Response to comments from Anonymous Referee #1 on manuscript egusphere2022-565: "Development of an automated pump efficiency measuring system for ozonesonde utilizing the airbag type flowmeter"

We appreciate your valuable comments on our paper.

General remarks:

The paper is well structerized and written, whereby it is recommended that a native english speaking person should improve some of the english in the paper.

We are considering to make proofreading by a native speaker.

Some comments

L10 Replace: emulating by simulating

L14 Replace: accumulated by collected

L24 Replace: the detailed by a detailed

L25 Replace: flew up by flown

L27 Replace: chemical by electrochemical

L31 Replace: 80% by more than 90%

L62 Replace: research themes in the past by other investigators

L63/64 Replace silicone membrane by bubble

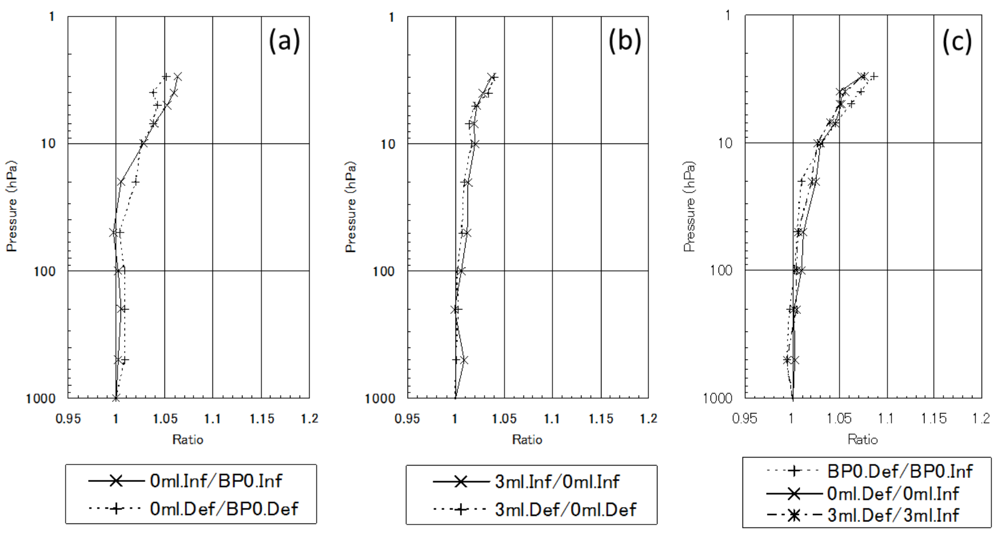
L66 Replace: the ECC- by ECC-

L124 Replace: to a small by of a small

We will replace as you stated.

Figure 8: Larger charactersize in legends

We increased charactersize in legends. We will modify the diagram as follows.

