

Advancements in Citizen Science Implications for Community Air Quality Management

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with thanks to Brayden Nilson, Nazrul Islam and the 2017 UNBC ENSC 412

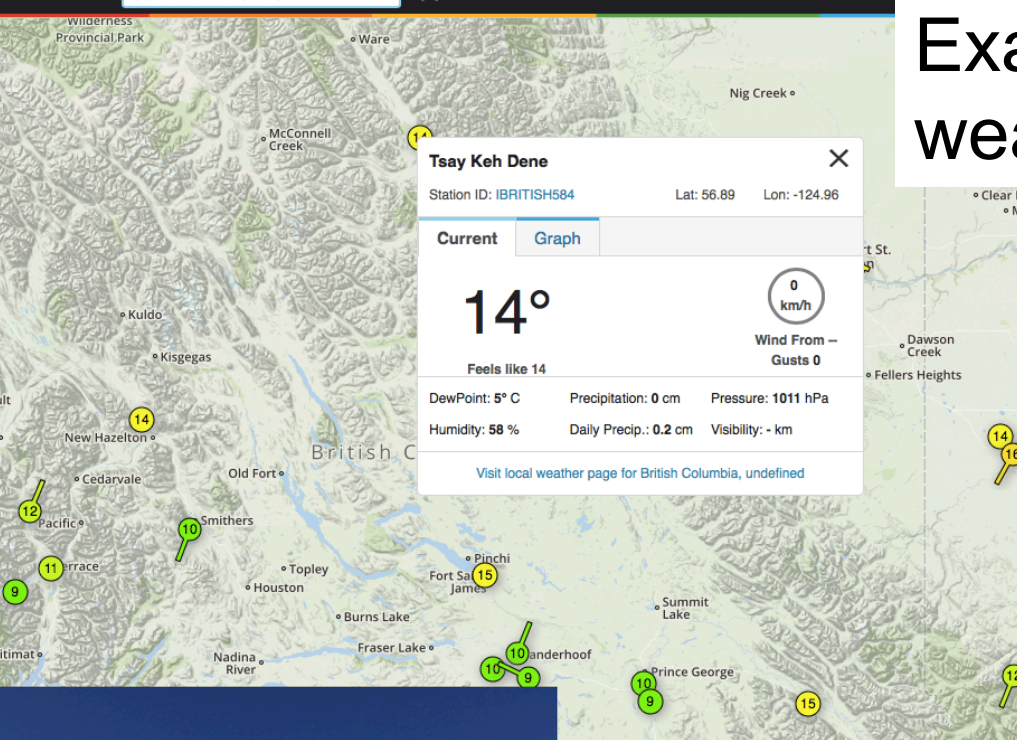
Air Pollution Class: James Albino, Cody Birch, Brayden Nilson, Jordan
Pawluk, Taras Tereshchak

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Citizen Science:

citizen science n. scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions. (added to the Oxford English Dictionary in 2014)

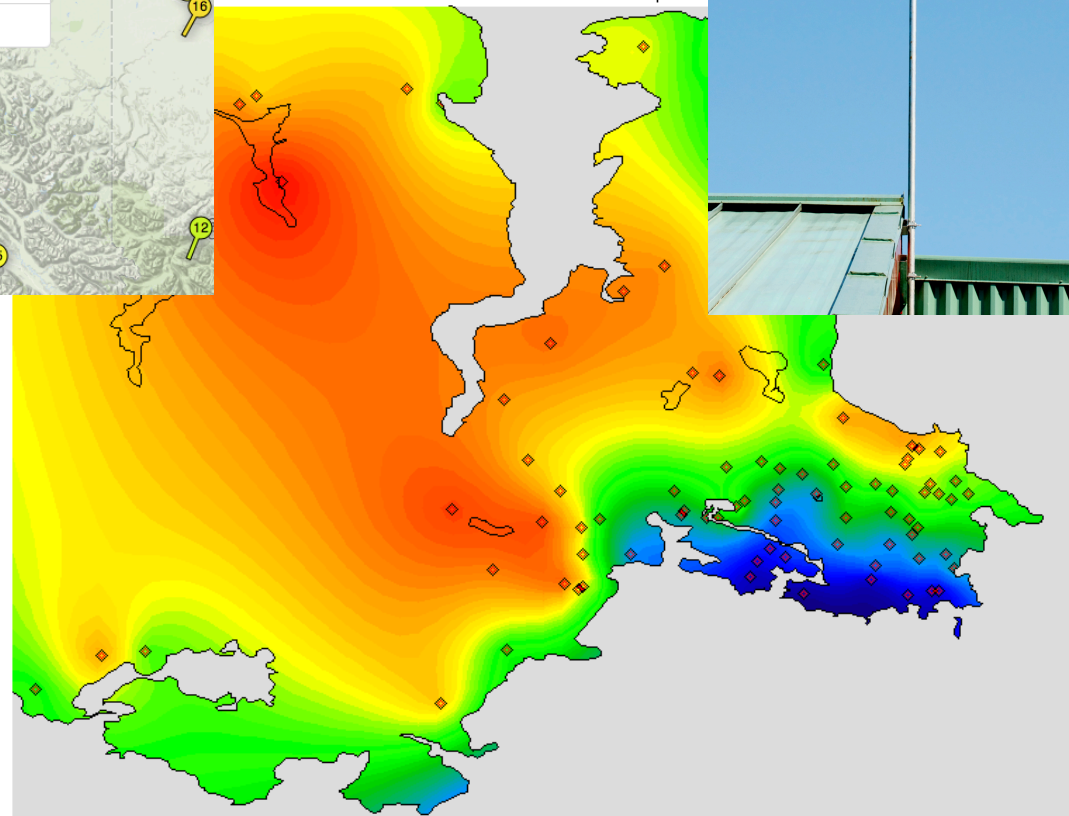
- Members of the public are becoming involved in every field of science by collecting and analysing data of all kinds
- For example, Wikipedia (itself a crowd-sourced project) has an incomplete list of over 210 active citizen science projects on every topic from astronomy to zoology, including several projects related to weather and air quality monitoring
- However citizens don't have to be part of a "project" to participate...



