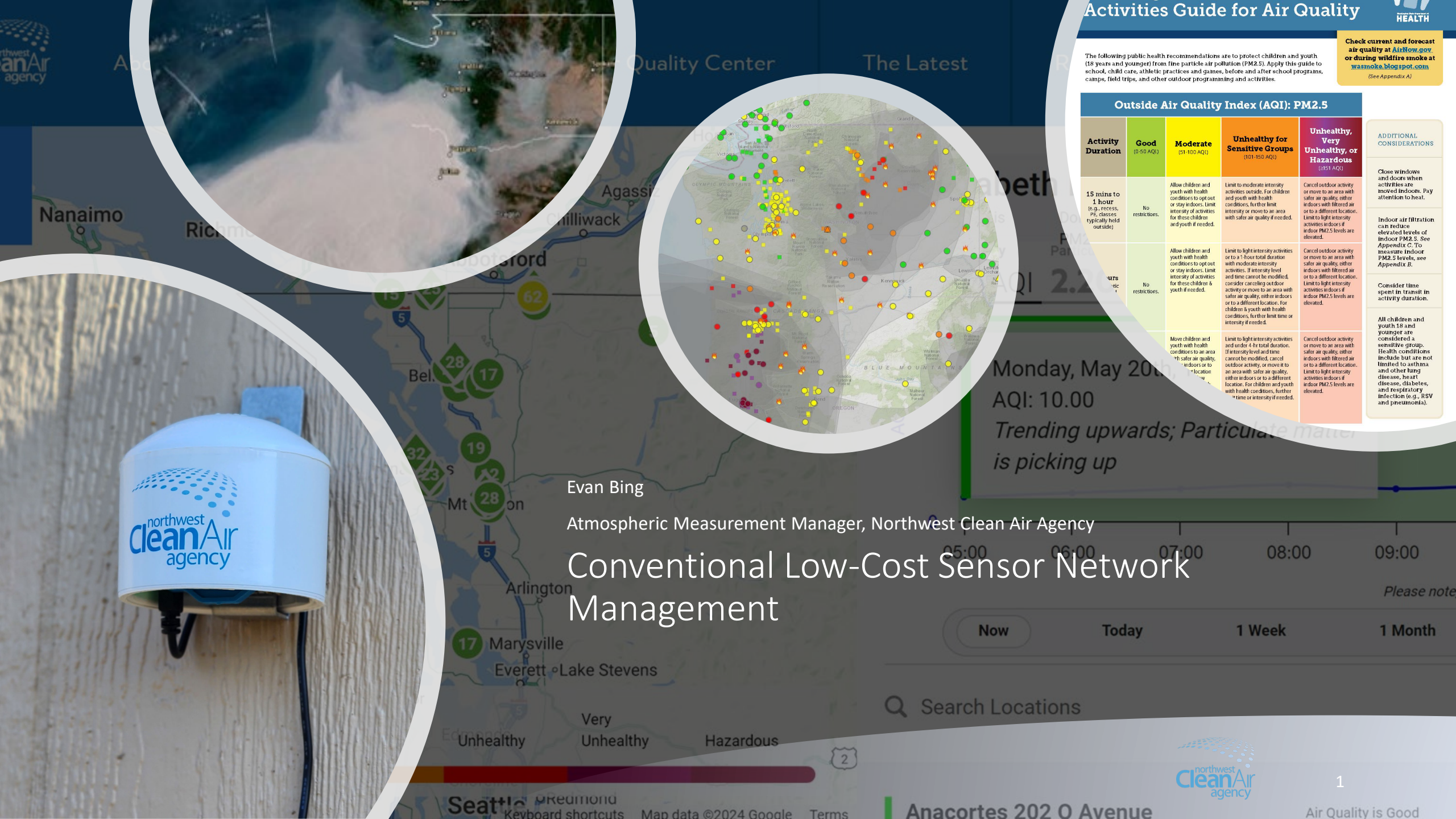




Check current and forecast air quality at [AirNow.gov](https://airnow.gov), or during wildfire smoke at wasmoke.blogspot.com (See Appendix A)

The following public health recommendations are to protect children and youth (18 years and younger) from fine particle air pollution (PM2.5). Apply this guide to school, child care, athletic practices and games, before and after school programs, camps, field trips, and other outdoor programming and activities.

Outside Air Quality Index (AQI): PM2.5				
Activity Duration	Good (0-50 AQI)	Moderate (51-100 AQI)	Unhealthy for Sensitive Groups (101-150 AQI)	Unhealthy, Very Unhealthy, or Hazardous (151 AQI)
15 mins to 1 hour (e.g. recess, PE, classes typically held outside)	No restrictions.	Allow children and youth with health conditions to opt out or stay indoors. Limit intensity of activities for these children and youth if needed.	Limit to moderate intensity activities outside. For children and youth with health conditions, further limit intensity or move to an area with safer air quality if needed.	Cancel outdoor activity or move to an area with safer air quality, either indoors with filtered air or to a different location. Limit to light intensity activities indoors if indoor PM2.5 levels are elevated.
1-2 hours	No restrictions.	Allow children and youth with health conditions to opt out or stay indoors. Limit intensity of activities for these children and youth if needed.	Limit to light intensity activities or to a 1-hour total duration with moderate intensity activities. If intensity level and time cannot be modified, consider canceling outdoor activity or move to an area with safer air quality, either indoors or to a different location. For children and youth with health conditions, further limit time or intensity if needed.	Cancel outdoor activity or move to an area with safer air quality, either indoors with filtered air or to a different location. Limit to light intensity activities indoors if indoor PM2.5 levels are elevated.
2+ hours	No restrictions.	Move children and youth with health conditions to an area with safer air quality, either indoors or to a different location. For children and youth with health conditions, further limit time or intensity if needed.	Limit to light intensity activities and under 4-hr total duration. If intensity level and time cannot be modified, cancel outdoor activity, or move to an area with safer air quality, either indoors or to a different location. For children and youth with health conditions, further limit time or intensity if needed.	Cancel outdoor activity or move to an area with safer air quality, either indoors with filtered air or to a different location. Limit to light intensity activities indoors if indoor PM2.5 levels are elevated.

ADDITIONAL CONSIDERATIONS

Close windows and doors when activities are moved indoors. Pay attention to heat.

Indoor air filtration can reduce elevated levels of indoor PM2.5. See Appendix C. To measure indoor PM2.5 levels, see Appendix B.

