Answer to Reviewer 2

After a careful homogenization effort of the OHP ozonesonde record, as described in Ancellet et al. (2022), the OHP team proposes an additional correction for anomalous low ozone records in the 2002-2007 time period. As those low ozone partial pressures in this period coincide with low internal pump temperatures during this period, a correction method that linearly increases the pump temperatures with height is proposed. This method is then evaluated making use of co-located lidar and MLS overpass stratospheric ozone profile measurements and of the total column ozone amounts retrieved from a collocated SAOZ instrument.

General comments

I want to congratulate the authors with their very detailed and careful assessment of their dataset and the identification of the origin of anomalous ozone partial pressure time records in their high-quality dataset. Clearly, also taking the basic ozonesonde conversion formula (1) at hand, there is clear relationship between the low pump temperatures and low ozone partial pressures recorded in the 2002-2007 period.

The authors thank the reviewer for his interest in our analyzis of the quality of the OHP ECC data record.

1. *However, and here I second the other reviewer, there could/should be done more analysis to rule out potential causes and seek to find an explanation for this anomalous behaviour: a temperature measurement, with a thermistor, is a fairly easy measurement and large errors on precision or large uncertainties are rather impossible. In other words, the measurement of the pump temperature is right and cannot be off so much compared to earlier and later periods. So, the only possible explanation for those much lower pump temperature measurements is a change in the environmental conditions of the measurement. Here, different causes might be thought of:*

- change of the thermistor location. This happened in July 2007. I'll come back to this later.

- change of batteries for the pump motor (e.g. from water-activated batteries to Lithium/Alkaline batteries). For instance, the water-activated batteries released much more heat than Lithium or Alkaline batteries

- change of the position of the pump motor batteries (e.g. in the separate battery compartment of the Styrofoam box or inside the Styrofoam box itself)

- change of the isolation properties of the Styrofoam box

- change of the performance of the pump itself (e.g. higher pump currents, higher pump friction, heating up the box more)

We agree with the reviewer regarding the various causes. However, some metadata and written documents related to the ozonesonde preparation during the 2004–2007 period have been lost, and the individuals who worked at the OHP station during that time are no longer employed there. It is therefore now difficult to conduct a detailed assessment of all possible causes. Only three changes potentially related to differences in pump temperature between 2002 and 2007 have been clearly identified from the existing written records. A new Section 4.2 has been added to the article to describe the changes that occurred during the 2002–2007 period (modification of the TMAX interface, use of NOAA STRATO software) and the uncertainties regarding the preparation of ozonesonde (position of the thermistor in the styrofoam box):

« 4.2 Analysis of the 2002-2007 ECC homogneized temperature drop in 2002-2007

Before discussing the selected correction procedure of the ECC pump temperature, it is important to review the known changes during this time period. First, there was a change of the electronics interface between the ECC and the radiosonde in January 2002 switching from TMAX-HMOS to TMAX-C. An update of the software to read the binary files was made to handle the dataframe from the TMAX-C interface but documentation about this step has been lost. We cannot exclude a bug in the implementation of this software. The use of the TMAX-C interface was discontinued in July 2007 when MODEM radiosondes replaced the VAISALA radiosondes.

Second, we make the hypothesis that the thermistor was taped to the pump during this time period 2002-2007 in Ancellet et al. (2022) but this information has not been precisely recorded in the metadata and there is a large uncertainty about the position of the thermistor position in the styrofoam box. The pump temperature correction applied during the homogenization process performed in Ancellet et al. (2022) might not be correct.

Third, the NOAA STRATO version 8.66 has been implemented at OHP to produce level 1 files between February 2004 and June 2007 with two consequences: (i) a different processing software has been applied for the ozone retrieval without a recording of the ECC current in the level-1 files, (ii) the binary files with the ECC current have been lost. In order to include cell current in the data files, Ancellet et al. (2022) performed a reverse calculation of cell current since the necessary variables to back-calculate the cell current from the ozone partial pressure were available in the data file. We are confident that this process produced very small uncertainties in the ECC current retrieval. Use of the STRATO software has been discontinued in July 2007 when switching to the MODEM data acquisition system. »

Change of TMAX electronics is also specifically mentioned in section 2.1 lines 69-71.

