

# ***Interactive comment on “Characterization of lower-cost medium precision atmospheric CO<sub>2</sub> monitoring systems for urban areas using commercial NDIR sensors” by Emmanuel Arzoumanian et al.***

## **Anonymous Referee #2**

Received and published: 23 November 2018

## **1 General comments**

This manuscript reports on newly developed commercial CO<sub>2</sub> sensors which were tested in order to assess their suitability for deployment in urban monitoring networks. The sensitivity of the low-cost sensors to environmental factors is quantified and corrected by means of a multivariable regression. The topic is of high interest in the community and the presented work fits well the scope of AMT. The authors have carried out a series of experiments well suited to assess the accuracy that can be expected in

Printer-friendly version

Discussion paper



the proposed use case.

Unfortunately, the manuscript in its current state does not realise the full potential of the extensive data set collected. Structure, precision and clarity of the language as well as formal aspects need substantial improvements. In general I strongly recommend consultation of AMT's Manuscript preparation guidelines for authors, especially the sections on manuscript composition, mathematical notation and terminology as well as the English guidelines and house standards.

The structure of the manuscript suffers from loose connections between sections and a lack of coherence in the order in which information is presented. It is not easy to see which sections in the text and which figures belong together. This might be improved by referencing the short names of the corresponding experiments in every figure caption and at the beginning of each subsection. The explanation of the different experiments in Sect. 3 needs to be extended and improved. In the current manuscript, important details are missing or the reader has to combine bits of information from different sections, tables and figures to understand how the experiment was carried out. I suggest to give all descriptions a common structure, e.g. like this: (1) Purpose of the test (2) Which sensors were tested? (3) Which air was measured, i.e. ambient or from cylinder? Was the drier used? If cylinders were used, for how long and how often was switched between them? (4) Which pumps and means of flow control were used? (5) Was there a reference measurement by a CRDS analyser? If yes, how was it connected to the system? (6) What were the ambient conditions of the sensors? In case of controlled temperature and pressure, describe the pattern. Show a graph of the ambient conditions where they matter for the experiment. All in all, make sure that the reader gets all information necessary for repeating the experiment and that this information is provided in a single section.

Precision and clarity of the language is a big issue in the current form of the manuscript. Some passages are hard to understand (see Specific comments). In several places in the manuscript the value of a quantity is given without naming the quantity itself. To

avoid misinterpretation, name and value of a quantity should always be provided together, e.g. “an operating voltage of 12 V direct current”. See the “International vocabulary of metrology – Basic and general concepts and associated terms (VIM)” (JCGM 200:2012) for details. AMT demands that “wherever possible, SI units should be used”. Throughout the manuscript, “atm” should be replaced by “kPa”. Other problematic units are listed under Specific comments and Technical corrections.

I strongly urge the authors to differentiate between the substance CO<sub>2</sub> and its abundance. “CO<sub>2</sub>” cannot be the quantity plotted on the axis of a diagram. What is really meant is a measure for the abundance of CO<sub>2</sub>. The abundance can be expressed e.g. as a mole fraction (measured in ppm) or a concentration (measured in different units like g/L, mol/L), see e.g. the IUPAC Gold book. The expression “[A]” is commonly used for the concentration of substance A. The Picarro analysers report mole fraction, not concentration, so “[CO<sub>2</sub>] from CRDS” is misleading. Mixing ratio is yet another quantity (see WMO Guide to Meteorological Instruments and Methods of Observation). As far as I can see, there is no need to refer to concentrations or mixing ratios in this manuscript and all occurrences of these quantities can be adapted such that CO<sub>2</sub> is quantified by its dry air mole fraction. Even when wet air is measured, the correction for the influence of water vapour leads to an estimation of dry air mole fraction.

One important factor that makes the text hard to follow is the lack of consistency in names and categories. To give an example of the problems with the current naming scheme: Sect. 3.1 is named “Laboratory tests”, Sect. 3.3 is called “Field tests with urban air measurements”, suggesting that laboratory and field tests are two different things. However, Table 1 has the caption “Summary of all laboratory tests”, yet it contains also the measurements WA2-1 and WA2-2 which seem to be the experiments described in Sect. 3.3. Moreover, the location for WA2-1 and WA2-2 (field tests?) according to Table 2 is “Laboratory (Saclay)”, while the location for PT1 (a laboratory test) is “plastic chamber (Saclay)”.