Examples of citizen science weather monitoring

Vancouver Island School-Based Weather Station Network

VictoriaWeather.ca — Tempera



CMOS BC
Interior/Yukon
project to install
weather stations
in schools



Air Quality Monitoring

- Until recently, due to cost, AQ monitoring has been in the realm of governmental and professional research agencies
- Regulatory “gold standard” monitors are designated as Federal Equivalent Method (FEM) or Federal Reference Method (FRM) through rigorous testing by the US EPA
- Single FEM monitors typically cost \$20-50K and require periodic calibrations and maintenance by qualified technicians to generate reliable and accurate data, as well as data quality control / quality assurance procedures
- Consequently there are relatively few FEM AQ monitors in most cities
- However we know that air pollution levels vary a lot over short distances...

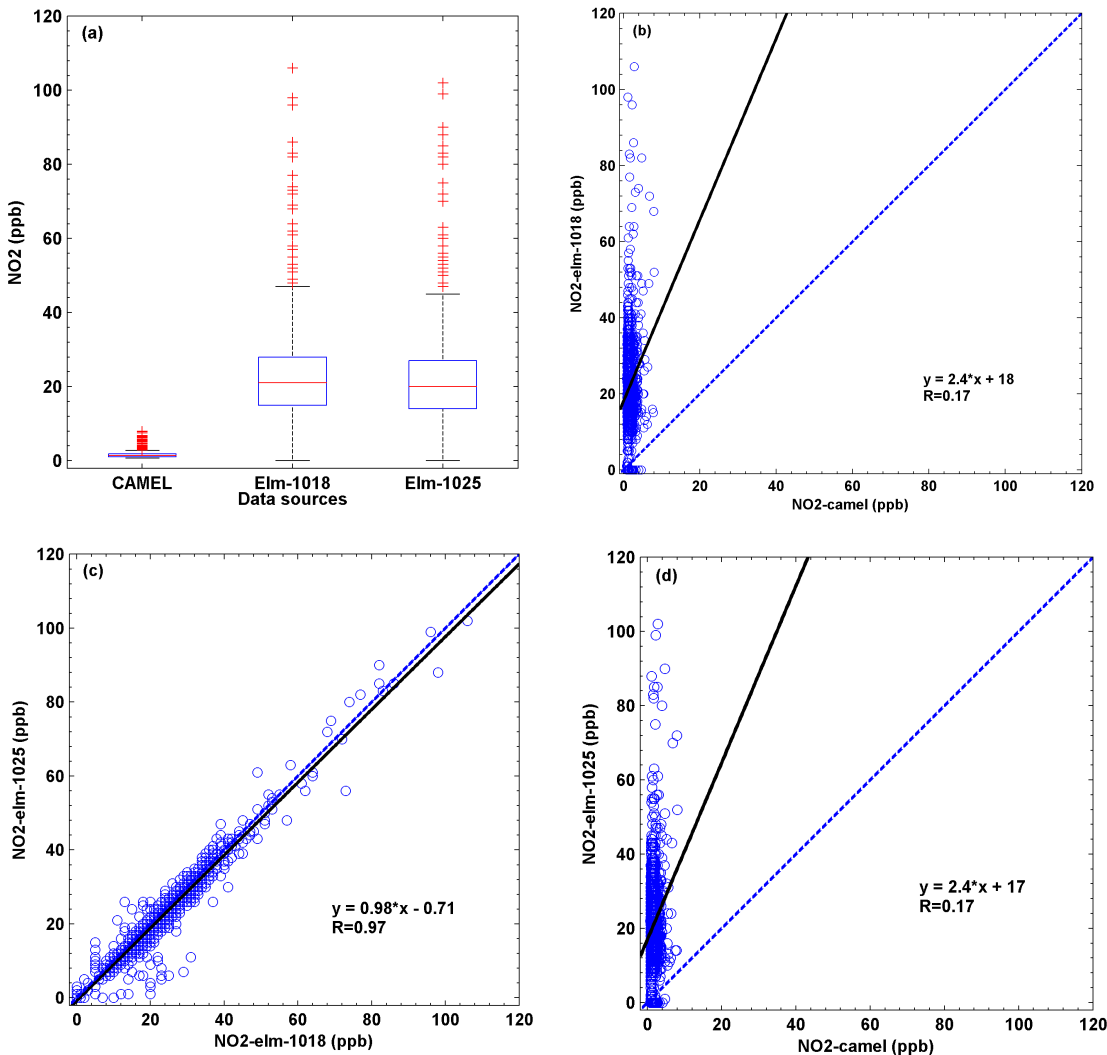
“Small Sensors” for AQ

- The past decade has seen development of many low-cost sensors for gases and particulates
- Gas sensors are typically electro-chemical or metal oxide semi-conductors
- PM sensors usually use light scattering by particles to estimate particle counts by size and mass concentration
- Cost and size offer ability to densely monitor areas, and to mount monitors on mobile platforms (e.g. drones) to better understand AQ patterns, validate models, assess exposure, etc.