The authors therefore could/should analyze their metadata records and try to determine any coincidences with the beginning and end of the 2002-2007 period. In this respect, it would also be very helpful to provide some additional plots:

- The ozonesonde serial numbers versus time

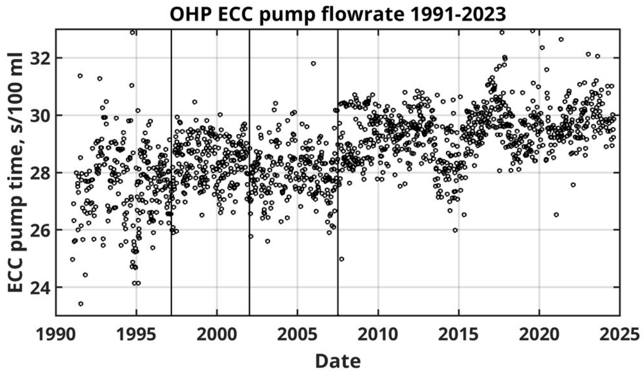
The serial number of the ECC sondes used in 2002-2007 did not correspond to known problems in the production of ENSCI ozonesonde. A new paragraph to discuss this point is added in section 4.1 line 121-125 with a reference to Stauffer et al. 2022:

« Stauffer et al. (2022) reported that ENSCI ECC total ozone column drop occurring at selected sites after 2013 could be related to ozonesonde production changes as well as station-specific factors due to ozonesonde preparation. ECC serial number are above 20000 for the sounding with TCO drop larger than 3-5%. The ENSCI serial number are between 6200 and 12800 for the OHP sounding made between January 2002 and June 2007. We therefore cannot identify a clear connection with the sonde production quality discussed in that paper. »

- The ECC pump flow rates versus time

We are aware that the ECC pump flow rate error could be a possible cause for the low ozone in 2002-2007. However contrary to the ECC pump temperature recording, the metadata about the ECC flow rate recording are very reliable and there are no obvious reasons to doubt the pump flow rate recorded in the level 0 data files. The full data record of the pump flow rate is now shown in Fig. 3 and lines 115-120 have been added in section 4.1 to discuss the possible link with the low ozone values in 2002-2007:

« ECC pump flow rate is expected to change especially when switching ECC type or motor power supply. Its time evolution is shown in Fig.3. There is indeed lower pumping time values from 2002-2007 in the range 27-29 s. However these values are within the 25-35 s recommended values in Smit and Thompson (2021). The time evolution shown in Fig.3 is taken into account in the ozone calculation using equation 1 and OHP metadata records are very reliable for this parameter. Therefore we do not expect the low ozone values observed at 25 km to be caused by incorrect values of the ECC flow rate used in the data processing. »

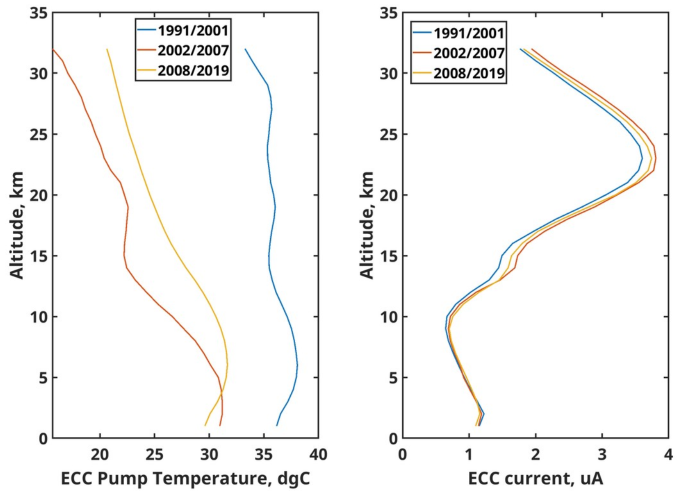


- The mean vertical profile of both the measured and O3S-DQA corrected (see Ancellet et al., 2022 and my point 4) internal pump temperatures for the three periods. This information is to some extent provided in Fig. 3 (is it the measured or corrected internal pump temperature?), but I guess that a mean vertical temperature profile would give more information if the anomalous low temperatures in period 2 are arising at all vertical levels or from some typical altitudes onwards. Of course, period 3 might be further split in subperiods, so that the number of years for each period does not differ too much.

We agree with the reviewer that the submitted version does not provide sufficient information on the mean vertical distribution of ECC temperature and current, beyond what is shown in Figure 4. The temperature of the pump T_P is always the homogenized temperature in the paper (this point has been clarified throughout the text, and we apologize for not having made it clear earlier see answer to point 4).

