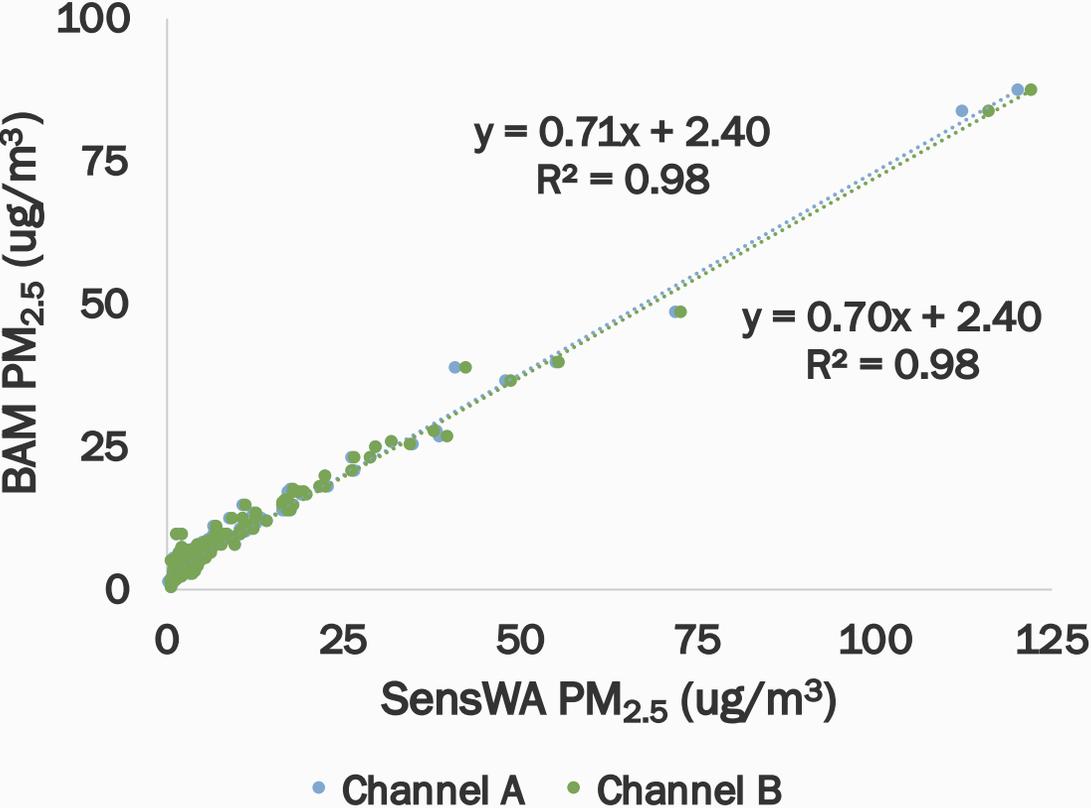
# BAM PM10 Central & Eastern WA Collocations (March – June 2023)



