Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2019-299-AC2, 2019

Atmospheric Measurement Techniques
Discussions
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AMTD

Interactive comment

Interactive comment on "Field Calibration of Low-Cost Air Pollution Sensors" *by* Andres Gonzalez et al.

Andres Gonzalez et al.

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Received and published: 15 November 2019

(1) The paper states that the MAAQSbox also contains sensors for SO2, CO2 and VOC, but only calibration for the five pollutant sensors mentioned above is reported here

(2) âĂć The air monitoring station using as reference does not measure SO2, CO2 and VOC. âĂć Generally, CO2 is not measured in air monitoring station. âĂć The concentration of SO2 is ∼ 0 ppb therefore we are not going to include in the measurements. âĂć The data of VOC is limited to other air monitoring stations that don't measure CO, NO NOÂň2 and O3 and PM2.5. The VOC calibration would have required a separate study.

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(3).

Fig1.

"The MAAQSbox holds five gas sensors and two particle sensors. The gas sensors included in the calibration are CO, CO2 O3, NO2, and NO (B4 sensors AlphaSense, Inc.)" ___________________________ (1). In both the Introduction (Line 80) and the Methods (Line 180) it is stated that the aim of this work is to 'evaluate' the performance of the sensors in their MAAQSbox, yet the design of their study and the data presented only reports a calibration (and not even the full calibration data), not an evaluation.

(2) âĂć A new aim of this study was established including the reviewer comments for line 80 and 180.

(3)

Line 85. "We seek to relate sensor response, temperature, humidity, and concentrations other species exhibiting cross sensitivities to reference field measurements performs. Our analysis seeks to determine the accuracy and precision with which low-cost sensors perform during periodic "in-use" calibration."

Line 190. "The aim of the field calibration is to compare the low-cost sensor performance to a reference instrument in the field." _______________________________ (1). The co-location dataset comprises a single 6.5-day (154 hour) co-location at one time of year at one site. This dataset is then used to derive a multivariate linear regression calibration for each sensor against its relevant 'reference instrument' value using sensor signals and the internal airstream T and RH values as dependent variables. For calibration of the NO2 and O3 sensors, sensor signals from the other species sensor were also included to allow for potential cross-species interference.

(2)

âĂć The field measurements were conducted during two different periods. The period 1 was during September-October 2018 and the period 2 was during March-April 2019.

Period 1 includes 154 hours of data for all sensors. Period 2 includes 244 hours for CO, 169 hours for NO, 86 for NO2, and 87 hours for O3. There are no PM2.5. data available for period 2. Calibration 1 is based on data collected during the first half, hours 1 to 76, of period 1. Calibration 2 is based on data collected during the second half of period 1, hours 77 to 154. Calibration 3 is based on the entire 154 hours of data collected during period 1. Calibration 4 is based on all the data available from period 2. âĂć The stability of the calibrations was determined as follows: o Calibration 1, based on the first half of period 1 was tested against data from the second half of period 1. o Calibration 2, based on the second half of period 1 was tested against data from the first half of period 1. o Calibration 3, based on all 154 hours of period 1 was tested against data collected during the first half of period 1, and separately against data collected during the second half of period 1. o Calibration 4 is based on all the data available in period 2. The performance of calibration 3 and calibration 4 was tested against period 2 data. (3) Fig.2, Fig3, Fig4, and Fig5 _____ (1). However, the authors do not present the actual calibration equation coefficient values and their p values (they only state which variables are included in each sensor calibration equation).

(2) âĂć A table with the p-values for Calibration 1, 2, 3, and 4 were added. Table S1, S2, S3, and S4. The Table S1 is shown as an example. (3)

See Fig.6 (Table S1).

Line 315 “Among the variables included in each model, the We signal presented the lowest p-values. Details of p-values are shown in Table S1, S2, and S3 in additional material.”