Citizen Scientists and Air Quality

- Members of the public want to know the air quality in their neighbourhood so they can make informed decisions about their activities that might be impacted by AQ
- New small sensors should make this possible
- However... at this time not all low-cost AQ monitors give meaningful data – buyer beware...

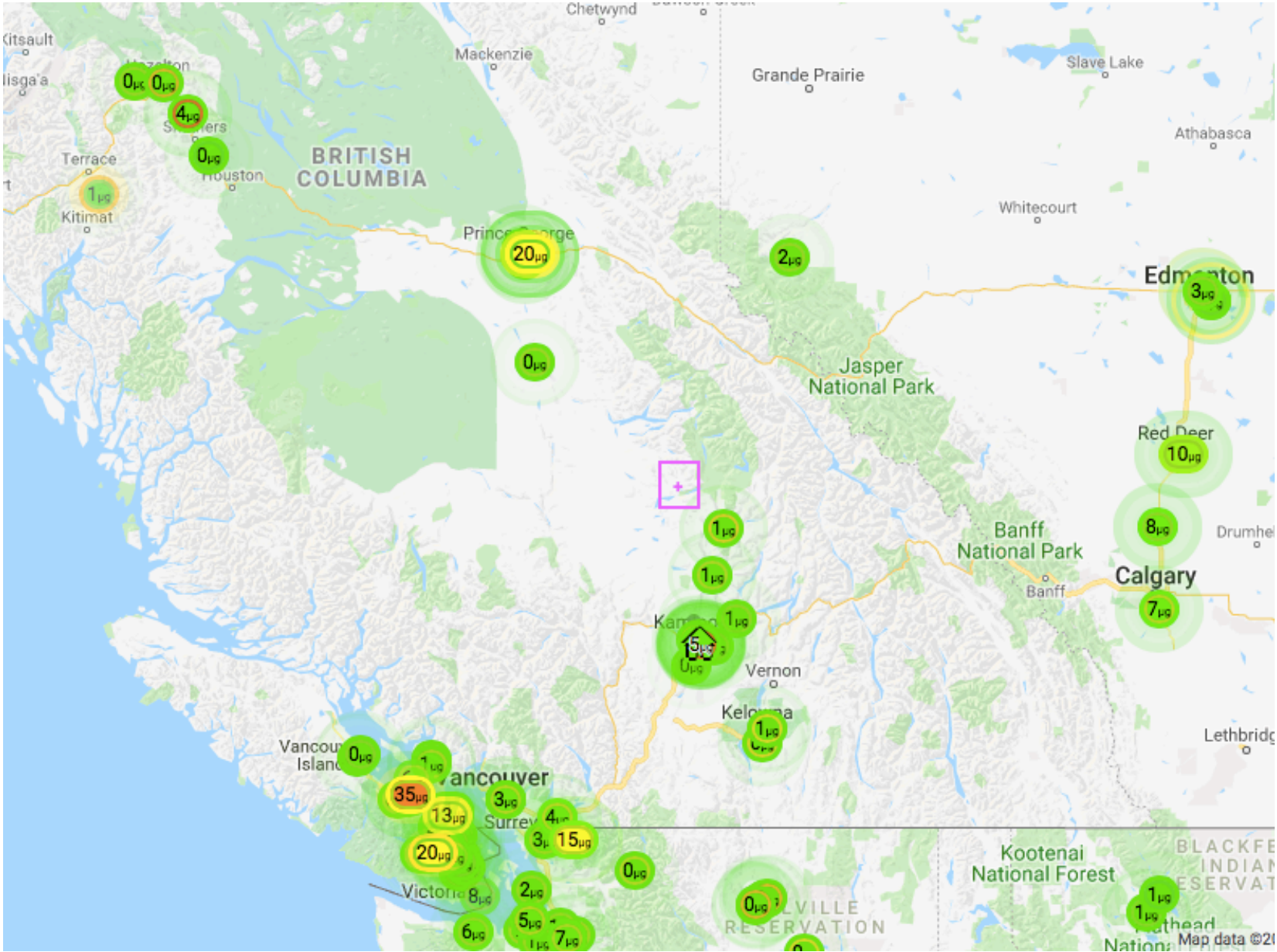
Cautions with low-cost monitors



- A colocation study in NEBC between a FEM NO₂ monitor (CAMEL) and two low-cost multi-sensor monitors
- They correlate well with each other, but not with FEM monitor
- What do their numbers mean?

