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.

"Measuring the pump efficiency of each pump is not normal practice in ozonesonde launches, as it is considered technically difficult and time-consuming. As a result, almost all 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 the airbag internal volume V_{airbag} when most inflated and most deflated are assumed to be constant regardless of ambient pressure, as long as the pressure inside is equal to that outside, 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 the differential pressure during deflation, folded 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 the ground level is stable, we can consider the elapsed time to be equivalent to the internal volume of the airbag. From these facts, we can conclude that the differential pressure during inflation and deflation each represents a certain the airbag volume, respectively. From the above, we can determine the pump efficiency from equation (2) by measuring the time interval at which a certain differential pressure is detected."

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.

"By measuring the differential pressure, we can determine whether the bag is full or empty and detect the internal volume of the airbag."

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.".

"It has been confirmed that Charles' law is obeyed when the pump temperature is changed using the same experimental apparatus. This is likely due to the effect of the change in airbag elongation and elasticity due to the thermal properties of the polyethylene film offsetting the effect of the volume change due to Charles' law by about 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 in reality it is a polytropic change because of the effect of heat exchange with the pump in addition to the adiabatic change, the following approximate equation is 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

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

where n is the polytropic index depending on the ozone sensor, c_0 is constant depending 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 329-331 with

“~, and the stability of the speed was not good depending on the production lot. We thought that the effect was affecting the pump efficiency. Therefore, since the characteristics of ozone sensors currently in circulation are different from those of sensors before the sensor serial number 24000, the measurement results of sensors after the serial number 24000 are used to calculate the representative data of JMA. ”.

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.

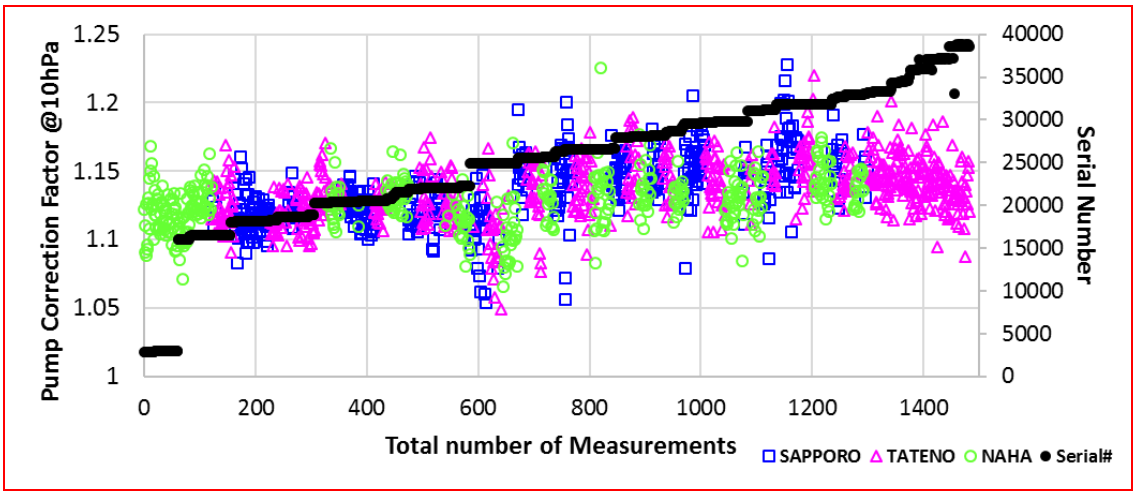

Figure 15: (Upper) Pump correction factors at 10 hPa measured during 2009 to 2022, sorted by ozone sensor serial number.

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 the impact for the total ozone integrated values if the table values of the pump correction factors measured by JMA for the ozone sensor serial number before 24000 was used instead of using the measured individual pump efficiency correction values. We calculated the impact using the average ozone partial pressure of JMA from 1994 to 2008, which is a typical mid-latitude profile. The ozone partial pressure using the table values of the pump efficiency correction is obtained by dividing the average partial pressure value by the measured pump correction factor and then multiplying that value by the table value. Each of these ozone partial pressure values at each pressure levels (the ground level pressure, 500, 200, 100, 50, 30, 20, 10, 7, 5 hPa) was integrated to determine the total ozone integrated value, and the relative difference was determined for each of the pump efficiency measurements during 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.

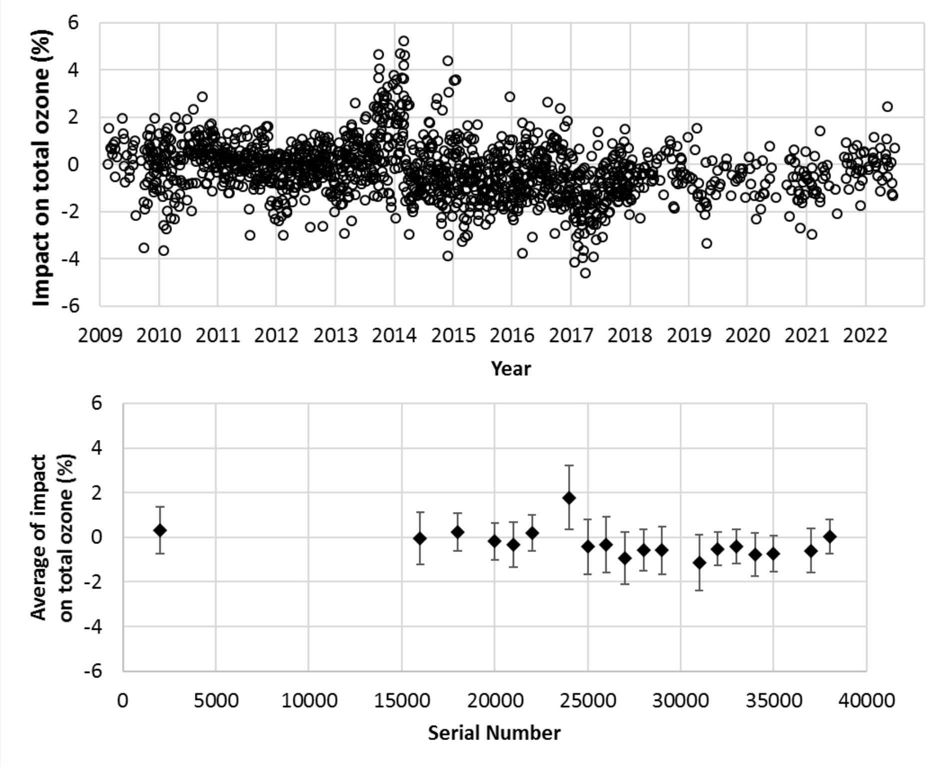

Figure 17: (Upper) Estimation of impact on total ozone integrated values when using average pump efficiency correction table. (Lower) The impact on total ozone integrated values for each serial number lot, with the error bars indicating the standard deviation.

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

"~, we recommend to investigate the pump efficiency of each lot to understand the trend of the pump correction factor and to adapt it to the calculation of ozone concentration.

Although the production cost of this system was not so reasonable to introduce easily at this moment, we hope any similar systems be commercialize in near future at a reasonable cost.".