Line 385 “Table S4 in additional material shows the p-values for Calibration 4. The We p-values for CO and NO, and O3 are lower than 0.01. The humidity p-values are lower than 0.01 for NO and O3. The temperature p-value is lower than 0.01 only for CO.” _____ (1). Nor do they present visualisations and/or statistics for the raw comparisons of sensor values against respective reference concentrations. Consequently, in the absence of such information the reader is not able to gauge how well or not each sensor performs prior to the multivariate regression fits, i.e. to gauge how much modification to raw sensor output is being made by the derived multiple regression calibration equation. In other words the reader does not get a sense of how much the sensor signal needs to be corrected for the contribution of other variables to the signal, particularly the extent to which there has to be correction for cross-interference between the NO2 and O3 sensors. Such information would tell the reader how important other variables are.

(2). âĂć Charts with the raw signal and explanations are added. âĂć Table S1, S2, S3, and S4 in additional material show the p-value

(3) Line 260. “Before describing the performance of the various calibrations, it is useful to consider the stability of the primary raw signal of the sensors, We. The raw responses of the sensors during three time windows; the first half of period 1, the second half of period 1, and period 2 are plotted against AMS data in Figs.5 (a-d).” See Fig. 7 ___________ (1). A more fundamental flaw, however, is that there is no independent evaluation of the calibration: the same data is used both to derive a calibration equation and then to justify the goodness of the calibration once applied to that data. If one derives a predictor equation from a dataset and then applies the predictor equation to exactly the same dataset then of course the predictions (and their ‘evaluation’ statistics) are likely to be very good. At the very least, there needs to be sufficient co-location data to (randomly) split into ‘training’ and ‘test’ sub-datasets in order to provide some (quasi)independent statistical evaluation of a derived calibration. More usefully still, what potential users of this MAAQSbox need to know is how well does a calibration equation hold in time and at different locations. Is there evidence of any long-term drift in sensor performance/ calibration?

(2) âĂć This was answered above. ______

(1). If the sensors in the MAAQbox is calibrated at one location, does the same calibration hold at another location and/or at another time? If the MAAQbox is calibrated prior to a mobile deployment and is then used as intended on a mobile platform how well does its calibration hold up when the MAAQBox is co-located back at the reference monitoring station?

(2) âĂć This was answered above.

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(1). All that the data presented in this paper show is that an underlying relationship for sensor performance self-consistently holds within a single 154 hour period.

(2) âĂć This was answered above.

Some additional comments: (1) The regression equation written on the panel of Figure 6c does not seem correct. The intercept appears to be much larger than 0.29 ppb, and eyeballing this panel suggests that the plotted regression line is giving much higher values for estimated NO2 than the stated regression line would predict; for example, for a reference value of 15 ppb the regression equation predicts a sensor value of 12.14 ppb but the plotted line shows higher estimated NO2 than this. Also, this panel should include the origin of the scatter plot.

(2) âĂć It was an error in the calculation of the equation. The equation is $y = 0.86x + 2.1$. This is shown in Fig6 (c) in Calibration 3.

(3) See Fig.8

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(1) The scatter plot in panel 6a should also include the origin of the plot, and why does the regression equation for this panel not have an intercept coefficient? Even if the coefficient is not statistically significant its value should be included to indicate that the regression included an intercept in the fit.

(2) âĂć It was an error in the calculation of the equation. The equation is y = 0.96x + 0.02. This is shown in Fig.6 (a).

(3) See Fig9.

(1)The increased scatter in the calibration scatter plot for NO2 (Figure 6c) is noted but there is no discussion of this. Given that NO2 is a key pollutant in the urban environment, for which quantification by instruments such as MAAQSbox is most keenly sought, there needs to be further comment on what is underlying this poorer performance for NO2 measurement.

(2) âĂć The P-value inputs for NO2 are presented in additional material. âĂć The NO2 and O3 signals are presented in the paper. âĂć Explanations for poor NO2 performance are presented in the paper.

(3) Line 340 “Poorer performances for NO2 has also been reported by other researchers where R2 = 0.4 to 0.89 (Castell et al., 2017; Mijiling et al., 2017). The poorer performance of the NO2 sensor compared to other low-cost sensors is because it is sensitive to environmental conditions, wind speed, impurities from the air, VOCS concentrations, sensor aging, and CO2 cross-sensitivity (Tian et al., 2019; Pang et al., 2018).”