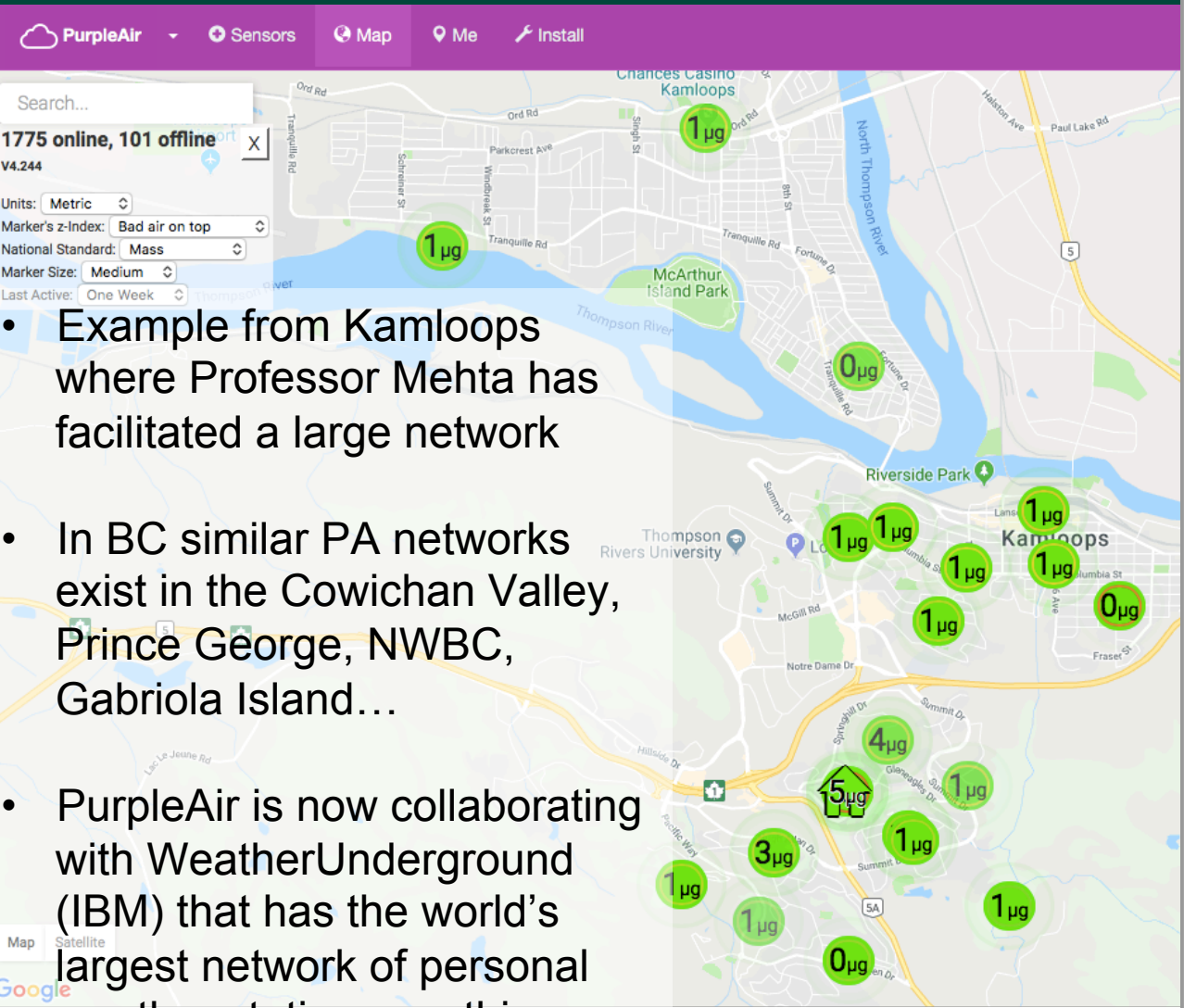
Some small sensors work better...

- We (and many others) have become interested in PurpleAir monitors for PM_{2.5}
- These monitors have dual Plantower light scattering sensors (mini nephelometers), and connect to a home WIFI network enabling them to upload data in realtime to a central server (<https://www.purpleair.com/map>)
- They cost \$US230-260



2018-06-05

North Central BC Clean Air Forum



- Example from Kamloops where Professor Mehta has facilitated a large network
- In BC similar PA networks exist in the Cowichan Valley, Prince George, NWBC, Gabriola Island...
- PurpleAir is now collaborating with WeatherUnderground (IBM) that has the world's largest network of personal weather stations, so this network is expanding

On Fri Jun 01 2018 20:34:17 GMT-0700 (PDT)

Real Time PM2.5 is LOW at 0µg/m3

Enjoy your activities.

Real Time AQI

2

Good

Good | Moderate | **Warn** | Unhealthy | Very | Hazardous

0-50: Air quality is considered satisfactory, and air pollution poses little or no risk

Trends | Particles | Sensor | **Current Weather**

Channel A Running Averages

Real Time	Short-term	30 minute	1 hour	6 hour	24 hour	One week
3	3	3	3	6	8	17
1µg/m3	1µg/m3	1µg/m3	1µg/m3	1µg/m3	2µg/m3	4µg/m3

Channel B Running Averages

Real Time	Short-term	30 minute	1 hour	6 hour	24 hour	One week
1	3	4	4	7	9	18
0µg/m3	1µg/m3	1µg/m3	1µg/m3	2µg/m3	2µg/m3	4µg/m3

Excellent Confidence

100%

A score comparing channel A and B. Higher is better.