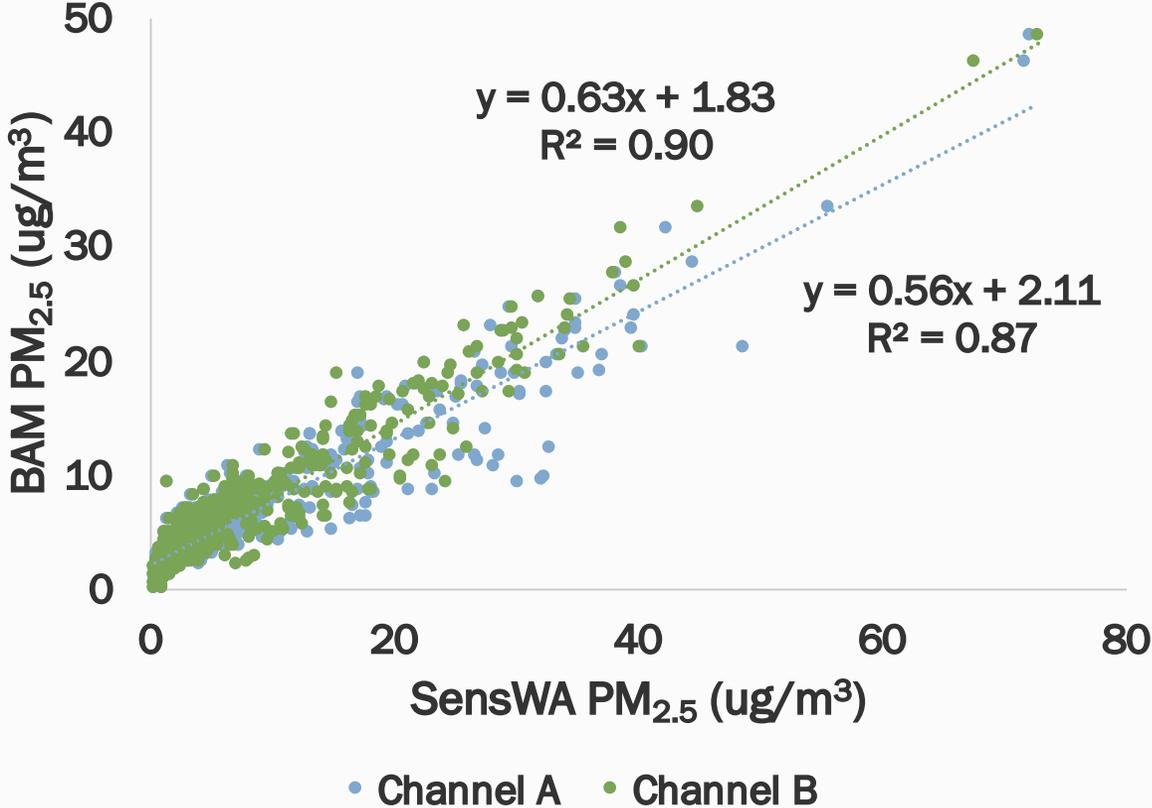
24 hr. averages

# SensWA Ellensburg BAM Collocation

Ellensburg Smoke Season 2021-2022  
(Jul. - Oct.)



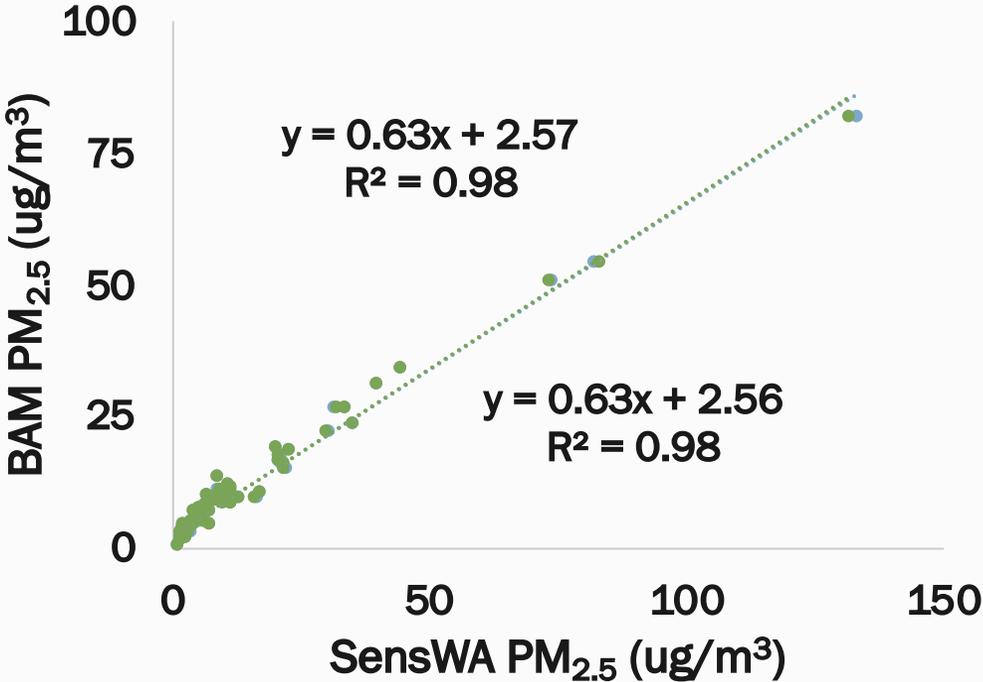
Ellensburg Non-Smoke Season 2021-2023  
(Nov. - Jun.)