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(1). As indicated above, we are not given the magnitudes or p values of coefficients in the calibration equations: which one of the variables is having the most influence on the NO2 response during this deployment?

(2) âĂć This was answered above.

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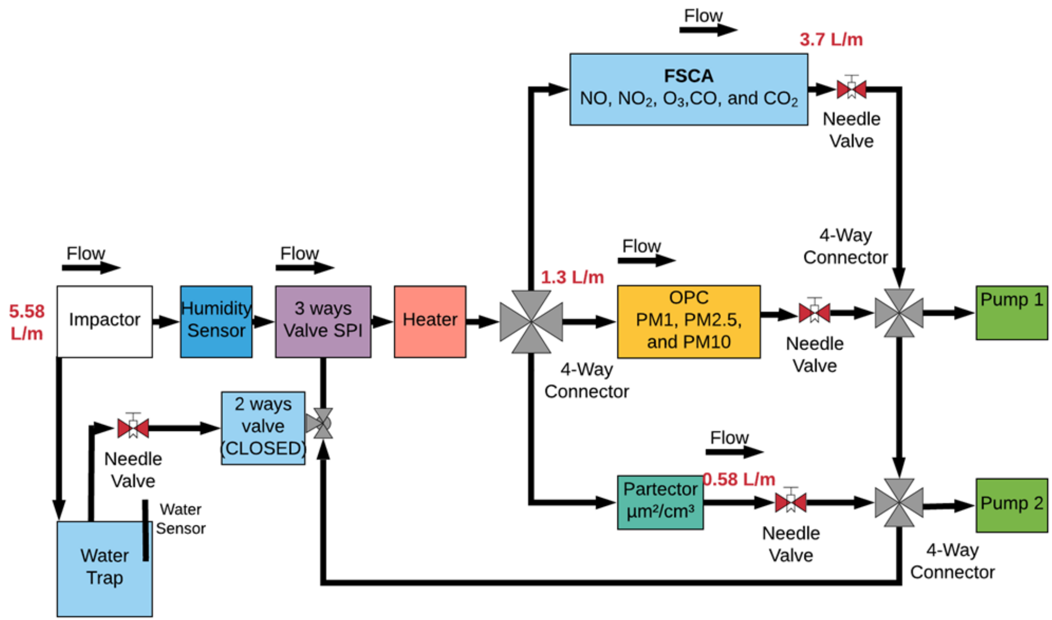

Fig. 1.

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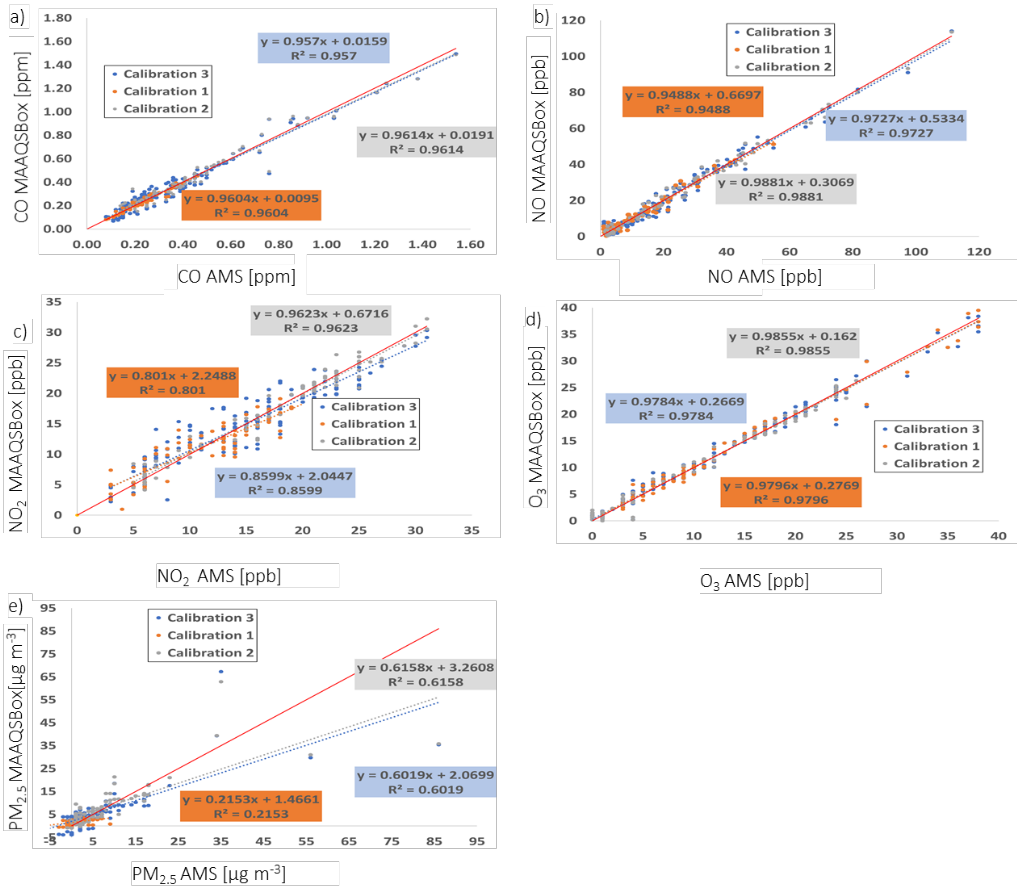