Please decide for either of the terms “HPP sensors” or “HPP3 sensors” when referring

[Printer-friendly version](#)[Discussion paper](#)

to all sensors that were tested. Mixing the terms confuses the reader. Likewise, please refer to specific sensors consistently with their short name defined in Sect. 2.1, e.g. “S2.2”. Do not occasionally use “HPP3.2 S2.2” or similar constructs.

Calibration vs. correction: It would help the clarity if the act of determining correction coefficients was consistently referred to as “calibration” and the act of applying these correction coefficients to raw measurements was consistently referred to as “correction”.

The abbreviation RMS for root mean square is used many times in the manuscript. As far as I can see, in all instances the root mean square difference or root mean square error is actually meant. It needs to be clear which quantities are subtracted to obtain this difference. To this end, I suggest a notation like  $\text{RMS}(x_{\text{S1.1}} - x_{\text{CRDS}}) = 0.5 \text{ ppm}$ . Writing “RMS = 0.5 ppm” is not acceptable.

As for the formal aspects I refer the authors to the comments below and AMT’s guidelines for authors.

Note also that authors are requested to include a statement on how the data used in the work can be accessed by others (see AMT Data policy).

## 2 Specific comments

II. 1–2: “using commercial NDIR sensors” should be left out or moved to a different position in the title. Suggestion: “Characterization of lower-cost commercial sensors for atmospheric carbon dioxide monitoring systems in urban areas”

II. 36–39: sentence should be split. Furthermore, the second clause “[...] use networks [...] for [...] networks” is not very specific and should be reformulated. Suggestion: Replace “urban CO<sub>2</sub> networks” with the higher goal, i.e. “monitoring of urban CO<sub>2</sub> emissions”.

[Printer-friendly version](#)[Discussion paper](#)

I. 22: “of a HPP commercial NDIR sensors manufactured by Senseair AB ” -> “of a newly developed sensors”.

II. 65–66: The meaning of the sentence is not clear, “only” seems to be in the wrong place. The cited reference does not include a case with four stations, please correct.

I. 99: “measure CO<sub>2</sub> based on controlling parameters for ambient air” -> “measure the dry air mole fraction of CO<sub>2</sub> in ambient air”

II. 102-103: A reference instrument can be calibrated over a range, but a standard has just one value. Suggestion: “[...] a suite of gas standards with CO<sub>2</sub> dry air mole fractions between 330 and 1000 ppm [...]”

II. 137-139: What is the technical improvement of the sample cell redesign with respect to the topic of this publication, i.e. the use as a CO<sub>2</sub> sensor? If there is none, please remove this point.

II. 155–162: How where the in- and outlet of the pump, the HPP sensor, the pressure and temperature sensor and the air feed-through of the enclosure connected to each other? What is the response time of the sensors at the flow speeds used?

II. 156–157: This sentence is redundant with II. 142–143. Remove it.

II. 157–159: Use SI units for pressure (Pa). Please make the statement “a high resolution mode of # RMS” clearer. What is the quantity that has the value given?

II. 165-166: The number of GPIO pins and the WiFi and Bluetooth connectivity seem irrelevant to your application. I suggest to replace it with a description of how the HPP sensors were connected to the RPi3.

I. 169: Please clarify what you mean by “external speed adaptor”.

I. 170: I suggest to replace “A 12 V power supply is sufficient to power the integrated package.”, i.e. the statement of a possibility, with your actual realisation, e.g. “The package is powered by a switching power supply providing an output voltage of 12 V.”