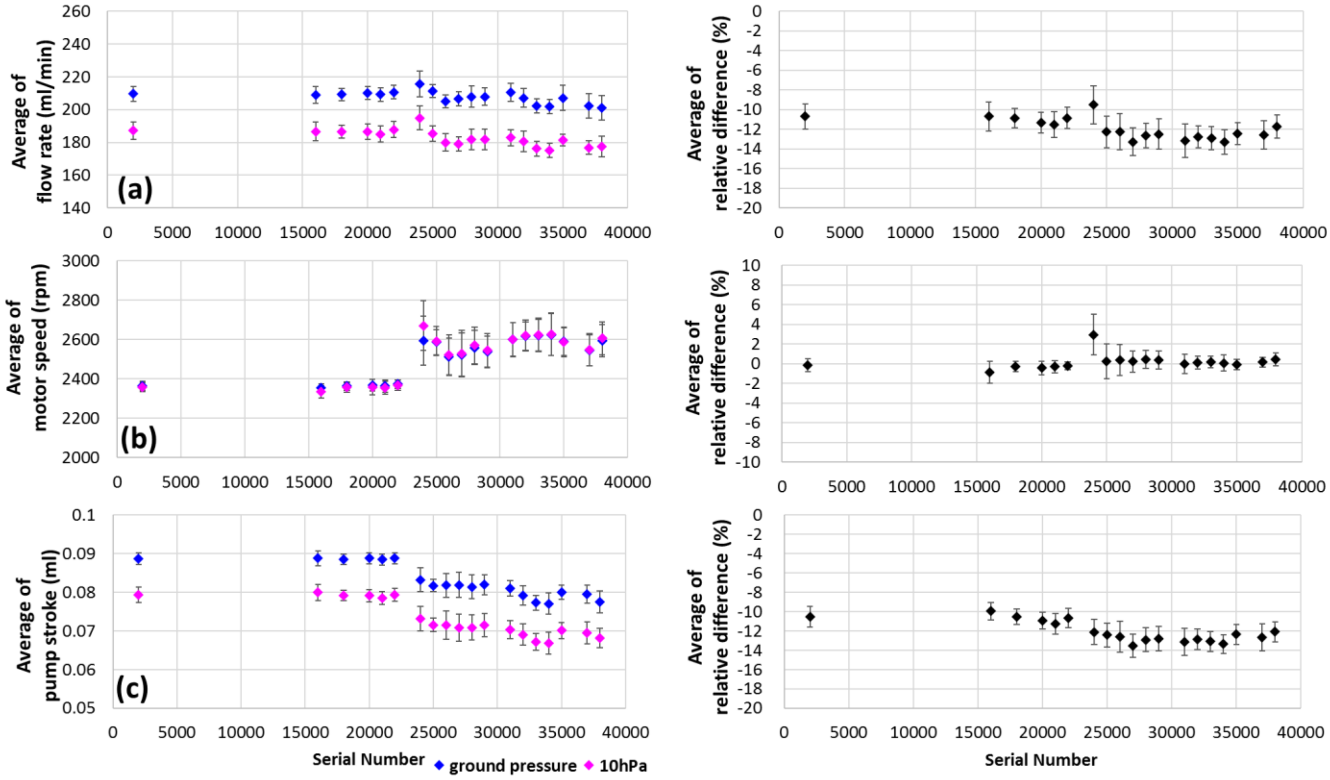


To be clear to the reader that after section 3-3 all further pump efficiencies reported in chapters 4 and 5 are always measured and determined with a 3 ml sensing solution in the cathode cell.

At the end of line 237 in section 3.3, we will note that "All further pump correction factors reported in chapters 4 and 5 are always measured and determined with a 3 ml reaction solution in the cathode cell."

Figure 16: Larger charactersize of axis

We increased charactersize of axis. We will modify the diagram as follows.



Response to comments from Anonymous Referee #2 on manuscript egusphere2022-565: "Development of an automated pump efficiency measuring system for ozonesonde utilizing the airbag type flowmeter"

We appreciate your valuable comments on our paper.

Line 25: Replace- "flew up" with "flown"

Line 27: Replace- "chemical" with "electrochemical"

Line 27: Replace- "The downlink of the data is taken care of by the radiosonde - also providing pressure, temperature, humidity and position measurements – the ozonesonde is coupled with.

with

"The downlink of the data, through the coupled radiosonde transmission, also provides pressure, temperature, humidity and position measurements.

We will replace as you stated.

Lines 33-34: Reference – If available, please add a publication reference on the KI Carbon electrode type (KC) ozonesonde.

We will add "(Kobayashi et al., 1966a; Kobayashi and Toyama, 1966b, 1966c; Hirota and Muramatsu, 1986)" after lines 33-34.

We will add references as follows to Reference.

"Kobayashi, J., Kyozuka, M., and Muramatsu, H.: On various methods of measuring the vertical distribution of atmospheric ozone（Ⅰ）– Optical-type ozone sonde, Pap. Meteor. Geophys., 17, 76–96, 1966a.

Kobayashi, J., and Toyama, Y.: On various methods of measuring the vertical distribution of atmospheric ozone（Ⅱ）– Titration type chemical ozonesonde, Pap. Meteor. Geophys., 17, 97–112, 1966b.