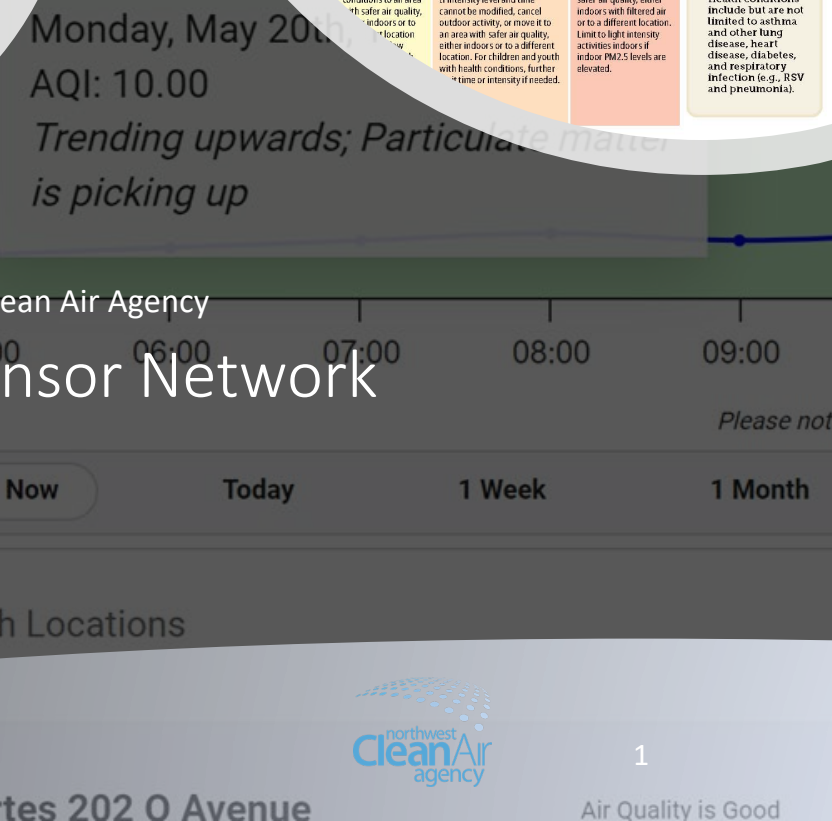
Consider time spent in transit in activity duration.

All children and youth 18 and younger are considered a sensitive group. Health conditions include but are not limited to asthma and other lung disease, heart disease, diabetes, and respiratory infection (e.g., RSV and pneumonia).

Evan Bing

Atmospheric Measurement Manager, Northwest Clean Air Agency

Conventional Low-Cost Sensor Network Management



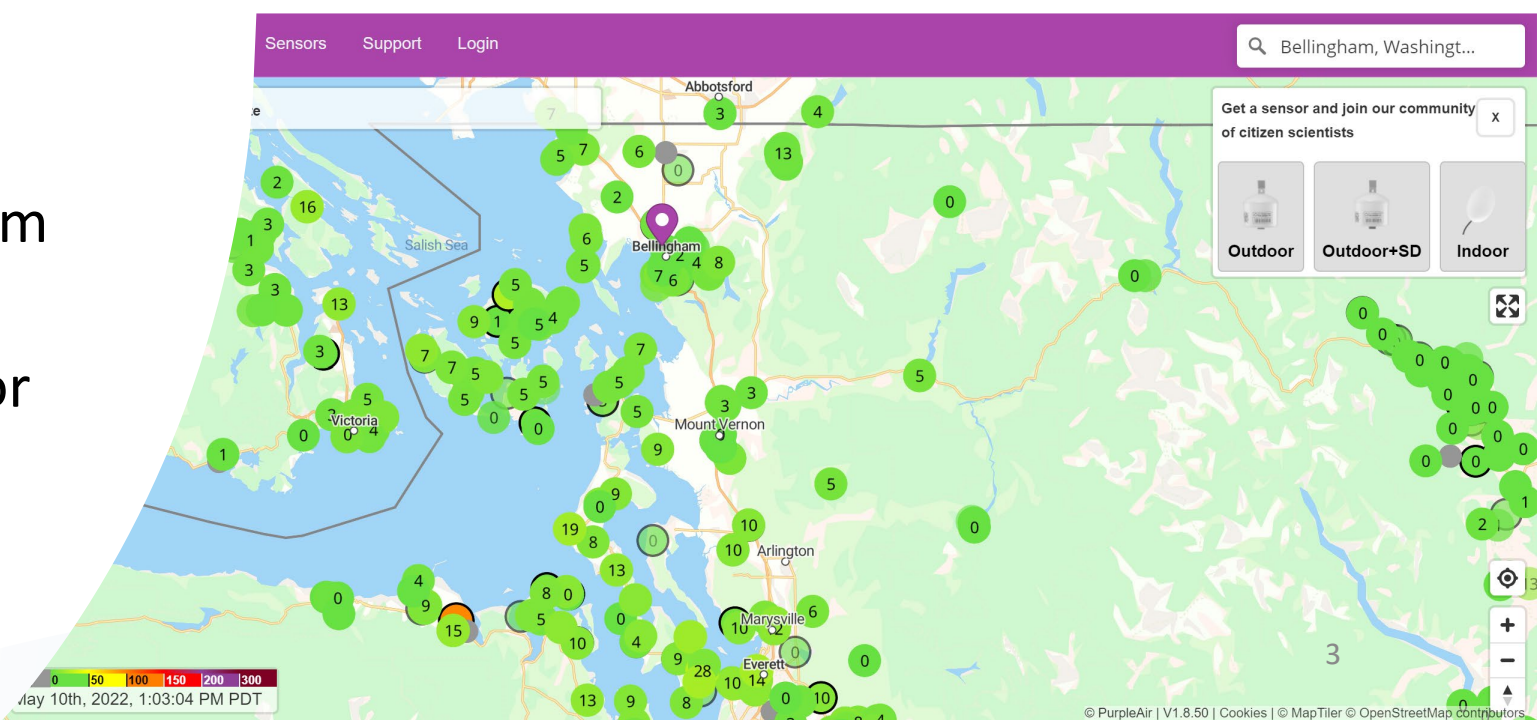
Northwest Clean Air Agency

- Local clean air agency in NW Washington State
 - Responsible for 3 counties: Skagit, Island, and Whatcom (San Juan County joining in 2025)
 - Operate and maintain several long-term traditional monitoring stations for regulatory and informational data collection (BAM/gas/nephelometer)
 - Very small monitoring team: monitoring manager and 1 technician
 - Do not have the staff and equipment resources to pursue a program like SensOR® or SensWA
-



NWCAA and Low-Cost Sensors

- Help NWCAA fill gaps in monitoring station coverage due to cost, ease of installation and low power consumption
- Currently over 75 units installed across Island, Skagit, and Whatcom counties
- Plan to continue expanding sensor network in coming years due to public interest



Low-Cost Sensor Model Selection

- Due to agency size and staff resources, our strategy is to align with the most widely used product with a high relative accuracy and low intra-model variability. This led us to select PurpleAir PA-FLEX (SCAQMD, 2022)
- PurpleAir sensors have already been extensively evaluated against FRM/FEM monitors and have an EPA-developed correction factor that can be used to compare data nationwide

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Sensor Description

Manufacturer/Model:
PurpleAir/PA-II-FLEX

Pollutants:
PM_{1.0}, PM_{2.5} and PM₁₀ mass concentration

Time Resolution:
2-min

Type: Optical

Additional Information

Field evaluation report:
<https://www.aqmd.gov/aq-spec/evaluations/field>

Lab evaluation report:
<https://www.aqmd.gov/aq-spec/evaluations/laboratory>

AQ-SPEC website:
<http://www.aqmd.gov/aq-spec>

Evaluation Summary

- The accuracy of the PA-II-FLEX sensors was 56.6% to 94.5% and 71.4% to 98.1% for PM_{1.0} and PM_{2.5}, respectively, in the laboratory evaluation. Overall, the PA-II-FLEX sensors underestimated PM_{1.0} levels and overestimated low PM_{2.5} levels (10 to 15 µg/m³) and underestimated high PM_{2.5} levels (50 to 300 µg/m³) compared to the T640x in the lab.
- The PA-II-FLEX sensors exhibited high precision for all conc., T/RH combinations for PM_{1.0} and PM_{2.5}.
- The PA-II-FLEX sensors showed low intra-model variability for PM_{1.0} and PM_{2.5} in both the field and lab evaluations.
- Data recovery was ~94% and 100% from all units tested in the field and laboratory evaluations, respectively.
- PA-II-FLEX sensors showed very strong, strong, and very weak to weak correlations for PM_{1.0}, PM_{2.5} and PM₁₀, respectively, with GRIMM and T640 from the field; and very strong correlations with the T640x in the laboratory studies (R² > 0.99 for PM_{1.0} and PM_{2.5}).
- The same PA-II-FLEX units were tested both in the field (1st stage of testing) and in the laboratory (2nd stage of testing) against reference PM instruments (except for Unit 716d, unit damaged during transport).

