Reply to reviewer #4

We thank anonymous referee #4 for his helpful comments and corrections. Please find below the reviewer's comments (in black), our responses (in blue), and changes or additions to the text (in red).

All page / line numbers refer to the <u>old</u> version of the manuscript.

Please note that we identified an issue in the GTO-ECV data record, which affected ozone values from 2017 onward, in particular in the middle latitudes of the southern hemisphere. We had to reprocess the data record for this period. The comparison with Adjusted-MERRA was repeated and all figures were updated. In general, the main findings did not change, except for the unclear behavior in 2017/18 in the middle latitudes of the SH (see p.6, ll.25-26), where the differences are smaller now.

Anonymous Referee #4
Received and published: 27 November 2019

General comments

The authors present the newest version of the GTO-ECV dataset, containing long-term harmonized total-column ozone measurements from the GOME, SCIAMACHY, OMI, and GOME-2A satellites, and compare it with the Adjusted-MERRA dataset which assimilates measurements from the SBUV and SBUV-2 satellite instruments, as well as MLS, IASI, CRIS, ATMS, as well as OMI.

First, a comparison of the two datasets in terms of zonal mean ozone and its trends and seasonal cycles is presented. Then the two datasets are analyzed and compared seasonally at 5 x 5 degree spatial resolution. Similarly, the ozone anomalies for selected 5x5 grid cells are shown and a comparison of the two datasets is made. The inter-annual variability of the anomalies is calculated as a standard deviation, and once again the two datasets are compared.

Finally, the authors perform an empirical orthogonal function (EOF) analysis on the total column ozone anomalies, within 25 degrees of the equator. The first four EOFs are found to explain 92% of the variance, and these are related to climatic indicators: quasi-biennial oscillation (QBO), solar flux, and the multivariate ENSO index (MEI). This analysis and presentation of large public datasets is important, since users of the data will probably not do this analysis themselves before using it in their specific application. Thus, users will not be aware of potential problems which hide in the details. However, the present paper does not draw any new scientific conclusions, despite the huge effort in gathering, processing and analysis of the data. The article is generally well written and the figures are of a suitable quality, if often quite small on the page (however, see the section on technical corrections).

Specific comments

When initially looking at Figure 1, and investigating the genealogy of the two datasets that are being compared, one's initial conclusion is that the clear change in October 2004 is because of the OMI data that is being assimilated into both of the datasets.

Therefore, it is easy to conclude that after this date, the comparison is simply OMI-to-OMI. The adjustment of the MERRA using SBUV is described in one sentence in page 5, and this subtlety is easy to miss. The start to section 3.1 on page 6, which is not very clear, further adds to the confusion.
→ We have expanded this part to make it more clear.

It is almost impossible to make sense of the present paper and the data presented without a thorough reading of Coldewey-Egbers et al (2015) and Garane et al (2018), with particular attention to the subtle changes that have been made. A genealogy/timeline of the evolution of the datasets will assist readers to understand what they are working with.
→ We agree with the reviewer and have reformulated the beginning of Sec. 2.1 to make it more clear.

Technical corrections

Pg 1
line 11: "second period", "later period": without the context of reading further into the paper, it's not clear what this means. The abstract needs to stand alone.
→ This part now reads:
"...whereas the difference is -1.1±1.2% for the period from October 2004 to December 2018. The variability in the differences is considerably reduced in the period after 2004 due to..."

Pg 3
line 33: why is the analysis limited to the low and middle latitudes? Surely total-column ozone is important at high latitudes? In your 2015 AMT paper (which I call CE2015), (pg 3924 second column, second paragraph) you state that GODFIT is robust at high SZA.
→ We added:
"...middle latitudes, but also toward higher latitudes the data sets present a uniform and stable behavior."

Pg 4

Line 1: "seperate" -> "separate"
→ Corrected.

Line 4: "remarkable long-term stability": where is this remarkable stability demonstrated?
→ We now provide a reference and add:
"w.r.t. the ground-based reference (Garane et al., 2018),"

Perhaps you should point out here that this is different to CE2015, where GOME is used as the long-term reference. Also, in the 2015 edition of your dataset, you use a "soft-calibration" procedure, which has since been discontinued. Indeed a genealogy of the various data products (GTO-ECV and SBUV/OMI-MERRA-derived) and their versions, and the changes from version to version, would be helpful to make sense of them all.
→ We provide a note here on the different versions of GTO-ECV and the change of the long-term reference.

Line 22: the url takes me to news about the ocean-colour dataset, rather than ozone.
→ Replaced with the correct url.