Fig. 2.

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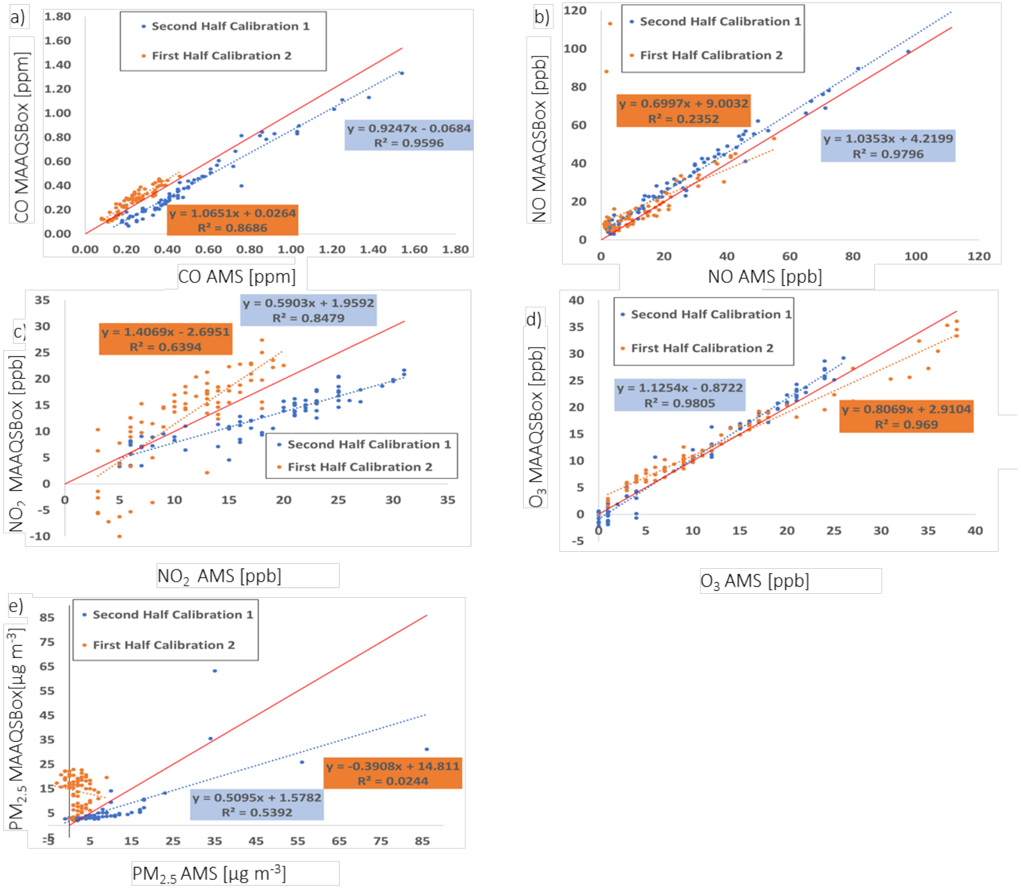

Fig. 3.