Kobayashi, J., and Toyama, Y.: On various methods of measuring the vertical distribution of atmospheric ozone（III）–Carbon iodide type chemical ozonesonde–, Pap. Meteor. Geophys., 17, 113–126, 1966c.

Hirota, M., and Muramatsu, H.: Performance characteristics of the ozone sensor of KC79-type ozonesonde, J. Meteorol. Res., 38, 115-118, (in Japanese), 1986."

Line 37: Replace- "with take the ambient air into" with "with bubble the ambient air into"

Line 39: Replace- "sampling air" with "sampled ambient air"

We will replace as you stated.

Line 39: The flow rate is also needed to calculate concentration of ozone. Please add this in the last sentence to make it: "The ozone concentration is calculated from this electric current and the volumetric flow rate of the piston pump.”

We will add the sentence as you suggested.

Line 46: Replace “(4). Then again, the force of the piston takes the ambient air into the pump.” with “(4). The piston draws in a fresh sample of ambient air.”

Line 46: Replace “During the ozonesonde observation, this cycle is repeated” with “The cycle is repeated for each pump rotation. The steady pump speeds typically range from 2400-2600 rotations per minute (RPM).”

We will replace as you stated.

Lines 47-48: I am having difficulty in understanding the first part of this sentence. I believe this is saying the back pressure is always the same from ground level to low pressure while ambient pressure is decreasing.

We replace lines 47-48 with

“Hydraulic head pressure, which is the main factor causing back-pressure, can be considered essentially uniform regardless of ambient air pressure, ~”.

In addition, since the influence of the Teflon rod is not important here in explaining the concept that pump efficiency arises, so we will replace lines 42-43 with

“First, ambient air taken into the pump is compressed until its pressure is balanced with the back pressure associated with the hydraulic head pressure of the reaction cell (1).”.

Line 63: Replace “silicone membrane” with “bubble” contraction

Line 67: Replace “airbag contraction” with “airbag evacuation”

We will replace as you stated.

Line 67: Remove this part of the sentence “and a gear pump with high pump efficiency” The gear pump (nearly 100% pump efficiency) was only used at NOAA to confirm the accuracy of the oil bubble flow meter.

We will remove as you stated.

Line 70: Replace “The system was designed to perform the entire series of measurement automatically, in order to be able to obtain pump efficiency with uniform quality.” with “The system was automated in order to obtain pump efficiency measurements with uniform quality.”

Line 73: Replace “we could build up a” with “we accrued a”

Line 104: Replace “exhaust limit” with “minimum pressure”

Line 117: Replace “Flowmeter controller” with “The flowmeter controller”

Line 118: Replace “flow values of them” with “flow data”

We will replace as you stated.

Line 121: Just a question on what is time-dense control?

We will replace Line 121 with “This allows real-time measurement control on a millisecond scale, thereby significantly reducing the control PC load.”

Lines 130-133: Figure 6 text: Replace “The bag is made of polyethylene in a volume of 140 ml.” with “The 140 ml. bag is made of polyethylene.”

Replace “in thermometers with “by thermometers”

Replace “measured in optical instrument” with “measured by an optical instrument”

Line 202: replace “back pressure” with “back pressure (load)”. This is a suggestion since back pressure and load are both used in the next sections. I assume they refer to the same thing so it would be good to include both in the title of section 3.3.

Lines 227-229: Figure 8 text: Suggest replacing “reaction solution” with “silicon oil” to be consistent with the text that notes silicon oil was used to represent the head pressure instead of actual sensor solution – which would create very large errors due to boiling of the KI/water solution.

Line 245: Replace “(sucked out)” with “pushed out”

We will replace as you stated.

Line 245: Please add the typical pump temperature observed during a test. For example, it would be helpful to know what the typical pump temperature at surface (beginning of test) and at the lowest pressure (3 hPa).