* Laser Temperature: **21.67°C** * Laser Humidity: **26%**

* Approximate conditions the laser is exposed to. Readings are affected by the electronics, sunlight or wind. Temperature may be elevated and humidity under estimated.

Real Time Average	Short-term Average	One Hour Average	24 Hour Average
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Comparing channel A and B:

R² = 0.98 (values close to 1.0 are better)

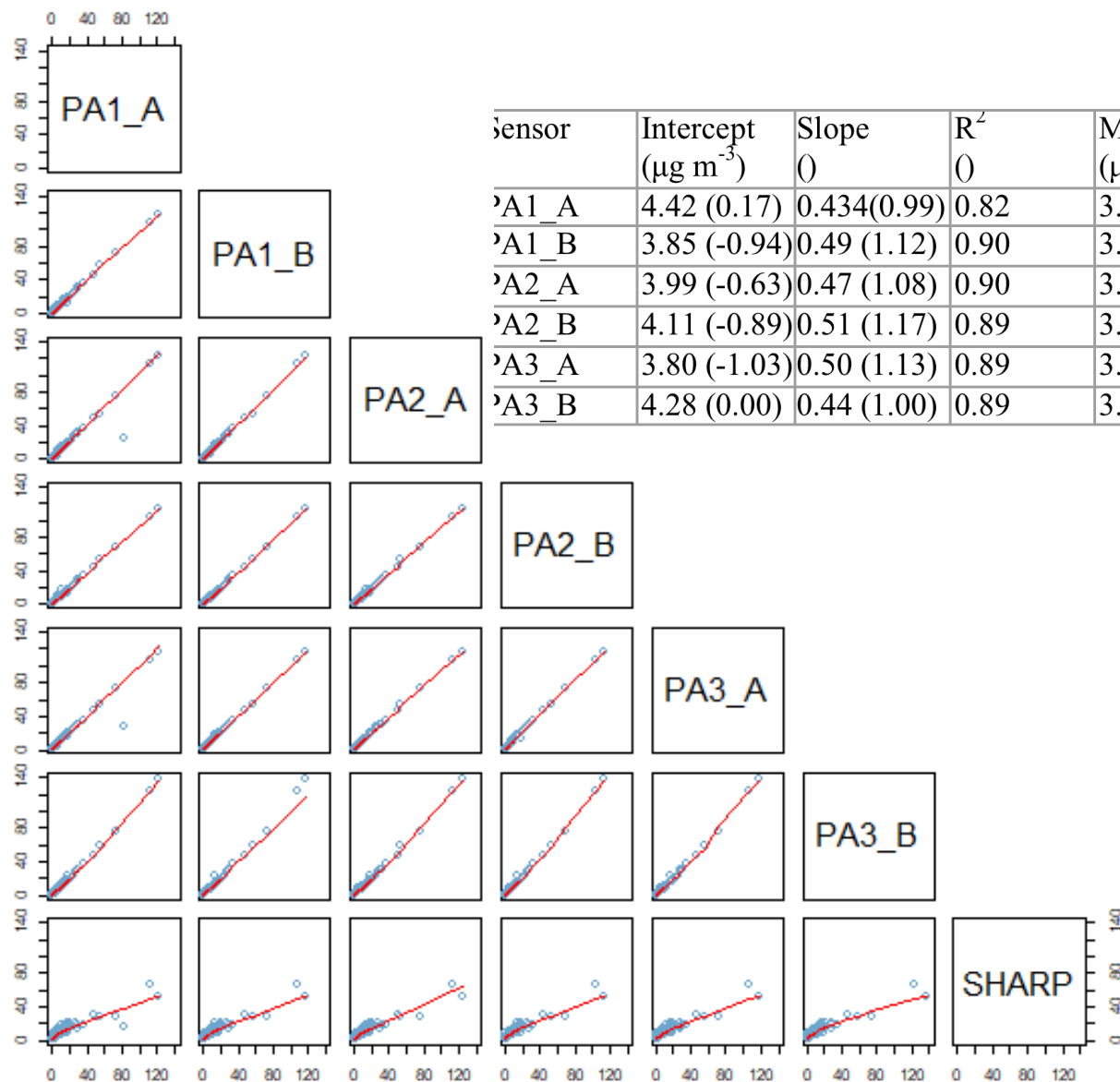
Formula: $y = 0.87 * x - 0.02$

Evaluation of PurpleAir PA II

- Colocation of three PA II monitors with the PG Plaza SHARP (FEM) monitor from February through August 2017 showed very promising results...

