Calibrating and deploying low-cost particulate matter sensors in the GTA

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Introduction

We used a correction model to calibrate twenty-seven PurpleAir sensors to be deployed for long-term monitoring of air quality across the GTA. PurpleAir sensors are low-cost particulate matter (PM) sensors that measure PM2.5, PM1.0, PM10.0, temperature, humidity, and pressure. Due to PurpleAir sensors' nature as optical sensors, they are affected by environmental factors such as temperature and humidity causing discrepancies between low-cost optical PM sensors and regulatory-grade instruments (Mailing et. al, 2020). We collocated the sensors on McLennan roof with one sensor collocated with a regulatory-grade PM2.5 sensor, on the Wallberg Memorial Building roof. We then applied a correction model to the PurpleAir sensors to account for discrepancies.

PurpleAir Sensors

PurpleAir sensors are low-cost particulate matter (PM) sensors that measure PM2.5, PM1.0, PM10.0, temperature, humidity, and pressure. Each of the sensors has two Plantower PMS 5003 laser counters that measure PM. Each laser counter consists of a fan, a laser, and a light detector. The fan brings in samples of air and past the laser beam. The particles in the air sample deflect the laser's light. The light detector measures the intensity and angle of the deflected light. Utilizing this information, a microprocessor calculates the particle sizes and the number of particles (Zhou, 2016).

Figure 1: Ten of the PurpleAir sensors collocated on the roof of McLennan for calibration.

Figure 2: MP2 (circled in blue) collocated with the SHARP instrument on the Wallberg building.

Methods

We begin by choosing a benchmark sensor - MP2. Then, we performed a linear regression analysis of each of the remaining PurpleAir sensors against the MP2 sensor and obtained calibration coefficients and intercepts. To put MPX on the MP2 standard, we use the equation:

$$PM2.5 = a_1\, PM2.5_{MPX} + a_0$$

where a_1 is the calibration coefficient, and a_0 is the calibration intercept (see Table 1) .

Next, we collocated the MP2 sensor with the Thermo 5030 Synchronized Hybrid Ambient Real-time Particulate Monitor (SHARP) instrument - a regulatory-grade PM2.5 instrument - for two weeks.

Mailings et al. (2020) provide an empirical correction method that accounts for environmental factors such as humidity, temperature, and dew point. First, using the data collected during this period, we performed a multivariate linear regression, taking into account relative humidity (RH), temperature (T), and dew point (DP):

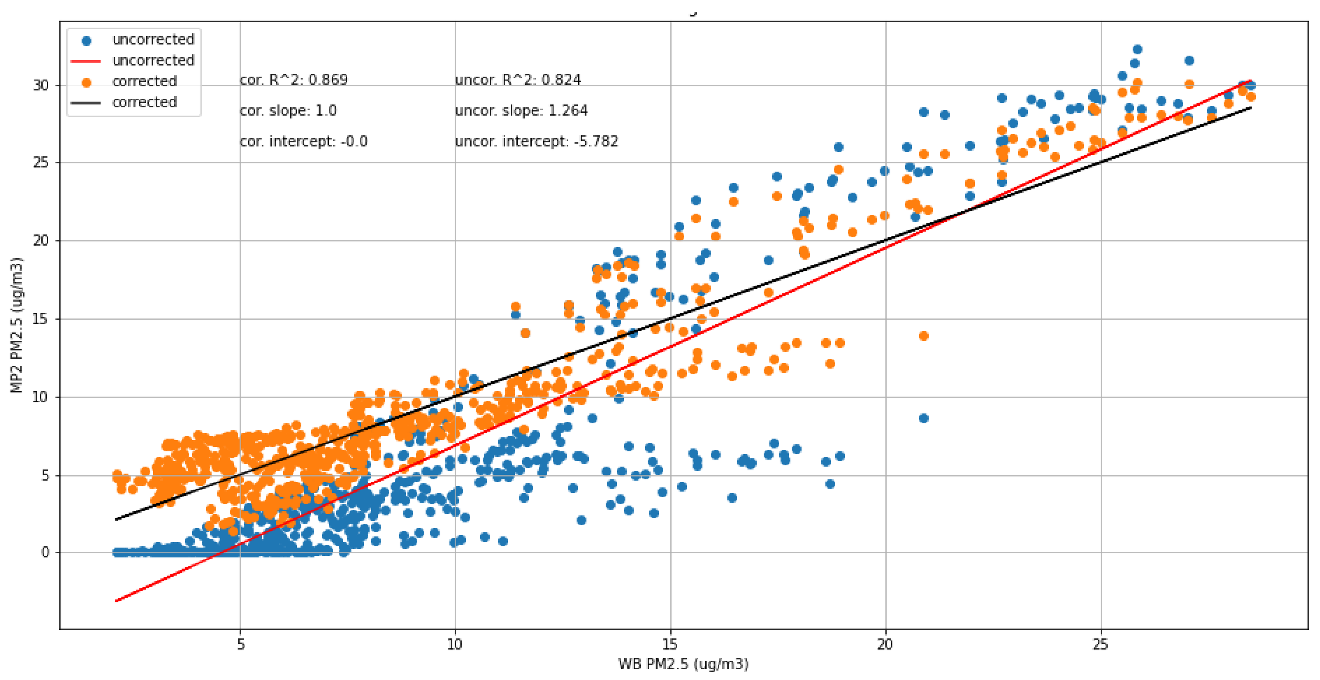
$$PM2.5_{MP2} = c_0 + c_1 PM2.5_{SHARP} + c_2 T + c_3 RH + c_4 DP$$