We will add a table follows and add “Table 1 shows the average pump temperature during efficiency measurements performed by JMA from 2009 to 2022. Measurements started after 30 minutes of warm-up measurements, and the temperature typically increased by 5 -6 °C as the measurement progressed” to the end of section 4.1.

Table 1: Pump temperature measurement results for Sapporo, Naha from 2009 to 2018, and Tateno from 2009 to 2022.

Pressure (hPa)	Pump Temperature (℃) [JMA 2009 - 2022]
3	37.0 ± 2.2
4	36.7 ± 2.2
5	36.4 ± 2.2
7	36.1 ± 2.1
10	35.7 ± 2.1
20	35.4 ± 2.1
30	35.1 ± 2.1
50	34.6 ± 2.1
100	33.9 ± 2.1
200	33.1 ± 2.0
1000	31.1 ± 2.0

Lines 335-336: It appears that "reaction solution" is being used for referring to more than one thing. It is used early in the paper when referring to the actual sensor solution (the KI salt water solution) and then in line 335 it looks like in this text "reaction solution" is referring to head pressure simulation of the sensor solution for NOAA/CMDL pump efficiency measurements, when NOAA/CMDL actually used non-evaporative oil to replace the reaction solution. Then in Line 336, I believe JMA is using extra tubing length to create a simulated back pressure of the 3cc of reaction solution.

It would be helpful to be clear where "reaction solution" is actually back pressure or simulated head pressure of the 3cc of reaction solution.

We replace line 335 with

"~, and NOAA/CMDL made measurements with exhaust-side loading using non-evaporative oil instead of a reaction solution (Johnson et al., 2002).",

and line 336 with

"We replicated this work with longer tubing to simulate back-pressure from 3ml of the reaction solution." .

Figure 12: Replace "UMYO 2002" with "UWYO 2002" within the graph for Univ of Wyoming (blue line).

We will replace as you stated.

Figure 16: The figure text letters (a) (b) and (c) should be in front of the data being described. For example: (a) Variation over time of pump flow rate.

We will correct the position of letters (a) (b) (c) in line 398.

Response to comments from Anonymous Referee #3 on manuscript egusphere2022-565: "Development of an automated pump efficiency measuring system for ozonesonde utilizing the airbag type flowmeter"

We appreciate your valuable comments on our paper.

Line 31: "…about 80% of stations of WMO..." In fact, all except Hohenpeisenberg and several stations in India use the ECC sonde.

We will replace "80%" with "more than 90%". Anonymous referee#1 also made a similar comment.

Lines 60-61: I think it is important to make the point here that measuring the efficiency of each pump is NOT normal practice in ozonesonde launches, as it is considered difficult and time-consuming. As a result, almost all ozonesonde profiles are produced using average pump efficiency curves as described in the paragraph beginning in line 62. This is a source of uncertainty that the system described in this paper eliminates. It is a major advance and should be introduced here properly, as the scientific question that this paper addresses.

We added the following text after line 70–71.

"However, such determination is not normal practice in ozonesonde launches, as it is considered technically difficult and time-consuming. As a result, most ozonesonde profiles are produced using average pump efficiency curves."

Line 65: Actually, it is the pump corrections that are underestimated, not the efficiencies.

We will replace "standard pump efficiency tables" in lines 64-65 with "standard pump efficiency correction tables", and "pump efficiencies" in line 65 with "pump efficiency corrections"

Lines 139-140: Why does the airbag get wrinkles?

The airbag is so thin and deform unevenly, that it gets wrinkles just by letting the air in and out.

We will replace line 139 with "~ wrinkles caused by uneven deformation as the airbag repeatedly expands and contracts can cause erroneous measurements, ~".

Line 157: I think you mean that the volume of the airbag when inflated is assumed to be the same regardless of ambient pressure, as long as the pressure inside is equal to that outside.

Exactly. We will replace line 157 with

"Assuming an airbag internal volume of V_{airbag} when the most inflated/deflated states are assumed to be constant regardless of ambient pressure, as long as internal/external pressure are equal, the pump~"

Lines 170-177: I find this description quite confusing. I see that there is some hysteresis, but it appears that the whole point of folding the inflation and deflation curves back on each other is to show that the inflation and deflation times are equal. Could this not be simply stated?

