



# Maine DEP Low-Cost PM Sensor Comparison

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MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION

*Protecting Maine's Air, Land and Water*

Rumford, ME

Bar Harbor, ME  
McFarland Hill

# A Tale of Two Sensors:

PurpleAir and Clarity Node compared to  
MetOne's BAM and Thermo's SHARP:

# Costs vs Performance



# Why Low-cost Sensors?

- Low start-up costs
- No ancillary costs: save big \$\$\$ with no shelter or data logger requirements
- Rapid deployment, highly portable
- Numerous sites → higher regional data resolution
- Positive public involvement: residents host sites & access instantaneous data online



PurpleAir PA-II-SD: \$279



Photo: purpleair.com

Clarity Node-S: \$1000/yr



Photo: clarity.io

Met One BAM 1020: \$22,000



Photo: metone.com

## Start-up Costs

(Excluding shelters and logging hardware where necessary)

Thermo SHARP 5030i: \$24,000



Photo: thermofisher.com



# Low-Cost Sensor Feature Comparison

Sensor features	PurpleAir	Clarity Node-S
Measurement Frequency	2-minute averages	Default: 15m on solar/battery. Can sample every 3 minutes on AC.
Detection Sizes	1, 2.5, <u>AND</u> 10 $\mu$ m (PM10 data viewed as questionable)	
Power	Line power	Solar powered lithium-ion battery, with line power option.
Data Logging & Recovery	<ul style="list-style-type: none"> <li>- Cloud based by default</li> <li>- Streamed to PurpleAir website</li> <li>- "SD" version allows manual download/backup</li> <li>- Compatible with AirVision polling</li> <li>- Data readily accessible to the public</li> </ul>	<ul style="list-style-type: none"> <li>- Cloud-based only</li> <li>- Streamed to Clarity Dashboard</li> <li>- Compatible with AirVision polling</li> <li>- Data accessible to subscribers</li> </ul>
Internet Connectivity	Requires on-site Wi-Fi to connect to internet	Connects directly to internet: global SIM card and cellular service included



<b>Sensor features</b>	<b>PurpleAir</b>	<b>Clarity Node-S</b>
Laser Particle counter	2 Plantower PMS5003 sensors	2 Plantower PMS6003 sensors
Cost	\$249 (no SD card)-\$279 one time expense	Approx. \$1000 annual subscription/lease
Warranty	1 year	Hardware replacement, if needed, included with subscription.
Conversion Factors/ Calibrations	<ul style="list-style-type: none"> <li>- Data can be graphed online with a variety of optional conversion factors applied (US EPA preferred)</li> <li>- All downloaded data requires conversion factors to be applied</li> </ul>	<ul style="list-style-type: none"> <li>- Sensor needs to collect data for a week or more for remote calibration is applied (proprietary formula)</li> <li>- Downloads include calibrated <u>and</u> raw data, allowing for custom CF applications</li> </ul>
Advancements	PA-II-FLEX adds an LED indicator of current AQI (similar to their indoor PA-I)	Node-S II provides NO2 sensing plus expansion for Ozone, MET, or Carbon modules