SHARP and PA II Plotted Against Each Other for Daily Average PM_{2.5} at Plaza

Daily PM2.5

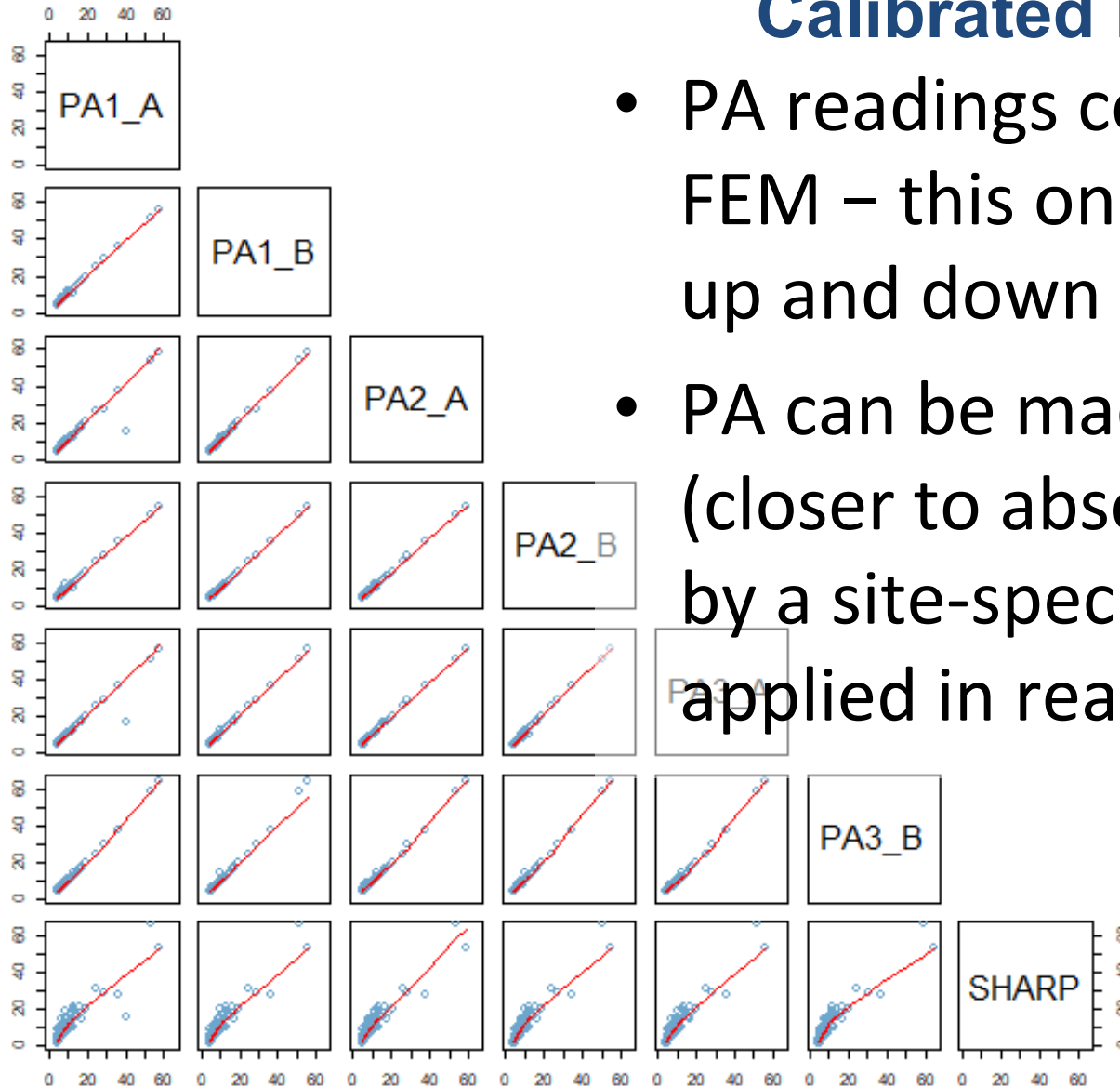


Sensor	Intercept ($\mu\text{g m}^{-3}$)	Slope ($^{\circ}$)	R ² ($^{\circ}$)	MAE ($\mu\text{g m}^{-3}$)	RMSE ($\mu\text{g m}^{-3}$)	MBE ($\mu\text{g m}^{-3}$)	MAPE (%)
PA1_A	4.42 (0.17)	0.434(0.99)	0.82	3.85 (1.94)	9.56 (3.21)	0.67 (-0.10)	39.7 (31.9)
PA1_B	3.85 (-0.94)	0.49 (1.12)	0.90	3.25 (1.76)	7.87 (2.60)	0.67 (-0.04)	34.0 (31.7)
PA2_A	3.99 (-0.63)	0.47 (1.08)	0.90	3.44 (1.78)	8.43 (2.55)	0.84 (-0.03)	35.2 (31.4)
PA2_B	4.11 (-0.89)	0.51 (1.17)	0.89	3.27 (1.83)	7.27 (2.76)	-0.16(-0.44)	37.5 (30.9)
PA3_A	3.80 (-1.03)	0.50 (1.13)	0.89	3.27 (1.79)	7.79 (2.64)	0.82 (-0.03)	33.5 (32.0)
PA3_B	4.28 (0.00)	0.44 (1.00)	0.89	3.54 (1.84)	9.50 (2.61)	0.75 (0.00)	35.6 (32.3)