We will replace lines 169-177 with

“Plotting of differential pressure during deflation from around the time of maximum inflation (red line) shows that the inflation and deflation times are equal, since they match at the time of maximum deflation. In addition, since the pump flow rate at ground level was stable, the elapsed time can be considered associated with the internal volume of the airbag. These results indicate that differential pressure values during inflation and deflation each represent a certain airbag volume. From the above, pump efficiency can be determined from equation (2) by measuring the time interval at which a certain differential pressure is observed.”

Lines 183-185: This is confusing, and the first sentence seems like it belongs somewhere else in the paper. I suggest writing simply: “The pump correction factor (the reciprocal of the pump efficiency) is obtained only from the time required for airbag inflation and deflation, and in the case of differential pressure Δp is expressed from equation (2) as follows”.

We will replace lines 183-185 the sentence as you suggested.

Line 212: “the thin line”. Do you mean “the narrow tubing”?

We mean “the Teflon rod”. We will replace “the thin line” in line 212 with “the Teflon rod”.

Lines 220-223: I’m not sure that these remarks, or Figure 8c, add anything to the paper. Figure 8c is not mentioned further. The remarks are also confusing, coming in the middle of a discussion about “real-world” back pressures. I suggest dropping these lines, and Figure 8c.

We will remove lines 220-225 and Figure 8c.

Lines 255-256: Why is there a differential pressure? Is that because it is the method to determine when the bag is full/empty? It might be helpful to say this.

We will add the following text after lines 255-256.

“Differential pressure, thus enables determination of bag content and internal volume.”

Lines 294-299: “…we found about half of the airbag temperature change rate affected the pump correction factor…”. So what happened to the other half? This paragraph appears to state that “our observations only followed Charles’ Law about halfway, so we used 0.5 as a fudge factor”. This is not acceptable.

Polyethylene fill, the material used in airbags, also has thermal properties, which affect its elongation and elasticity as temperature changes. It is believed that this effect offset half of Charles' Law. We have confirmed that Charles' law is obeyed in an experiment in which the pump temperature is changed using the same experimental apparatus.

We add the following text after line 295 “~ affected the pump correction factor.”.

"Charles' law also held when the pump temperature was changed using the same experimental apparatus. This is attributed to the effects of changes in airbag elongation and elasticity due to the thermal properties of the polyethylene film offsetting the effects of volume change relating to Charles' law by around half."

Line 305: This contradicts the previous equation. Which one is correct? Is the pump change adiabatic or not? By the way, all equations should be numbered.

The latter formula is equivalent. We have added the power term, considering the case where the equation (Kobayashi and Toyama, 1966) is a further adiabatic change.

We will replace lines 306 with

"Assuming that this is actually a polytropic change relating to the effects of heat exchange with the pump in addition to adiabatic change, the following approximate equation can be given:".

We will number all equations.

Line 306: Please explain what approximations were used to arrive at Equation 8. The reader should be able to reproduce your analysis without guessing.

We will replace line 307 with

"$$pcf(p) = \frac{1}{k(p)} = \frac{1}{1-K\cdot\left(\frac{1}{p}-\frac{1}{p_0}\right)^{\frac{1}{n}}} = \frac{1}{1-c_0\left(\frac{1}{p}-\frac{1}{p_0}\right)^{c_1}}, \qquad (8)$$

where n is a polytropic index dependent on the ozone sensor, c_0 is a constant dependent on the ozone sensor and c_1 is $\frac{1}{n}$.".

Line 313: $pcf_3(p_0)$ should be 1.

We will replace $pcf_3(p)$ in line 313 with $pcf_3(p_0)$.

Line 330: Why use the measurements after #24000, rather than before #24000? You've just said that stability was not good after #24000.

Ozone sensors after the serial number 24000 have worse stability in motor speed depending on the production lot than before 24000, but in order to express the characteristics of ozone sensors currently in circulation, we calculated the representative value using the value after 24000.