Pg 5

Line 17: A glance at your Figure 1 shows that the discontinuities have not been removed (or perhaps they exist in the GTO-ECV dataset?). Here you speak or "renormalizing", while lower down in the page it is referred to as simply normalizing. Use consistent naming.
→ We now use "normalizing" throughout the manuscript.

Pg 6

line 4: "which is completely independent of GTO-ECV": at first reading this might be taken to mean that Adjusted-MERRA is independent of GTO-ECV. Perhaps "which is itself completely..." is clearer. This paragraph as it is currently written adds to the confusion regarding the different datasets and their history.
→ We inserted "itself" here.

line 17: "difference in zonal mean total ozone column is ..." here you quote a single number while talking about the zonal means. This is shown later on in the paper (i.e. Fig 5) however here it is somewhat surprising. Does this refer to the global mean?
→ Thanks for pointing out this inconsistency. We now state, that this is number refers to the average over all zonal means, and we provide a range for the individual zonal mean differences to make this more clear.

line 27: "high latitudes and before 2002: that is probably caused by sparse data coverage..." this is in stark contrast to your detailed explanation in CE2015 where you show that the poles receive better spatial coverage.
→ We specify this and add "...high latitudes close to the polar night and before 2002...".

Pg 7

Fig 1: When you say A-MERRA vs GTO-ECV, what does this mean? There is no agreed-upon meaning for 'vs' in this context. In C-E2015 you spell it out, e.g. (AM -GE) / AM. Later on in the present paper (pg 13) it becomes clear that this "vs" is not calculated how one might assume it is.
→ We agree and remove "A-MERRA vs. GTO-ECV" from the title and instead of that we provide the formula in the figure caption.
Fig 1: In Garane et al 2018, their Fig 9, the lifespans of each satellite are shown as horizontal bars on a figure similar to Fig 1. It be helpful to show these, for both GTO-ECV and A-MERRA. For example, one might unkindly split the GTO-ECV into the Gome-SCIA-ECV and the OMI-ECV, such is the heavy influence of OMI measurements on the dataset;
→ We can understand the reviewer's request to show horizontal bars indicating the satellites' lifespans, but we think that adding 10 lines would make the plot too confusing. For GTO-ECV the temporal coverage is provided in Table 1, and for MERRA-2 we would like to refer to Wargan et al., 2017, their Table 1.
However, one might for example ponder if there has been a change since the launch of GOME-2. Might this also give a clue as to the subtle change towards the end of the time-series?
→ The unclear change in the behavior toward the end of the time period (2017/18) has been solved, since we identified a problem in GTO-ECV, which could be eradicated. The complete analysis has been repeated and all figures were updated.
Fig 1: The upper figure shows differences as a percentage, the lower figure shows differences in stdev as Dobson units. Is this intentional?
Honestly, for us this is just a matter of taste. We prefer to show differences in standard deviation as absolute differences.

Line 10: "differences are found the north": insert "in"
→ Done.

Page 8

Table 2: Here you describe a global dataset. However, you describe DJF as being "Winter", which is only true in the northern hemisphere. Similarly for the other seasons. This is repeated several times throughout the figures and text.
→ We have corrected this throughout the entire manuscript and provide either only month names or specify the hemisphere (boreal/austral). In all corresponding figures, we changed the titles.

Line 2: "5ˆ{\circ}latitude band separately": space missing
→ Corrected.

Line 11: "introduction of OMI data into GTO-ECV data record..." OMI data is also introduced into the adjusted-MERRA dataset. This omission is made several times in the text.
→ Solved.

Line 17 & 18: "trough" is spelled "through"
→ Corrected.

Page 9

Lines 7 & 8: the seasons for a global dataset are described in terms of northern hemisphere seasons.
→ Solved; please see reply to comment p.8, Table 2.

Page 10:

Line 1: "Atlantic Ocean, in particular in autumn" is this the North Atlantic, or the South Atlantic? Is this the boreal autumn or the austral autumn? This is extremely confusing.
→ Solved; please see reply to comment p.8, Table 2.

Line 7 & 8: "southern hemisphere minimum ozone columns in autumn" is this the boreal or austral autumn? This is particularly confusing after reading the beginning of the paragraph, and looking at the figure.
→ Solved; please see reply to comment p.8, Table 2.

Page 11:

Figure 4: This figure describes the seasons in terms of the northern hemisphere, for a global dataset. Also, the small title above each global map indicates the northern hemisphere seasons. Perhaps you could put the southern hemisphere season below the map? This might make the figure too busy: you decide. This figure is very small. It could easily be split across 2 full pages.

→ We replaced the season in the title above each map with the names of the months that are covered. Furthermore, the figure is split into two (new Figures 4 and 5, see also reply to reviewer#2).