[Printer-friendly version](#)[Discussion paper](#)

I. 183: I suggest to use  $p$  and  $U$  for pressure and relative humidity, respectively, to comply with the standard WMO symbols (WMO Guide to Meteorological Instruments and Methods of Observation)

I. 186: “The G2401 accuracy is estimated to be below 0.05 ppm (Rella et al., 2013).” There are two problems with this statement. Firstly, “accuracy” should be replaced by “uncertainty”, because ‘accuracy is a qualitative term, the numerical expression of which is uncertainty’ (WMO Guide to Meteorological Instruments and Methods of Observation). Secondly, the accuracy of the G2401 analyser depends heavily on the calibration procedure, the standards used for calibration and the correction model. This information would be crucial to support the claim for 0.5 ppm uncertainty, whereas the publication of Rella et al. on water correction seems less important here.

I. 189, rows 1, column 8: suggesting “in **ambient** air” as presumably the cylinders specified in the next column are also filled with air

I. 189, rows 2 and 3, column 2: “Correlation between [CO<sub>2</sub>] and  $P / T$ ” could be read as  $\text{corr}([\text{CO}_2], \frac{P}{T})$ . The fraction  $\frac{P}{T}$  is probably not intended.

II. 203–204: Where these ambient changes or was there some kind of control? Please show the time series of both pressure and temperature during the experiment. Which was the CO<sub>2</sub> dry air mole fraction of the air delivered to the sensors?

II. 205–206: As far as I can see from the data sheet, the Keller 33x sensors use temperature for correction of their pressure indication, but they do not output temperature indications. Moreover, the 0.01% precision quoted is refers to full scale of the sensor. As the reader does not know which model was used in the experiments, this number alone is meaningless. Please specify the precision in Pa.

I. 216: A variation cannot be calibrated. Please reformulate this heading.

II. 224–226: Whether dry air is the best case for the sensors depends on how they are intended to be operated in the field. Please explain this introductory sentence better or

[Printer-friendly version](#)[Discussion paper](#)

leave it out.

Figure 2: Please redraw this diagram using standard P&ID symbols as listed e.g. here and here. In particular, the use of a 2 port valve symbol where probably a 3 port valve is meant confuses the reader. It would be worthwhile to explain the figure in the text. What is the purpose of the pump's vent? Is the CRDS analyser really connected directly to the overpressure created by the pump? *Caption:* Specify for which of the tests this setup was used – for all tests and the calibration?

I. 231: “The experimental setup is shown in Figure 2.” Redundant with I. 188. After introducing the setup in the beginning of Sect. 3, I suggest to only mention the modifications, if any, in the following subsections.

II. 261–263: Either the residuals are larger than 1 ppm or the quoted  $R^2$  is too low. In any case  $R^2$  is not particularly helpful in this context. Consider to calculate the mean absolute error, which can support the interpretation of measurements taken by the sensor under test.

Figure 3: Label the panels (a) to (c) (AMT figure content guidelines) and refer to these labels in the caption. Left panel: Earlier in the manuscript, “HPP3.1” refers to the first version of the series 1 instruments. Assuming that the blue line is the measurement from a single sensor as the caption suggests, please change the label to “S1.1”. Upper right panel: same as left panel. Lower right panel: Plot residuals ( $x_{\text{HPP}} - x_{\text{CRDS}}$ ) versus  $x_{\text{CRDS}}$  in addition to or in place of  $x_{\text{CRDS}}$  vs.  $x_{\text{HPP}}$ . In any case, as the CRDS analyser is your reference, its measurements should be on the horizontal axis. Label the axes with the quantities displayed, not with the names of the sensors.

I. 267: “all environmental variables”: There are many more environmental variables, such as irradiance or quantities related to the air surrounding the sensors. I suggest to simply name the quantities that are independent variables in the regression: pressure, temperature and humidity.

II. 272–277: This passage can and should be simplified. In the equation, replace  $xP$  with  $p$ ,  $xT$  with  $T$ ,  $xw$  with  $U$  and  $xxy$  with  $t$  for time. Adapt the indices of the parameters  $a$  and the explanation of the variables accordingly.

II. 277-278: “Baseline [...] time.” This sentence is misleading. The meaning of both  $x$  and  $y$  has changed compared to the two sentences before. A function  $y = x$  cannot be fitted because it contains no parameters. If you rewrite the equation as suggested above and explain that  $t$  is time, this sentence can be removed altogether. Otherwise, a better explanation is needed.