We will replace line 328-331 with

"The results indicate air pressure dependence in terms of motor speed, and suggest that speed was unstable among production lots. This is considered to have affected pump efficiency. Accordingly, as the characteristics of current ozone sensors differ from those of sensors before serial number 24000, the measurement results of later sensors are used to calculate representative JMA data.".

Lines 351-352: I think you mean "for this experiment only"?

We will replace lines 350-351 with

"In addition to the correction explained in section 4, for this experiment only, we have corrected the pump correction factor ~,”.

Figure 15 (upper) appears to be wrongly labelled on the x-axis.

We will replace the x-axis label with “Total number of measurements”, add "Serial number" to the second vertical axis, and replace the description of the figure in Fig. 15 (upper) as follows.

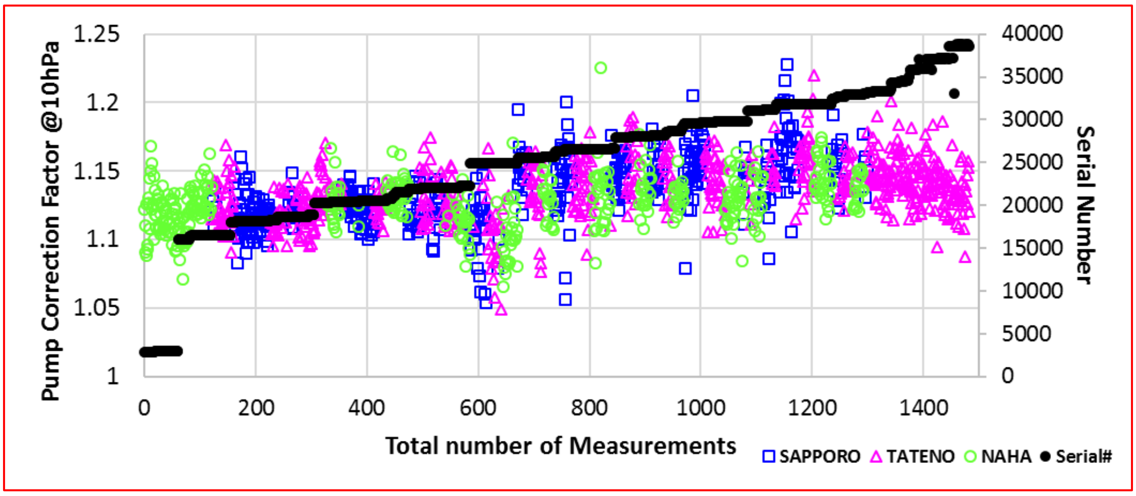


Figure 15: (Upper) Pump correction factors at 10 hPa measured during 2009 to 2022, sorted by ozone sensor serial number.

Lines 403-406 (and Figure 17 caption): I am confused by this description. Should you not simply calculate the difference, for each sounding, in the total ozone found using your measured pump corrections to that using the average pump correction curve (either CMDL or your average before serial #24000 – or after serial #24000)?

We recalculated for Figure 17.

We will replace lines 403-407 with

“Fig. 17 shows impacts on total ozone integrated values if the table values of pump correction factors measured by JMA for ozone sensor serial numbers before 24000 were used rather than measured individual pump efficiency correction values. The effects were calculated using JMA average ozone partial pressurevalues for the period from 1994 to 2008as a typical mid-latitude profile. The ozone partial pressure obtained using table values for pump efficiency correction were obtained by dividing the average partial pressure by the measured pump correction factor and then multiplying the result by the table value. Each of these ozone partial values at each pressure level (ground-level and 500, 200, 100, 50, 30, 20, 10, 7 and 5 hPa) was integrated to determine the total ozone integrated value, and the relative difference was determined for each pump efficiency measurement during the period from 2009 - 2022.”.

We will add the following text after line 409.

“In section 5.3, we showed that the pump correction factors tended to increase, but when converted to total ozone integrated values, it tended to decrease. The fact that there is a step after 2014 is consistent with the drop off of total ozone pointed out by Stauffer et al. (2020a, 2020b).”