Page 12:

Figure 5: This figure is very small. The bars are too close together in these histograms, e.g. in the left-hand pair of figures, I can't see if the blue or the orange is taller for a given total ozone amount. Are adjacent orange and blue bars meant to be for the same interval or for consecutive intervals?
→ We increased the figure size and inserted space between the individual bars.

Line 11: Northern-hemisphere seasons are described for a global dataset
→ Solved; please see reply to comment p.8, Table 2.

Page 13:

Figure 6: northern hemisphere seasons in the figure and caption
→ Solved; please see reply to comment p.8, Table 2.

Line 1: "i.e. Adj-MERRA standard deviations are higher..." if you simply give the formula for what you mean by "vs" on your graph titles (such as in CE2015), then this sort of clarification is not necessary. Indeed, this clarification makes me go back and question how I have interpreted all of your figures, since this is the opposite of my intuition.
→ We removed "A-MERRA vs GTO-ECV" from the titles of all related figures and provide the formula in the text.

Line 10: "corresponding seasonal cycle": is this the seasonal cycle presented in Figure 3?
→ Yes, this is correct.

Line 11: on what basis do you select your seven grid cells, or rather, the longitude at which you have selected them?
→ We selected this longitude, because it covers not only the regions where the anomalies indicate an extremely high correlation, but also the region, where we found the "minimum" correlation (tropical southern Atlantic; shown later on in Fig. 9).

Page 14:

Line 3: "variability is dominated by the QBO". While there is clearly a biennial cycle in the data, the QBO itself is a climatological phenomenon, and you present no mechanism or evidence linking ozone column anomalies to the QBO.
→ We added an explanation and a reference.
"In this latitude band ozone anomalies result from a QBO-induced residual circulation, i.e. ascending/descending motion (Steinbrecht et al., 2003). For instance, westerly winds lead to downward transport and, thus, to an increase in total ozone. At the same time, less ozone-poor air from the lowermost layers is lifted upward."

Line 10: "coffcient" spelling

→ Corrected.

Page 15:

Line 4: "ozone anomalies" are these the same as the ones presented in Fig 8?
→ Yes, we computed the standard deviations from these ozone anomalies.

Page 16

Fig 9: does [-] denote the units?
→ Yes.

Line 5: "variability maximizes ..." this is not idiomatic English. "variability reaches a maximum..." would be better.
→ Changed as suggested.

Line 7: "also linked to wave activity." Have you demonstrated this connection somewhere?
→ We have replaced "wave activity" with "dynamic processes" and provide two references: Hood et al. (1999) and Entzian and Peters (1999).

Line 7: "Fig 10 indicates an excellent agreement..." by using an eyeball to examine the differences on a very small plot perhaps. A plot showing the difference between (i.e. GTO-ECV - A-MERRA) the two datasets would show the agreement more clearly.
→ Instead of a plot, we would prefer to provide some numbers to underpin the good agreement. We added:
"The mean difference in the standard deviation of ozone anomalies between Adjusted-MERRA and GTO-ECV is -0.2±0.5DU or -1.5±3.8%."

Line 11: "lower correlations between GTO-ECV and A-MERRA ozone anomalies." Are these the correlations shown in Figure 9?
→ Yes. We added the reference to this Figure.

Line 13: "According to Press et al..." perhaps "Following Press et al..." would be better.
→ Changed as suggested.

Line 21: "To a large extend..." -> "extent"
→ Corrected.

Page 18

Title and Line 1: Is it PCA or EOF? Please use consistent naming.
→ We now use EOF throughout the manuscript.

Line 7: "to a lesser extend..." -> "extent"

→ Corrected.

Line 8: Perhaps "The EOF analysis is performed on the detrended and deseasonalized 5x5 monthly mean ozone columns presented earlier" is better?
→ Sentence has been reformulated.

Line 9: You give a reference for the EOF analysis in line 2, do you have one describing the Savitzky-Golay filter?
→ We added a reference:
Savitzky, A. and Golay, M. J. E.: Smoothing and Differentiation of Data by Simplified Least Squares Procedures, Anal. Chem., pp. 1627–1639, https://doi.org/10.1021/ac60214a047, 1964.
Why did you choose 13 months?
→ We wanted to remove fluctuations/noise with frequencies of less than one year.

Page 19

Fig 12: The units in on the colour-scale in the first column of plots don't match the second column.
→ Solved.

Page 20

Line 15: "extend" -> "extent"
→ Corrected.

LIne 20: "also a positive correlation..." delete "also"
→ Done.

Page 21

Line 8: "included in GTO-ECV." and also in A-MERRA.
→ Added.

LIne 13: "seaonsal"
→ Corrected.

Line 21-22: "more than 97% of the grid cells..." mention here the size of the grid cells.
→ Done.