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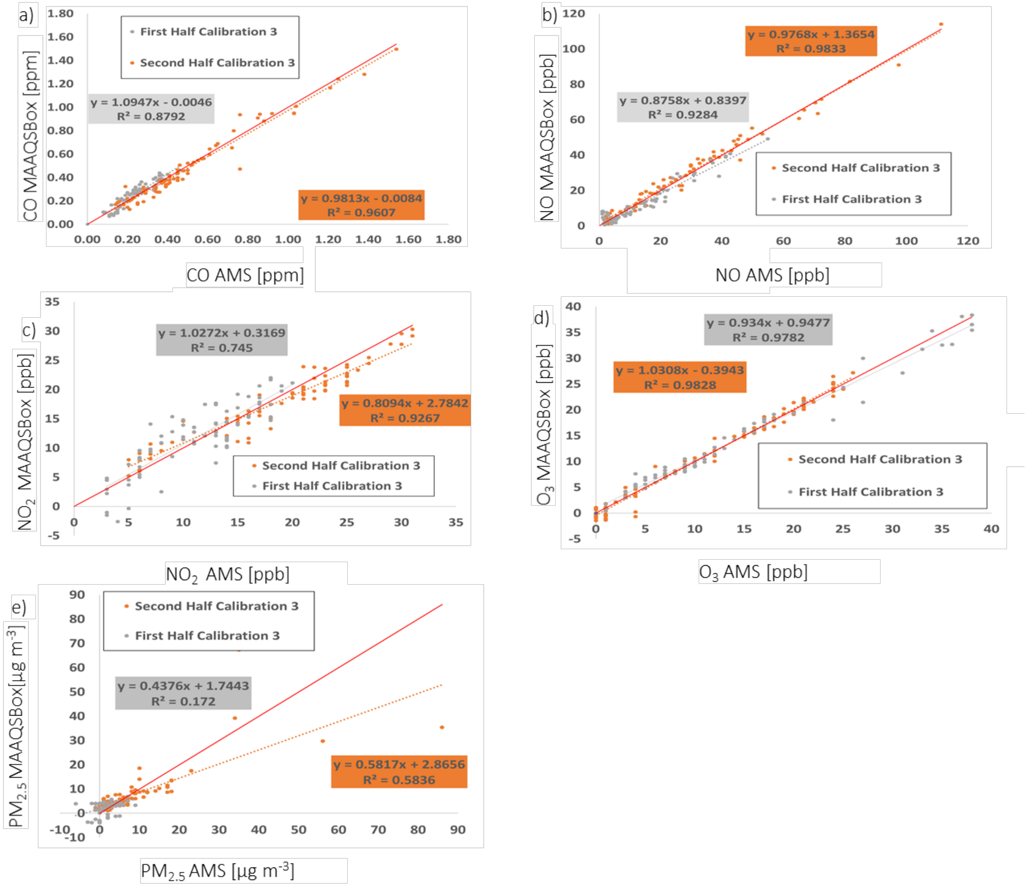

Fig. 4.