We will modify Figure 17 as follows.

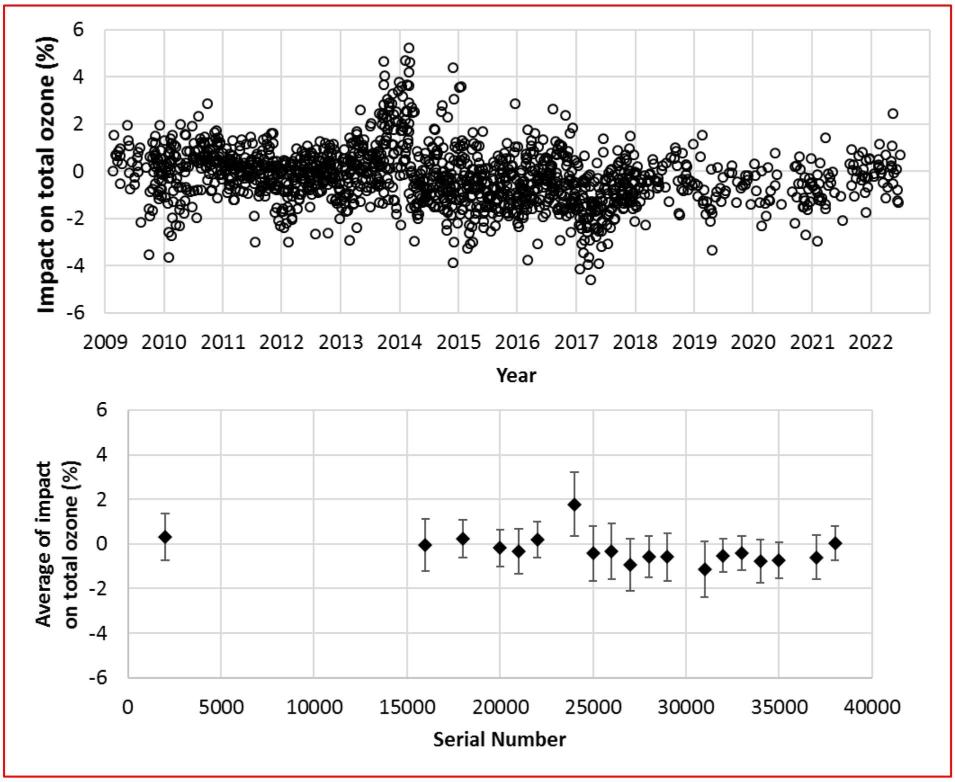


Figure 17: (Upper) Estimation of impact on total ozone integrated values when using average pump efficiency correction table. (Lower) The impact on total ozone integrated values for each serial number lot, with the error bars indicating the standard deviation.

Line 432-433: Can such an automated system be built and operated by other stations at a reasonable cost? Can it be commercialized? If so, this recommendation would carry much more weight.

Unfortunately, this system was not built at a reasonable cost and there are no plans to commercialize this system at this moment. We will replace lines 431 -433 with

"~, it is advisable to determine the pump efficiency of each lot to pinpoint pump correction factor trends and enable adaptation to the calculation of ozone concentration. Although the costs of system production may hinder introduction at present, commercialization may enable the use of similar systems at lower cost in the near future.".

Response to comments from Roeland Van Malderen on manuscript egusphere2022-565: "Development of an automated pump efficiency measuring system for ozonesonde utilizing the airbag type flowmeter"

We appreciate your valuable comments on our paper.

the two reviewers provided excellent review reports, so I don't want to add too much on these. But I have one comment and one suggestion that you might take into account when updating your manuscript according to the comments of the reviewers. It relates to your choice of displaying in Fig. 12 only the average pump correction factors for serial numbers superior to 24000. In the text, lines 327-331, the following explanation is given: "The pump motor specifications were changed from the ozone sensor (serial number 24000 or later) delivered to JMA in 2013. As a result, air pressure dependence was seen in the motor speed, and the stability of the speed was not good. We thought that the effect was affecting the pump efficiency. Therefore, the measurement results of sensors with serial number 24000 and above are used to calculate the representative data of JMA." However, in Fig. 16, where the variation of the motor speed and pump stroke is shown as a function of serial number, the variability (standard deviations) of those measurements for serial numbers below 24000 seems to be lower than for serial numbers higher than 24000, which seems to contradict a lower stability of the speed for the lower serial numbers. Can you comment on that?