I. 285: I support differentiation between the “naked” sensors and complete instruments, but then it needs to be consistent. Up to here the two terms seemed to be used as synonyms. Please check all occurrences of “sensor” and “instrument”.

I. 298–306: This is the third paragraph with a reference to the schematics of the experimental setup. The fact that the setup is explained here makes the reader wonder what the details of the setup were during earlier experiments? Was it the same? If yes, please move this explanation to the first paragraph in Sect. 3. If no, please state the differences precisely. It would also be helpful to mark in Fig. 2 which parts were same for all experiments and which ones were changed. Depending on the number of changes it might even be advisable to have a separate schematic for each individual setup. I am especially confused about the flow control: If the instruments were connected in parallel as shown in the schematics, how did you ensure a specific flow rate through each of them with only one flow controller?

I. 305: “each HPP was flushed every 12 hours for 30 minutes” 30 minutes per cylinder or 30 minutes for all cylinders together? Please clarify.

I. 308–310: Please split this sentence in two for clarity.

I. 358: The true value of the CO<sub>2</sub> dry air mole fraction in the cylinder is unknown, please use “assigned value”

[Printer-friendly version](#)[Discussion paper](#)

Figure 4: *Upper panel*: Name the quantity on the vertical axes (both left and right hand side) *Lower panel*: Please explain the meaning of the black dot on the line representing the assigned value or remove it. *Caption*: “true value” -> “assigned value”

Figure 5: *Caption*: “true value” -> “assigned value”

Figure 6: *Both panels*: To convince the reader that the relationship is linear, please show a residuals plot ( $x_{\text{Measured}} - x_{\text{LinearFit}}$  plotted vs.  $p$ )

Figure 7: *Both panels*: To convince the reader that the relationship is linear, please show a residuals plot ( $x_{\text{Measured}} - x_{\text{LinearFit}}$  plotted vs.  $p$ )

Table 3: *Caption*: “Sensors 1 to 3 ... HPP3.2” – there is no “Sensor  $n$ ” in the table and the relation between sensor name and generation was defined in the first paragraph of Sect. 3. To emphasise that three sensors apply their own pressure compensation you could write explicitly “S2.1, S2.2 and S2.3 have builtin pressure compensation.”

II. 404-410: The terms “standard deviation” and “standard error” (= standard deviation of the mean) seem to be used interchangeably here, although they are very different quantities. I assume that standard deviation is meant. If the distribution of the residuals is not Gaussian than the interquartile range of the residuals would be a better measure of the spread in the data. I suggest to include the calculated values in Table 2, possibly instead of  $R^2$ . Additional point: What is the spread after application of both the temperature and the pressure correction? Are these not the really important results? Please clarify!

I. 411: This short discussion neglects important points: (1) S1.1, S1.2 and S1.3 were tested over a much smaller pressure range than the newer sensors. (2) The second generation sensors apply the pressure correction outlined in Gaynullin et al. 2016, which is of a different form than the multivariable regression used in this article. (3) Are the standard deviations after pressure correction **significantly** different between the two sensor generations (“do not exceed 0.3 ppm” vs. “0.9, 0.2 and 0.2 ppm”)?

[Printer-friendly version](#)[Discussion paper](#)

II. 424: If we write the block-wise 1-minute averages of a time series  $x$  as  $\bar{x}$ , did you calculate the root mean square of  $x_{\text{HPP}} - \bar{x}_{\text{CRDS}}$  or the root mean square of  $\bar{x}_{\text{HPP}} - \bar{x}_{\text{CRDS}}$ ? Please clarify!

II. 431–432: Figure 8 indicates the opposite: For a calibration interval of 6 days, the root mean square difference between the HPP measurements and the CRDS measurements is higher than 1 ppm for all sensors.

II. 435–438: Other SenseAir sensors have a feature called Automatic Baseline Correction (ABC). Does the HPP platform use such a feature and could it be related to the observations? Additional point: Explain why two different measures (root mean square difference and mean) are used and which factors affect them. Which implications do the mean and RMS deviation have for the intended use cases of the sensors?