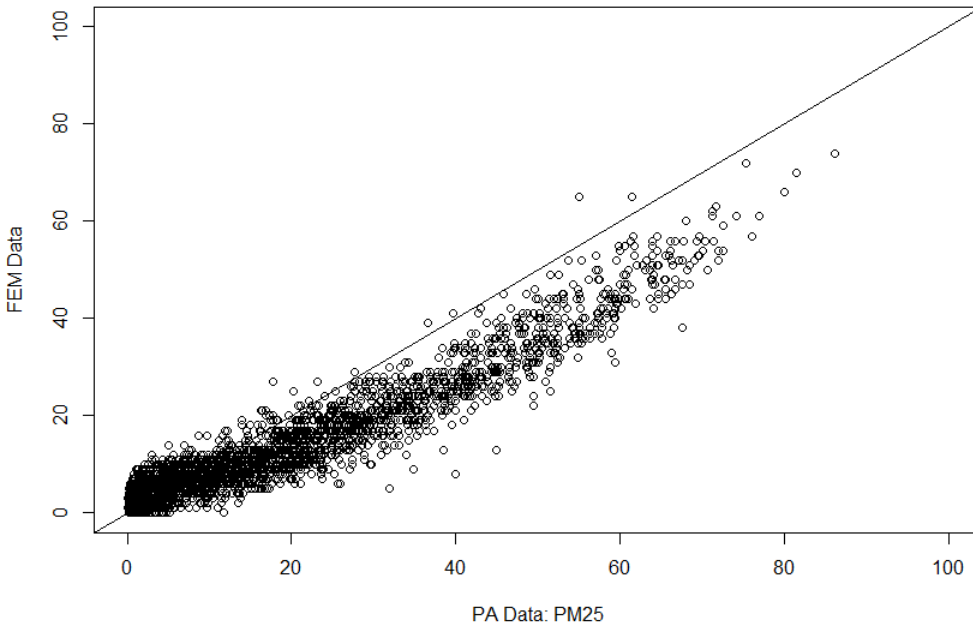
SHARP and PA II Plotted Against Each Other for corrected Daily Average PM_{2.5} at Plaza

Calibrated Daily PM2.5

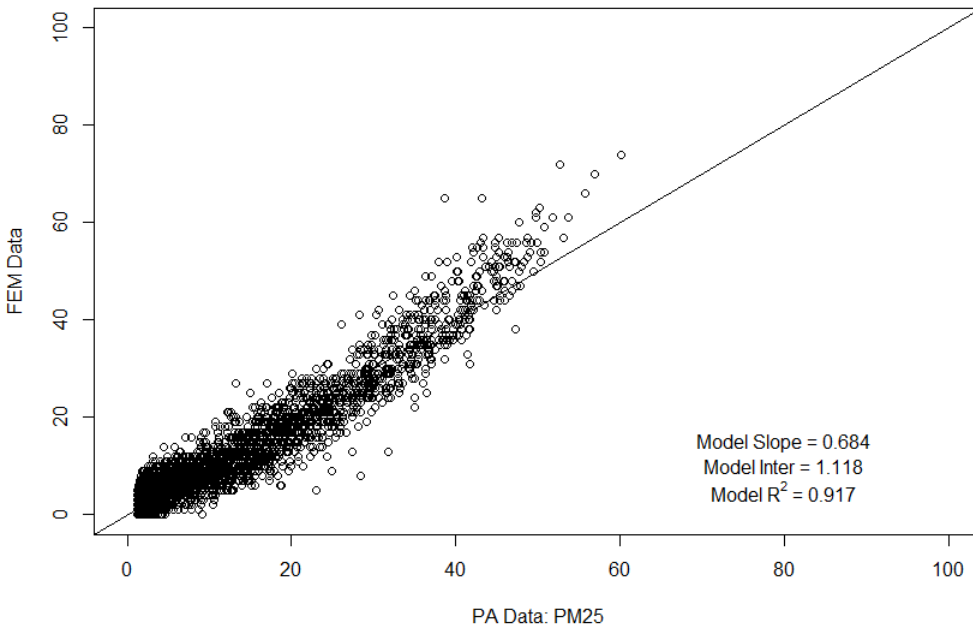
- PA readings correlate well with FEM – this only means they go up and down together
- PA can be made more accurate (closer to absolute FEM values) by a site-specific calibration applied in realtime