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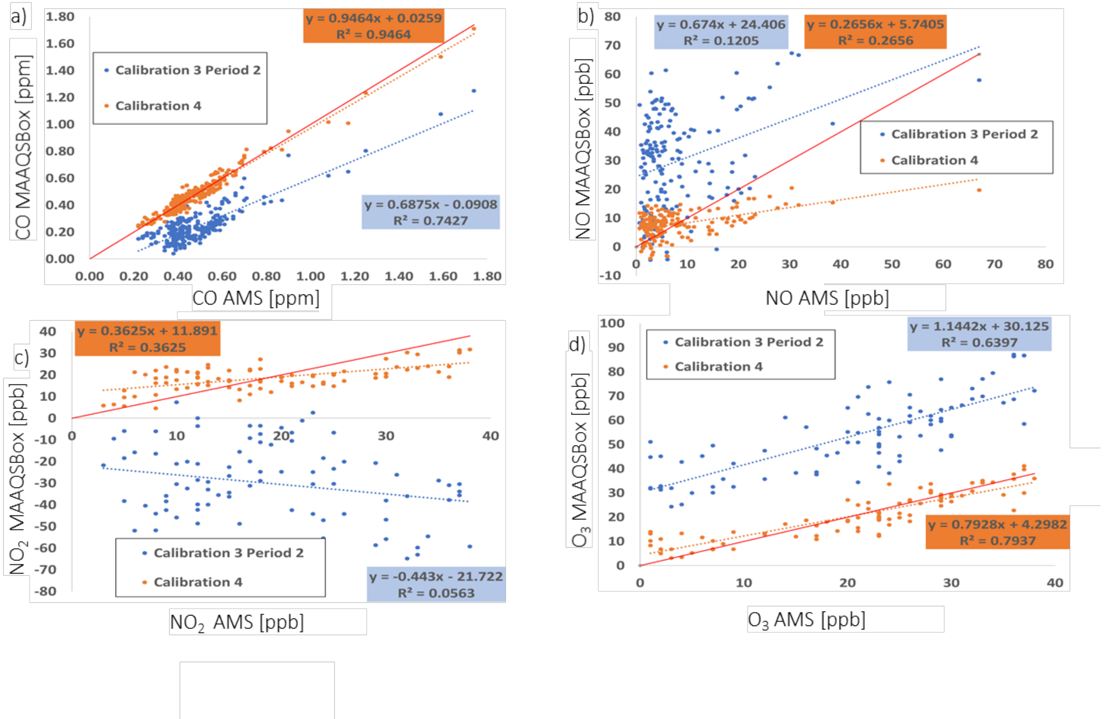

Fig. 5.

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Table S1

Variable	CO	NO	NO_2	O_3	$PM_{2.5}$
Humidity	4.09E-02	6.43E-06	1.63E-	9.44E-06	9.37E-02
Temperature	5.75E-02	6.70E-36	3.50E-	5.97E-02	1.92E-02
*We*_CO	3.18E-49				
*Ae*_CO	9.95E-11				
*We*_NO		2.51E-43			
*Ae*_NO		3.80E-01			
*We*_NO_2			2.99E-	6.92E-35	
*Ae*_NO_2			6.85E-	4.05E-01	
*We*_O_3			2.60E-	1.48E-36	
*Ae*_O_3			4.83E-	2.01E-01	
$PM_{2.5}$					3.02E-02

Fig. 6.