Field Evaluation Highlights

- Deployment period 03/17/2022 - 05/24/2022: the PA-II-FLEX sensors showed very strong and strong correlations for PM_{1.0} and PM_{2.5}, respectively; and very weak to weak correlations for PM₁₀ as compared to GRIMM and T640
- Data recovery from the units was ~94% for all PM fractions.

PurpleAir PA-II-FLEX vs FEM T640

1-hr mean, all ref. inst.

PM_{1.0}: 0.90 < R² < 0.95

PM_{2.5}: 0.78 < R² < 0.90

PM₁₀: 0.22 < R² < 0.43

PM_{2.5} (1-hr mean, µg/m³)

Y = 0.92X + 1.6461
R² = 0.937

Coefficient of Determination (R²) quantifies how the two sensors followed the PM_{1.0}, PM_{2.5}, or PM₁₀ concentration change by the reference instruments.

An R² approaching the value of 1 reflects a near perfect agreement, whereas a value of 0 indicates a complete lack of correlation.

Laboratory Evaluation Highlights

Accuracy (PM_{2.5})

$$A(\%) = 100 - \frac{|X - R|}{R} \times 100$$

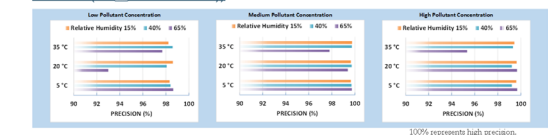
Steady State #	1	2	3	4	5
1. Sensor Mean (µg/m ³)	10.5	18.4	51.3	142.1	287.3
2. FEM T640x (µg/m ³)	9.3	14.3	52.6	154.1	327.1
3. Accuracy (%)	87.2	71.4	97.6	92.2	87.8

Accuracy was evaluated by a concentration ramping experiment at 20°C and 40% RH. The sensor's readings at each ramping steady state are compared to the reference instrument.

A negative % means sensor's overestimation by more than two fold. The higher the positive value (close to 100%), the higher the sensor's accuracy.

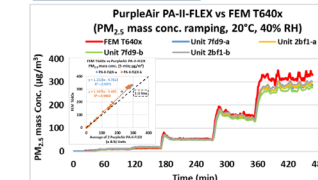


Precision (PM_{2.5} from channel Δ)



Sensor's ability to generate precise measurements of PM_{2.5} concentration at low, medium, and high pollutant levels were evaluated under 9 combinations of T and RH, including extreme weather conditions like cold and dry (5°C and 15% RH) cold and humid (5°C and 65% RH), hot and humid (35°C and 65% RH), or hot and dry (35°C and 15% RH).

Coefficient of Determination



The PA-II-FLEX sensors showed very strong correlations with the corresponding FEM PM_{2.5} data (R² > 0.99) at 20°C and 40% RH. For conc. ramping experiments of PM_{2.5}, please see the lab report.

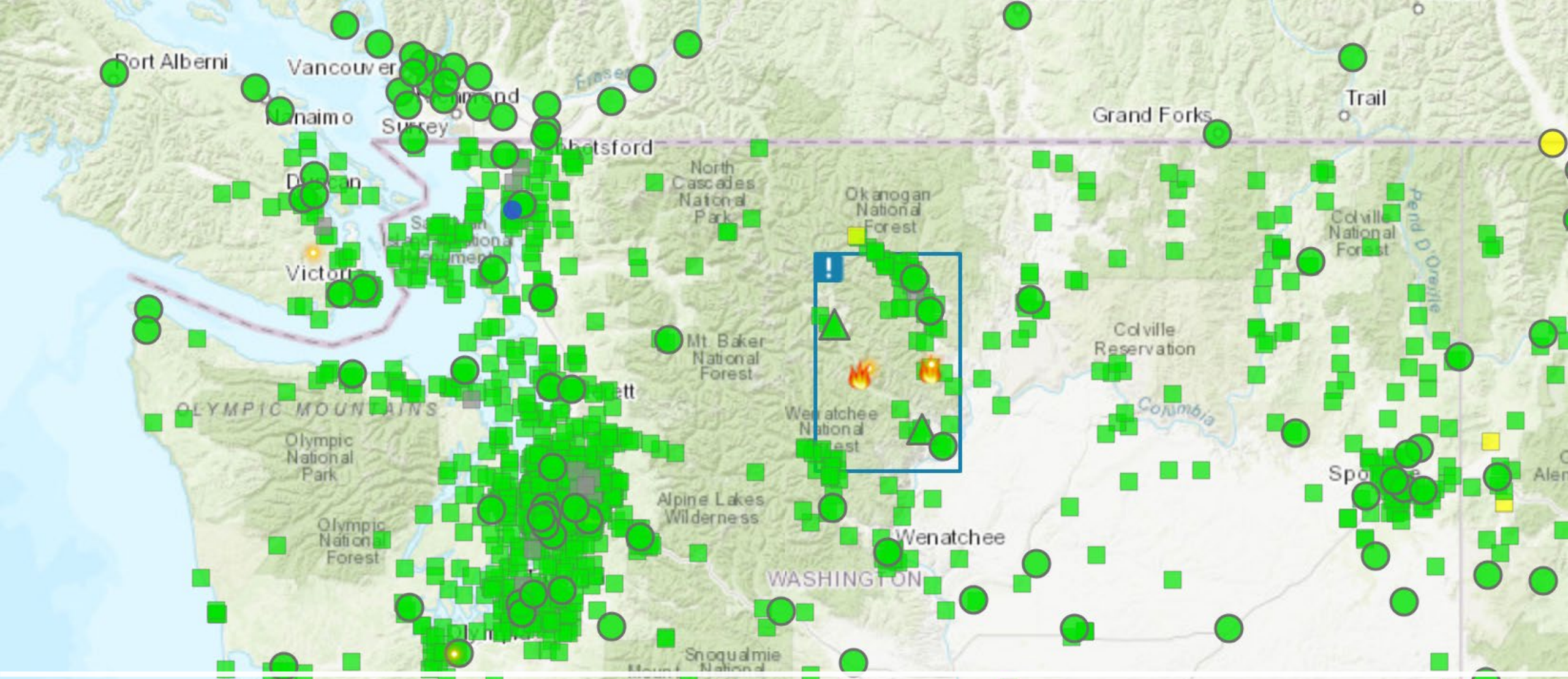
Climate Susceptibility

From the laboratory studies, temperature and relative humidity had minimal effect on the PA-II-FLEX sensors' precision. Spiked concentrations were observed at the 65% RH change point.