Figure 8: *Caption*: “an independent accurate CRDS Picarro” -> “a CRDS analyser”; “reference cylinders” -> “calibration cylinders” to be consistent with the rest of the manuscript

II. 450–452: I suggest to leave out this sentence as it belongs to the methods. Also, “all atmospheric variables [...] which affect the performance of the instruments” might be too bold a statement (think e.g. about aerosol content).

II. 460–466: The fact that offset correction reduces the offset to 0 is not worth noting – it is the sole purpose of this correction. The correction on the basis of CO<sub>2</sub> dry air mole fraction is not mentioned neither in Fig. 9 nor in Table 3. If both corrections are applied in a single step, “offset correction” is a misleading name for this step. The different corrections are judged based on root mean square difference, mean difference or both, which seems arbitrary. I suggest to interpret both measures for all corrections or to use just one.

Figure 9: *Panel f*): From the text I assume that all the data shown in this figure is used for calibration. However, the curve reveals that drift is dramatically increased by

[Printer-friendly version](#)[Discussion paper](#)

the drift correction. How is this possible? Why does, according to Table 3, the root mean square difference nevertheless decrease due to the drift correction? *Caption:* “the Picarro” -> “a CRDS analyser”

Table 9: *Row 2, column 2 and 3:* This looks like erroneous formatting, I assume  $1.0 \cdot 10^{-3}$  and  $8.5 \cdot 10^{-4}$  was meant. Why is the offset not 0 after offset correction?  $10^{-3}$  is too big to blame it on floating point accuracy. *Caption:* If we write the block-wise 1-minute averages of a time series  $x$  as  $\bar{x}$ , did you calculate the root mean square of  $x_{\text{HPP}} - \bar{x}_{\text{CRDS}}$  or the root mean square of  $\bar{x}_{\text{HPP}} - \bar{x}_{\text{CRDS}}$ ? Please clarify. This information must also be provided in the text. Additional note: Please move the sentence “A second instrument ... in the data” into the methods section.

I. 481–482: This sentence seems out of place, the connection to the preceding and following part is not clear.

I. 482: Description of a new analysis begins here, please start a new subsection. It would be helpful to state explicitly that you are again using data from a single sensor, S2.2.

II. 484–486: Where in Fig. 10 is data for a calibration period of a single week? Additionally, “High mean  $\Delta\text{CO}_2$ ” is not the right wording here as nearly all values in the right panel of Fig. 10 are negative.

II. 486–487: Indicate if the results of these tests are presented somewhere.

II. 487–489: According to Table 1, WA2-1 lasted 45 days. How could you assess the calibration with “raw measurement data not used in the learning period” when the calibration period span the entire 45 days?

II. 497–498: “Cross-validation” is a helpful term in this context. I suggest to also use it earlier in this section.

II. 499–502: So despite the statement in II. 487–489 you are using the learning period for validation? This needs to be clarified! If the same data is used for training and

[Printer-friendly version](#)[Discussion paper](#)

validation, why is the mean difference between the HPP and CRDS measurements not 0, given that your model contains a term for offset correction?

I. 501: Suddenly hourly values are used, which is confusing for the reader. Please explain somewhere between I. 483 and I. 498 the averaging that you applied. What is the rationale for using hourly values as opposed to the 1-minute averages used earlier? Please consider the experimental conditions during WA2-1 and the intended use cases of the sensors when answering this question in the text or leave out the hourly values if they are not needed. Is the learning also carried out with hourly averages?

II. 505–510: A solid interpretation of these results is only possible if the variation of the ambient conditions is taken into account. Please provide this information in a figure, calculate interquartile ranges and revise this part accordingly.

II. 506–507: I suggest to refer to Fig. 9, provided I am right to assume that it shows the same data.

I. 516: “and a residual slope of 0.14 and 0.28 ppm/week is shown in the black (W1) and the red (W6) curves of the figure, respectively” -> “and a residual drift of 0.14 and 0.28 ppm over one week, respectively, remains (Fig. 11).” Note that this both contains a logical improvement and avoids the mixture of “ppm” and “week” in a single unit, which is not in accordance with the rules of the SI. The latter applies to the next sentence as well.

II. 520–523: This reads as if  $\Delta\text{CO}_2$  was presented in Fig. 10, which it is not according to the legend. Whether it might change the results depends on which averages are used for the training (see comment to I. 501).

