

Review of Smit et al., *New Insights From The Jülich Ozone-Sonde Intercomparison Experiments: Calibration Functions Traceable To One Ozone Reference Instrument*

Anonymous Referee #2, 06 August 2023

We thank referee#2 for her/his complete and thoughtful review of our manuscript and providing thoughtful comments and suggestions that have helped us improve this manuscript. We also thank Editor Birgit Hassler for handling our paper and coordinating the reviews. Our responses to reviewer comments are provided below in red italic text.

RC2: 'Comment on egusphere-2023-1466'

General comments

The submitted manuscript reports, with great care and thoroughness, recent results that address two very long-standing issues in the ozonesonde community, namely the existence of a slow reaction component as well as a constant component to the traditional concept of background current, and also the separation of the traditional "pump correction factors" into a true pump efficiency and a second calibration function for different combinations of sondes and solutions.

While neither of these concepts are new the authors have performed an important job by their careful testing and now, with this manuscript, documentation, and I don't hesitate to recommend acceptance by AMT with only very minor revisions.

It is also very pleasing to see additional value being extracted from previous JOSIE studies and I suspect there is yet more value still to be gained from analysis of the many experiments conducted at the WCCOS over the years.

The analysis has been very carefully performed and I could not find any examples of errors or statements that seemed illogical.

The manuscript is very long and at times, quite repetitive. Personally, I would have preferred a shorter study with a tighter focus, but I accept that there are also some advantages to the very thorough approach taken by the authors here.

I think it is to the authors' credit that the results on the fast and slow responses are carefully compared with those of Voemel et al. 2020 and the differences clearly noted and discussed. This is very good scientific practice. (I see that "stimulating discussions" are noted in the acknowledgements).

Perhaps surprisingly, the manuscript also contains numerous mentions of effects that cannot yet be properly accounted for, or where only speculative causes can be postulated, eg lines 230, 235-236, 551-559, 611-614, 656, 870-872, 894-895, 1157-1160, 1196-1198, 1220-1223, 1246-1248. It is good that the authors are candid about the lack of understanding of these topics but I hope that further work will help improve the situation.

I assume, however, that these remaining unknown effects can all be accounted for empirically by comparison to the photometer, even if the mechanism is not understood?

I have two very general questions I would like to pose to the authors.

Firstly, it seems to me that the authors consider the pump efficiencies as a function of pressure determined by Nakano and Morofuji 2023 to be, essentially, "correct". I would have

thought that these values might well have varied considerably over the very many years that ECC sondes have been manufactured and flown – could the authors please comment on that point?

>>> *For the Nakano and Morofuji (2023) pump efficiency table we used the average pump efficiencies and their uncertainties derived over all individual pump flow calibrations (1387 samples) which are listed in Table 2 of their publication and covers the entire period 2009 - 2022. Within 1-2% uncertainties these average average values are rather stable over time, however, Nakano and Morofuji demonstrated that the pump efficiencies at pressures below 30 hPa can usually vary by a 1-2 percent between production badges. An exception is the period 2014-2018 whereby a systematic drop of 1-3 % in the pump efficiencies at reduced pressures below 30 hPa were observed. It is clear that in such cases when the actual pump efficiency values deviate significantly from the average Nakano and Morofuji pump efficiency then the calibration functions reported in Table 4 of this study have to be adjusted accordingly". To make this clear we therefore included at Line 865 an extra sentence stating this.*

"Of course, the numbers are for the calibration functions, i.e. the conversion efficiencies, directly linked to the pump efficiency values used, and it is assumed here that the average pump efficiency values from Nakano and Morofuji (2023) in Table 4 are correct within their uncertainties and representative of this study. However, if known pump efficiency values have changed over time, the calibration functions must be adjusted accordingly."

A similar statement we have included in the conclusion in Chapter 8 at Line 1140

Secondly, do you expect the results also to hold in the light of fluctuations in the manufacturing process of the ozonesondes, eg the "drop-off" reported by Stauffer et al. which affected ENSCI sondes and recent anecdotal reports in the community of poor production quality of SPC ozonesondes?

>>> *Of course applying the TRCC methodology neither the conventional method cannot avoid the TCO-drop or other inconveniences in the quality of the recorded ozonesonde data that have occurred in the past or in the future. However, in all these cases it had been shown again and again that to achieve the best possible quality and stability of the long term ozonesonde records it is of crucial importance the existence of a good functioning QA (Quality Assurance) management plan that covers all aspects of ozonesoundings in practice: (i) good functioning and stable instruments (manufacturing) (ii) good quality and well maintained ground equipment at the sounding station; (iii) unified SOPs (Standard Operating Procedures); (iv) and on top well trained and motivated personal who do the ozone soundings. Over the last 25 years large QA efforts have been done by the ozonesonde community within GAW-NDACC-SHADOZ and GRUAN, such as. (i) experimental activities (e.g. JOSIE 1996-2017, BESOS-2004); (ii) assessment to harmonize operating procedures (ASOPOS 1.0); (iii) homogenization of long term ozonesonde records (O3S-DQA); (iv) most recently the ASOPOS 2.0 (GAW Report No. 268). The ASOPOS 2.0 panel has also recognized that QA monitoring in quasi real time should be an important QA-component in the future. In this context a first example is the TCO drop study by Stauffer et al. (2020, 2022) by comparing sonde TCO data with satellite and ground based (Dobson/Brewer) TCO observations*

But thanks for this question, for the sake of clarity we have included a short statement in the conclusions on this topic.