Observed Interferents

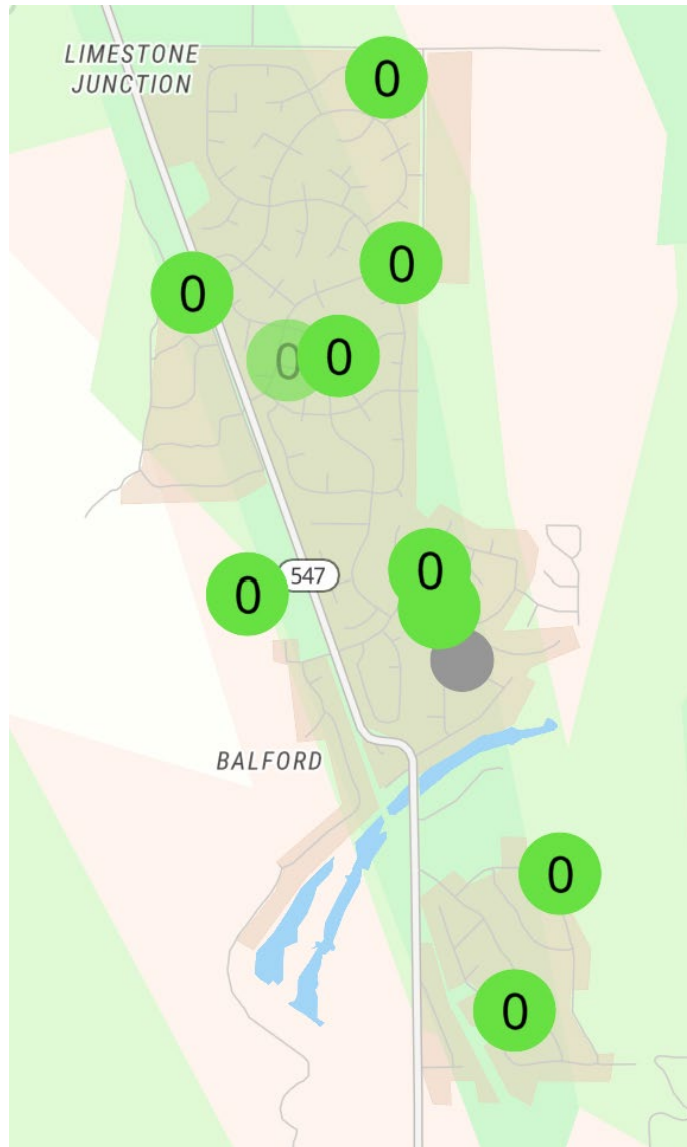
N/A

All documents, reports, data, and other information provided in this document are for informational use only. Mention of trade names or commercial products does not constitute endorsement or recommendation. As a Government Agency, the South Coast AQMD and its AQ-SPEC program highly recommend interested entities to make use and purchase decisions based on the requirements of their study design, the technical aspects and features of their specific project applications.



PurpleAir and the Fire & Smoke Map





Early Low-Cost Air Quality Sensor Deployments

- ~10 site high spatial density deployment in Columbia Valley (near Mt. Baker) Significant portion of the network is still in operation, though a few have been “lost”
- When sensors would begin to fail, they were replaced with entirely new units. This led to a discontinuity of the data record associated with the sensor

NWCAA Air Quality Sensor Loan Program

- In 2023, NWCAA partnered with Whatcom County in pilot project to provide participating schools with PurpleAir PA-FLEX sensors and continued maintenance and support
- NWCAA-School agreements outline responsibilities between the two organizations and require designation of on-site support
- Goal of balancing growing sensor/data demand with management limitations
- Expanding program to include Skagit and Island County schools, as well as health departments and other gov-affiliated organizations



Integration with WA Activities Guide for Air Quality

- PurpleAir sensor loan program integrates nicely with WA Dept. of Health Children and Youth Activities Guide used by schools in WA state
- School administrators and faculty can use on-site sensor data to help make decisions about outdoor sports and activities during smoke events
- School faculty frequently take interest in the sensors and incorporate sensor data and air quality topics in curriculum



Public health recommendations are to protect children and youth (18 and younger) from fine particle air pollution (PM2.5). Apply this guide to school, athletic practices and games, before and after school programs, camps, field trips, and outdoor programming and activities.

Check current and forecast air quality at [AirNow.gov](https://airnow.gov) or during wildfire smoke at wasmoke.blogspot.com
(See Appendix A)

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				Cancel outdoor activity or move to an area with safer air quality, either indoors with filtered air or to a different location. Limit to light intensity activities.

ADDITIONAL CONSIDERATIONS

Close windows and doors when activities are moved indoors. Pay attention to heat.

8

Long Term Sensor Network Goals

- Better understand air quality in previously unmonitored, smaller-scale regions within NWCAA's jurisdiction
- Provide long-term support for an expanding network of low-cost air quality sensors by implementing equipment cost and staff time-saving strategies
- Produce high-quality sensor data for NWCAA and public use by monitoring network health and addressing quality issues in a timely manner, ideally in a few days or less

NWCAA Sensor Database

- Maintain a database with sensor metadata, including:
 - Sensor MAC address
 - Purchase date
 - Installation date
 - Lat/long/alt.
 - Sensor common name
 - Individual particle sensor cleaning/replacement dates
 - Other notes, siting, details, etc.



5/14/24

Jo Moccia
South Whidbey School District
5476 Maxwellton Road
Langley, WA 98260

Dear Dr. Jo Moccia

Thank you for agreeing to host a PurpleAir Flex air sensor (the Sensor). Community-owned PurpleAir sensors provide real-time air quality data via the PurpleAir map, and can serve to supplement data collected by air quality monitors in areas where air quality monitoring data is limited. This letter serves as an agreement between you and Northwest Clean Air Agency (NWCAA), to help clarify roles, responsibilities, and liability regarding sensor installation and operation.

This Sensor is intended to collect information for educational and non-regulatory purposes. Data from the Sensor will be made public via the [Purple Air website](#). Data may also be available on other public websites such as [NWCAA's website](#), and [EPA's website](#). While NWCAA owns the Sensor, NWCAA will not own the data from the Sensor. As a result, NWCAA cannot be responsible for its use or misuse.

The Sensor will be installed by a NWCAA employee on an exterior wall of a building on the property at the address above, in coordination with you. NWCAA retains ownership of the Sensor and may request its return and terminate this agreement at any time. You may request that NWCAA remove the Sensor, and terminate this agreement, at any time. Sensor replacement, regardless of reason, is not guaranteed.

NWCAA will be responsible for the ongoing verification of sensor functionality and data quality. NWCAA will remotely perform basic quality assurance of sensor data but will rely on designated personnel at the host facility to inspect the sensor upon request. It is expected that the host facility be able to coordinate with NWCAA if any interruptions to the sensor's power or communications are experienced (upon notification from NWCAA). NWCAA may request that the host inspect the sensor for theft, damage, dirtiness, unplugged power cords, and similar issues. Changes to Wi-Fi networks, including network names and passwords, are a frequent cause of disconnected/offline sensors, and NWCAA may request the designated host personnel perform basic troubleshooting in coordination with NWCAA and attempt to resolve such communication problems.

You will be responsible for providing communications to your community about the installation and use of these sensors. The data that is collected from these low-cost sensors overestimates air pollutant concentrations. You will need to educate you community about the conversion factor that will need to be applied to bring data from these sensors in line with data from regulatory monitors. More information about the conversion factor can be found [here](#).