24 hr. averages

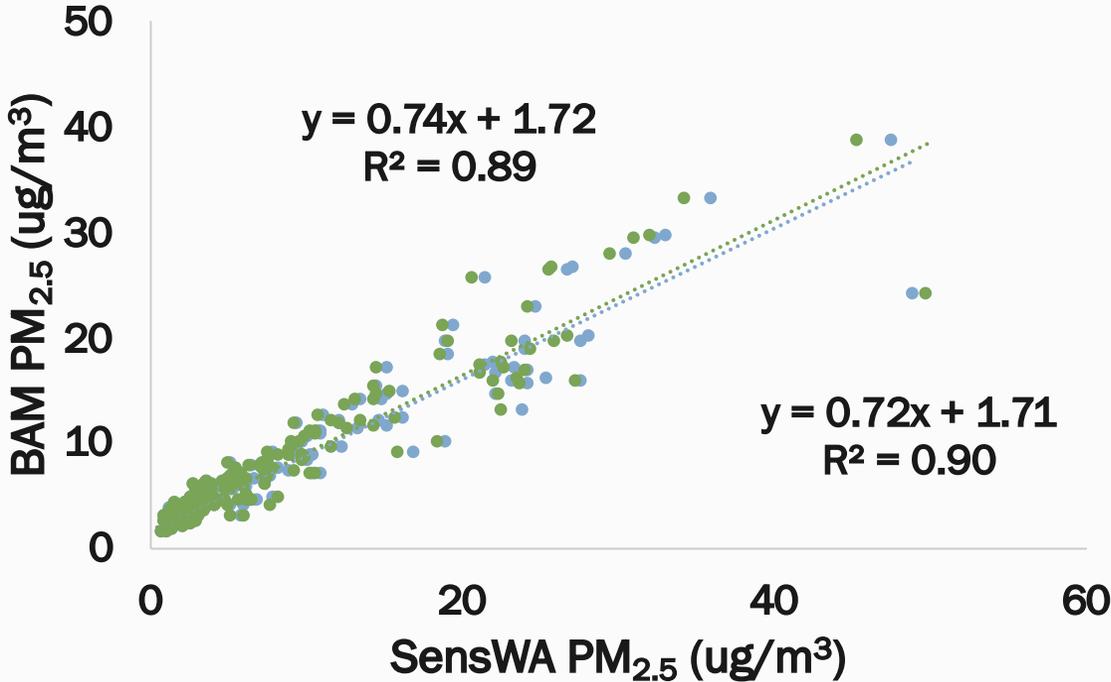
# SensWA Vancouver BAM Collocation

Vancouver 84th Smoke Season  
(August – October 2022)



• Channel A • Channel B

Vancouver 84th Non-Smoke Season  
(November 2022 – June 2023)