Figure 10: *Panels*: Inappropriate labels at the vertical axis (see earlier comments). The horizontal axis needs a label. The tic labels on the horizontal axis (15d, 30d, 45d, week1-week6) are unclear. Maybe the label “Learning period” and the tic labels “1st”, “2nd”, “3rd”, “w1-6” with a clear description in the caption would be appropriate? The

legend should be made bigger for improved readability. It is as important as the axes labels, so it should be written in the same font size. *Caption*: “15 consecutive days each in x-axis” is unclear. The horizontal axes are identical for both panels, so I suggest to explain it before giving specific comments on either panel. Remove the sentence “Hourly and minute values are represented in full and empty symbols respectively.”, the information is in the legend.

Figure 11: *Caption*: A term of the form  $a(b - c)$  can be read as “a times the difference b minus c”. Suggesting  $\Delta x = (x_{\text{CRDS}} - x_{\text{HPP}})$  or directly using the difference  $x_{\text{CRDS}} - x_{\text{HPP}}$  for the vertical axis.

II. 541–570: Several of my comments to the previous section also apply in this section. Please check and revise.

II. 543–548: Explanation is unclear. I suggest to first describe precisely the analysis, then the names for the different learning periods and only then referring to Fig. 12.

I. 550: “seem to provide” sounds like this observation was deceptive, but for this data set it is a fact, so I suggest replacing this phrase with just “provide”.

II. 552–554: This sentence is highly confusing because it requires reading the diagram “back in time” and involves slopes of means of differences of different training and validation periods. Please simplify, possibly leaving out the slopes.

Figure 12: *Panels*: Same issues as Fig. 10. *Caption*: Explanation unclear, “learning” and “validation” period seem to be mixed up. The horizontal axes are identical for both panels, so I suggest to explain it before giving specific comments on either panel. Remove the sentence “Hourly and minute values are represented in full and empty symbols respectively.”, the information is in the legend.

II. 576–577: “significantly decreased” and “even” contradict each other. Either stress that the sensitivity is reduced or emphasise that even the second generation sensors are sensitive to pressure.

[Printer-friendly version](#)[Discussion paper](#)

I. 585: Remove “a process called learning”, it brings machine learning to mind which is not used in this study. I suggest to generally replace all occurrences of “learning” by “calibration”.

II. 592–593: Remove “that only becomes more apparent for longer-term observations”. The drift component is always in your regression model.

### 3 Technical corrections

I. 30: “month” -> “months”

I. 35: missing space in “1–2months”

I. 49: “information on emission” -> “information on emissions”

I. 52: missing opening parenthesis before “Mays et al.”

I. 82: “in time, and in space” -> “in time and space”

I. 89: remove comma

II. 89-91: Split sentence to make it easier understandable

I. 100: Delete “for CO2 measurements”, it is redundant in this sentence. “instrument sensitivities” -> “instrument’s sensitivities”

I. 104: Spell out the acronym CRDS once

II. 106–107: “Paris region environment” -> “Paris region”

I. 108: “Empirical” -> “empirical”

I. 118: missing space in “1m”

I. 121: “light in these wavelengths” -> “light at these wavelengths”

[Printer-friendly version](#)[Discussion paper](#)

- I. 124: Name the quantities, e.g. “an operating voltage of 12 V direct current”
- I. 126: Replace comma by period
- I. 128: Replace “versions” by “generations” as the term versions is later used for differentiation within the third generation
- I. 140: “improve long-term drift” -> “reduce long-term drift”
- I. 144: “Leakage problems impact are minimized [...]” -> “The impact of leaks on the measurement is reduced [...]”
- I. 150: Remove “better”
- I. 156: To measure the pressure
- I. 160: The DHT22 is not made by Adafruit but by “Aosong(Guangzhou) Electronics Co., Ltd”
- I. 161: “interfaces” -> “interface”
- I. 161: Provide the names of the quantities. In the data sheet of the DHT22/AM2302 the accuracy in humidity is specified as  $\pm 2\%RH$  (Max  $\pm 5\%RH$ ). If you think that the larger uncertainty is not relevant for your application please explain why.
- II. 164–165: “The RPi3 is a small (85x56 mm) processor running with Raspbian OS which is a Linux distribution.” -> “The RPi3 is a small (85 mm x 56 mm) single-board computer running Raspbian OS, a GNU/Linux distribution.”
- I. 185: “same air than” -> “same air **as**”
- I. 186: “HPP” -> “HPP sensors”. Applies at several locations in the manuscript.
- I. 187: Remove “upon”
- I. 188: “Figure 3” -> “Fig. **2**”
- II. 199-202: This sentence belongs to section 2.1 where the HPP sensors are described