# Why Apply Conversion Factors/Calibrations to Raw Data?

Data imperfect out of the box: can be about 2x higher than FEM concentrations

**PurpleAir:** EPA correction factors from US wide study, validated for wildfire and woodsmoke

**Clarity Node:** Vendor applies a calibration equation customized to each deployment location

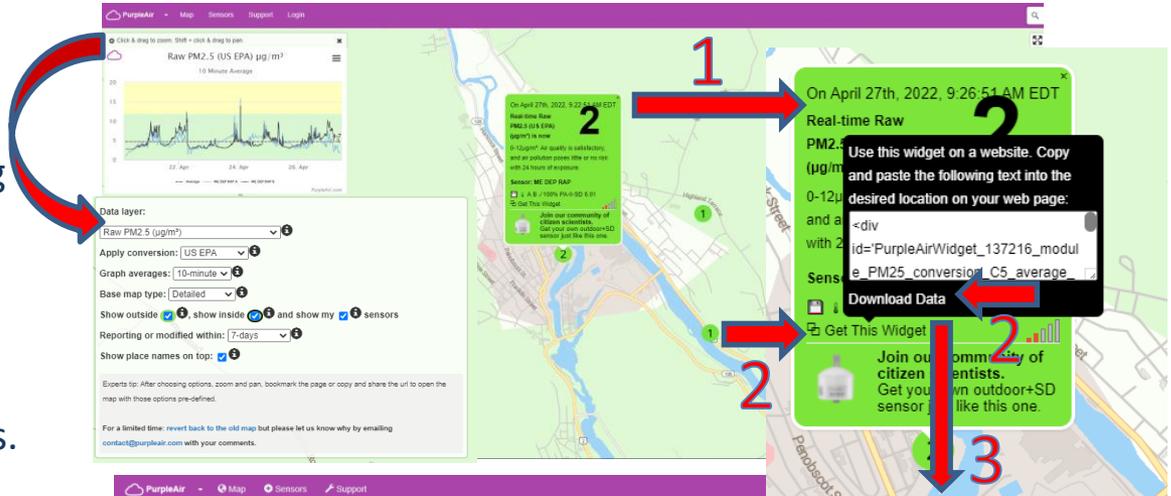


# PurpleAir Map and Data Downloads

After setup, view live data online: set interval and Conversion Factor (CF)

Or....

1. Click on the “dot” representing the PurpleAir device: an information box will appear.
2. Scroll cursor over “Get This Widget” and select “Data Download” in box that appears.
3. This takes you to “Sensor data download tool” for the device. Select start and end date, rollup interval, then select “Download Primary A” and “Download Primary B”.
4. Data are raw and will be in CSV format.



Select:  All  None Start Date:  End Date:  Average (minutes):  Download Selected

For information on the data and APIs provided by PurpleAir, please see this document: [https://docs.google.com/document/d/15j9r4dXJ-YAZL9iZ\\_RaBwz24K7reCY08goGwmbC/uedit?usp=sharing](https://docs.google.com/document/d/15j9r4dXJ-YAZL9iZ_RaBwz24K7reCY08goGwmbC/uedit?usp=sharing)  
**Please note:** This download tool now provides corrected headers for CF=1 and CF=ATM values. See the above link for more information.

ME DEP RAP (outside)

16	15	19	23	29	22	19
16	16	18	22	27	20	17

Created: 11/10/2021  
 Last Seen: 4/27/2022  
 Age: 1 minute  
 Version: 6.01  
 Show on Map

1 sensor found, 1 online, 0 offline

created_at	PM1.0_CF1_ug/m3	PM2.5_CF1_ug/m3	PM10.0_CF1_ug/m3	Uptime	RSSI_dbm	Tempera	Humidity	PM2.5_ATM_ug/m3
2022-04-26 0	1.62	2.94	3.37	6702	-53.47	48.13	61.8	2.94

# PurpleAir: US EPA Correction Equation

\*Data downloaded is raw; no correction equation yet applied

## Multi-tiered based on PM2.5 concentrations

### Full Equations:

$$y = \{0 \leq x < 30: 0.524 * x - 0.0862 * RH + 5.75\}$$

$$y = \{30 \leq x < 50: (0.786 * (x/20 - 3/2) + 0.524 * (1 - (x/20 - 3/2))) * x - 0.0862 * RH + 5.75\}$$

$$y = \{50 \leq x < 210: 0.786 * x - 0.0862 * RH + 5.75\}$$

$$y = \{210 \leq x < 260: (0.69 * (x/50 - 21/5) + 0.786 * (1 - (x/50 - 21/5))) * x - 0.0862 * RH * (1 - (x/50 - 21/5)) + 2.966 * (x/50 - 21/5) + 5.75 * (1 - (x/50 - 21/5)) + 8.84 * (10^{-4}) * x^2 * (x/50 - 21/5)\}$$