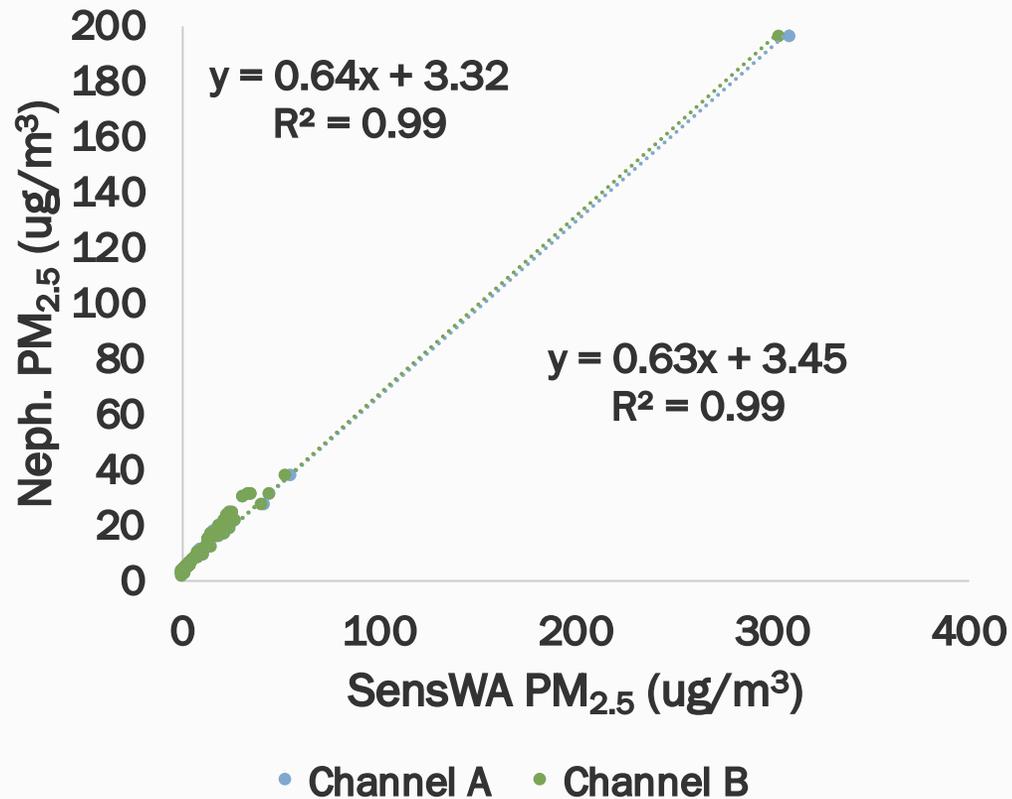


• Channel A • Channel B

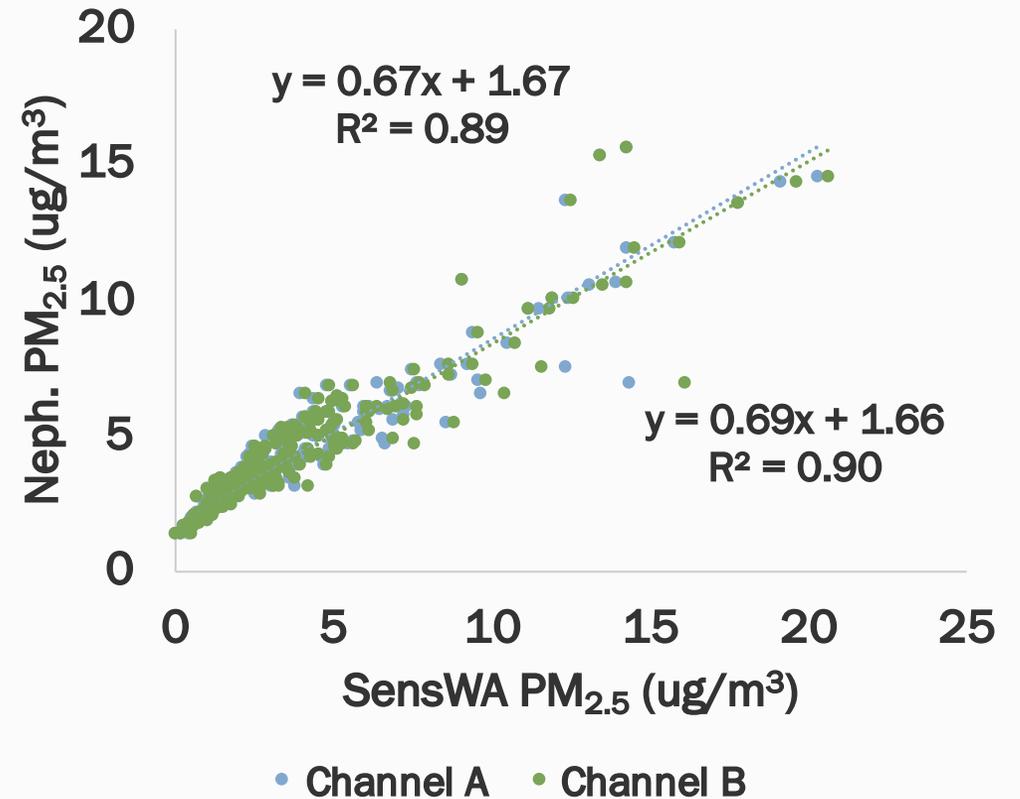
24 hr. averages

# SensWA Chelan Nephelometer Collocation

Chelan Smoke Season 2022  
July - October



Chelan Non-Smoke Season 2022-2023  
November - June



24 hr. averages

# PM Sensor Deployment Progress

June 2023

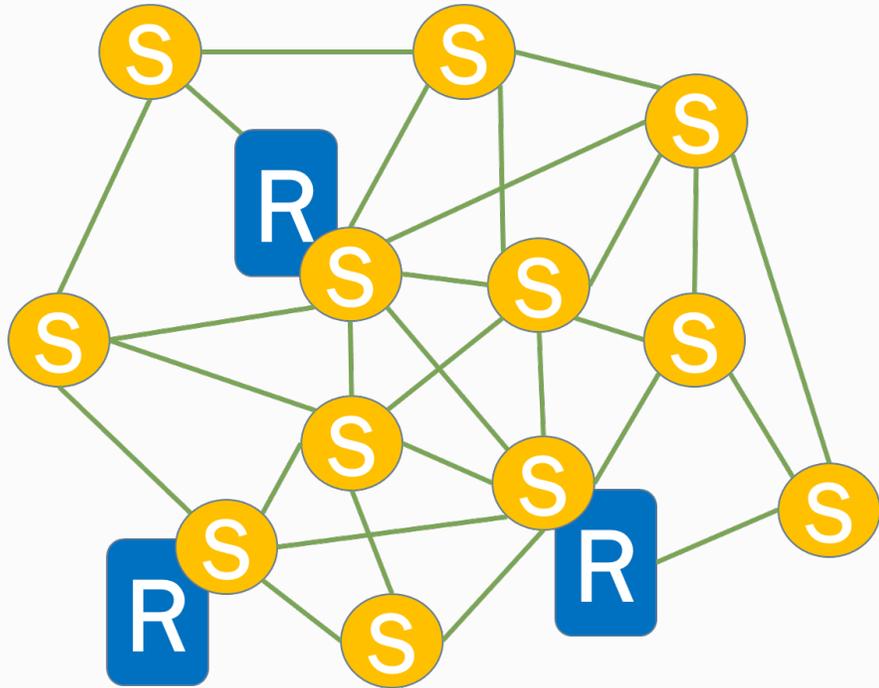
## Online (60)

- BAM collocation
  - 29 SensWA PM<sub>2.5</sub>
  - 9 ModPM PM<sub>10</sub>