Apart from these two questions, I only have very minor comments to make.

Specific comments

Lines 17-35 The abstract is almost all about the fast and slow responses, and it is not until line 31 that the new calibration functions are mentioned, even though they are also a very important result from this work. I suggest that the abstract be slightly re-worded so that the two main results appear earlier and more prominently.

>>> *We add an extra sentence in Line 24:*

"The methodology resolves the slow and fast time responses of the ECC ozonesonde and in addition apply calibration functions to make the sonde data traceable to the JOSIE ozone reference UV-photometer (OPM).

Line 47 Missing closing bracket

>>> *Done*

Line 52 I would prefer some references to the original literature here (Haagen Smit etc) rather than just a textbook. For the stratospheric ozone discussion which follows, many original references have been cited which I think is better.

>>> *We included the first Haagen-Smit, 1952 reference and changed the sentence by more focusing on the origin of the photochemical summer smog. Further, we think in the previous lines (43-51) the photochemistry of ozone in the troposphere has been already discussed in a balanced way comparing to the stratospheric ozone discussion part.*

Line 75 I would prefer a word such as "approximately" to the use of the tilde symbol here in the text.

>>> *Done*

Line 76 Would it be possible to include a map of the sixty stations? This would help the reader to understand that the work is relevant to a true global network. I appreciate it can be difficult to determine whether a station is "currently active".

>>> *We have considered that too, but finally decided not to include an extra figure because of the large number of figures already existing. However, therefore we have explicitly referred to figure 1-2 of the new GAW-Report No. 268 which is shown such a map of all global ozonesounding stations that are operational in the global network.*

Line 77 Insert "the" before "stratosphere"

>>> *Done*

Line 132 Please re-word "giving artefact low readings". Do you mean "artificially low" or "unreliably low" or something like that?

>>> *Thanks for alerting. The sentence has been completely changed into: "A special challenge of tropical soundings is that near the tropopause the ozone concentrations can be*

very low (Thompson et al., 2007b), such that the signal to noise is very small, causing large relative uncertainties in the ozonesonde readings (Smit et al. 2007)".

Line 175 Insert "the" before "redox"

>>> Done

Line 189 Replace "convert" with "is converted to"

>>> Done

Line 209 I would prefer a sentence here explaining to the reader how this result was obtained without having to go back to the cited studies – ie how is it known that the absorption efficiency is 1.0 within 1% for all ECC ozonesondes?

>>> We added an extra sentence in Line 209:

"This was confirmed by Davies et al. (2003), who determined experimentally at different pressures in a vacuum tank. the absorption efficiency η_A from the responses of two ECC-sondes connected in series."

Lines 302-308 I found this a very helpful paragraph!

Lines 351-355 Figure 1 is a little bit confusing, because in part (a) the fast response is clearly extrapolated from the first three points, but in part (b) it's not obvious how the solid red line has been obtained and the reader might be given the impression that there is also a third, even slower response.

>>> You are right. We have modified the figure by adding a new curve: $IM(t)-IB0$ and at $t=10$ min. we add the 25 min slow response (i.e. 25 min decay) that match very close the measured $IM(t)-IB0$ curve. We have changed the text in the manuscript accordingly.

Line 435 Please re-word "approximately exponentially to a change in U"

>>> Thanks to alert to re-word: correct is that the measured signal U is approximately proportional to its change over time dU/dt . We have correct in "approximately proportional to a change in time of U ".

Line 443 You say, in effect, that the method assumes that the time-step is small compared to the rate of change of ozone in the atmosphere, but you don't say whether this is a good assumption.

>>> Sentence has been revised into: "In case the time step Δt_k is chosen small relative to the response time τ . then it can be assumed that the "true" (ambient) signal U_a is quasi-stationary during time step Δt_k such that $U_a(t_k) = U_a(t_{k-1})$ "

Line 609 Please re-word "for 50% contributing"

>>> Done

Line 655 Please re-word "may display be due to processes"

>>> Done

Line 656 "min" -> minutes

>>> *Done*

Line 803 I would prefer "factor of 2" and "factor of 3"

>>> *Done*

Line 805 Remove "been" – and I think replace with "significantly" or "non-negligibly"

>>> *Done*

Line 962 I would prefer "factor of 2"

>>> *Done*

Line 1048 Please reword – perhaps "In addition, the total uncertainty of the conventional method is also shown (dashed red lines)."

>>> *Done*

Line 1053 Please re-word "remote air conditions". (Or delete it altogether, I don't think you need to say it at all, and the sentence is too long.)

>>> *Done*

Line 1056 Please re-word "strongly restricted to its detection limit" – what does that really mean?

>>> *We replaced "restricted to" by "determined by"*

Lines 1060-1065 It's very good that you have shown how the procedure influences the results in these three different situations.

>>> *Done*

Line 1135 Please re-word "Essential thereby is .. "

>>> *Done*

Line 1136 I am not sure that you have smoothed it enough?

>>> *Done*

Line 1165 Delete the two "is"

>>> *Done*

Line 1188 "resp" should be "respective"

>>> *Done*