Field Testing PurpleAir Sensors at IMPROVE Monitoring Sites

Nicholas Spada        IMPROVE Steering Committee Meeting        November 2, 2022
Objectives

- Determine potential benefits of low-cost sensors at IMPROVE sites
- Explore feasibility of real-time PM2.5 concentrations
- Assess durability and longevity at remote sites
PurpleAir and Low-Cost Sensors (LCS)

- LCS are generally real-time instruments that are priced for general consumers
- PurpleAir sells a few versions of their highly-popular PA-II device
  - 2-sensor Plantower PMS-500X
  - Red diode laser, 657 nm
  - Effectively an integrating-nephelometer
Estimating PurpleAir PM2.5: Relativity Humidity Correction

Uncorrected PM2.5 Concentrations vs. PM2.5 (IMPROVE, \(\mu g/m^3\))

PM2.5 Concentrations after EPA Correction vs. PM2.5 (IMPROVE, \(\mu g/m^3\))

EPA US-wide correction: 
0.53 \times \text{PA-II} - 0.08 \times \text{RH} + 5.60

PA-II PM2.5 "cf_atm" data averaged to align with IMPROVE sampling schedule
Estimating PM2.5: Site-Specific Correction

Additive elemental terms (stepwise selection)

\[ PA-\text{II (corrected)} = \text{function (OC, EC, EC/TC, fAbs, Soil, Sulfate, Nitrate, RH)} \]

Model created by Prof. Hanyang Li
Diurnal Variations

Hourly-averaged PM2.5 concentrations
Corrected using IMPROVE site-specific, chemical-speciation models
All available data used
Generally, Low Daily Variability Year-Round at IMPROVE Sites
Experiment Summary

- Site-specific models more accurate than network-wide
- Low temporal variability at most IMPROVE sites
- Encouraging for remote sensing applications
## LCS Longevity at IMPROVE Sites

**Objective:** Quantify how long PA-II sensors last at remote IMPROVE sites

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site Code</th>
<th>Start Date</th>
<th>End Date</th>
<th>Days of Observations</th>
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<tbody>
<tr>
<td>Mount Baldy</td>
<td>BALD</td>
<td>March 23, 2018</td>
<td>July 13, 2018</td>
<td>36</td>
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<tr>
<td>Fresno, California</td>
<td>FRES</td>
<td>April 1, 2018</td>
<td>-</td>
<td>1356</td>
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<tr>
<td>Hercules Glades Wilderness</td>
<td>HEGL</td>
<td>May 23, 2018</td>
<td>January 20, 2020</td>
<td>461</td>
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<tr>
<td>Grand Canyon National Park</td>
<td>GRCA</td>
<td>May 24, 2018</td>
<td>July 15, 2018</td>
<td>41</td>
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<tr>
<td>Wichita Mountains National Wildlife Refuge</td>
<td>WIMO</td>
<td>May 24, 2018</td>
<td>May 12, 2019</td>
<td>216</td>
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<tr>
<td>Mammoth Caves National Park</td>
<td>MACA</td>
<td>May 22, 2019</td>
<td>August 6, 2019</td>
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<tr>
<td>Shenandoah National Park</td>
<td>SHEN</td>
<td>June 20, 2019</td>
<td>May 1, 2021</td>
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<tr>
<td>Great Smoky Mountains National Park</td>
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<td>July 26, 2019</td>
<td>-</td>
<td>1030</td>
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<tr>
<td>Theodore Roosevelt National Park*</td>
<td>THRO</td>
<td>August 23, 2019</td>
<td>-</td>
<td>163</td>
</tr>
</tbody>
</table>

*The PA-II at THRO has infrequent reporting. Root cause currently unknown.*
For each day (plotted point):
- OLS regression of sensor A and B
- calculate the COD ($R^2$)

Dashed lines locate $R^2 = 1$
Longevity at Great Smoky Mountains NP

Comparison of PurpleAir Sensor Readings at Great Smoky Mountains NP
Data is binned by density of points. Orange line is the last site maintenance visit.

March 7
August 27
April 10-20
Great Smoky Mountains NP
Sensor Degradation

Less scatter after March 7, 2021
(also less observations per day)

Drop in slope (B < A) after April 20
and again after August 27, 2022

Slope a useful metric to determine parts replacement
Longevity Summary

- Trend of coincident sensor disagreement with deployment duration **not quantified**. Changes appear to happen rapidly, not gradually.
- Degradation of coincident sensor agreement is inconsistent between sites.
- Sensors should be tested prior to deployment (as recommended in Ouimette et al. 2022).
- Routine maintenance should improve long-term stability.
Computer Vision and LCS
One Idea

Objective: Reduce validation guesswork when PM2.5 elevated

Logic: IF PA-II high AND CV detect AND sample day THEN notification

ISLE1 – Lawn Mowers
Detect mowing activity on sample days

PHOE1 – Dogs
Detect dust plume from neighboring lot on sample days
Thank you for your attention
Comparison of PurpleAir Sensor Readings at Great Smoky Mountains NP

Blue line is a smoothing approximation using generalized additive models. Orange line is the last site maintenance visit.
Questions:
• What was the precision between the two PA-II sensors at the beginning of each deployment?
• Were all sites consistent?

Use the first 1,000 observations to determine

$$ARD = \frac{(CH1_A - CH1_B)}{(CH1_A + CH1_B)/2} \times 100\%$$

Observed precision generally within 20%.

Average ARD < 10% for all sites except Fresno (scales with magnitude).