[Printer-friendly version](#)[Discussion paper](#)

- I. 212: “temperatures” -> “temperature”, “with linear rates of change” -> “with constant rate of change”, “1 °C/hour” -> 1 °C/h
- I. 214: “increment” -> “decrement”
- I. 219: “operations” -> “operation”
- I. 228: “H<sub>2</sub>O” -> “U”, “0.05 ± 0.05 % H<sub>2</sub>O” -> “0.05 ± 0.05 %”
- I. 234: Suggesting to spell out “above ground level” as it is used only once
- I. 236: “were measured successively each 13 hours during 30 minutes” is unclear. Suggestion: “Once every 13 hours, four cylinders were sampled successively for 30 min each.”
- I. 238: “periods” -> “period”
- I. 267: “multivariate” -> “multivariable”. A multivariate regression has more than one outcome.
- I. 270: same as I. 267
- I. 272: Consult AMT’s guidelines on mathematical notation. Symbols should be typeset in italics (and in fact they are in the text, but not in the formula). Additional note: “ $a_{p x P}$ ”: typo in the indices (small and capital P mixed).
- I. 283: Remove “of the sensors”
- I. 287: “outside air on top of” -> “outside air sampled on top of”
- I. 294: “inner tube” -> “inner diameter”?
- I. 298: “Figure 3” -> “Fig. 2”
- I. 297: “CRDS” -> “CRDS analyser” – CRDS is a technique, not a measurement device. Please check all occurrences of “CRDS” in the manuscript as to whether this replacement is applicable.

[Printer-friendly version](#)[Discussion paper](#)

- I. 301: Non-SI unit “500 mln min<sup>-1</sup>”, please correct.
- I. 315: “Picarro” -> “CRDS analyser”. Picarro is a company, not a measurement device. Please check all occurrences of “Picarro” in the manuscript as to whether this replacement is applicable. Remove comma before “and”
- I. 317: Non-SI unit “500 mln min<sup>-1</sup>”, please correct.
- I. 319: Suggesting to replace “410 ppm and minute averages varying between” with “410 ppm. 1 minute averages varied between”
- I. 328: Figures 6 and 7 are referenced before Fig. 4 and 5. Please swap their positions in the manuscript.
- I. 338: Use “PT2”, the experiment’s name, instead of “PIT”, the name of the lab
- Figure 4: *Caption*: “please not” -> “please note”
- Figure 5: *Caption*: “please not” -> “please note”
- I. 386: “HPP3.1 versions” -> “HPP3.1 sensors”
- I. 387: “newest HPP3.2 versions” -> “newer HPP3.2 sensors”
- I. 391: “that is correction” -> “that this correction”
- I. 393: “ranges” -> “range”; “-0.2 to -0.7 ppm/°C” -> “-0.7 to -0.2 ppm/°C”
- I. 453: “Panel of Figure 9” -> “Panel a of Figure 9”
- I. 505: “when learning is form the first 15 days” -> “when the first 15 days are used for validation”
- I. 515: “When using the first week (W1) and the last week (W6) for learning” -> “When using either the first week (W1) or the last week (W6) for learning”
- I. 542: “carried” -> “carried out”

[Printer-friendly version](#)[Discussion paper](#)

Figure 12: *Panels*: The tic label “15d” is displaced vertically

II. 606-608: This is a new result, please move it to the results section, possibly into a new subsection and accompanied with a few more details.

---

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2018-329, 2018.

**AMTD**

---

[Interactive  
comment](#)

[Printer-friendly version](#)

[Discussion paper](#)