**Before Corrections Applied
Courtenay Elementary**

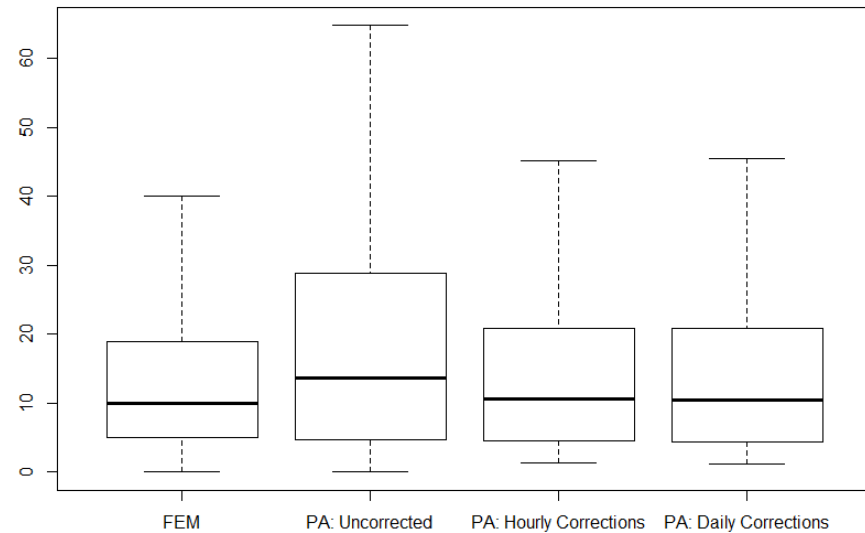


**After Daily Corrections Applied
Courtenay Elementary**



Colocation results from Cowichan

Courtenay Elementary



Map

Sensor

Contact

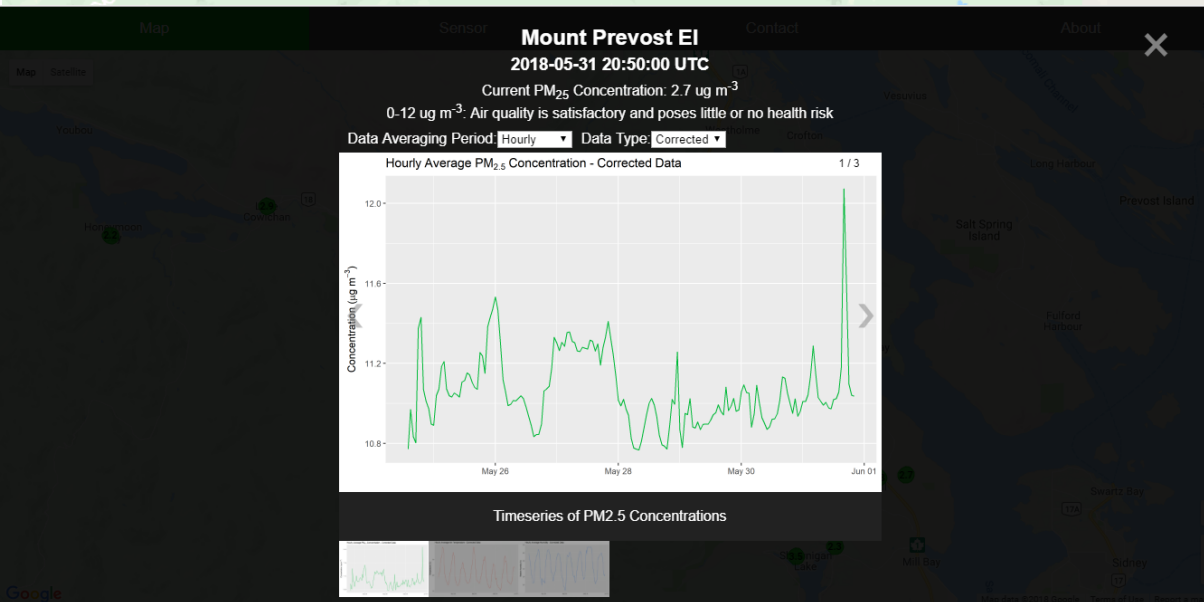
About

We have a project to “correct” PA in realtime and combine with other sensor networks

UNBC Intern, Brayden Nilson is developing code to:

- Download (realtime) a list of specified PA monitor data
- Apply a calibration correction to the “raw” PA data
- Display the corrected data on a PA-like map
- Can also toggle the raw PA data, as well as correcting and displaying T/RH

- We are working with Cowichan Valley data, and will soon add in PG and other locations
- We will also be able to integrate new monitors currently being developed by PhD student Tereshchak



Where can “citizens” get more information?

- If you are considering purchasing an AQ monitor there are several reputable and helpful sources for reviews / colocation studies that compare many monitors:
 - AQ-SPEC (Air Quality Sensor Performance Evaluation Center) of the California South Coast AQMD
 - US EPA Air Sensor Toolbox for Citizen Scientists, Researchers and Developers

Air Sensor Toolbox for Citizen Scientists, Researchers and Developers

CONTACT US

SHARE



Attend the Air Quality Sensor Workshop

June 25 and 26, 2018
EPA Research Triangle Park Campus in
Durham, NC

- [Register to attend \(in-person or webinar\)](#)



• [What's New](#)



South Coast Air Quality Management District



AQ-SPEC

Air Quality Sensor Performance Evaluation Center



Recently added/updated:

- **NEW!** Purple Air PA-I Indoor - Field Evaluation (posted, 5/30/18)
- **NEW!** AQ-SPEC in the news (posted, 5/25/18)
- Article by Hagler et al. in Environmental Science & Technology
- Article by Papapostolou et al. in Atmospheric Environment

ts and others on how to select and use low-cost, portable air sensor technology and information can help the public learn more about air quality in their communities.

Interpretation of low-cost monitor data

- Low-cost monitors will give different values compared with FEM monitors but this does not mean they are not useful
- If they have a high correlation, then at least they go up and down together, and the low-cost monitor can be used to detect when AQ levels are changing – this can be helpful for people to make decisions regarding their activities
- If they have a high correlation but biases or large RMSEs, they can also be corrected with site-specific calibrations, so that their values are closer to FEM values

Implications for AQ management

- There will be a proliferation of small sensors that will improve over time
- The allow monitoring at the neighbourhood level, better exposure assessment and optimization of FEM networks
- However, if their accuracy characteristics are not understood, their “numbers” are difficult to interpret for both the public and professionals
- Other issues include correct siting, servicing and replacement as the sensors age and degrade
- Besides monitoring, in what other ways can the public be involved in AQ science?