Reply to reviewer #2

We thank anonymous reviewer #2 for her/his valuable comments. 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 old 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 behavior in 2017/18 in the middle latitudes of the SH (see p.6, ll.25-26), where the differences are smaller now.

General comment:
This is an extremely well-written and well-presented paper on the comparisons between space-born and modelled total columns. It is quite important for non-informed users of all the datasets described in this text to have this work as reference for their own particular applications. I strongly suggest that the authors include a clear statement on their opinion for the capabilities of these datasets: can they be used as they are for trend studies? for inter-sensor comparisons? for climate forcing applications? a paragraph with a strong message in this direction in the conclusions should be enough.
→ We have added the following paragraph to the conclusions:
Based on the results of our comparison, we conclude that both the GTO-ECV and the Adjusted-MERRA-2 total ozone data sets can be used for a number of relevant applications. GTO-ECV fulfills official user requirements (Garane et al., 2018) and is suitable for longer-term analyses that require good stability, e.g. trend studies, and for the evaluation of model simulations. The Adjusted MERRA-2 was developed primarily for input into climate models and for data intercomparison studies, but has not been evaluated for long-term trend studies (i.e. high spatial resolution trends) and should not be used for this purpose.

Detailed comments and suggestions for improvements can be found in the attached annotated document.

p.2, l.13:
Maybe you could recommend other similar works such as:
https://rdcu.be/bQFVw
https://science.sciencemag.org/content/353/6296/269
etc.
→ We have added "Solomon et al., 2016", "Kuttippurath and Nair, 2017" and "Kuttippurath et al., 2018" to p. 2, ll. 9-10.

p.2, l.24:
Are you sure this is the most appropriate reference to make at this point?
→ We have added "Weber et al., 2018a" here.

p.2, ll.30-32:
This sentence is too vague, you can either not mention it at all or you can add proper references to the proper teams that work on the merged ozone profiles.
→ We decided to remove this sentence.

p.4, l.5:
Here you mean GOME as well as the two GOME2 sensors? Please re-write more clearly.
→ We have re-written this part of the sentence as follows:
"… while GOME, SCIAMACHY, GOME-2A, and GOME-2B are adjusted in terms of..."

An explanation of the terms “GOME-2A” and “GOME-2B” has been added to the footnote of Tab.1.

p.4, l.6:
… of the sufficiently...”
→ Corrected.

p.5, l.4:
From which time onwards?
→ We added: “(from 1980 to September 2004)”

p.5, ll.8-10:
Shouldn’t you first mention which model has actually assimilated the TOC data? This phrase reads a bit out of sequence.
→ We agree with the reviewer and added the information on the model in lines 2-5:
“It is produced with version 5.12.4 of the Goddard Earth Observing System (GEOS-5.12.4) atmospheric data assimilation system, whose key components are the GEOS-5 Atmospheric General Circulation Model (Molod et al., 2015) and the Gridpoint Statistical Interpolation (GSI) analysis scheme (Kleist et al., 2009).”

p.5, ll.10-12:
Surely you need more detail here and not just a general phrase on the "realistic" global distribution of ozone and two references. If you include more details further below in the text you could also state this here, so that it is not lacking.
→ This part now reads:
“The MERRA-2 assimilation produces realistic global distributions of ozone in the stratosphere and upper troposphere (Stajner et al., 2008; Wargan et al.,2015, Davis et al., 2017). The column ozone values agree with NASA’s Total Ozone Monitoring Spectrometer (TOMS) to 1.8±2.8% in the tropics and 1.4±3.7% at higher latitudes. A more detailed validation of the MERRA-2 ozone fields and parameterized ozone chemistry are discussed in Wargan et al. (2015, 2017).”

p.5, ll.12-14:
You definitely need to include more details on the model input parameters. Which meteorology was used? which chemistry? where was the model validated? [not the ozone output, the model itself]. Where was it used in the past? and so on.
→ The MERRA-2 assimilation is based on the GEOS-5 Atmospheric General Circulation Model, which includes no input meteorology per se. The meteorology is generated by the model, which ingests temperature, pressure, and other state variables from satellite IR instruments and ground/balloon-based radiosonde measurements, among other data sources. Time dependent sea surface temperatures and sea ice data are input as boundary conditions. Only a simplified two-dimensional ozone production/loss chemistry scheme is included. Wargan et al. (2015) [https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2014JD022493] argue that this simplified chemistry is sufficient as ozone data are being ingested daily in the assimilation process, and ozone chemical time scales throughout most of the stratosphere are longer than a day.
The validation of the MERRA-2 ozone is relevant to this publication, but a comprehensive summary of validation studies of the GEOS-5 AGCM and MERRA-2 dynamical fields is beyond the scope of this manuscript. However we include the website of the GMAO GEOS project as a source of summary information [https://gmao.gsfc.nasa.gov/GEOS_systems/].
We note that MERRA-2 is often used as meteorological/dynamical input, which, coupled to a comprehensive chemistry package, constitutes a chemistry climate model. In this work, though a model is being used, it is used in the sense of a “smart interpolater” to give high resolution spatial coverage from lower-resolution satellite data.