We calculated the correction coefficients and intercept to be c_0 = -13.055, c_1 = 0.867, c_2 = 0.102, c_3 = 0.118, c_4 = 0.320. Dew point was calculated as a function of relative humidity and temperature.

To correct the other twenty-six PurpleAir sensors against the SHARP instrument, we used:

$$PM2.5_{MPX} = [PM2.5_{MP2} - c_0 - c_2 T - c_3 RH - c_4 DP]/\, c_1$$

Figure 3: MP2 v.s. Wallberg (WB) SHARP instrument before and after correction.



Results

Figure 3 shows a 1-1 plot of MP2 against the SHARP instrument before and after applying the correction to MP2.

Figure 4 shows MP1 against the SHARP instrument attained by calibrating MP1 against the corrected MP2 instrument.

Figure 4: MP2 v.s. Wallberg (WB) SHARP instrument before and after correction.

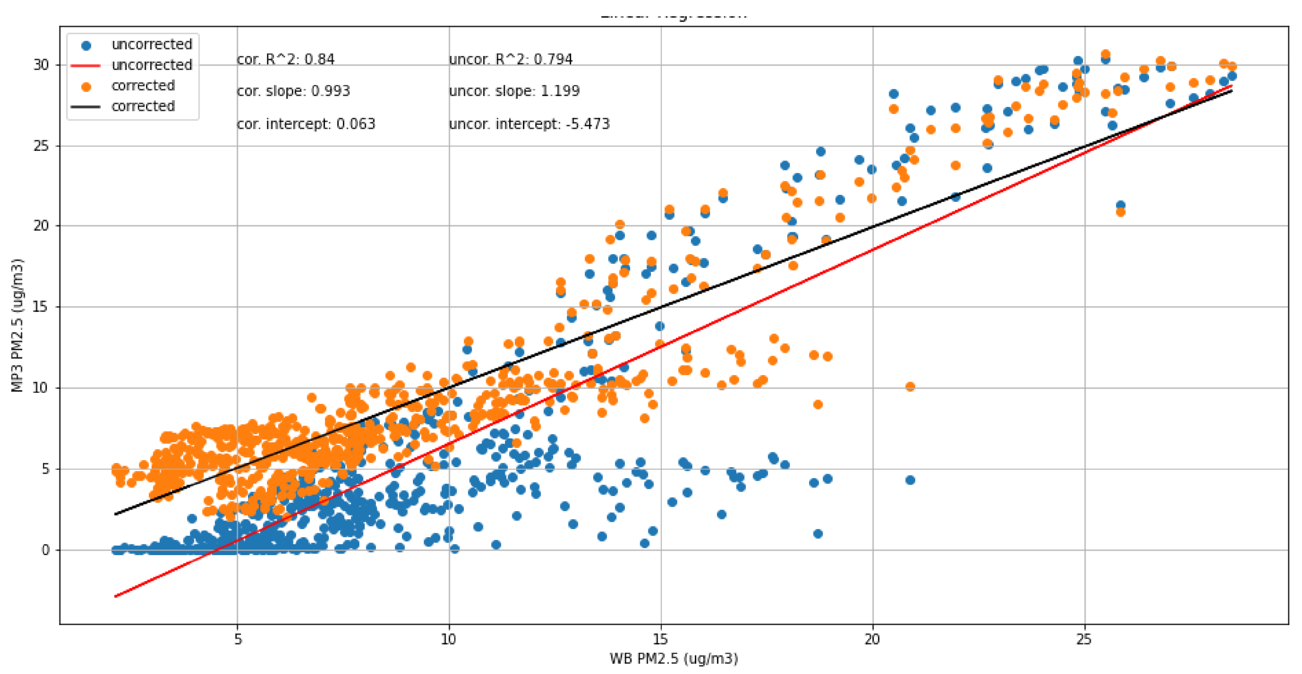


Table 1: Calibration coefficients and intercepts of PurpleAir sensors (MP1, MP3-MP27) against MP2. A and B refer to the two different PM2.5 sensors each sensor is equipped with.