- Nephelometer collocation
  - 10 SensWA PM<sub>2.5</sub> (1 solar)
- Supplemental
  - 7 SensWA PM<sub>2.5</sub> (public display)
- Solo site
  - 2 SensWA PM<sub>2.5</sub> (public display)
  - 3 ModPM PM<sub>10</sub>

## Offline (85)

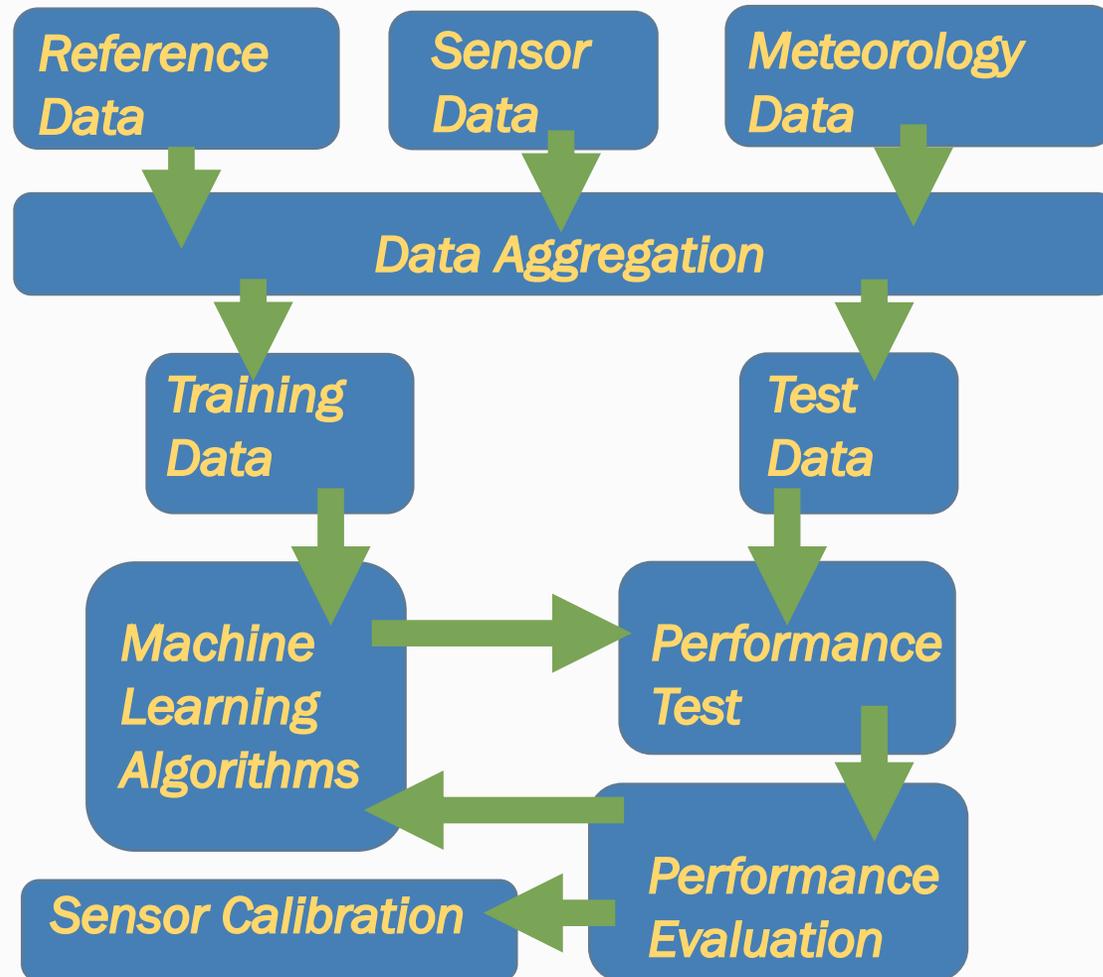
- Awaiting deployment
  - 45 SensWA PM<sub>2.5</sub>
  - 7 ModPM PM<sub>10</sub>
- Under Construction
  - 33 SensWA PM<sub>2.5</sub>
  - 35 solar power systems