The Sensor requires a small amount of electricity and a Wi-Fi connection to operate. Both the electricity and the Wi-Fi connection will be provided by you, at no cost to NWCAA.

By signing this agreement, you agree to not assert any claim or demand against NWCAA or its employees or officers for

Sensor Loan Agreements

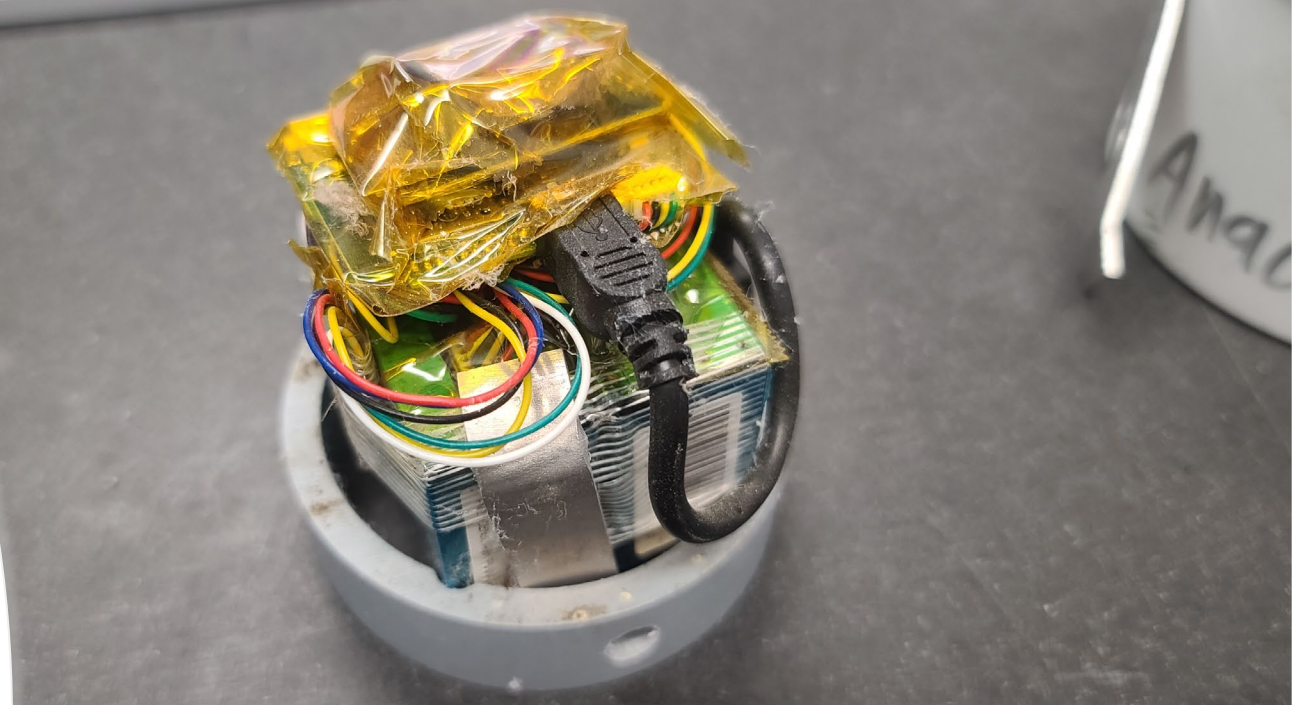
- County liaison to public schools provided initial round of contacts that expressed interest in hosting an air quality sensor at their school
- Sensor hosts required to sign agreement that outlines program details and responsibilities
- Agreement seeks to identify a responsible individual(s) at host facility that will assist NWCAA with remote troubleshooting and other sensor maintenance

“PurpleAir” Disambiguation

- A few PurpleAir outdoor models exist and two are being sold concurrently:
 - PurpleAir Classic (\$229-259), previously called the PA-II Outdoor
 - PurpleAir Flex (\$289)
- The two units have significant hardware and usability differences air agencies may want to be aware of when deploying sensor networks at scale/long term

PurpleAir Classic (PA-II Outdoor)

- Older model
- Difficult to service in the field
- Tape and adhesives made sensor replacement/cleaning difficult and time consuming
- Some basic hand tools required for sensor removal and disassembly





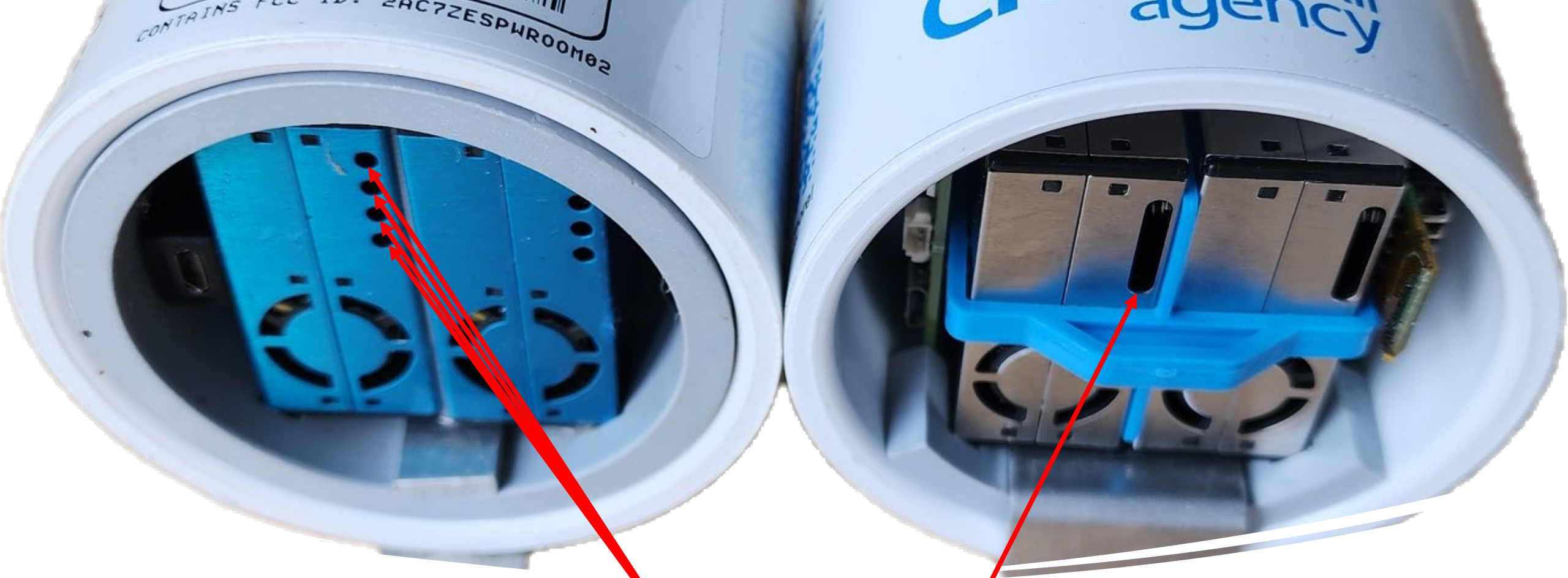
PurpleAir Classic
(Old)



PurpleAir Flex
(New)

PurpleAir Flex (New Model, 2022-Current)