A new figure 5 added to the paper shows the mean vertical distribution and lines 141-148 discuss the possible interpretation of this figure:

« First, the mean vertical distribution of the homogenized ECC temperature and of the ECC current for three periods (1991- 2001, 2002-2007, 2008-2019) are shown in Fig. 5 to emphasize that the ECC temperature drop in 2002-2007 increases with altitude in the stratosphere as does the difference between internal and external ECC pump temperature shown in the analysis of Smit et al. (2012). The differences of ECC current between 2002-2007 and 1991-2001 does not show a clear altitude dependency with no evidence of lower current difference at 30 km than at 20 km in 2002-2007 as we might expect if the ECC solution temperature is so cold that it becomes frozen. In fact the relative differences of ECC current between 2002-2007 and 1991-2001 are however -5.4% at 20 km, -5.7% at 25 km and -6.8% at 30 km. Wrong values of the recorded ECC pump temperature in 2002-2007 would thus remain as the possible primary cause of the negative ECC ozone concentration bias at 25 km. »



In Fig. 5 the period 3 and 1 have now the same duration (10 years) but this does not change the values used in tables 1 and 2. A period long enough for the reference values before 2002 and after 2007 are necessary considering the limited number of sonde launched per month (of the order of 4).

The conclusion has been updated to summarize the additional analyses requested by the two reviewers in lines 232-237:

A detailed assessment of the possible causes for the low pump temperature recording in 2002-2007 is difficult due to the limited number of written documents still available, but section 4.2 provides a discussion of the known changes, namely a possible wrong recording of the ECC temperature values in the level-0 files or/and a large uncertainty about the actual location of the thermistor in the ECC gondola. Although frozen ECC solutions in the styrofoam box could be another candidate for the ECC low ozone values in 2002-2007, the altitudinal change of the ECC current in the altitude range 20-30 km does not provide clear evidence that such an indirect effect is the main reason for the ECC ozone bias observed at OHP.

2. *In addition to the direct (mathematical) impact of lower pump temperatures on the ozone partial pressure values through Eq. (1), there is also an indirect impact. As the ECC cell temperatures are typically around 5 to 10 °C lower than the measured pump temperatures (with the 5°C more typical for SPC ozonesondes, and the 10°C applying for En-Sci ozonesondes), as measured in simulation chamber tests with ozonesondes, the lower pump temperatures in the 2002-2007 period might be associated with ozonesonde cells with frozen solutions (cell temperature close to 0°C). In such cases, the chemical reactions inside the cells will be less efficient or slow down, and as a consequence much lower currents will be generated. In the Uccle station, I could identify this feature quite regularly in the upper parts of the ozone profile when the En-Sci ECC (measured) pump temperatures drop to below 10°C or lower (despite active heating). However, at OHP, from your table 1 and Fig. 4, it seems that during the anomalous period 2 (2002-2007), higher cell currents are measured at 25 km compared to the periods before and thereafter. I found this rather surprising and this argues against the hypothesis of frozen solutions during this period 2. Can you therefore more extend on this analysis and also look at e.g. other altitude levels? It would also be interesting to produce some mean vertical profiles of pump temperature, ozone partial pressure, and cell current for (the) different periods to analyze in greater detail the hypothesis of frozen solutions (relation between pump temperature close to 10°C from given altitudes & cell current and/or ozone partial pressure drops from that given altitude as well?).*

That's a very interesting point raising the possible indirect effect of frozen solutions. It is addressed in the answer to point 1 and especially by showing the mean vertical profile of the ECC current in Fig. 5. Indeed we would expect faster decrease of the ECC current in 2002-2007 than for the periods where we do not suspect the solution to be frozen. So we believe fig.5 and the discussion line 141-148 answer the questions raised by the reviewer.

3. *As shortly mentioned earlier in point 1., the impact of the lower ECC pump flow rates on the lower ozone partial pressures in period 2 should be discussed and highlighted as well. As shown in Fig. 4b, the pump flow rates (or better: times to pump 100 ml of air, t100) are lower in the 2002-2007 compared to the periods before and therefore. From Eq. (1), it follows immediately that those lower t100s (phi_p = 100/t100) will result in lower ozone partial pressures as well. This effect also contributes to the low ozone anomalies in 2002-2007. So, the anomalous low ozone partial pressures seem to be caused by a combination of effects.*

This question has been addressed in the answer to point 1. The new Fig. 3 indeed shows pumping time values in the range 27-29 s for the time period 2002-2007. But these low pumping time are already taken into account in the ozone calculation using equation 1. We have no obvious reasons to doubt the pump flow rate measured in the lab during this period. The values in the range 27-29 s remain in the range of reliable values. See discussion added in lines section 4.1 line 115-120 and the answer to point 1.