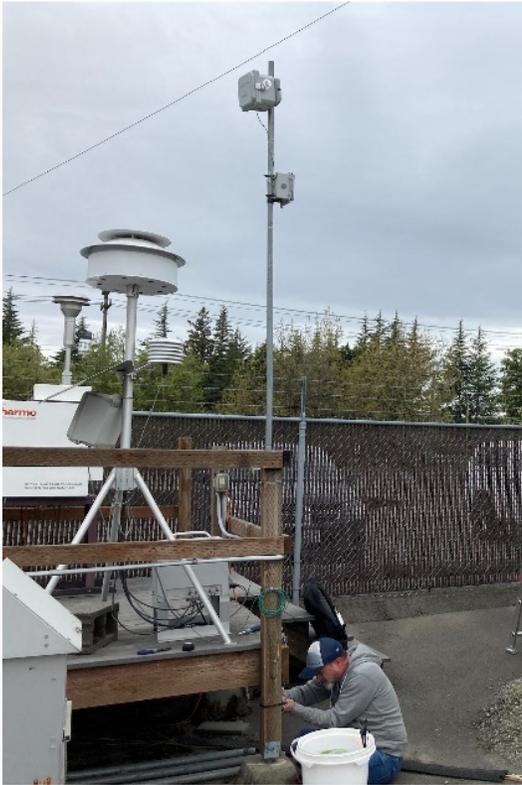
# Machine Learning: The Future of SensWA Calibration



Sensor monitoring network diagram

**R** = Reference Monitor      **S** = Sensor





**Thank you!**

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# Ecology Monitoring Advisory Committee Policy on Air Sensors



## Tier 1 = Purple Air

- Education/information
- EPA correction, not reviewed by Ecology
- EPA Fire and Smoke Map



## Tier 2 = Ecology SensWA & QuantaQ MODULAIR-PM

- Temporary monitoring
- Ecology regional correction, limited QA review
- Ecology Dot Map, EPA Fire and Smoke Map

## Tier 3 = Ecology SensWA & QuantaQ MODULAIR-PM

- Longer deployment and higher data quality needs
- Ecology collocation-correction, more extensive review by QA, annual maintenance by lab
- Ecology Dot Map, EPA Fire and Smoke Map



# Sensirion SPS30 PM<sub>2.5</sub> Sensing Element

- Polarized 660 nm laser
- Photo diode detector
- Airflow generated by in line fan
- Selected based on top performance in external and internal evaluations



*Internal view of Sensirion SPS30 PM  
sensing element*

# Quality Control of PM Sensors

- Weekly data review:
  - Correlation with nearby monitors
  - Agreement of unit paired sensors
  - Decrease in overall response
  - Drift in the baseline
  - Outlier events
  - Odd patterns
- Quarterly site visits
  - Clean to prevent the buildup of spider webs, bugs, dust, etc.
  - Confirm mounting and connections stable
- Annual Cal. Lab. zero test
- Annual Cal. Lab. maintenance