- New design is significantly more field-serviceable
- Tape/adhesive-free removeable particle sensor chassis
- No tools required for sensor removal
- Redundant temperature sensors (2)
- Expansion port for future improvements/upgrades



Sensor Inlet Vulnerability

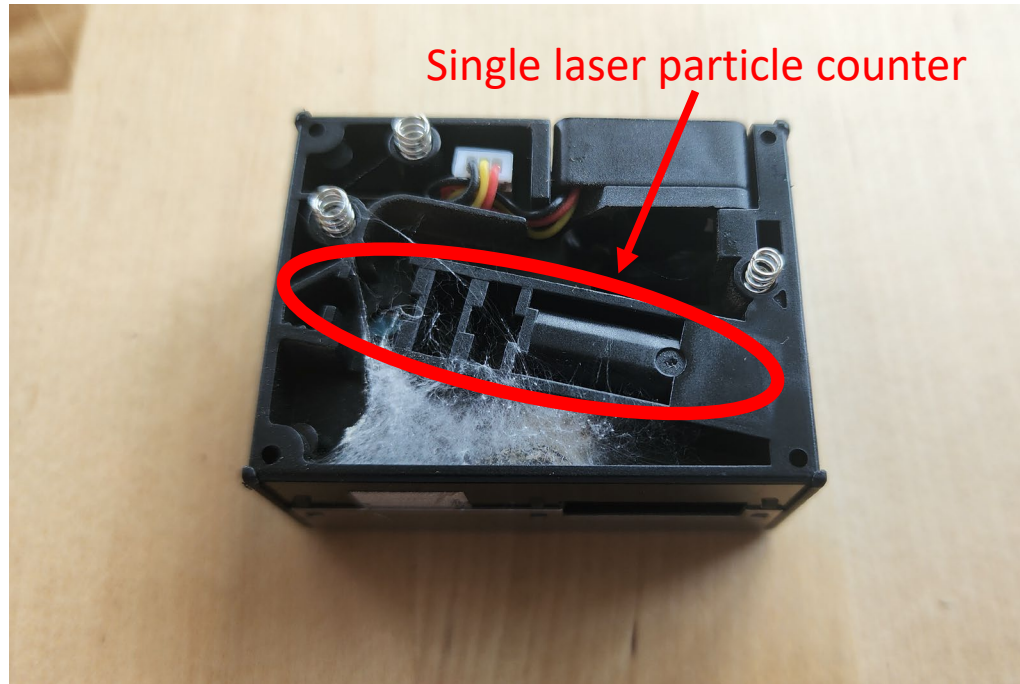
- The most common source of poor inter-particle sensor agreement is due to spiders entering the inlet holes and building a web in a sensor compartment. This prevents proper flow and particle ingestion, thereby causing poor correlation between the two sensors

Sensor Cleaning/Replacement

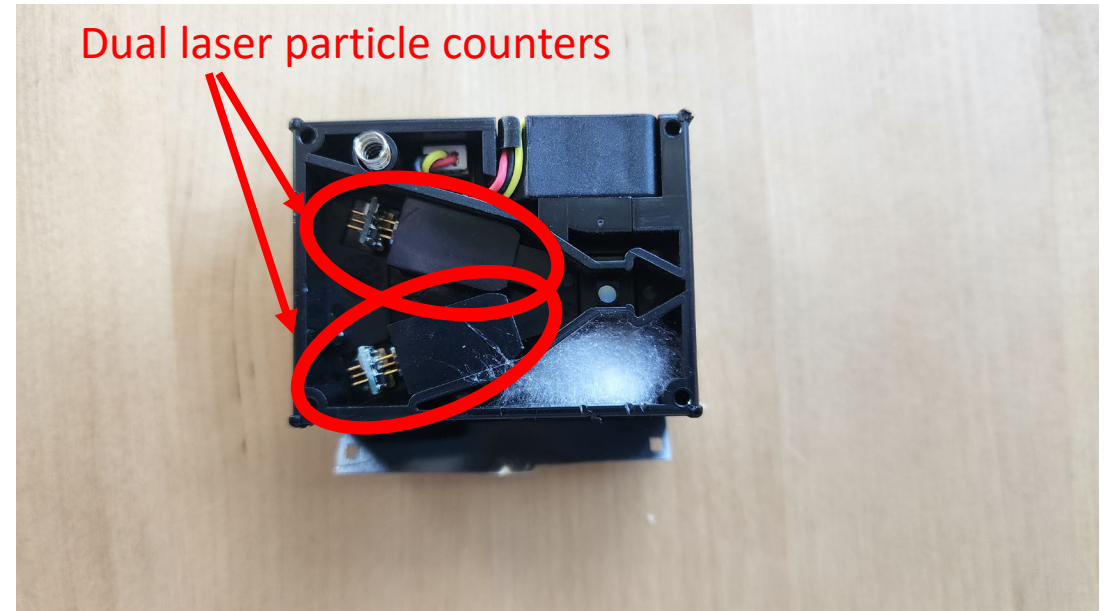
- Previously, entire PurpleAir units were replaced when a sensor reported poor inter-particle sensor agreement
- Individual particle sensors are now either cleaned or replaced in the field
- Cleaning cuts down on cost (~\$50 per particle sensor) and helps reduce e-waste
- Sensor hosts staff are trained on replacing particle sensors for newer model (PurpleAir Flex)

Plantower PMS5003 vs. PMS6003

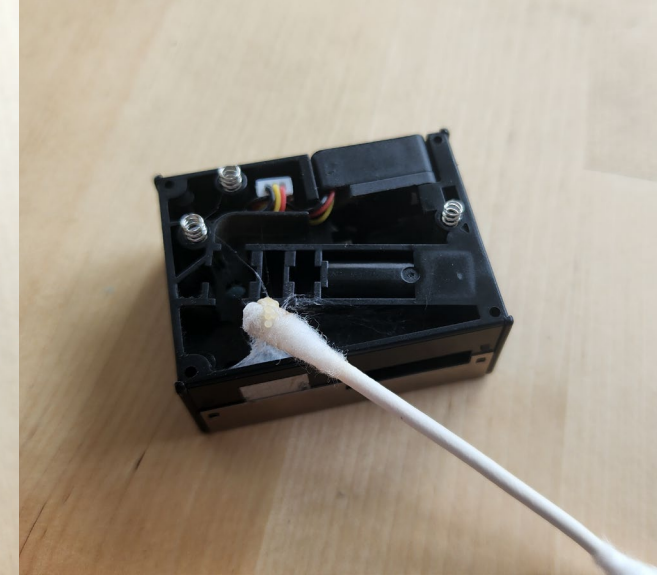
PMS5003 (Old/PurpleAir PA-II)



PMS6003 (New/PurpleAir PA-FLEX)