$$y = \{260 \leq x: 2.966 + 0.69 * x + 8.84 * 10^{-4} * x^2\}$$

X\* = PM2.5\_atm  $\mu\text{g}/\text{m}^3$

RH = Relative humidity as measured by the PurpleAir

y = corrected PM2.5  $\mu\text{g}/\text{m}^3$



# Clarity Dashboard: data download page

clarity

Analytics / Explore

Data Loaded: 2022-05-04 15:32 ~ 2022-05-06 15:32 | 2 datasources Edit ↓

Parameter: **PM2.5 | NowCast | Mass Concentration**

Show raw data:

Search Map     Black Mountain

Search Datasource

Wind Roses:

Legend:

- Clarity
- Reference Station

56  $\mu\text{g}/\text{m}^3$

45  $\mu\text{g}/\text{m}^3$

34  $\mu\text{g}/\text{m}^3$

22  $\mu\text{g}/\text{m}^3$

11  $\mu\text{g}/\text{m}^3$

mapbox Rumford Center © Mapbox © OpenStreetMap Improve t

Select data and time range and parameter and click download button



# Rumford, ME Low-Cost Sensor Comparison Study

Monitoring location:  
Rumford Ave. Parking (RAP)

2 low-cost sensors:

- PurpleAir
- Clarity Node-S

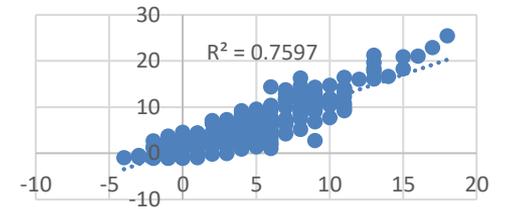
1 FEM Monitor: MetOne BAM 1020

*(part of a previous collocation study that included  
Teledyne T640 and Thermo SHARP 5030i)*