p.6, l.26:

...investigation…
→ Corrected.

p.8, l.2:
I know that it might make a busy graph even busier, but it might be worth adding two vertical lines at the +/-1% levels hence showing that the drift almost for all latitudes is well-within this limitation, to optically also convince the reader that these wiggles seen are not "serious". You could also of course increase the x-axis limits to +/-5%, might also achieve the same effect.
This is a simple suggestion, not massively important.
→ Thanks for the suggestion. We added two vertical lines at the +/-1% levels and increased the x-axis limits to +/-4.5%.

p.9, Reference to Figure 4:
Very nice, very useful but incredibly small plots! Either make this plot a one page plot or include columns 3&4 in a supplement and make the two first columns into one page.
→ We split the figure into two separate figures (new Figs. 4 and 5) and increased the size to enhance the readability.

p.10, ll.1-2:
You definitely need references corroborating this fact and even enumerating it at this point.
→ We expanded this point and added references. It now reads:
“Both parameters are low and nearly constant throughout the year in the tropical region, except for a little enhancement over the Atlantic Ocean. This enhancement is due to zonal variability in tropospheric ozone in terms of a persistent wave-one pattern (Fishman et al., 1992; Ziemke et al., 1996; Thompson et al., 2003), which maximizes near 0° longitude in the South Atlantic. The minimum occurs in the South Pacific near the date line. The amplitude of this wave pattern shows a seasonal variation with minimum values of ~15DU in austral autumn and maximum values of ~25DU in austral spring, associated with large-scale biomass burning in southern Africa and South America (e.g., Thompson et al., 2003).

p.11, l.6, Reference to Figure 6:
Again, this plot is very small to be able to see much, make it one page long.
→ Done. We have enlarged the figure.

p.11, l.9:
In numerics? how significant?
→ We have included numbers here. This part now reads:
Positive differences of about 0.5-1.0% occur in the tropical Pacific and in the northern part of the tropical Atlantic. On the other hand negative differences of -1.5 - -2.5% occur in the southern part of the tropical Atlantic and over southern Africa.

p.11, l.12:
Can you state some numerics from the climatologies used? this would help in quantifying if these differences are due to the climatology or whether we are seeing a "true" effect, i.e. un-related to the apriori conditions.
→ We have investigated the longitudinal structure in the tropics in more detail. The amplitude of the wave-one pattern in ozone is slightly lower for Adjusted-MERRA, which leads to the observed differences. We added:
An investigation of the zonal structure of total ozone columns from GTO-ECV and Adjusted MERRA yields that the wave-one pattern known from tropospheric columns is visible in the total column data, too. Locations of the maximum and the minimum are identical for both data records. However, the amplitude is slightly lower for Adjusted-MERRA compared to GTO-ECV, which leads to the observed longitudinal pattern in the differences (Fig. 7).

p.12, l.8:
Again, are there any numerics you can add to state how much of "non-negligible" this sampling issue can be?
→ The errors are up to ±5%. We provide this number in the text.

p.12, l.10, Reference to Figure 7:
As before, this figure is rather small.
→ We have enlarged this figure.

p.12, l.13:
Number?
→ We have added the number (2.0 – 2.5 DU).

p.13, l.1:
Number?
→ We have added the number (0.5 DU).

p.15, l.5, Reference to Figures 10 and 11:
Again, please make these slightly bigger.
→ Done. We have enlarged these figures.

p.16, l.7:
...between…
→ Corrected.

p.16, l.10:
Not sure I understand what you mean here.
→ The previous paragraph describes Figure 10, that shows the standard deviations of the ozone anomalies for two individual months (April (top) and October (bottom)). The next sentence (p.16, ll.9-11) refers to the standard deviation obtained from all months. For this, we do not show a figure. We removed “(without figure)” to avoid confusion.

p.19, l.3:
...between…
→ Corrected.

p.19, l.4:
...a result of the…
→ Corrected.

p.20, l.5:
...months…
→ Corrected.

p.20, l.5:
A beat frequency?
→ The beat frequency is the difference between two individual frequencies, which interfere. See

also p. 19, ll.5-6 for more details.

p.20, l.16:
Missing comma.
→ Corrected.