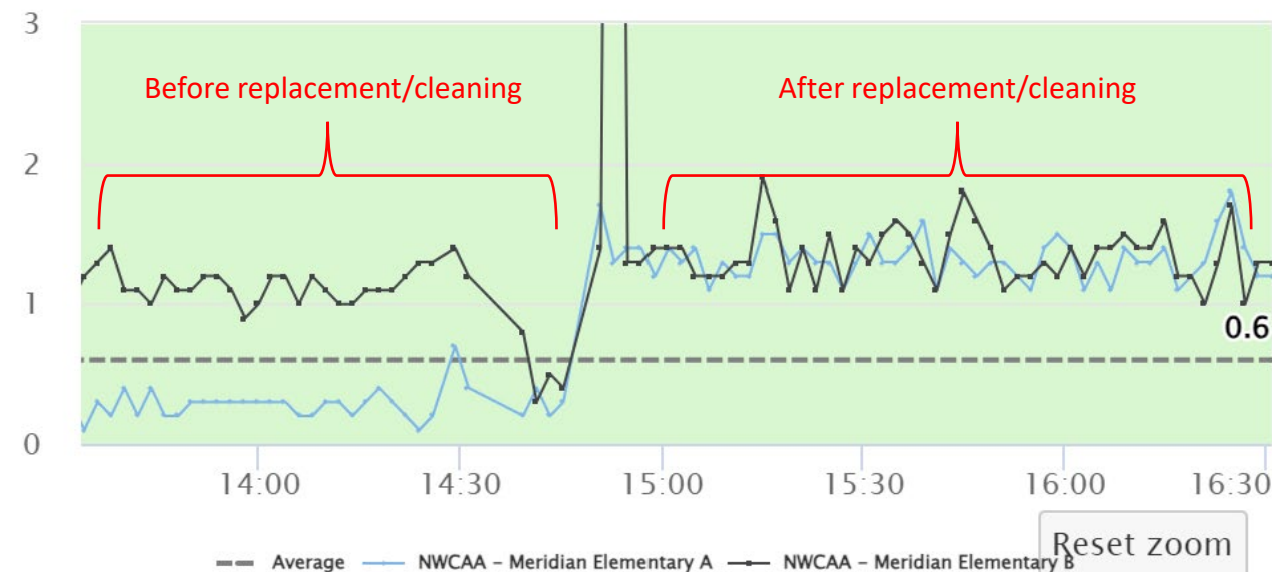
Particle Sensor Replacement



Click & drag to zoom. Shift + click & drag to pan. [How to use the graph.](#)

Raw PM2.5 (ALT cf=3) $\mu\text{g}/\text{m}^3$

Real-time



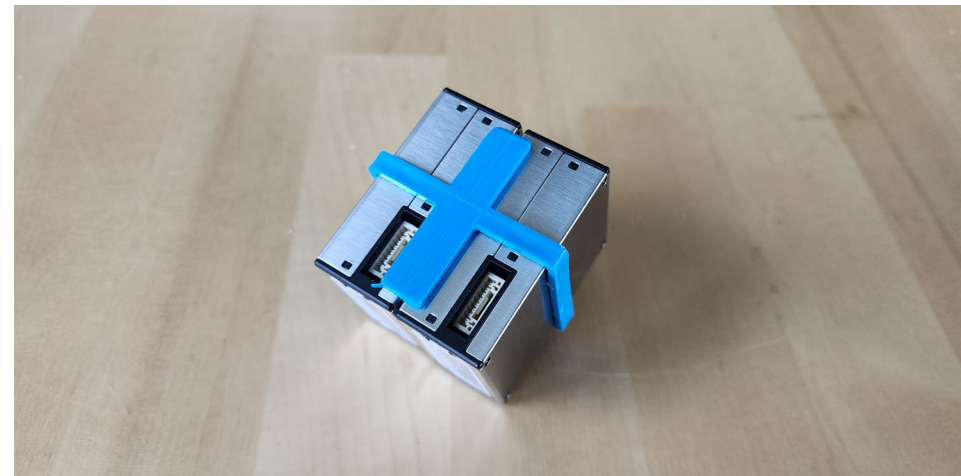
- Both PMS5003 (old) and PMS6003 (new) prone to spider webs in certain sensor compartment
- Both generations can easily be opened and cleaned using a very small flathead screwdriver, a small cotton swab, and isopropyl alcohol

Sensor Replacement Advantages/Strategies

- Depending on sensor location, the value of the staff time required to perform a full sensor swap can exceed the cost of a new PurpleAir unit. We significantly cut down on time and costs by supplying sensor hosts with replacement/clean dual-particle sensor chassis and providing instructions for replacing the chassis within PA-FLEX units
- Hosts then ship the old units to our office, NWCAA staff perform cleaning and ensure data validation for each sensor, then return units to our field-ready inventory for future replacements
- Individual Plantower PMS5003 & PMS6003 sensor metadata is independently tracked and maintained in database using sensor serial numbers on barcode label

Particle Sensor Chassis Replacement

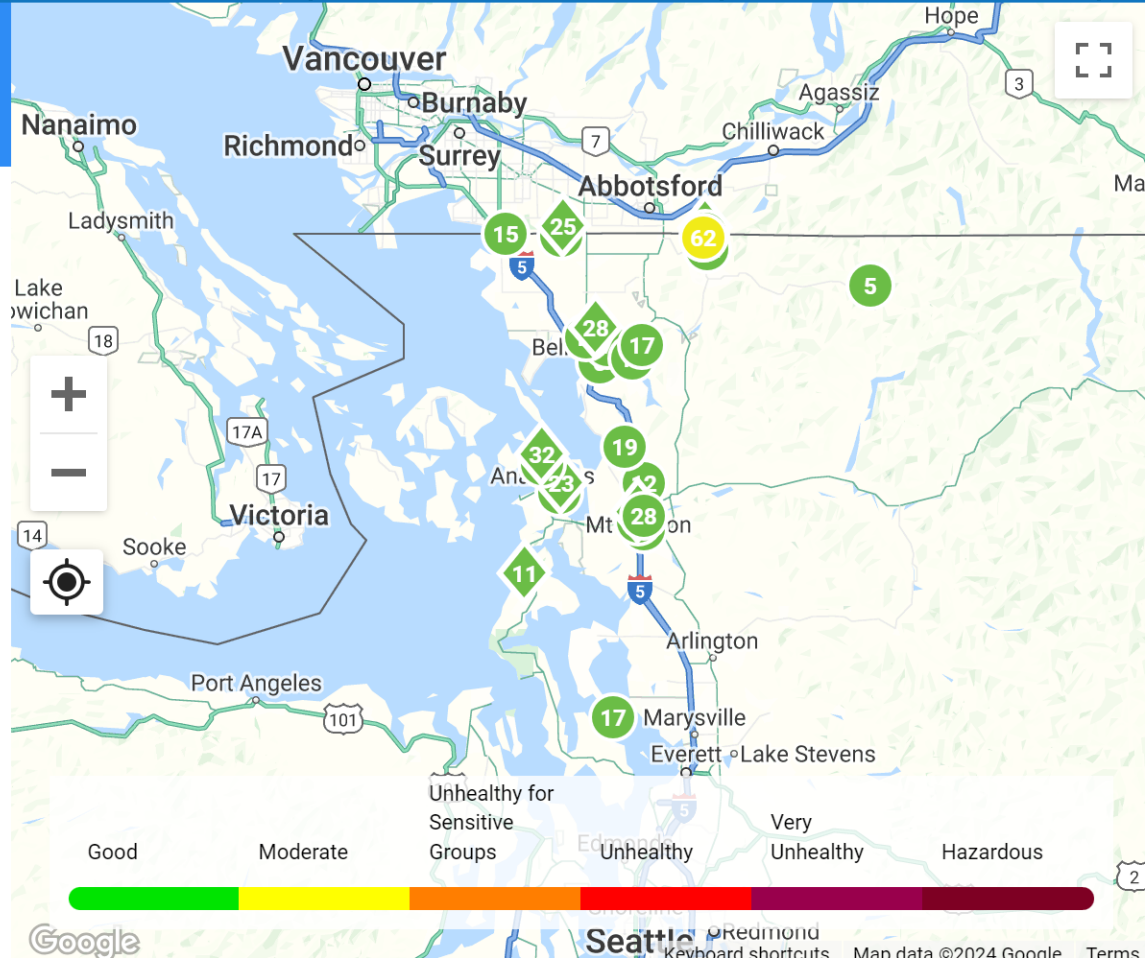
- NWCAA supplies sensor hosts with a clean, dual-sensor chassis and instructions on how to swap them out with the old unit.
- We request they then mail us back the old unit so we can ensure proper cleaning and sensor performance before returning the units to our field-ready inventory