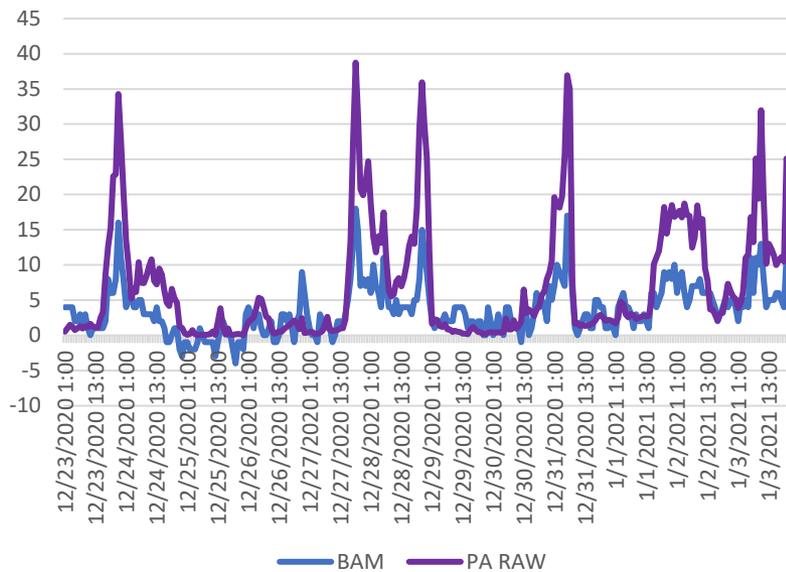


# RAP MetOne BAM & PurpleAir: Raw vs Corrected

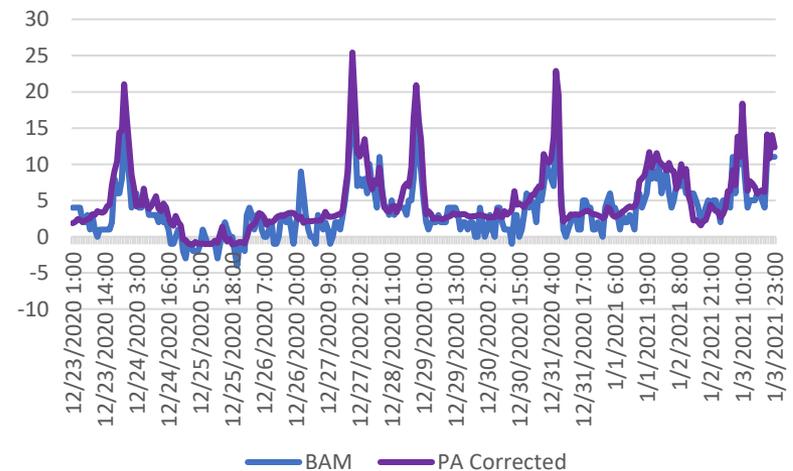
Regression BAM and  
Purple Air Corrected