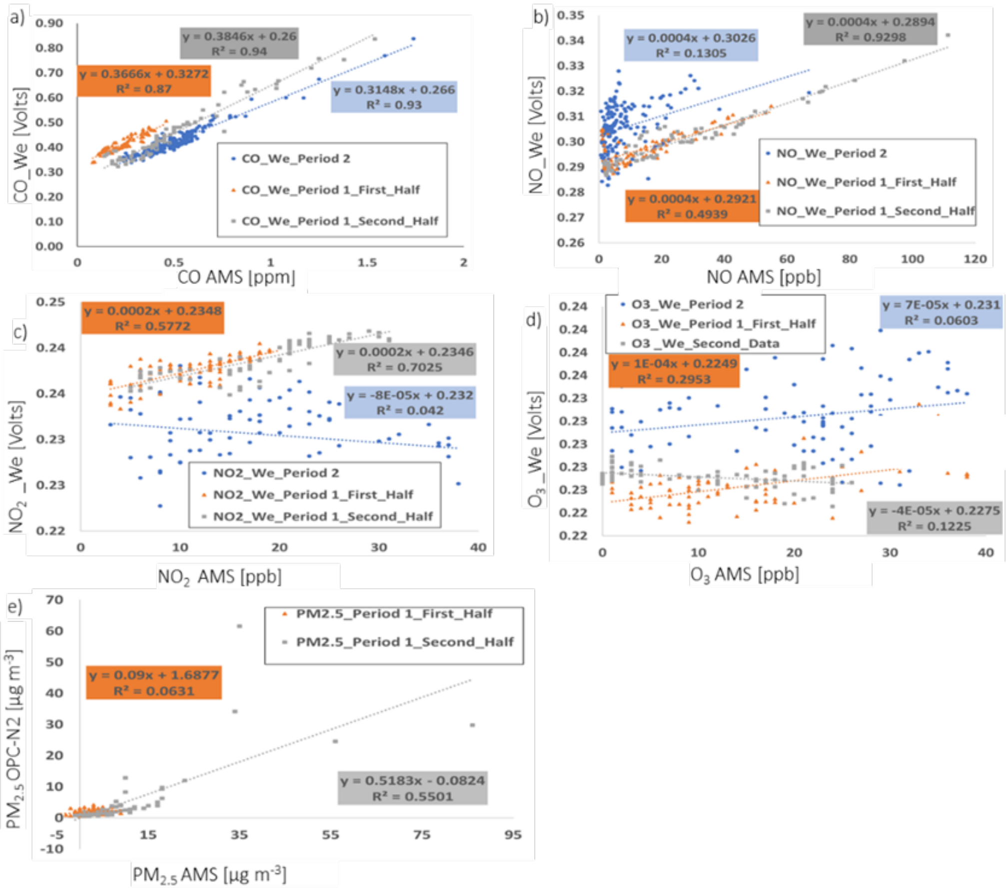

Fig. 7.

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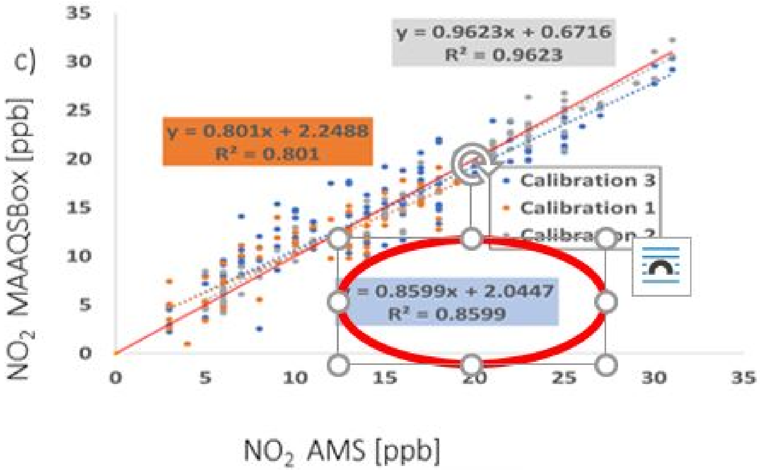

Fig. 8.

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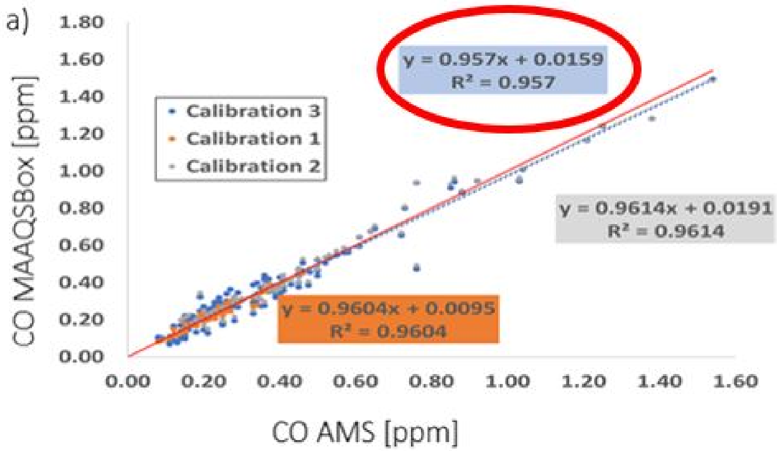

Fig. 9.

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