PurpleAir Name	R^2 a	Slope a	Error in Slope a	Intercept a	Error in Intercept a	Slope b	Error in Slope b	Intercept b	Error in Intercept b	R^2 b
MP1	0.987518865	1.069538251	0.005995858	0.511874899	0.024925707	1.096472101	0.007155488	0.523623325	0.030093617	0.986170132
MP2	1	1	1.95e-15	-1.13e-15	1.01e-14	0.995277485	0.002382576	-0.081340014	0.01162795	0.996751385
MP3	0.990806636	0.999640094	0.004772747	0.099937554	0.022655741	1.030306872	0.003894523	0.358967286	0.018519915	0.992974007
MP4	0.988409328	1.033935114	0.004513014	0.485022538	0.021015459	1.048708256	0.004441474	0.478765645	0.018502911	0.991148322
MP5	0.982247706	1.093007357	0.007681053	0.699775545	0.029673955	1.09810102	0.007190034	0.58402835	0.026917034	0.985325246
MP6	0.994404185	1.045425861	0.004277033	-0.045048616	0.01744534	1.003843028	0.002090307	0.199943884	0.014479862	0.997113352
MP7	0.9835033	0.913877411	0.006554446	-0.321640589	0.024385522	1.01216508	0.004110528	-0.133465669	0.016054987	0.990754488
MP8	0.990990953	0.962610553	0.005028974	0.133735366	0.020670062	0.973716011	0.0076255	-0.263110602	0.027671072	0.984243594
MP9	0.987672662	1.073899392	0.00581874	0.609462246	0.030868663	1.006458023	0.004401268	-0.126738318	0.018889202	0.99129359
MP10	0.986417187	1.067285124	0.004997775	0.577639512	0.029134089	0.929520332	0.017812114	0.156498691	0.056464666	0.93503903
MP11	0.99047855	0.972251287	0.005078582	-0.333691512	0.018754905	1.069864269	0.003772696	0.393036265	0.021073725	0.99382899
MP12	0.975721492	1.159161045	0.007647629	1.094853688	0.046920384	1.117697672	0.005830215	0.888079505	0.034413156	0.980089875
MP13	0.976281583	1.073038891	0.009047478	0.647202826	0.037927097	1.067351773	0.008960657	0.444770672	0.036386483	0.983441337
MP14	0.99617173	1.034642307	0.003276682	0.114129482	0.015594345	1.03890505	0.003660657	0.424383349	0.019611402	0.99370858
MP15	0.97949711	1.141122338	0.006799137	0.997554187	0.039921529	1.057443887	0.004042109	0.38458304	0.020812447	0.991026318
MP16	0.975754522	1.031644717	0.008252035	0.428216511	0.033081534	0.948508078	0.006414144	0.133085047	0.019381403	0.982384481
MP17	0.989777308	0.985652887	0.003740527	0.128963492	0.015392661	1.005706714	0.003938457	0.223324722	0.017527816	0.989817298
MP18	0.981265899	1.001881701	0.00712845	-0.024519804	0.025647185	1.154296744	0.007716076	0.725454986	0.032709701	0.979124787
MP19	0.992758301	1.067804644	0.003959423	0.282388532	0.019922334	1.163886857	0.007072253	0.907150275	0.034105819	0.982960059
MP20	0.963180692	1.145845423	0.012107017	0.953443421	0.050643356	1.079697823	0.00672274	0.459742296	0.029534925	0.987562209
MP21	0.96454194	1.069599995	0.009483346	0.678816097	0.046784666	1.016226154	0.005510552	0.314555296	0.019073574	0.984076316
MP22	0.982709976	1.040616171	0.005723017	0.308671192	0.028287003	1.014027485	0.006328704	0.160691329	0.025389491	0.982556857
MP23	0.982182291	1.10271823	0.005610886	0.692080582	0.03376147	1.129608276	0.006662246	0.848407926	0.029360004	0.978729473
MP24	0.98663958	0.997959214	0.007303013	0.25354983	0.024512542	1.03781808	0.006017319	0.197856877	0.023515232	0.984928138
MP25	0.978751611	1.162036061	0.008357227	0.793049129	0.044424788	1.123134955	0.005133534	0.456740195	0.024671963	0.990436469
MP26	0.930853521	1.000166273	0.009428553	0.521675109	0.077301845	1.095184059	0.008074817	1.308669479	0.09027515	0.93099921

References

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