BAM and PurpleAir RAW

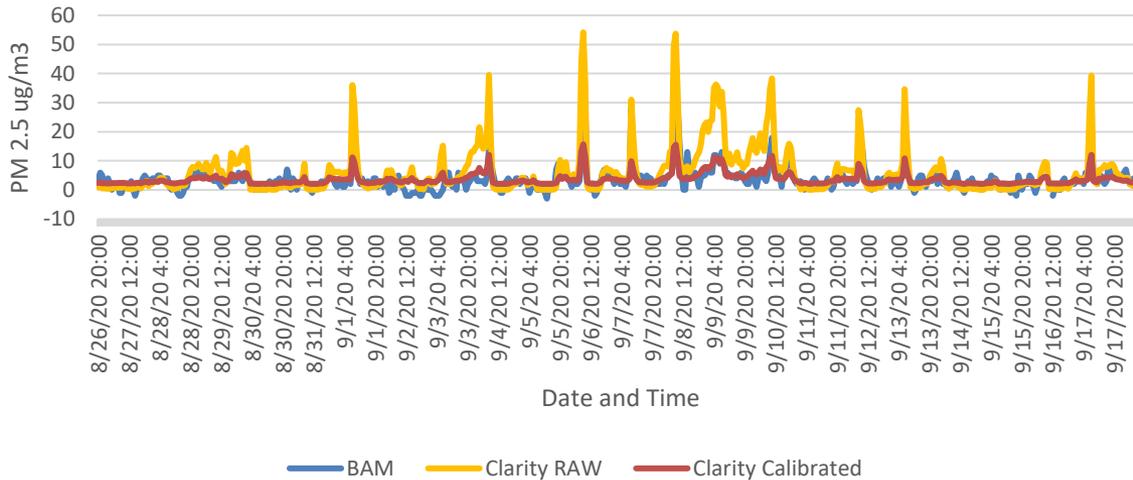


BAM and PurpleAir US EPA Correction  
Equation

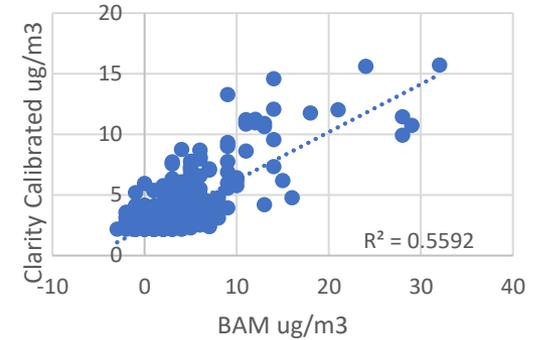


# Clarity Raw Data

RAP Comparison  
BAM, Clarity Calibrated, Clarity Raw  
8/26/2020-9/18/2020

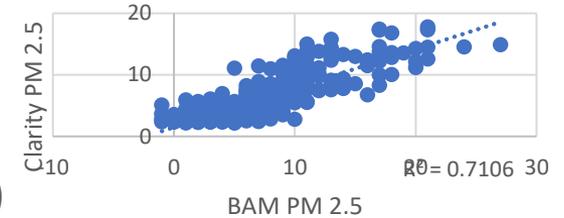


Regression BAM and Clarity

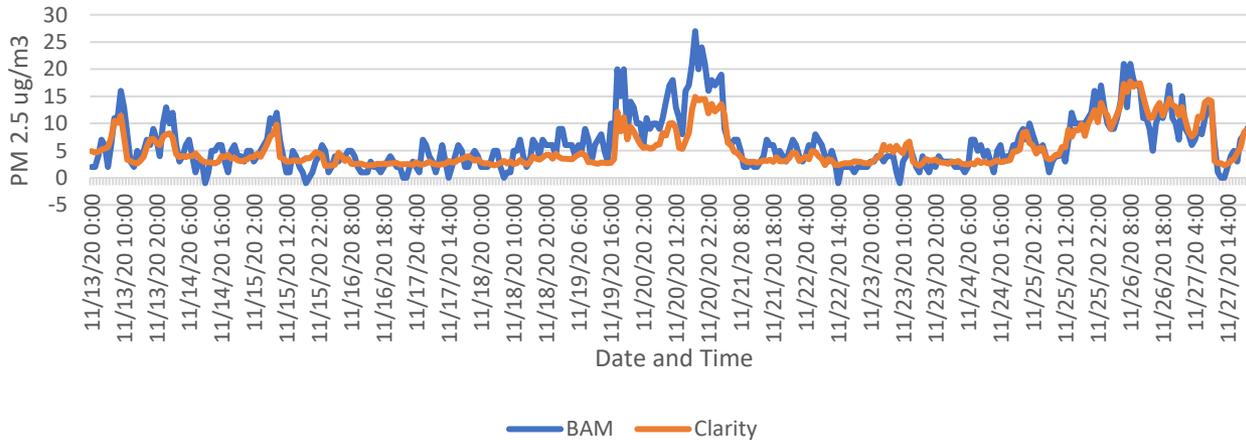


# Clarity Calibrated Data

Regression BAM and Clarity



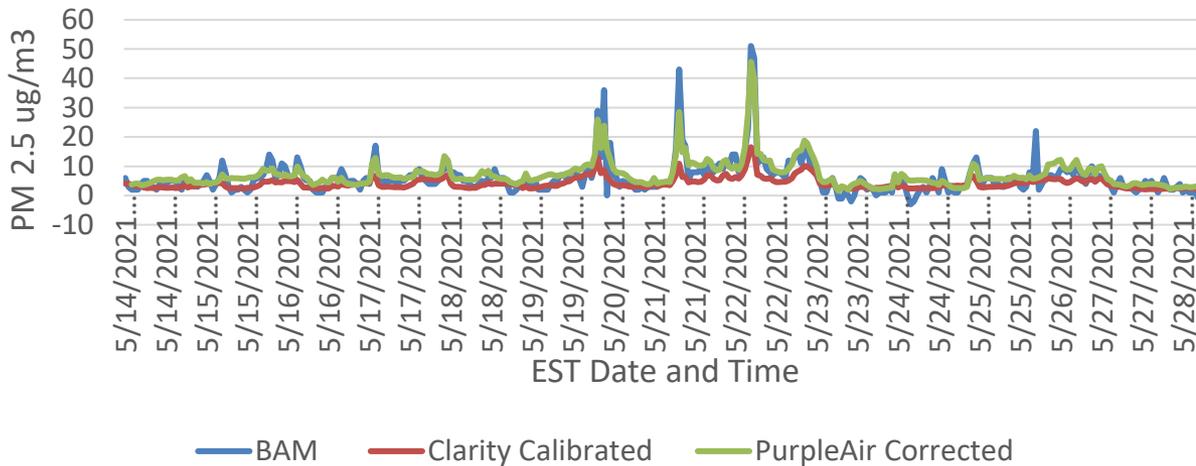
RAP Comparison  
BAM and Clarity Calibrated (15 minute samples)  
11/13/2020-11/27/2020