Ozone sensors after the serial number 24000 have worse stability in motor speed depending on the production lot than before 24000, but in order to express the characteristics of ozone sensors currently in circulation, we calculated the representative value using the value after 24000.
We will replace line 328-331 with
"The results indicate air pressure dependence in terms of motor speed, and suggest that speed was unstable among production lots. This is considered to have affected pump efficiency. Accordingly, as the characteristics of current ozone sensors differ from those of sensors before serial number 24000, the measurement results of later sensors are used to calculate representative JMA data.".

Also, as you referred to the paper by Stauffer et al. 2020 (and follow-up study available at https://www.essoar.org/doi/10.1002/essoar.10511590.1, accepted with doi 10.1029/2022EA002459), who noted a drop in total column ozone in a number of En-Sci ozonesonde sites around S/N 25500, you might provide an additional figure+table (similar to Fig. 12, can be e.g. in an appendix, or as supplementary material) in which you show the pump correction factors for (i) the entire time period, (ii) serial numbers lower than 24000, (iii) serial numbers higher than 24000. This would be very valuable information for the ozonesonde community.

Please take this comment and suggestion in consideration.

We will replace line 331-333 with

"Stauffer et al. (2020a) also reported the discovery of an apparent instrument artifact that caused a fall in total ozone measurements from around a third of global stations starting in 2014–2016, limiting suitability for ozone trend calculation. Stauffer et al. (2020b) also noted a fall in total column ozone in various En-SCI ozonesonde sites around serial number 25250.".

We will add reference as follows to Reference.

"Stauffer, R. M., Thompson, A. M., Kollonige, D. E., Tarasick, D. W., van Malderen, R., Smit, H. G. J., Vömel, H., Morris, G. A., Johnson, B. J., Cullis, P. D., Stübi, R., Davies, J., and Yan, M. M.: An Examination of the Recent Stability of Ozonesonde Global Network Data, Earth and Space Science, Accepted Articles, e2022EA002459. doi: 10.1029/2022EA002459, 2020b."

We will remove the table of pump correction factors in Figure 12 and add Table 1 as follows after Figure 12,
and we will add "For evaluation of past observation data, pre-24000 values are shown in Table 2. The standard deviation is larger for sensors after this serial number." after line 330 -331.

Table 2: Average JMA pump correction factors for pre andpost-24000 sensor serial numbers and for the entire time period (2009 -2022).

Pump Correction Factor [JMA 2009 - 2022]			
Pressure (hPa)	Serial # ≧ 24000 (821 samples)	Serial # < 24000 (566 samples)	ALL (1387 samples)
3	1.381 ± 0.047	1.330 ± 0.037	1.361 ± 0.050
4	1.307 ± 0.040	1.260 ± 0.026	1.288 ± 0.042
5	1.254 ± 0.034	1.216 ± 0.022	1.239 ± 0.035
7	1.191 ± 0.028	1.164 ± 0.018	1.180 ± 0.028
10	1.140 ± 0.023	1.122 ± 0.016	1.133 ± 0.022
20	1.078 ± 0.017	1.072 ± 0.013	1.076 ± 0.016
30	1.056 ± 0.015	1.054 ± 0.011	1.055 ± 0.014
50	1.038 ± 0.013	1.038 ± 0.009	1.038 ± 0.011
100	1.021 ± 0.010	1.024 ± 0.007	1.022 ± 0.009
200	1.011 ± 0.008	1.014 ± 0.005	1.012 ± 0.007