Integration with Revamped NWCAA Air Quality Center

- QR code on side of the sensor takes users to NWCAA's revamped "Air Quality Center"
- NWCAA uses PurpleAir's API to ingest sensor data and display converted data (60-min avg./EPA correction factor) alongside data from existing FEM/nephelometer network

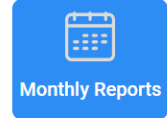


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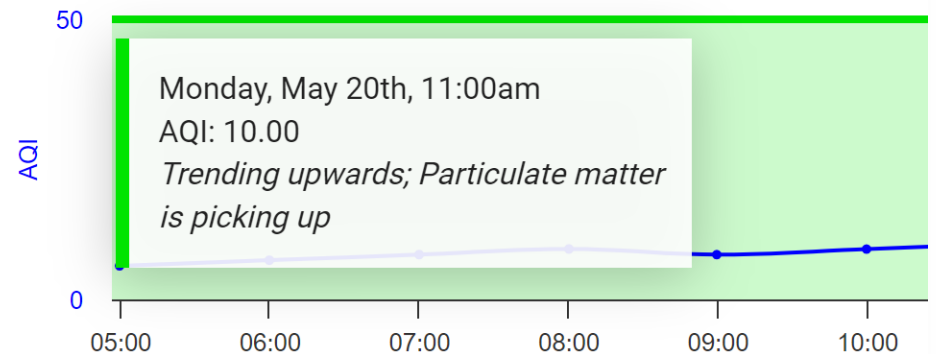
Elizabeth Park

Air quality is
Good
Overall Air Quality

Dominant Pollutant:
PM2.5
Particulates



10.00 AQI **2.20** $\mu\text{g}/\text{m}^3$



Please note, all times are s

[Now](#)[Today](#)[1 Week](#)[1 Month](#)[Year](#)

Search Locations

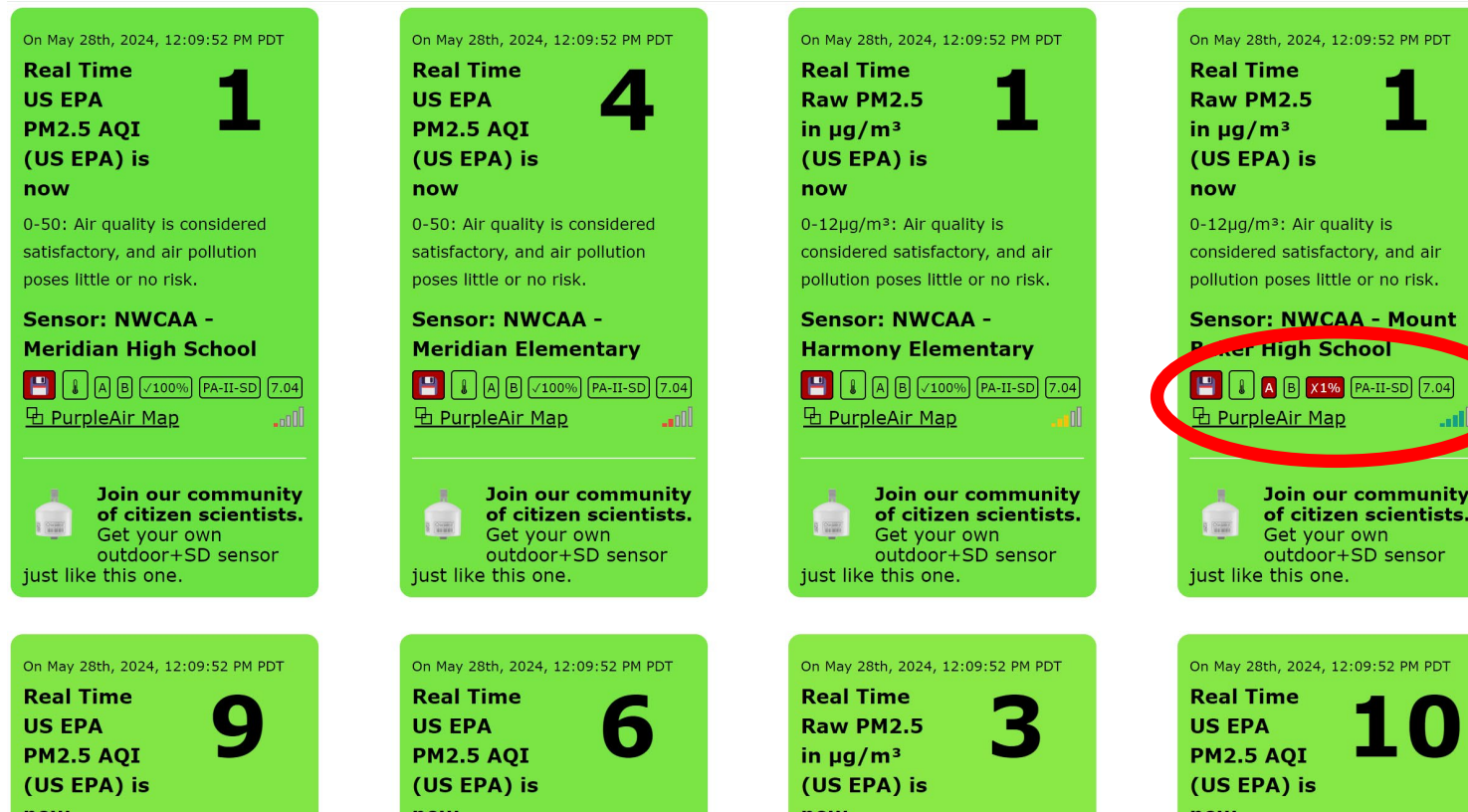
Anacortes 202 O Avenue

Air Quality is Good

Dominant Po

Evaluating Sensor Network Health

- PurpleAir “widget” HTML code to consolidate NWCAA sensors on single webpage for quick overview of network health
- Ensure data type (AQI/pollutant value), conversion factor, and averaging period are set properly before grabbing the HTML code



poor inter-particle
sensor agreement

Conclusions

- Conventional low-cost sensor networks can be both useful and realistically managed while continuing to expand in number of units and spatial coverage
- Implementing relatively simple time and equipment-cost saving strategies can significantly reduce management headaches while improving both data capture and quality
- Many data consumers only know about/use sensor data and maintaining a high-quality sensor network benefits the public even if maintaining a sensor network isn't explicitly in an air agency's mission

NORTH WEST CLEAN AIR AGENCY

Contact Information:

Evan Bing

Atmospheric Measurement Manager

Northwest Clean Air Agency

evanb@nwcleanairwa.gov

(360) 941-7103