# Woodsmoke Event Comparison

## RAP Comparison

BAM, Clarity Calibrated, PurpleAir Corrected  
5/14/2021-5/28/2021



- The Clarity Node-S was biased low. Was the calibration not working as well with wildfire smoke particle pollution?
- The US EPA conversion equation applied to the PurpleAir raw data showed much better agreement with Met One BAM, but biased a little low during peak readings.

# Rumford PM 2.5 Study Conclusion

Low-cost sensors have proven to be useful. Data, for the most part, consistently trended well with Met One BAM (except Clarity smoke values)

Inexpensive and low maintenance (PurpleAir had more problems; Clarity Node-S problem free but higher cost)

If we continue to utilize low-cost sensors more permanently, we should consider polling the data with datalogger/server

Both sensors provide higher resolution PM 2.5 data than what is currently available with MetOne BAM

Rumford Area Parking (RAP)



# Bar Harbor, ME Purple Air Elevational Study

McFarland Hill:  
Purple Air,  
Ncore, Castnet,  
NADP, MET

College of the  
Atlantic:  
Purple Air

Cadillac Mt: Purple  
Air, Seasonal  
Ozone, MET



# Bar Harbor, Maine Purple Air Elevational Study

- Three Purple Air locations:
- College of the Atlantic (COA) coastal location (sea-level).
- McFarland Hill (BHMH) N-Core/CastNet /NADP site. Shared location with the Acadia National Park Staff. (490ft above sea level)
- Cadillac Mountain (BHCM) seasonal ozone & MET site. (1,525ft above sea level)