4. *Please, be also more specific on the different pump temperatures used throughout the paper. I could identify the following ones:*

- *the measured pump temperature: measured value by the thermistor the O3S-DQA corrected internal pump temperature: here, please specify which corrections have been applied. I guess that, before 2007, you used Equations [E-D3A/B/C] and [E-3-15] (or [E-D-6] & [E-D-7]) and only [E-3-15] after 2007, where the equation numbers refer to those from the WMO-GAW N°268 document. Please, also clearly mention that those corrections will increase the measured pump temperature, and that due to the pump temperature sensor location change in 2007,*
- *the O3S-DQA corrected pump temperatures before that date will be increased by values around 8°C compared to the O3S-DQA corrected pump temperatures after that date, which would resolve part of the biases between the measured pump temperatures before and after 2007.*
- *The calculated pump temperatures using the lidar ozone concentrations (used in Table2)*
- *The corrected ECC pump temperatures (Eq. 3).*

Clearly describe those different pump temperatures and you might even use different symbols for them. Also, specify for every figure which pump temperature is shown. For instance, it is not clear to me if the "ECC temperatures" in Figs. 3, 4, 5a are the measured pump temperatures or the O3S-DQA corrected internal pump temperatures!

We agree with the reviewer that it was not clearly stated that what we called measured ECC pump temperature is actually the homogenized temperature calculated in Ancellet et al. 2002 using the O3S-DQA recommendations. The symbol T_P corresponds to the homogenized temperature throughout the paper. It is the parameter used in Fig. 4 and 6. The calculated pump temperatures derived from the other parameters (ozone, pump flow rate and ECC current) is called T_{Pc}. It is used in Table 2. and Equation 2. Last, the new corrected pump temperature calculated in section 4.3 is called T_{Pcor}. This has been clearly stated in section 2 and 4 and in the figure captions (Fig. 4, 5, 6, 7, 8) .

See line 73 "However the homogenized ECC pump temperature T_P remains inhomogeneous for the the period 1991-June 2007"
See lines 127-130:

"the correction of ECC pump temperature applied in (Ancellet, 2022) can be as large as 10 K to account for wrong thermistor position. Figure 4 shows its time evolution with three periods showing changes in the range of the homogenized ECC pump temperature (in this work the measured ECC pump temperature always refers to the homogenized ECC temperature retrieved in Ancellet2022).

5. *I would also be very cautious about the terminology used for the proposed correction method. You "correct the ECC pump temperature" in the 2002-2007 period, but the measured pump temperatures are not wrong! These are truly measured values. What you ultimately correct for, are the anomalous low ozone partial pressure values, and you do this by increasing or even "manipulating" the pump temperatures. But, under (too) low pump temperature regimes, the conversion efficiency of the chemical reactions will change, possibly giving too low measured cell currents (to be investigated further). Therefore, physically, the conversion efficiency coefficients should be altered for the 2002-2007 period, and not the pump temperatures. I do not disapprove your pragmatic approach by increasing the pump temperatures, but I would merely call it an empirical correction and not necessarily a "pump temperature correction". In this sense, you might introduce an extra correction factor in Eq. 1.*

That's an interesting point. Indeed, we could use the same correction in Equation 1—one that increases linearly with altitude—without necessarily calling this parameter a "temperature correction." The results of the ozone correction would remain the same, since our temperature correction is in fact adjusted using the differences with the lidar and MLS. It is therefore similar to a correction factor. We ultimately decided to retain the term "temperature correction" in Section 4.3 because, as explained in previous answers, we were unable to clearly establish that other parameters (current or pump flow rate) are incorrect.

Minor comments

Line 9: I guess you are referring to the ECC pump flow rate trend, instead of the ECC pump motor speed (which is expressed as rotations per minute or RPM). Yes this has been corrected

Line 41: add "in OHP" after "The ECC ozonesondes have been used". Done

Line 56: how many ozonesonde profiles are discarded based on the normalization factor limit? And did you not apply a lower limit for the normalization factor? Why only an upper limit? So, you also do not consider ozonesonde profiles with lower burst altitudes? What is the criterion?

We added a small discussion about the ozone normalization factor calculation in lines 57-64: « The residual ozone above the 10 hPa pressure altitude or above the balloon burst altitude are derived from the McPeters and Labow (2012) satellite monthly mean climatology at pressure smaller than 10 hPa. The normalization factor is not calculated for ballon burst altitudes lower than the 25 hPa pressure level or when the SAOZ measurement is not available. The corresponding sounding are nevertheless included in the OHP data set. This corresponds to 9.5% of the 1524 OHP soundings from 1991 to 2023. Only ozonesonde profiles with a normalization factor below 1.3 are considered here (i.e. only 3 soundings out of the 1524 excluded of the data base). The fraction of soundings with normalization factor higher than 1.2 is 1.3%. Normalization factor is always larger than 0.83 and no filtering is applied for low values of the normalization factor. »

Caption Table 1: specify that those values are taken at 25 km. It should however be instructive to also see some values at other altitudes.

The caption has been corrected. The new figure 5 provides values of the pump temperature T_p and the ECC current at different altitudes. See answer to point 1.