# Thermo SHARP & PurpleAir: Raw vs Corrected

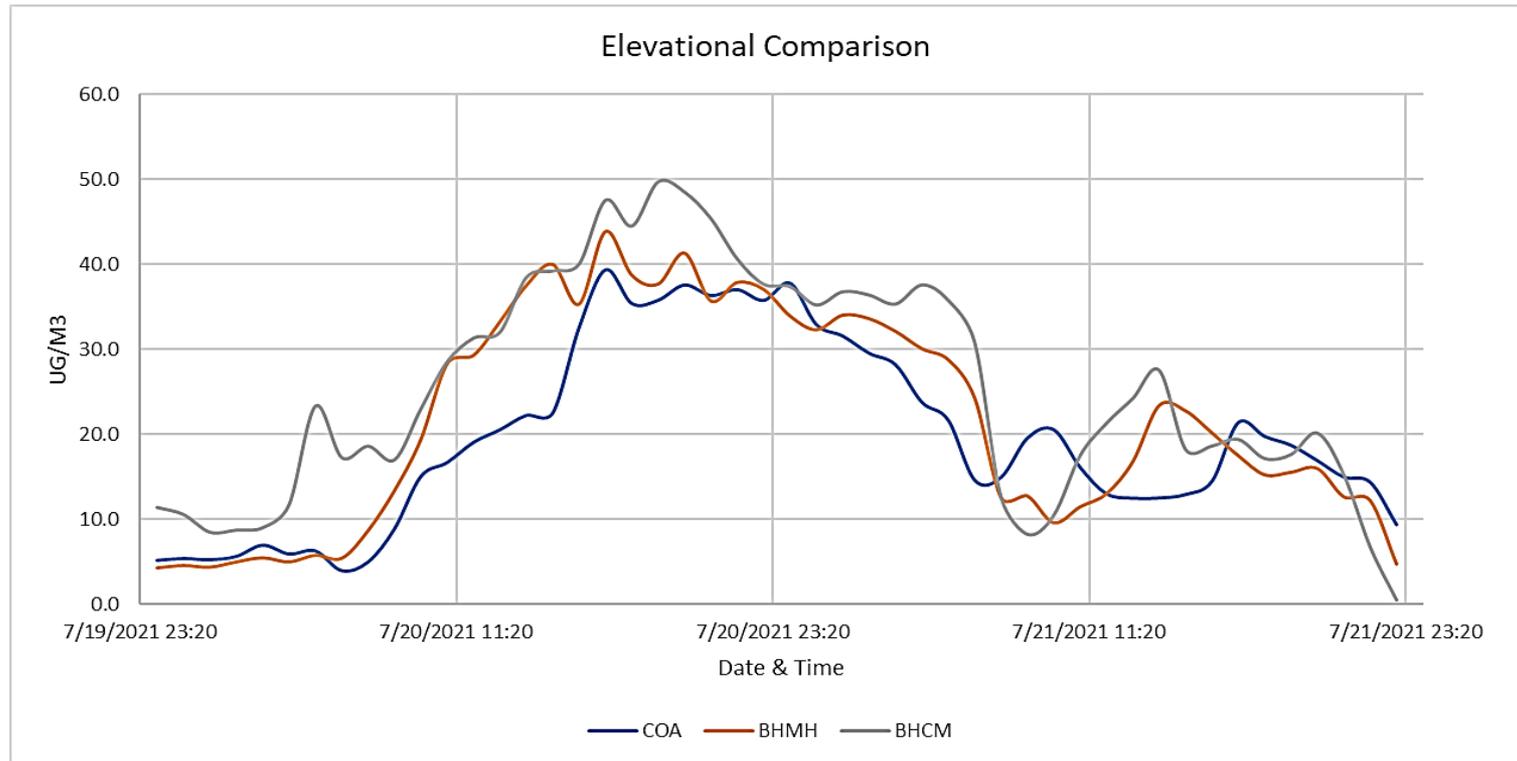
### 5030i vs PurpleAir Raw



### 5030i vs PurpleAir US EPA Corrected



# Canada Forest Fire PM Event July 2021



# Bar Harbor PM 2.5 Study Conclusion

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Elevation differences may not be a *significant* factor in Bar Harbor PM concentrations.

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In this one instance, the Cadillac PA caught a small portion of the air mass before the other two locations while sea level readings showed a delayed detection.

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These three locations also tested the durability of the PAs. Surprisingly, the Cadillac sensor performed well and lasted the longest, even during high wind events and consistent elevated humidity. Salt spray/fog impacted COA sensor.



# Low-Cost Pros and Cons

## Purple Air

Pros	Cons
CHEAP!	CHEAP! Lemons, sensors can fail
Small, lightweight, easy to attach	Spider web contamination
US-wide EPA conversion equation provides good agreement with MetOne BAM	Requires wi-fi, power source
Customer service: quick to archive data & redeploy at new site (or replace under warranty)	Sensitive to wet/corrosive conditions
Data retrieval from cloud	Power cord connection is flimsy
Polling with DAS	Only un-corrected raw data

## Clarity Node-S

Pros	Cons
Solar powered, robust build (sealed unit)	Cost \$1000/year
Cellular SIM Card simplifies telemetry	May need to collocate with FEM for two weeks before calibration equation can be applied
Customer Service	Redeployment is not as rapid as Purple Air due to site-specific Calibration.
Data retrieval from cloud includes both raw & calibrated values	Calibration didn't always provide data that tracked closely with BAM. Most noticeable with wood smoke.
Polling with DAS	No data access post-subscription





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PDF version of presentation can be found here:

[https://www.maine.gov/dep/ftp/Low\\_Cost\\_Air\\_Sensors/](https://www.maine.gov/dep/ftp/Low_Cost_Air_Sensors/)

**[www.maine.gov/dep](http://www.maine.gov/dep)**

